TOPICAL ISSUES 2020 OF RATIONAL USE OF NATURAL RESOURCES June 17 - 19

United Nations Educational, Scientific and Cultural Organization

International Competence Centre for Mining-Engineering Education under the auspices of UNESCO

SAINT-PETERSBURG MINING UNIVERSITY

17-19 June 2020

SCIENTIFIC CONFERENCE ABSTRACTS

VOLUME 1

XVI INTERNATIONAL FORUM-CONTEST OF STUDENTS AND YOUNG RESEARCHERS

TOPICAL ISSUES OF RATIONAL USE OF NATURAL RESOURCES

UNDER THE AUSPICES OF UNESCO

Saint-Petersburg
Mining University

XVI INTERNATIONAL FORUM-CONTEST OF STUDENTS AND YOUNG RESEARCHERS "TOPICAL ISSUES OF RATIONAL USE OF NATURAL RESOURCES"

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SAINT-PETERSBURG
2020

УДК 001:(622+55+669+33+502)=111

ББК 26+33+35.514+34.3+65
М432

The Volume contains works of young researchers - participants of the XVI International Forum-Contest of Students and Young Researchers “Topical Issues of Rational Use of Natural Resources”, which was held at St. Petersburg Mining University on June 17-19, 2020. The Volume can be of great interest for a wide range of researchers, scientists, university lecturers, specialists and managers of industrial enterprises and organisations as well as for businesspeople involved in exploration, prospecting, development and processing of minerals.

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ISBN 978-5-94211-915-7(*Volume 1*)
ISBN 978-5-94211-914-0

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Session 1. NEW APPROACHES TO RESOLVING OIL & GAS SECTOR - SPECIFIC ISSUES

Oil & gas field development

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GEOPHYSICAL AND HYDRODYNAMIC ANALYZE FOR COMPLEX RESERVOIR DEVELOPMENT IMPROVING

Most of the fields entered into development are classified as "complex" and "very complex" because of their geological structure. Productive layers are characterized by a clear-cut macroheterogenity of reservoirs properties. The above factors are related to the specifics of oil reserves development: with a high degree of heterogeneity, the most permeable layers are included in the production first, which can lead to their outstripping flooding with significant current reserves. With the introduction of reservoir pressure maintenance systems, there is such a problem as the formation of waterflood-induced fractures. Also, due to the presence of a large number of layers of different permeability, there are difficulties in the uniform development of oil reserves associated with their localization on different oil-saturated layers.

In conditions of high geological heterogeneity and complexity of the development system, methods of development monitoring– hydrodynamic and field-geophysical research are of particular importance. Monitoring by hydrodynamic methods includes assessment of reservoir pressure, changes in filtration properties and well productivity. Methods of field-geophysical research allow us to monitor the production of reservoirs (the flow profile or injectivity profile, the composition of the inflow, the current and residual oil saturation), well technical conditions. There are also special geophysical methods such as CO-logging, which is used for determination of the current reservoir saturation in the cased borehole. Sequential interpretation of research results provides more reliable information about the state of the deposit development and the effectiveness of the applied development strategy.

On the example of a complex high-heterogeneous reservoir, an algorithm is proposed for assessing the impact of dynamic waterflood-induced fractures on field development. The development state is characterized by high water cut and a low rate of reserves recovery. The algorithm is based on a simultaneous analysis of various data such as geology, field development, production logging tests and pressure transient tests. A sequential analysis of well research in combination with analytical methods allowed us to implement an integrated approach to solving waterflood-induced fracturing problem and suggest possible methods for improving the field development system.

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BAHRAIN OIL INDUSTRY

The prosperity of the Bahrain and its rapid transformation from a back ward desert region to one with a booming economy have been made possible by revenue from oil exports. Bahrain possesses nearly 10 per cent of the world’s total reserves, and there is no doubt that oil will continue to provide the income for both economic growth and the expansion of social services for several more decades at least. In the coming years, natural gas will playan increasingly

important role in the Bahrain's development – particularly as a fuel source for power generation, petrochemicals and manufacturing industry. Bahrain has also taken the initiative indeveloping an intra-Gulf gas network that could eventually link up with the Indian subcontinent. Early in 2000, Bahrain marked the fiftieth anniversary of the drilling of the first oil wellat Ra's Sadr, north-east of Bahrain's capital. It was an inauspicious start for the oil industry, because the well proved to be dry. Not for another decade were major discoveries made, although the Trucial States (the areas which became Bahrain in 1971 after the British withdrew from the Gulf) swiftly made up for lost time. In a matter of a few decades supported by Bahrain into one of the major players in the international oil export industry.Proven recoverable oil reserves in 2000 were put at 98.8 billion barrels. At the same time, proven recoverable reserves of natural gas in Bahrain were estimated in 2000 at 6 trillioncubic metres, or 4 per cent of the world total. This makes the Bahrain's gas reserves the third largest in the Middle East (after Iran and Qatar)

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EFFICIENT RAW HYDROCARBON PRODUCTION ENGINEERING INCLUDING ENHANCEMENT OF OIL AND GAS RECOVERY METHODES

By increasing in the use of nonrenewable energy and decreasing in discovery hydrocarbon reservoirs, in near future the world will encounter with a new challenge in the field of energy, so increase in recovery factor of the existing oil reservoirs is necessary after the primary production and pressure drop.

To solve the problem of pressure drop (decreasing the production of hydrocarbon) we must return the pressure to original position by using several methods, these called are enhanced oil and gas recovery (EOR). Improved oil recovery (IOR) refers to any practice used to increase oil recovery.

This can include (EOR), as well as practices to increase sweep such as infill drilling horizontal wells and polymers for mobility control or improved conformance, As fewer large new discoveries are made, EOR will be an option to maintain or increase production for mature fields. EOR will continue to be an important technology to increase the value of the late life assets and as new techniques evolve, EOR will play a greater role in the global supply of oil.

Another solve to increase the production of oil or gas by using the final method is called tertiary oil recovery or we use the modern method by microbial ways (MEOR) we should consider factors such as the reservoir fluid and rock characteristics, availability of injection material, available equipment and other items, as well as EOR can include methods of thermal (combustion, hot water drive, etc…) and chemical & others (Alkaline, Micellar – Polymer, Microbial – foam).

EOR helps to maximize the oil reserves recovered, extend the life of field,and increase the recovery factor.It is an important tool for firms helping to maintain production and increasing returns on order investments.

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ESP MOTORS INCREASING TEMPERATURE

The use of oil and natural gas had considerable growth before the pandemic of COVID-19 as they were representing 58% of World total primary energy consumption in 2018. For that most of the oil producing countries were working to maintain or increase their production rate. Some of the reservoirs were getting depleted in pressure and using an artificial lift method is considered one the steps to substitute the pressure depleting and the ESP(s) is representing the best option/method for most of most of the reservoirs. One of the significant problems that are encountering within ESPs system in Iraqi oil field is increasing the temperature of ESP's motors. This trouble could be eliminated by the right ESP system selection for a specific producer well.

At the beginning it's required to calculate how many feet (head) requires LIFTING in order to achieve a desirable flow rate from the well. This LIFT (head) is called Total Dynamic Head (TDH) which is calculated by following formula: TDH =Net Vertical Lift (NVL) + Friction loss (FL) + Wellhead Pressure (WHP). After calculating the LIFT (head) start pump sizing based on two charts where the first one shows the pump performance curve and the second shows MULTI HZ CURVE. Also it's necessary to take the following information into the consideration which are (internal casing diameter, the completion string type, type of well vertical deviated, is there any down hole tool can cause a size restriction?, fluid properties, general data of a well, changing of reservoir behavior in the future & other general surface information).

Follow the guideline for motor selection to choose the desirable motor (series & type) so that's can be fit for casing size and also has the suitable temperature rating. And then it should select single motor or tandem motor and this is will be determined by checking the amperage & voltage that are available on the field for a given horse power value. Software like SubPUMP is used to run that motor to get the actual motor's performance, operating temperature in addition to its velocity. If the motor is running in recommended operating range (ROR) limits that's mean this motor can be used for the designed ESP system.

In some circumstances the technical solution can not fit the client requirements due to either for budget concern, delivery timeframe or inventory plan. Generally the bigger motor is better than small one because of its providing higher horse power without tandem connections and also less expensive. The voltage value of a motor should consider motor voltage plus the voltage loss in the power cable, so a motor will be chosen with total voltage value. So it's important to ensure the total voltage value does not exceed the power cable rated voltage, surface control panel, transformers, wellhead feed thru mandrel voltage value. When tandem motors are used, the horse power and voltage values will be doubled/ or tripled by depending on the number motors that are used BUT the amperage value does not change.

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PARTICLE TRACING IN POROUS MEDIA EXPERIMENTAL AND NUMERICAL PRACTICES AND ADVANCES

The application of tracers in the oil field industry have roots in hydrology and they have occurred within the past forty years. The first stage of development of application of tracers in the oil industry was based on radioactive tracers which was a result of Atoms-for-Peace programs of World War II and it was dependent on the support from small companies. Moreover, recent advances in technology has shed light on new computer based methods to simulate and model the tracer response curves mathematically (Zemel 1995).

Tracers are particles which are injected to the reservoir to characterize the dynamic flow path in porous media. The application of tracers in the oil field industry have roots in hydrology and they have occurred within the past forty years. Tracer tests provide relatively accurate measurement of the heterogeneity of the reservoir, e.g. high permeable regions. The benefits of

well to well tracer testing has become well-known because the technology has matured, and the results have become reliable. Particle tracing has also been used in micro models to monitor fluid flow in porous medium and to investigate wettability, capillarity, heterogeneity, and pore-size distribution on particle velocity.

Tracers are classified based either on their nature or from a practical point of view. In the last few years, there have been a growing interest about fine particles migrations in oil and gas reservoirs in the petroleum industry. To model particle tracing in the reservoir, several computational modeling methods have been developed. Therefore, these models need to be validated by experimental data in microfluidics systems. In this study the methodology and the experimental setup of the tests are investigated. Moreover, three case studies are reviewed deeper as illustrations of the experiments.

In this article, after classification of different tracers, experimental aspects of particle tracing are reviewed by investigating three case studies. Furthermore, practical aspects of particle tracing and its in-field applications are illustrated.

These applications have also been investigated by both numerical and experimental practice, and there have been many advances achieved by these practices. In the cases which were presented in this paper, the behaviour of immiscible two-phase flow in porous media, and blood flow in human body were investigate. The investigations are validated by numerical simulations and help to understand the dynamics mechanisms governing each type of investigated flow.

Large scale practices of particle tracing have also led to much more efficient management of oil and gas fields. These practices include implementation of tracers in WAG programs, fractured reservoirs, geological model validation, gas injection and reservoir saturation identification. In each case particle tracing acted as a valuable source of information for optimization and future development purposes.

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DEVELOPMENT AND TESTING OF THE INTEGRATED DESIGN METHODOLOGY BASED ON THE INTEGRATED ASSET MODEL

Oil and gas companies need to constantly find and implement new concepts of oil and gas production organization, technical re-equipment of obsolete equipment, increase productivity, reduce operating costs of production.

The paper considers the rationale for the development of integrated models of land facilities for oil, gas and gas condensate fields, provides a methodology for integrated design based on integrated models, and develops an integrated asset model [1].

Real-time monitoring of field development is one of the key components of the modern oil and gas industry [2]. From a managerial point of view, this concept means a continuous process of preparation and decision-making on managing the development of oil and gas fields.

Making informed decisions should be based on reliable data, their methodologically correct interpretation and integration with each other. Currently, such tools are integrated models, which include the parameters of the produced fluid, the structural and technological characteristics of the pipeline networks, as well as the loading profiles of the objects for preparing gas-liquid mixtures [3].

The companies Shell, Chevron, BP, etc. actively introduce the integrated and conceptual modules of design (Smart Field, I-Field, Field of the Future, etc.) for forming most economically and technologically optimum way of development and operation of fields. This, in turn, generates the development of information technologies in the field of design in the oil and gas complex, due to the need to develop software products for the exchange of modular data (formation - ground development - economy).

The basic distinctive characteristic of integrated design is the identification of risks and uncertainties affecting the end result (NPV, IRR, CAPEX, OPEX, etc.) and their minimization taking into account the selection of optimal project implementation options. Our research is aimed at developing an integrated approach to optimization of oil and gas fields operation, methods and algorithms for determining reserves of ground infrastructure.

The technology of "integrated design" connects all stages of industrial development of the asset. The core of the technology is the integrated field model (IFM), ideally having algorithms for obtaining and processing data from remote field development control systems. IFM includes mathematical models of formation, fluids, wells, ground infrastructure of the deposit, built on the basis of all available data on the deposit. IFM enables integration of well models and collection systems with larger formation and object models, as well as real-time model updating. On the basis of IFM, it is possible to automate control/monitoring processes, forecast the operation of each of the constituent systems of the deposit with elimination of labour-intensive manual processes [4].

Currently, only selected instruments of geological, hydrodynamic, oil field and economic modelling of the deposit are widely used. They have become an integral element of planning measures for development or optimization of oil and gas fields and tools for calculation of technological indicators of design and technological documentation for field development. The main disadvantage remains the absence of a single model of the deposit, which would include all elements of integrated planning.

In research, a phased development of an integrated asset model was completed, formations, wells, linear and on-site facilities (systems for collecting, transporting and preparing oil, energy facilities, etc.) were introduced. The output «product» is a constantly operating integrated current asset model that combines all the main elements of the development of oil and gas fields: formation - well - collection system - transport system, which serves as the initial data for creating economic models.

The methodology developed by us for the development of an integrated model of the land arrangement of an asset / field is universal in its practical application, that is, without a “link” to a specific oil and gas producing enterprise, field or asset. A practical application of this methodology is possible for various oil and gas, oil and gas condensate, gas and gas condensate fields of any geographic location, method of operation, as well as the development stage and degree of maturity of the asset or field.

As a toolkit in developing the integrated model, a specialized software package was used that uses the direct dependencies "PVT fluid properties - reservoir - well model" for iterative calculations of oil gathering networks and areal objects, taking into account the boundary conditions at the entrance and exit to the areal object, and carry out the calculation sequentially.

The main constraints of the integrated model are: taking into account the limitations on compressor station capacity at integrated gas treatment plants; consideration of limitations of

capacitive and separation equipment at end facilities of oil and gas preparation; taking into account the limitations of the discharge of the volumes of sub-commercial water at cluster pumping stations; consideration of maximum gas factor limitations; consideration of maximum pressure limitations in well fluid collection system and prepared product transport; taking into account the maximum velocity of gas movement in gas pipelines.

The resulting model allows us to assess, at the current and future level, the mutual influence of all factors of field development and exploitation on each other, as well as obtain operational results in the form of digital information when changing input parameters or parameters affecting the model at one of the stages.

The viability of the developed integrated model has been practically proven by the example of hydraulic, material and energy calculations. The resulting integrated model meets the criteria of stability and adaptability for a new version of the prospective levels of hydrocarbon production for the asset, and also shows similar calculation results.

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INFLUENCE FACTORS OF WELL'S INDEX PRODUCTIVITY ATER FRAC IN THE KASHIRSKIY AND PODOLSKIY RESERVOIRS OF PERM REGION OIL FIELDS

Hydraulic fracturing is one of the most used methods to increase oil production. There are several factors affecting the index productivity of wells after hydraulic fracturing [1, 2]:

- geological factors: reservoir thickness, permeability, porosity and pressure;
- fluid properties: oil and water viscosity and density;
- fracture factors: fracture length, fracture width and etc.

The paper presents the results of hydraulic fracturing in Kashirskiy and Podolskiy reservoirs of the Shumovskoye oil field.

The productive formations of Kashirskian and Podolskian horizons see Table 1 [3].

Table 1 - Geological and Physical Characteristics

Description	Ksk	Pod
Average depth of occurrence, m	1,103	1,027
Average net oil thickness, m	3	4
Initial formation pressure, MPa	11,7	11,2
Oil viscosity in reservoir conditions, mPa·s	45,7	18,6

Porosity, %	16	19
Permeability, μm2	0,19	0,73

The analysis considers the main technological parameters that affect the results of hydraulic fracturing for groups of wells depending on the mass of injected proppant, which is an integral characteristic of the length and width of the fracture, with an average permeability of the formation, where the extremes of oil flow rate are clearly traced at 4.7 tons per day during injection proppant mass of 16.3 tons per tonne and fluid flow rate at the level of 11.2 m^3 / day with proppant injection of 15.6 tons.

The dependences of the oil and liquid flow rate per 1 m of perforated thickness after hydraulic fracturing on the volume of proppant pumped are in satisfactory agreement with the size of its injection of 16.3 tons.

It is noteworthy that with an increase in the amount of proppant there is a tendency to a decrease in the flow rate of oil and liquid.

The index productivity and well production rate decrease after hydraulic fracturing if bottomhole pressure decreases.

According to the graphs of the distribution of hydraulic fracturing by effective thickness, it was found that with an increase in the effective thickness, the oil and liquid flow rate after hydraulic fracturing increases.

The largest number of hydraulic fracturing activities was carried out at flow rates from 5.1 to 16.1 t/day for oil and from 9.7 to 31 m^3/day for liquid, the maximum flow rate after the frac was 16.1. We create plan fpr well № 113 and carrying out proppant hydraulic fracturing. Scheduled fluid flow rate of 13.5 m^3 / day, oil flow rate of 6 tons / day and volumetric water cut of 50%, the proppant mass is 28 tons and guar loading is 2.8 kg / m^3.

The optimal conditions for hydraulic fracturing in the field under consideration according to the results obtained are: maintaining of bottomhole and reservoir pressures above the saturation pressure, specific proppant flow rate - about 2 t / m, proppant type – BoroProp.

ACKNOWLEDGEMENTS

The reported study was partially supported by the Government of Perm Krai, research project No. C-26/786 from 21.12.2017.

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DYNAMIC ANALYSIS OF TECHNOLOGICAL PLATFORM ON THE OIL PLATFORM

During these last years there is a growing tendency to build light footbridges. Due to decreasing mass, slenderness of given objects and the increase of dynamic forces we should give special attention to dynamic phenomena of given objects. Dynamic phenomena occurring on a given object should be subjected to a detailed analysis [1]. Reducing the mass of the structure results in a decrease in the moment of inertia, this results in a decrease in the natural frequency,

which causes increasing the risk of resonance caused by people moving on the structure. There may be a resonance phenomenon in objects if the frequencies of the structure coincide with the frequencies of the forces acting on the structure. Construction may be stimulated for example by pedestrian use, power generators, drilling equipment drive, winding device, wind and sea waves. Vibration caused by devices having direct or indirect contact with the structure and pedestrian traffic can lead to problems with the functionality of the structure, problems with the well-being of people moving around the structure, and can cause serious damage to the structure. Structure vibrations can occur as bending, torsion and bending and torsion. Therefore, during modern designees of structures, we should take time to evaluate the phenomena [2], [3].

The work is aimed at analyzing the simplified technological bridge used on drilling platforms. The main goal is to obtain the form of natural vibrations of the structure. The ANSYS numerical program was used to analyze the dynamic structure. The subject of dynamic analysis is a single-span technological bridge. The analyzed structure consists of two IPE 200 I-sections at 1.0 m spacing, connected by transverse bracing made by CHS 101.6x10 steel profiles. Additionally, safety barriers were made of RHS60x30x2.5 and SHS30x30x2. When analyzing the structure, the following simplifications were adopted:

• Gratings used in structures of this type have been omitted.

• Gratings were replaced by 95 kg distributed over the upper I-sections.

Due to the use of steel elements in the analyzed construction, which are characterized by high strength at low weight dynamic phenomena occurring on a given object should be subjected to special analysis. It is not only necessary to design structures due to static impacts, but also to analyze dynamic phenomena in a given region and take them into account during dynamic analysis of structures. The environment of oil platforms is very rich in the possibility of dynamic interactions on structures. These objects have a large number of mechanical devices, which improperly mounted on the platform structure or as a result of wear of the anti-vibration pads can transfer vibrations to the objects in their vicinity. If there is a risk of resonance for a given structure, the structure should be redesigned or a vibration damping system should be used. The dynamic development of engineering programs enables quick analysis of structures. Each of the programs has an advantage in a different field from the other, so you should use several programs when creating numerical models to streamline your work. When creating a computational model in numerical programs, you need to control your work at every stage.

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ANALYSIS OF SANDING PROCESS IN THE HORIZONTAL WELLS DURING PRODUCTION OF HIGH-VISCOSITY OIL FROM WEAKLY CONSOLIDATED RESERVOIRS

Developing of high-viscous oil from weakly consolidated sandstones is a new stage of Russian oil and gas industry. Oilfields of that type were discovered in 70-s [for example – Russkoe field (1968)], but it’s development wasn’t needed for years due to many reasons.

Overall complexity, lack of technology and low revenue made such deposits just a “strategic reserve”. Enough time have passed and now these reservoirs must be developed to support production levels in Russia. Current paper must be accounted as actual due to early stages of development of Vostochno- and Zapadno-Messoyakhskoe fields, Russkoe, Van-Eganskoe and Severo-Komsolskoe fields.

Development of weakly consolidated sandstone reservoirs is always accompanied by sand influx into the well that leads to erosion of sub-surface and surface equipment and may lead to well collapse.

Recent studies have shown that sanding process is caused and depends on three factors:

1. Entrainment of sand particles by the flow of the fluid;
2. Stress distribution in the near-wellbore zone;
3. Weakening of the rock with water replacing high-viscous oil.

To study effect №1, an analysis of the performance of wells in one of the oilfields was performed - 300 horizontal wells were surveyed and the results are as follows:

1. Amount of suspended particles in the flow is independent from fluid flow rate;
2. Amount of suspended particles depends on watercut of the flow – grows with growth of water content in the flow;
3. For wells with flow rate < 40 m3/d wellbore clogging occurs with higher flow rate, higher watercut and lower amount of suspended particles, than of clean wellbore.

Effect №2 may be calculated via different models of wellbore stability – Mohr-Coulomb, Mogi-Coulomb, Lade and other models are widely used in the industry, but recent papers account for individual approach for each field with calibrating the equations to each field.

Pavlov V.A. and his colleagues recently studied effect №3 (that originally was observed in 1998 by ISAMGEO) in the LLC TNNC – they performed a series of tests with different saturation of porous media and then tested the core for uniaxial strength:

1. Displacement of oil by water may result in 10 times lower UCS (uniaxial compressive strength) of the core.
2. Displacement of oil by polymer may result in 2 times lower UCS of the core.

Accumulation of the data from sanding process helped the industry to surpass some of the problems, but there are still some issues that must be solved – how can sand be sufficiently blocked from influx into the well or even prevented from dragging by the fluid flow. The choices are - efficient methodology of filter-selection and thin-film chemical reagent, but they must be studied before approval.

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GEOMECHANICAL MODEL CONSTRUCTION FOR THE PURPOSE OF FRACTURING OPTIMIZATION ON THE EXAMPLE OF LANSKO-STAROOSKOLSKY DEPOSIT OF RECHITSA FIELD

The current stage of field development requires the constant introduction of the latest technological measures to increase well productivity. Today, a widely used method for productivity rising is hydraulic fracturing, which is based on stimulation of the bottomhole formation zone by creating channels of high conductivity. It is known that the design and parameters of a fracture during hydraulic fracturing strongly depend on the physicomechanical properties of the rocks, as well as on the distribution of stresses in the rock mass. Therefore, the

analysis and assessment of the elastic parameters of the rock plays a leading role in modeling fractures in the field along with the rheological properties of the fracturing fluid [1].

In this paper we will consider the results of geomechanical modeling application for the purpose of hydraulic fracturing design optimization on the example of terrigenous deposits of the Lansko-staroskolsky horizon of the Rechitsa field. While performing hydraulic fracturing on wells of the Western block of this field, the problem of STOP pressure was discovered. The analysis of the technological information for these complications showed many reasons that could contribute to it - starting from the difficult transportation of proppant through the crack in the clayey junctions with high stresses and low crack opening, up to the excessive growth of the crack in height due to its narrowing in the bottomhole zone, as well as the forming of competing cracks in different zones along the section.

The analysis of the problem was started with the construction of a map of the collector dismemberment in the intervals of the Lansko-staraooskolsky horizon, which characterizes both the thickness of clay interlayers and their quantity in the collector. On the basis of this map it was concluded that most of the studied wells fall into the zone of the dismembered reservoir, and all these wells have an inclined trajectory. Hence, we assume that the problem may be related to the geological structure and stress in the rocks: in the section of the Western block of Rechitsa deposit sandstone and clay interlayers are observed. Initially, it was suggested that the most likely reason of STOP pressure during fracturing is limited contact between a crack and a well, this is a typical situation for inclined wellbore trajectory. Different stresses in clays and sandstones prevent the proppant from spreading over the whole profile of the crack, because the opening of the crack in the clays is much lower than in the sandstones.

To check this assumption, it was decided to construct a model of mechanical properties, as well as a model of stresses and pressures. For this purpose, reference wells were selected, which include the most complete set of initial geophysical data and field studies, as well as laboratory core studies. Based on the results of the initial data analysis, the correlation dependencies of elastic strength and petrophysical properties were established, as well as directions of action of the main reservoir stresses - based on the data of cross dipole acoustic logging, acoustic TV and electric micro-imager. All these data formed the basis for the geomechanical modeling and the evaluation of such parameters as UCS uniaxial compression strength, FANG internal friction angle, Young's elastic modules, Poisson's and Biott's coefficients [2, 3].

Filtration properties data are taken from the hydrodynamic model of the Western block of Rechitsa field, created in the Eclipse Office program. The fracture was simulated in the hydrodynamic model by changing the skin factor. Skin factor after hydraulic fracturing is a function of half-length and dimensionless fracture conductivity. The value of the dimensionless conductivity function was determined from the Cinco-Ley and Samaniego correlation [4].

The data obtained from the geomechanical model allowed to recalculate hydraulic fracturing designs and estimate how the change in fracture geometry affects well flow rate. The results obtained in the course of analysis of a complex of geophysical data, construction of geomechanical and hydrodynamic models, as well as modeling of hydraulic fracturing, made it possible to formulate the following recommendations for optimization of hydraulic fracturing in the Lansko-starooskolsky deposit of the Rechitsa field:

- selection of propping agent size fractions of (proppant) in accordance with the reduced crack opening;
- Application of methods of excessive containment of crack growth in height;
- Conducting isolated stages of hydraulic fracturing in case of long perforation interval.
- Calculation of optimal wellbore orientation in accordance with the stress state and direction of the main maximum stress in order to minimize technological risks of hydraulic fracturing and increase well productivity.

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ABOUT NEW CONSTRUCTIVE SOLUTION OF SUCKER-ROD OIL PUMPING UNIT

Oil production have important position in the development of all sectors of the economy of Russia, Azerbaijan, Kazakhstan, as well as a number of Arab countries and therefore, they pay special attention to the oil industry. Today, the vast majority of wells in the world are operated on land. The mechanical drive of sucker rod pumps, which are also called the rocking machine, is an individual drive of a sucker rod pump, which lowered into the well and connected to the drive by a flexible mechanical connection - a rod column.

The leading role in oil operation belongs to pumping units, which have been used in oil fields almost since the beginning of the 20th century. According to experts, no other more reliable and easier to maintain equipment than these drives has yet been truly created. The design of the classic beam pumping unites is a four-link mechanism that converts the rotational movement of the engine into up and down stroke of the rods column and consists of a number of independent subassembly. Considering that the majority of onshore oil fields have entered the late stages of development, characterized by a decrease in production well flow rate, as well as a tendency to lower crude oil prices in the world market, increasing the efficiency of mechanized methods of oil production is of particular importance today.Therefore, the volume of produced oil largely depends on increasing the efficiency and reliability of operation of these units while reducing energy costs from their use.

The most of pumping units, which used now, are classic beam pumping units. After a long evolution, beam-pumping units have many advantages such as high unification and simple design. However, along with this, there are a number of disadvantages are also characteristic for beam pumping units [1, 3, 4]. One of the significant disadvantages of beam sucker-rod pumping units is the presence of significant unbalanced masses, the need to build expensive foundations due to the large weight of the unit, the low service life of the gearbox and high-energy consumption, which is due to the high value of the torque on its output shaft.

To solve these problems, for many years in the Department of Machine Design of the Azerbaijan Technical University has been developing to create new design solutions for sucker-rod pumping unit. One of such developments is a new constructive solution of beamless sucker-rod pumping unit, which is distinguished by its small overall dimensions and metal consumption, simplicity of design, low energy consumption and high reliability.

In the proposed design of the mechanical drive of sucker rod pumps, a transforming mechanism is used in the form of a crank-slide mechanism, a guiding system, which consists of two cylindrical pipes vertically aligned coaxially with the output shaft of the gearbox, rigidly connected by means of flanges and bolts to the lower and upper platforms of installation, a movable cross piece which articulated-link to the connecting rods, an adjustable counterweight mounted on it with the possibility of balancing the load and uniform loading of the electric motor when lowering and lifting the rod, which excludes the rotary counterweight from the system. To overcome the state of bifurgation of structural elements, on the cranks are installed gears and

satellites. In the Department of Machine Design created the working model of proposed new constructive design of sucker-rod pumping unit.

Using of movable counterweights in the design, allow to significantly reduce the load on the electric motor, which allows to reduce the required power of the drive electric motor and thereby significantly reduce energy consumption. The weight of the movable counterweights can be changed depending on the value of the load and the stroke of the rod suspension point. Given the downward trend in the global market for crude oil prices, we can confidently say that the use of the proposed design will be especially effective in the extraction of oil from low-production wells. In the drive of the pumping unit used a three-stage two-line gearbox [2] which, in comparison with the classic cylindrical gearbox, consists of only two shafts on which are installed cylindrical and block gears. By removing from the design of the intermediate shafts and their bearings, the new gearbox has a relatively much higher efficiency and reliability level, and smaller overall dimensions in comparison with classic gearboxes. In 2012 the industrial model of proposed three-stage two-line gearbox was successful tested on well in Pirallahi island (Azerbaijan) by support of Azerbaijan State Oil Company.

Conclusions:

1. The unique balancing mechanism makes it possible to almost completely balance the load of the gearbox during the whole stroke of the rod suspension point, thereby contributing to a significant increase in the service life of the gearbox and the drive motor.

2. The use of movable counterweights allows to take on a large share of the load of the rod suspension point, reducing the torque value on the output shaft of the gearbox up to 40%, which reduces the required power of the drive motor and thereby significantly decrease energy consumption of the pumping unit during the operation, which is especially important for oil production from marginal wells.

3. Elimination of the heavy horse head (balancing head) and balancer from construction reduces the metal consumption of the eqipment, thereby reducing the cost of equipment and increasing its capacity, as well as transportability.

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NOVEL PROCESS LIQUID FOR PROPPANT ACID FRACTURING OF CARBONATE FORMATION

Carbonate collectors, which contain about 40 % of the world 's oil reserves [1], often refer to deposits with hard-to-recover reserves due to the properties of the hydrocarbons themselves, as well as the heterogeneity of oil-containing rocks and the complexity of their development. Oilmen around the world face the challenge of optimizing and improving existing methods of extracting oil from carbonates, as well as creating new ways to achieve production efficiency. Hydraulic fracturing is among the most effective methods of intensification of oil production from carbonate collectors. Rock fracturing, which is organized by supplying process liquid under high pressure, contributes to increasing communication between the formation and the bottom-hole, thereby increasing the degree of oil recovery. Recent trends in the improvement of carbonate fracturing include attempts to combine proppant transfer and acid etching of the carbonate matrix. [2,3]. This makes it possible to optimize the hydraulic fracturing process by using a single process liquid and combining several operations within the acid-proppant fracturing process. This project focuses on the development of such a process liquid.

The main requirements for the developed liquid were: 1) high dissolving capacity (concentration of hydrochloric acid in the composition is not less than 12-15 wt%; 2) dynamic viscosity value is not less than 250 mPa·s at shear rate 100 s^{-1}; 3) sufficient proppant-holding capacity; 4) viscosity reduction of the liquid after neutralization of hydrochloric acid in the formation. Solutions of the viscoelastic surfactants were investigated in order to solve these problems. Viscoelastic surfactants are capable of showing high viscous characteristics, since formation of a dynamic system of cylindrical micelles.

As a result, a gelling agent was developed, which is performed by solution of cationic surfactant with a long side hydrocarbon chain in a solvent. This agent is capable effectively thickening hydrochloric acid at a concentration of 15 % by weight.

Within the framework of studies, the optimal concentration of gelling agent in the acid solution is selected from the data of dynamic viscosity - shear rate dependence curves. Analysis of the curves showed that the optimal gelling agent content was 8 % by weight. The viscosity reached at this concentration is 490 mPa·s at a shear rate of 100 s^{-1}.

After selection of gelling agent concentration, liquid properties were checked for compliance with other conditions. Proppant-holding capacity was evaluated by mixing the test liquid with the proppant fraction 30/60 at 250 kg/m^3 loading and observing its deposition for one hour. After the time of the experiment, it turned out that proppant precipitation did not occur, indicating a brilliant pass of the test. The reduction in viscosity during use of the new process liquid was evaluated and confirmed by analysis of the dynamic viscosity - shear rate curves. It turned out that an additional advantage of the developed liquid is the absence of a precipitate after reduction of its viscosity, in comparison to polymer thickeners, which lead to reduce filtration characteristics of the formation [42].

Thus, during the project, a new liquid for acid proppant fracturing was developed. Applying of such liquid will make it possible to optimize the process of oil extraction from carbonate collectors by combining and reducing the number of technological operations within the framework of the considered method of oil recovery intensification. The use of viscoelastic surfactants as a gelling agent will prevent a decrease in the filtration properties of the collector, which is also characterized by an increase in the oil recovery index compared to the use of similar compositions thickened with polymers. Efficient development of reserves contained in carbonate collectors is a current industrial task within the framework of development of hard-to-recover oil and gas reserves.

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TOMOGRAPHIC ANALYSIS OF FORMATION STIMULATION USING NOVEL NANO-BASED ENCAPSULATED ACID SYSTEMS

During the production time, it is crucial to manage the reservoir efficient productivity and keep it at a profitable level. Matrix acidizing in carbonate reservoirs is a common course of action to increase the efficiency of production [1,2]. The present project is based on an integrated multi-disciplinary plan as an arena to merge traditional and novel technologies in the field of petroleum engineering, petroleum geoscience, chemical engineering, computer vision and mineralogy. Some crucial parameters such as permeability/porosity changes occurred during carbonate acidizing will be modelled and analyzed based on various modern technologies, such as, the novel digital rock technologies. A waste variety of nanoparticles will be used in order to design a novel acid mixture for stimulating the carbonate reservoirs.

Specifically, this study will be considered as a one-step forward in development of smart encapsulated acid systems using a range of hydrophobic silica nanoparticles in various grades of hydrophobicity. Moreover, the present study will be considered as the first practical example for application of digital rock physics in improvement of acidizing operation in Iran and Russia.

The proposed research methods are consist of Preparation of encapsulated acids, Sample and data collection, Conventional core analysis, Digital Core analysis, Lab experiments and Modelling and conclusion. Characterization of the efficiency of this process will be once more characterized using the aforementioned digital rock technologies to visualize the effect of encapsulated acid fracturing operation, impact of surface modification of silica NPs on the etching efficiency, the physical properties of core samples, and subsequently the final productivity index [3,4].

Then, thin section, SEM and FE-SEM analysis will be performed to further evidence the efficiency of this method. Moreover, the efficiency of this method will be categorized based on the identified mineralogy and rock composition.

The dissolution rate will be significantly increased as a result of acid neutralization control and the reaction rate will be decreased ended in deeper wormholes, higher permeability, and so, more successful acid treatment. Thanks to the reduced accessible surface of acid systems caused by their emulsion-based nature, this novel encapsulation process can reduce the risks of corrosion in all the equipment in surface and bottom hole. It naturally reduces the extra costs of corrosion-related damages and subsequent workover operations, which are the common need of most of the wells treated by conventional acid fracturing operations.

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"RESERVOIR-WELL-GATHERING SYSTEM" MODEL AS A TOOL OF OIL AND GAS GATHERING PROCESS IMPROVEMENT

The development of oil and gas fields requires technical solutions aimed at maximizing profit at minimal cost. In order to choose the most effective solution, engineers recourse to using modeling tools. This approach helps to simulate various technological designs and calculate their effectiveness based on predicted values. Integrated models have a special place in the field of computer modeling because they consider all constraints which take place in the whole system of oil production. For example, an Integrated Production System Model (IPSM) is a model which simulates a field (or group of fields) from reservoir through the wells, pipelines and process facilities to sales or exports [1]. The integrated "reservoir-well-gathering system" model is a unique tool that opens up new opportunities in the design and management of oil and gas condensate and gas fields, allows to promptly and accurately predict the level of production, rationally plan measures to increase oil recovery, taking into account gathering infrastructure.

This research work considers the creation of an integrated model with the aim of optimizing the gathering system, choosing the most effective design and justifying its economic efficiency.

For those goals, the sector of the oil and gas condensate field was selected. This field has two formations. The overlying one (U_1) contains volatile oil, while the underlying formation (U_2) is identified as an oil-gas and condensate reservoir with a gas cap. Considered formations have significant difference in the physic-chemical properties of the hydrocarbon fluids and the reservoir properties. For this reason, they are being developed separately. However these formations are initially tied to a common gathering and separator node. The considered sector is being developed by fifteen production wells grouped into two clusters: nine of them are naturally flowing wells producing from formation U_1 and six wells are producing from formation U_2 (five of which use electric submersible pumps and one well is naturally flowing). Among the nine production wells producing from formation U_1, four wells are horizontal.

The problem of oil gathering and processing from considered sector is that wells producing from two formations have a large difference in the wellhead pressure. Specifically, wells producing from formation U_1 have wellhead pressure equal approximately to 20 bars while wells producing from formation U_1 have wellhead pressure equal to 190 bars. Maximum allowable flow line pressure is 40 bars. Consequently, wells producing from formation U_1 must

be equipped with a choke. When these wells are equipped with a small choke, they are often hydrated and blocked due to high pressure difference between the wellhead and the downstream choke flow line (Joule–Thomson effect). In case of using bigger chokes a bottleneck effect occurs in the flow line due to increased pressure. Some electric submersible pumps are unable to provide enough wellhead pressure. As a result, oil production schedule is delayed.

To solve the problem, the three designs were proposed. First of them is implementation of methanol treatment unit in common gathering system. Other two variants consider the separation of existing gathering system by using the previously installed pipeline as a low pressure line for wells with low wellhead pressure or building a new high pressure line for wells with high wellhead pressure. To determine the most effective design, it was necessary to build an integrated model in the METTE software. It was carried out in several stages. First of all, it was necessary to convert and adapt two initial reservoir simulation models from Eclipse to Tempest. Next part was construction of well trajectory profiles and its calibration which is based on the available information from pressure and temperature surveys obtained during well test. Final part of the research included network construction and its integration with well models.

As a result of modeling and calculations three integrated model were built. The model of the first conceptual design (implementation of methanol treatment unit in common gathering system) showed that the considered variant loses 30 m^3/d of oil from formation U_2 because of bottleneck effect in the gathering system. In case of separate gathering system, the impact of the bottleneck effect is absent. Moreover, the model with built high pressure line has the highest average daily production rates (1165 Sm^3/D) and value of NPV according to economic calculations.

Thus, the effectiveness of the integrated modeling method as a tool for optimizing oil and gas gathering process in the considered field sector is proved. The integrated model made it possible to establish that delayed oil production takes place in common gathering system. In considered conditions the separate gathering systems remove the bottleneck effect and maximize optimal production level and profit.

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PHYSICAL MODELING OF DEFORMATION AND FILTRATION PROCESSES IN LOW-PERMEABILITY RESERVOIR ROCKS WHEN IMPLEMENTING THE DIRECTIONAL UNLOADING METHOD

For the correct choice of the operating mode of oil and gas fields, including determining the stability conditions of the walls of the wells, it is necessary to determine and analyze the mechanical and filtration properties of rocks. No less important issue for the oil and gas industry remains the problem of increasing the production rate of oil and gas wells. The state of the well bottom zone and its filtration properties has the main influence on the amount of oil or gas inflow from the well of each particular oilfield. Any deterioration in permeability even in a small vicinity of the well can significantly reduce its productivity [1]. One of the key factors affecting the state of the well bottom zone is a change in the stress-strain state of rocks during drilling and

operation. Physical modeling of the real change in stresses that occur during field development allows, among other things, to prevent a decrease in flow rate and destruction of the walls of production wells, or, conversely, to increase their productivity many times. Despite a fairly large number of studies in the field of geomechanics both in Russia and in the world, at the moment there are no reliable models that can predict in advance the nature of changes in rock permeability with changing stress state [2]. This is largely due to a significant differentiation of the properties of most rocks, even within the same lithotype.

The search for effective methods for enhancing oil recovery for fields with hard-to-recover hydrocarbon reserves is becoming particularly relevant. One of the most promising approaches is the method of directed unloading of the formation created at IPMech RAS, which relies on the creation of artificial permeability in a low-permeability reservoir rocks through directed unloading of the formation from rock pressure. This method, known as the "geoloosening method" [3] has successfully passed pilot field tests, and is based on the capability of majority of rocks to fracture and to disintegrate in case of the emergence of certain level shear stresses. The required stress state can be created by decreasing the pressure in the well, combined with certain operations, intended priory to form a bottom geometry. The value of pressure drawdown and bottom hole design can be established by the direct physical modeling of the conditions that occur near the well.

The effect of the non-uniform triaxial stress state on the nature of deformation and filtration processes in rocks was studied using a Triaxial Independent Load Test System of the Institute for Problems in Mechanics of the Russian Academy of Sciences. This test bench allows us to load cubic rock samples independently along each of the three axes and measure the change in permeability during the experiment [4].

Physical modeling of the deformation and fracture of rocks of the Achimov deposits was carried out under real stress conditions that occur in the bottom-hole zone of the formation of a particular field at depths of about 4 km during various operations in the wells. Corresponding loading programs were compiled and implemented. The deformation curves are constructed, the time dependences of the rock deformations under complex triaxial loading are investigated, the deformation and filtration characteristics of the rocks and their dependence on stresses are established.

The conducted studies allow us to draw conclusions about the optimal operating mode of a well for a given field in order to maintain stability of the walls of the wells and prevent negative processes in the formation. Based on the obtained experimental data on the deformation and filtration characteristics of the rocks of the Achimov deposits, the technological operations, which are necessary for rising the productivity of wells by increasing the permeability of reservoir rocks using the directed unloading method, can be determined.

This study was supported by the Russian Science Foundation, Project No.16-11-10325-P.

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GENERALIZATION OF EXPERIENCE AND RESEARCH OF TECHNOLOGIES FOR DEVELOPING HYDROCARBON DEPOSITS IN FRACTURED RESERVOIRS

It is planned summarize the experience of developing hydrocarbon deposits in fractured reservoirs to study the" best practices" of development and assess the possibility of their transfer to more complex geological structures.

With carbonate sediments, occupying a large share of the total geological reserves not only in Russia but also in the world, tied to the resource base of fuel and energy complex development in the near future. The relevance of this topic is addressed in the programs of innovative development of many oil and gas companies in the Russian Federation, which reflects the need to study the problems of developing deposits in carbonate reservoirs. Thus, according to the program passports, companies such as Rosneft, Gazprom, Gazprom Neft and Zarubezhneft plan to pay significant attention to the study of various types of hard-to-recover reserves and unconventional resources, including in fractured/carbonate reservoirs [1].

However, the main part of the fields currently being developed is confined to carbonate deposits with mainly pore reservoirs. Development of deposits in fractured carbonate reservoirs, where the main reserves are contained in cracks, has not been more widespread for a number of reasons [2]. First, the methodological techniques for calculating reserves are based on the pore type of reservoir. Secondly, the problems of developing reservoirs with fractured types are caused by the significant impact of fractures on the recovery of hydrocarbons and, consequently, on the economic profitability of the field.

The presence of cracks is a critical factor that is associated with such major problems in the development of fractured reservoirs as high rates of production decline, high risks of well flooding through crack systems, the complexity of determining the distribution of reserves controlled by the distribution of crack systems, etc.

At the same time, the probability of risks arising in the development of such fields may arise at any stage of their development, including drilling, completion and operation of wells, as well as plans to implement methods of increasing oil recovery. I.e., the faster operators determine the impact of cracks, the lower their risks will be in the future.

Fractured reservoirs with natural fracturing are characterized by a system of parameters that are difficult to design and predict. Some reservoirs with natural fracturing manifest themselves in the event of emergencies at the initial stages of drilling wells. In other cases, the consequences of cracking may be obvious when the deviation of the design parameters of hydrocarbon recovery significantly exceeds the permissible limits. In practice, the data obtained that the formation has natural fracture may be ambiguous, which will lead to additional risk [3].

Many researchers believe that to justify the optimal system of field development in fractured reservoirs, it is necessary to generalize the existing experience based on the analysis of the developed deposits, as well as to study how to use the data obtained.

In this regard, an important task is to study methodological approaches to determine the nature of the impact of crack systems on the performance of wells and field development in General, both at the initial and final stages of development. Field data on developed fields and the results of projects to increase oil recovery in fractured reservoirs around the world will provide a real picture of the degree of influence of cracks in various types of deposits.

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DEVELOPMENT OF SOFTWARE FOR PREDICTING WATER CONE FORMATION PROCESSES IN GAS WELLS

The problem of appearing of water cone in gas and gas condensate wells appears on later and early stages of developing [2]. While gas is extracted, water is pulling up, closes perforation holes through which gas is being extracted. In this case water accumulates in a bottom hole of the well. If we don't clean up this water, it will completely close all perforation holes. This problem is actual for some countries, especially for Russia and USA. On statistics of Beregovoe and Pyrejnoe fields: 21 wells of 30 are closed due to a problem of water cone on Pyrejnoe field and 8 wells of 63 are closed owing to this problem on Beregovoe field. Moreover, in USA 80% of all gas wells – it is about 170 thousands wells – also have a same problem – American Oil&Gas Reporter writes.

The following methods are known to solve this problem: periodic blowdown of wells on the flare line; replacement of pumping and compression pipes with pipes of smaller diameter; use of concentric lift system; use of surfactants with their delivery to the bottom of the well; use of downhole layouts for pumping water [1].

Our solvation of this problem consists in developing special software for controlling and analyzing well data and for controlling special well machinery configuration. Configuration consists of electric screw pump, hydro protection module and electromotor. Well is drilled bellow gas-water contact mark and it is perforated in two places – in the gas-saturated part of the formation and in the water-saturated part of the formation. There are also two packers are installed in the well – one isolates tubing from water entering and another one installed 15-20 meters below gas-water contact, near input module of electric screw pump. When a water cone appears, water will enter the well and go to the lower packer. At a certain water level in the sub-gas zone the pump will turn on. For determine the efficiency of a particular pump, it is necessary to analyze the pressure curve of the unit. If you make a mistake when selecting the pump, serious problems will occur during the operation of the gas well, which can lead to the well stopping.

Our software will automate the process of gas production. Using level sensor SUDOS-automat 2, we will track the water level. After passing a certain height mark of the water cone, the pump automatically turns on. We can also use our software to analyze reservoir conditions and try to predict the time of a next cone appearing. To analyze this, pressure, temperature and flow sensors will be installed on the wellhead fittings. At the same time, the pressure and temperature indicators will also be installed in a well bottom. Data from all sensors will be sent to a programmable logic controller that will process the received data. Already processed data will end up on a commercial PC with installed software. At the moment, the main dependencies and parameters (reservoir and bottom-hole pressure, length of perforation) for determining the

optimal flow gas rate and optimal pump flow as well as the main equation of water flow to the well [3] are included in the software concept. To develop a software concept scheme, you need to create a mathematical model that will contain certain functions.

After performing certain calculations of the operation of the "well-electric screw pump-reservoir" system, it was concluded that the development of software is necessary for stable operation of the well equipped with an inverted pump layout. At this stage, it is planned to create a stand for the study of the formation of a water cone during the operation of an inverted pump. The stand will allow you to display the main dependencies that are necessary for creating a mathematical model. The stand will also allow you to check the correctness of the obtained equation for calculating the optimal pump flow.

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EXPERIMENTAL INVESTIGATION OF THE PERFORMANCE OF LIQUID-JET GAS PUMP FOR WATER-GAS STIMULATION OF OIL FORMATION

Presently, simultaneously water alternating gas injection (SWAG) in a reservoir is an effective and promising enhanced oil recovery method (EOR). One of the most effective and reliable technologies for SWAG implementation is the use of a liquid-jet gas (LJG) pump, as part of a pump-ejector system (PES) [1]. The LJG pump is intended to create a finely dispersed water-gas mixture, where the motion fluid is a liquid and a passive agent is a gas. Several papers have been devoted to studying the performance of LJG pumps for industrial needs, however, there are no systematic investigations of LJG pumps for SWAG implementation purposes. Thus, the enhancement necessity for this line of research is of high priority.

An analysis of actual studies of LJG pumps for SWAG technology has revealed several unsolved problems. One of the main challenges is the excess gas pressure effect on LJG pump performance. The study [2], was among the first, which demonstrated the effect of excess pressure in the LJG pump suction chamber. It was noted that the pressure increasing in the suction chamber from atmospheric to 0.2 MPa had led to an increase of pump efficiency and gas injection rate almost 2 times. The bench researches [3], which were carried out at suction chamber pressure of 0.5 MPa, confirmed the significant expansion of LJG pump work performance, as well as the effect of the LJG pump throat length was noted. The studies were carried out at the ratios of throat to nozzle diameters D_t / D_n in the range of 1.09 – 1.64 and the ratios of throat length to throat diameter L_t / D_t were 11.0 and 20.0. The excess pressure in the suction chamber was 0.5 MPa. It was noted that efficient L_t / D_t for LJG pumps should be taken in the range of 20 – 30. As a result, these studies have revealed a positive effect of excess pressure in the LJG pumps receiving chamber. However, there are still no systematic studies on the effect of excess pressure on the performance of the LJG pumps for SWAG technology necessities. Moreover, the influence of excess pressures in the suction chamber at varying throat lengths of the LJG pump is also not fully understood. Since at most oil fields, the associated petroleum gas pressure is varying from 0.2 to 0.6 MPa, the investigations of the LJG pump

performance at these pressure conditions are important to enhance the SWAG implementation with the PES.

The aim of this work is to study the performance of the LJG pump at excess gas pressures in the receiving chamber. To achieve this, the following investigations should be carried out: study of LJG pump characteristics at receiving chamber pressures varying from 0 to 0.6 MPa in range of D_t / D_n from 1.38 to 1.94 (at a constant value L_t / D_t = 29.63); determination of the efficient length of the throat in the range of L_t / D_t = 11.0 - 30.0 at the corresponding excess pressures in the receiving chamber (at a constant value D_t / D_n = 1.64).

The studies were carried out on a test bench, which is designed to study the characteristics of model ejectors, multistage centrifugal pumps and pump-ejector systems on water-gas mixtures using fresh water as a liquid and air as a gas agent. The test bench with a closed-loop system of operation allows us to effectively conduct studies of LJG pumps at excess gas pressures in the receiving chamber without involving high-pressure compressors and cylinders. A detailed description of this test bench is given in [4]. Water was used as the motion fluid, and air was used as the gas phase. A diaphragm nozzle with rectangular edges was used, as well as a diffuser with an opening angle of 6°. Processing of the experimental data was carried out according to the well-known method [4], which includes the plotting of pressure-energy graphic charts under various construction designs of the LJG pump. The main parameters for the calculation were the power pressure in front of the nozzle P_p, the pressure in the suction chamber P_{in} and the pressure output of LJG pump P_o. The studies were carried out at P_{in} = 0, 0.1, 0.2, 0.3, 0.4, 0.5 and 0.6 MPa. Nozzles with diameters of 3.3 and 3.9 mm were used, the diameters of the throats were 5.4 and 6.4 mm, and the ratio of Lt / D_t was taken as 11.11, 20.37 and 29.63.

The study results of the LJG pump performance at excess gas pressures P_{in} determined the presence of the most efficient region D_t / D_n = 1.64-1.7 where the highest performance of the LJG pump is achieved. The excess gas pressure conditions lead to an efficiency increase of 55 % in contrast to atmospheric pressures in the suction chamber (from 22 to 34 %). The main increase in efficiency occurs up to P_{in} = 0.2 MPa, and with further increase in P_{in} (0.2 – 0.6 MPa) there is no significant LJG pump performance enhancement. When gas is ejected from the atmosphere, a decrease in efficiency from 23% to 19 % is observed. This phenomenon indicates a difference in the work characteristics of the LJG pump at excess and atmospheric pressures in the receiving chamber. The gas injection factor U_g of pumping gas from the atmosphere in the range of D_t / D_n = 1.38 – 1.94 increases from 1.3 to 1.8. With an excess gas pressure P_{in} = 0.1–0.6 MPa, the maximum values of U_g = 1.505–1.6 are achieved with optimal D_t/D_n = 1.64-1.7.

For further study on influence on throat length variation, the optimal value D_t / D_n = 1.64 was chosen. The length of the throat L_t / D_t was 11.11, 20.37 and 29.63. It was determined, that the maximum values of efficiency at P_{in} from atmospheric to 0.15 MPa correspond to L_t / D_t = 29.63, and at P_{in} > 0.15 MPa (up to 0.6 MPa), the maximum values of efficiency are achieved at L_t / D_t = 20.37. It should also be noted about increased pulsations with short throat values disappearing with an increase in the length. The maximum values of the developed pressure by the jet apparatus ΔP_o / ΔP_p are achieved at L_t / D_t = 11.11. With the increase of L_t / D_t to 29.63, a decrease of ΔP_o / ΔP_p from 0.29 to 0.21 is observed. However, at values L_t / D_t = 11.11, ΔP_o / ΔP_p is equal to 0.26, indicating a less sharp drop, under optimal conditions. The injection coefficients at L_t / D_t = 11.11, 20.37 and 29.63 are on average 0.9, 1.2 and 1.5, respectively.

Main conclusions of the study:

1. There are optimal values of D_t / D_n = 1.64-1.7 at which the highest performance of the LJG pump is achieved at excess gas pressures P_{in} = 0.1 - 0.6 MPa.

2. The main increase in the efficiency of LJG pumps at excess pressures is achieved up to 0.2 MPa. Further P_{in} increase between 0.2 – 0.6 MPa did not lead to extra efficiency enhancement.

3. The highest values of LJG pump efficiency at P_{in} = 0 – 0.15 MPa are achieved at L_t / D_t = 29.63, and in the range of P_{in}= 0.15 – 0.6 MPa at L_t / D_t = 20.37. Moreover, with an increase in the throat length, the pulsations of the gas ejection disappear.

ACKNOWLEDGMENTS

The publication has been prepared with the support of the «RUDN University Program 5-100».

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INTENSIFICATION OF THE PROCESS DECOMPOSITION OF OIL-WATER EMULSIONS STABILIZED WITH HYDROCHLORIC ACID

Of the wide range of existing BHT methods, the oilfields of the Samara Region mostly use treatment involving acid (HCl) treatment. As a rule, when performing the BHT, in order to minimize consequences of HCl impact on the system of gathering and processing of well production fluid the wells are usually put back to work once a certain acid value is reached, but the process of reaching the required pH values of the produced fluid may be quite lengthy [1]. Despite the fact that pH levels of produced fluid is monitored, some part of the HCl residue and/or products of its reaction may get into the oil gathering system thus affecting the efficiency of preparation of production fluid [2]. The analysis of change in the water cut of well fluid on the oil preparation facilities shows that treatment with HCl has an adverse effect on the efficiency of oil dewatering processes. Experiments have shown that even optimum dosages of de-emulsifiers have not resulted in reaching the required degree of dewatering of the oil and water emulsion [3]. Possible way of efficient destruction of stable water-oil emulsions is the use of additional reagents ensuring increased efficiency of de-emulsifier performance and dewatering of oil.

Studies of IPT on the boundaries of the 'oil - formation water - HCl' phases have shown that the increased content of de-emulsifier and HCl in the water-oil emulsion causes the IPT level to go down, yet the concentration of HCl of 1300-1400 ppm shows a further growth of IPT. The observed regularities may be related to the process of protonation of tar and asphaltenes of the oil [4], this effect is most significant with HCl concentration in the water-oil emulsion above 0.1% w/w. To confirm possible sedimentation resulting from HCl and oil reaction additional research was done using the following method: on the first stage, a solution of oil and toluene was prepared, on the second stage, a solution of oil and hexane was prepared, on the third stage, a solution of oil, hexane and hydrochloric acid was prepared. The results of the experiments showed that HCl encourage build-up of sediment especially with concentrations above 0.1% w/w.

In order to evaluate the HCl effect on the rheological properties of the water-oil emulsion, artificial emulsions were prepared with acid content of 500 ppm. Once the acid was added to the water-oil emulsion, the acidic emulsion was mixed at 1000 rpm and cured for one hour (aged). At the shear rate of 5 s-1, the oil-water and acid emulsion is over nine times higher than the dynamic viscosity of emulsion with no acid added. The effect of HCl resulted in an exponential growth of viscosity of water-oil emulsion in the considered range of shear rates which increases the stability of emulsion in a significant way [5].

In order to decompose the water-oil emulsions stabilized with HCl, a research was performed of efficiency of water-oil emulsion decomposition using the widely accepted "Bottle Test" method by which the rate of dewatering and residual water content in the settled oil were determined. The experiment included addition of 500 ppm of HCl to the water-oil emulsion and mixing for 1 hour following which the emulsion was cured for one more hour (aging of water-oil emulsion). Next, decomposition of the emulsion was tested using five industrial de-emulsifiers of various manufacturers currently, their dosage varying in the range of 100 to 500 g/t. The results of the study showed that industrial de-emulsifiers did not provide complete separation of emulsion water, the best specimen providing 24% dewatering (dosage: 500 g/t, settling time: 2 hours). The HCl fosters production of stable water-oil emulsions decomposition of which by means of industrial de-emulsifiers hardly takes place.

Development of the reagent involved over 30 organic compounds. The research method was as follows: water solution of hydrochloric acid was prepared using model water, oil was added to it, the resulting water-oil emulsion was mechanically mixed at 1000 rpm for 10 minutes, after which the water-oil emulsion was cured for one hour (aging of water-oil emulsion). After aging, an industrial de-emulsifier was added to the emulsion, the dosage being 171 g/t (process dosage), after which the mixture was mixed at 1000 rpm for 10 minutes. Then, a viscosity reducing agent was added to the system, the emulsion was given a manual mix, and cured for 30 minutes. Then, the rheological parameters were determined.

Over 12 systems were studied, and below follow the results of most effective combinations of three components: non-ionic surfactant, alkaline organic agent, and solvent. The optimal composition of the reagent is 75% w/w of non-ionic surfactant, 15% w/w of alkaline agent, and 10% w/w of solvent. The results of the study showed that with the reagent concentration of 0.048% w/w it was possible to reduce the viscosity of the emulsion by 3.2-4.8 times depending on the shear rate; with the concentration of 0.09% w/w – by 5.3-21.9 times. The fold change of viscosity was calculated as the ratio of the viscosity of the original water-oil emulsion (containing also 500 ppm HCl and 171 g/t de-emulsifier) to the viscosity of water-oil emulsion with added viscosity reducer (containing also 500 ppm HCl and 171 g/t de-emulsifier). Thus, the designed reagent can be used to reduce the viscosity of highly stable water-oil emulsions formed in the presence of HCl, and its combination with the industrial de-emulsifier allows intensification of their decomposition. Evaluation of efficiency of the designed reagent for the above mentioned technologies involved research of performance of various concentration of the reagent to reduce viscosity of the water-oil emulsion with no de-emulsifier added. The results of the study showed that with the reagent concentration of 0.12% w/w it was possible to reduce the viscosity of the emulsion by 6.3-13.6 times depending on the shear rate, with the concentration of 0.47% w/w by 10.0-21.1 times (findings obtained for temperature of 20ºC). Thus, the possibility was demonstrated of the effective use of the reagent to decrease viscosity of the water-oil emulsion formed in the presence of HCl, and, possibly, with no de-emulsifier added, which demonstrates the many ways in which this reagent can be used in the industry conditions.

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SYSTEM FOR DISTRIBUTION OF OIL PRODUCTION IN MULTI-LAYERED RESERVOIRS

Most of the oilfields in the Udmurt republic are currently on the late stage of development. Due to multiple factors their productive formations have been unevenly covered by development and oil recovery factors have not reached design values. To correctly determine the location of concentrated remaining oil reserves, the production and injection history of these formations is required to be analyzed at the scale of individual producing layers. Empirical approaches to production and injection distribution at the level of producing layers have been considered before [1, 2, 3]. However, now their development has stopped, which is largely due to the capabilities of modern hydrodynamic models.

This work presents the scientific and methodological framework of a statistical approach for the distribution of production and injection volumes over producing layers. The methodology is based on fluid distribution by hydraulic conductivity [3], with consideration to changes in the perforation intervals over time and changes in the filtration properties of the formation depending on the inflow composition. Accountancy for independent changes in the water cut for individual layers was executed with the use of oil displacement characteristics.

To implement the above-mentioned approach, an application in Python has been developed. It was used for the calculation of production and injection distribution for the Bashkir formation of the Mishkinskoe oilfield. This object was selected due to its high degree of compartmentalization and the inability to achieve the designed oil recovery factor. Based on the distribution results, the development process for three waterflooding elements has been analyzed and several recommendations were proposed.

Scientific and methodological foundations of a statistical approach for the distribution of production and injection volumes over producing layers have been developed. For calculations, an empirical model in the form of a software application has been implemented. The model is applicable both for the analysis of oil reserves development at the level of individual layers, and potentially for refining the forecast of base production.

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GLASS CERAMIC PROPPING AGENT

Propping agent (proppant) is granular material used in oil production by hydraulic fracturing. The most common are aluminosilicate and magnesia-quartz proppants. The main properties of proppants are sphericity, roundness, mechanical strength and acid resistance. Glass-ceramic materials obtained on the basis of natural raw materials have high mechanical strength and chemical resistance, and therefore are promising materials for the production of proppants [1].

For the synthesis of glass-ceramic propants, it is necessary to use rapidly crystallizing glasses with a low viscosity, which ensure the formation of a monomineral composition of the obtained product. Multiphase systems degrade the mechanical strength and chemical resistance of materials.

As the main component for the synthesis of glasses, granitoid screenings of the Mikashevichi building stone deposit in the amount of 70–90 wt. % To control the rheological properties of the melt, hardening rate, and crystallization ability, soda ash, chalk, and also chromium oxide was additionally introduced into the charge as a crystallization initiator.

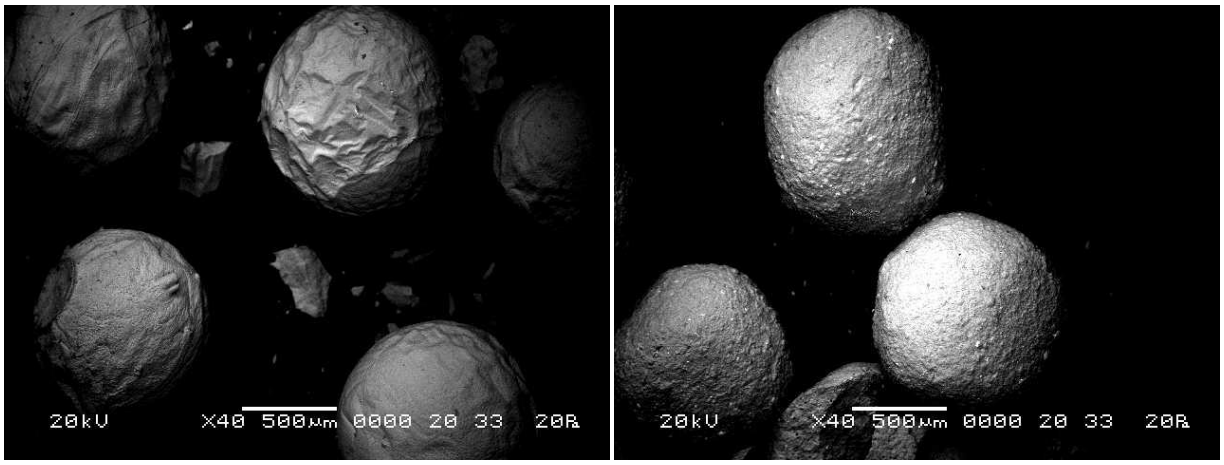
The technology for producing glass ceramics includes the synthesis of glass of a given chemical composition, the molding of materials from a melt with their subsequent directed crystallization to create products with a given set of properties. The technology is used in all cases when a material or product can be molded directly from a melt by known methods.

Glass melting to obtain glass-ceramic proppants was carried out in a gas flame furnace at a temperature of 1450 ± 10 ° C. The molding was carried out by dispersing the melt jet, followed by directed bulk crystallization of the spheres for 10–30 min at temperatures of 800–850 ° C. Using this molding method provides high sphericity and roundness compared to traditional methods of molding ceramic proppants (Figuge 1).

The synthesized glass-ceramic proppants have high mechanical strength (more than 600 MPa), high crush resistance at a pressure of 5000 psi (less than 0.3 % of broken granules) and low solubility in a mixture of HF and HCl (2.0 %).

High chemical stability and mechanical strength is ensured by the formation of a crystalline pyroxene solid solution of the augite type ((Ca, Mg, Fe^{2+}) (Mg, Fe^{2+}, Al, Fe^{3+}) [(Si, $Al)_2O_6$] during crystallization.

To assess the quality of the obtained glass-ceramic proppants, the basic properties of various magnesia-quartz and aluminosilicate proppants were studied. The results of the study showed that crushing resistance at a pressure of 5000 psi of magnesian-quartz proppants is 3-4 % of the destroyed granules, aluminosilicate granules - 2-3 %. The solubility in a mixture of HF and HCl is 8–9 % for magnesia-quartz propants, and 7–8 % for aluminosilicate.



(a) (b)

Figure 1 - SEM images of glass-ceramic (a) and ceramic (b) proppants with magnification x40

Thus, the glass-ceramic materials based on augite surpass the currently used aluminosilicate and magnesian-quartz proppants in basic operational properties. In addition, when forming spherical particles by the highly efficient method of dispersing the melt, the obtained proppants are characterized by an almost perfect spherical shape, which is difficult to achieve when molding ceramic proppants.

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THE GAS-PULSE-REAGENT PROCESSING OF WELLS

At the present time, water for local or centralized water supply systems is mainly extracted from underground aquifers by water wells. These structures must be highly efficient, durable and environmentally friendly. The extraction of water from underground sources has a number of advantages, however, the geological conditions of occurrence of aquifers, the violation of their hydrodynamic regime due to wells operation, directly affect the decrease in productivity and lifetime of water intake facilities.

Thus, as the result their specific capacity inevitably decreases. The reason for this is mechanical, chemical and biological colmatation. The bulk of deposits ate concentrated in the openings of the well screen and in the pores of the gravel pack surrounding it, which significantly decrease the flow of water into the well or its failure. Regular maintenance allows to increase their lifetime and prevent yield reduction.

Pulse methods sufficiently provide high degree of rehabilitation of specific capacity, when wells have short lifetime operations. However, pulse methods are ineffective to long operated wells. In this case the most appropriate combined processing, which include consistent or simultaneous pulse-reagent effect on sediments.

To that end, the pulse-reagent method of rehabilitation of specific capacity, based on hydrogen and oxygen gas mixture explosion in reagent, was proposed in Belarusian National Technical University (Minsk city). The equipment to realize this method consists of immersion explosion chamber with a spark plug and reflector, winch, that lowered chamber into the filter zone, remote electrolyzer, to produce and deliver by the special hoses gas mixture to the

explosion chamber, reagent tank with hoses to deliver reagent into the processing zone, remote control device.

Explosion chamber is lowered in the upper site of the well screen, and filled with a gas mixture. Then, reagent is delivered to the processing zone between chamber and reflector from the tank. The gas sets on fire. Explosion combustion creates steam cavity of high pressure and emits shock wave, compression waves to the water. This pulse action leads to destruction and dispersing colmotating deposits, and at the same time alternating flow of reagent, which occurs as a result of pulse activity of steam cavity, dissolves them. Combine pulse and reagent action provides high degree of sediments remove. In order to find factors, that effect on intensification of dissolve of deposits, such as flow filtration speed in the colmatated gravel package, were derive differential equation of transient water flow in the explosion chamber, gravel package and well casing.

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NATURAL GAS AS FUEL IS THE FUTURE OF RUSSIA

Natural gas-engine fuel is not only future of car energy, but it is already becoming present. At the last day there are three kinds of gas-engine fuels in the global market: liquefied natural gas (LNG), compressed natural gas (CNG) and liquefied petroleum gas (LPG) [1].

Natural gas as fuel are used in over 80 countries in the world. Over the period 2000 to 2019 global number of natural gas fueled vehicles has increased more than 20 times – from 1.3 million to 28 million cars. It is estimated approximately 2 % of global total car population. If the same tendency is going on, the number of vehicles will be exceeded over 30 million in 2021 [1].

At the beginning of the year, there are 28 540 819 gas fueled vehicles (over 150 000 in Russia [2]) and 33 383 filling stations (380 in Russia [2]) in the world.

Gas fueled transport is the most common in countries such as Pakistan, Iran, Argentina, Bangladesh and Bolivia, where it accounts for between 10% and 50% of the total car population. The top three countries by the number of natural gas fueled cars are China, Iran and India [3].

Demand for natural gas-engine fuel was low in Russia but had a positive trend: from 2000 to 2018 sales through gas filling stations increased from 82 million to 624 million m^3 [2]. The process came after the state price regulation was abolished. The consumption of GMT in Russia in 2019 increased by 30-40% compared to 2018 and reached close to 1 billion m^3.

The high demand for natural gas-engine fuel is caused by the following factors: the fuel is environmentally friendly [1] (consistent with EURO-6 standards), as well as the safest, in comparison with propane, gasoline and diesel fuel (the highest temperature of autoflammability is 540 ° C, the required concentration for this of 5 to 15%); there is no need to make significant changes in the design of gasoline fueled vehicles; cheap fuel cost [1].

Obviously, gas-engine fuel is cheaper than the most popular fuel - gasoline. Its price is 16 rubles per 1 m^3 against 42.7 rubles per 1 liter of Regular gasoline [2]. Moreover, since 2014 gas-

engine fuel has risen in price only by 11%, while diesel, gasoline and electricity - by 20% or more.

In our country state support is provided to stimulate the implementation of natural gas-engine fueled vehicles. In Russia, the cost of re-equipment is about 73 thousand rubles for a passenger car. It is noticeably lower than the world average value.

Since 2013, Russia has been implementing a state program to convert motor vehicles to natural gas fueled vehicles. However, experts claim that this mainly concerns municipal transport, buses and taxis.

For a variety of reasons, methane fuel (LNG and CNG) is most widely used in heavy-duty vehicles, buses and special equipment. One of them is the rapid payback period.

In Russia, annual demand for gas-engine fuel should reach 11 billion m^3 by the end of the next decade [1]. However, the convenience of using compressed natural gas is limited by the weight of cylinders and the volume of gas that can be filled in them. This disadvantage eliminates LNG – its volume during liquefaction decreases 600 times (for CNG – 200 times).

LNG, as a more expensive variant than another gas-engine fuel (e.g. CNG) due to the method of obtaining and storage conditions, is usually used in vehicles with high carrying capacity.

Also, under discussion is the possibility of expanding the annual state support for the period 2020-2024 to 10 billion rubles. It is also assumed that from 2020 1 billion rubles will be spent to support research and development work in the gas-engine fuel sphere [1].

By 2024 it is planned to increase the number of stationary gas filling infrastructure by 3.5 times (up to 1273 units), and the number of natural gas fueled vehicles - up to 307.5 thousand units. At the same time the market volume should increase by 6 times (up to 3.8 billion m^3 per year) [2].

However, it is necessary to convert and produce not only heavy vehicles, but also cars. To stimulate the process of converting cars to gas, the authorities reimburse residents up to 100% of the cost of re-equipping their cars. But the population is not motivated to convert their cars due to the small number of gas filling stations in the country. Therefore, firstly, the state should support the construction of the gas filling infrastructure.

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THE RESEARCH OF NEAR-WELLBORE ZONE PROCESSES USING NUMERICAL SIMULATION

Nowadays field exploration and development becomes more and more complicated. Sandstone oilfields has high risks of different formation damage processes even when enhanced recovery methods planned to use. The only way we can develop them is to choose right technology regime and well treatment methods. And results of this work can help in the process selection, comparing and making optimal decision.

This work is dedicated to understanding of how formation damage can influence on oil fields development and how this understanding can help us to improve development and technological strategy. Sandstone acidizing is one of the most complicated tasks in oil industry. The possibility of negative result is high and depends on well operation quality, design and well selection. Sandstone reservoirs includes huge number of minerals so for every case we need the right acid composition. We also need to understand the type and causes of formation damage for right acid composition selection. There are a lot of processes that influence on oil well productivity, and the first task in well candidate selection is to calculate the part of formation damage skin in the whole productivity decreasing. The second task is to evaluate type of formation damage. Formation damage evaluation implies understanding of all processes in near wellbore zone that could be described using hydrodynamic, geomechanics and geochemistry knowledge and a lot of laboratory and field equipment.

The main risks that are evaluated in field simulation refers to geological uncertainty. Nowadays field exploration and development becomes more and more complicated, and the influence of wellbore reservoir boundary on economic index becomes bigger. Thus the understanding of methods to avoid or solve formation damage problems will help us to make greenfields and even brownfields profitable. In this work formation damage uncertainty was included in oilfield simulation. Hydrodynamic models were improved with formation damage models to simulate different scenarios of well productivity changing. Then results of all simulation were used in economic model to calculate profitability of different cases.

Improved hydrodynamic and economic modelling allowed us to understand how formation damage and formation damage factor uncertainty influence on oilfield development project. Different formation damage simulation models were used and compared. A new methodology for selection the most effective technology strategy of oilfield exploration was developed.

Matrix stimulation in sandstones is high level complex technology that needs a special instrument for it’s use. To reach a high level of effectiveness after well stimulation we need to know the reason of productivity decline, chose right technology and reagents and to have a detailed plan of operation. This plan is usually named design and it includes a lot of characteristics from concentration to time-dependent acid rate that were calculated with aim of achieving the maximum effectiveness of well operation. Traditionally the high demand for design of well operations relies to hydraulic fracture. Today the technology level allows us to use full abilities of numerical simulation for improvement of matrix acidizing operations in sandstones.

The currently existing commercial software for design of acidizing can’t model all chemical and hydrodynamic processes that occurs in formation during well operation. Moreover, the opportunities of specialized software are limited in tasks of optimization issues. Optimization tasks usually is the prerogative of operator.

The main idea of new simulator [1, 2] is describing all processes in near-wellbore zone that affects on formation properties. The demo version of simulator considers user-friendly interface for working with data and visualization of results. Software can work with optimization algorithms to maximize efficiency of matrix stimulation creating different variant of operation design. The simulator provides modules for assessing the economic efficiency of well operations a machine learning module for analyzing the past real experience and for analyzing previous calculations and designs. That software allowed us to find most effective approach to stimulation technology in current conditions of brownfields based on sandstone reservoirs. The process was based on tgree stages: modelling of near-wellbore zone, modelling of acidizing and forecasting of well rate and economy of well in variety of different well stimulation designs.

The main idea is in improvement of the effectiveness of acid treatments in sandstone reservoirs by developing and realization of the comprehensive simulation based approach for well stimulation. The basis of this concept is to apply a scientifically based approach to all stages of the well stimulation program: from identifying the type of formation damage, selection of

wells - candidate, and ending with the design of the matrix acidizing and the processing of results. Computational tools with the assistance of laboratory studies have been created and analyzed to implement this approach and make it useful in real oil production.

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REDUCTION OF TIME FOR STIMULATION OF WELL AFTER FRACTURING

Currently fracturing is one of the most efficient methods to increase productivity of oil and gas wells. The most dangerous effect after fracturing is proppant entering the wellbore. Initially proppant places in the fractures, but it is taken out of cracks in the process of stimulation and exploitation. As a result proppant with gel sediments in the perforation channels and on the walls of the hole. It causes decline in efficiency of fracturing [1].

In order to solve the problem device washing perforation channels has been developed. The main advantage of the proposed device is the ability to wash the perforation channels due to the action of liquid jets at an acute angle to the casing. In addition the price of the device is lower in comparison to foreign analogues [2].

The device is lowered into the well up to necessary depth. Then flushing liquid is pumped through this one. As a result liquid jets wash perforation channels. Furthermore this equipment rotates relatively the surface of treatment while the constant flow goes through the device [3].

During the work the prototype of the device has been got and implementation plan has been developed. All gas and oil companies around the world can use the device after fracturing in order to reduce time for stimulation.

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IMPROVING EFFICIENCY OF GAS LIFT WELLS IN THE CONDITIONS OF THE FORMATION OF ORGANIC WAX DEPOSITS IN THE DOWNHOLE EQUIPMENT IN THE DRAGON FIELD

A principal challenge in many oil industry production situations is paraffin wax. Up to 75% of the world's oil suffers when wax precipitates out and solidifies in formation pores and fluid flow channels, at the wellbore, on the sidewalls of wells, in the tubing, casings, pump strings, and processing system. Wax deposition is costly and one of the oil industry's most expensive inconveniences, leading to dramatic reductions in production, equipment failures, loss of storage and transport capacity, and loss of efficiency. In the majority of cases, oil is a complicated dispersion system, which contains a variety of components [1]. In addition, the wax appearance temperature (WAT) and other parameters of oil will relatively be affected by changes in oil composition. Thus, only by elaborating and studying all information about the effect of external factors on changes in the WAT can engineers accurately predict the potential wax formation zone on the wall of a pipeline as well as the timing of its occurrence. [2,3,4].

Detailed design of production systems is required to improve the efficiency of oil production and exploitation. The novelty of this paper is to provide a detailed study of the effect of oil blend composition on conditions and nature of wax deposition based on a developed formation oil model. In addition, a methodology has been developed for determining changes in the component composition of oil in a gas-lift well during the injection of produced petroleum gas. Based on the results of calculating the change in the component composition of the gas-liquid mixture, the change in the wax appearance temperature was determined, and the depth of the onset of the wax formation was determined.

This work presents the effect of changes in the composition of high-wax reservoir oil on the condition and nature of the wax formation based on a developed reservoir oil model through the Multiflash 6.1 software product. The optimal operating regime of a gas-lift well (flow rate and the injection pressure of produced petroleum gas) has been determined using an analysis of the reservoir-well hydrodynamics system. Taking into account changes in the oil component composition during gas injection, the depth of wax formation has been determined by applying a developed method.

Using the system analysis function to evaluate the effect of a change in the volumetric flow rate of the produced compressed gas injection on the liquid flow rate of a gas-lift well with an increase in the water cut makes it possible to determine effective well operation regime.

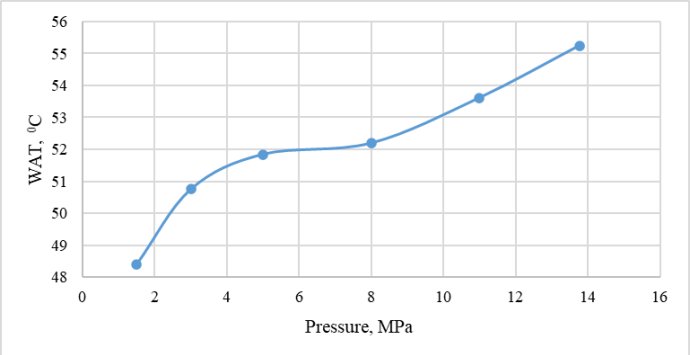

Figure 1 - Changes of the wax appearance temperature in accordance with the change in the pressure and temperature using the developed algorithm

A methodology has been developed for determining changes in the component composition of oil in a gas-lift well during the injection of produced petroleum gas. As a result of the analysis of the gas lift well of the Dragon field in Vietnam, it was observed that when the pressure decreases during the lifting of the fluid along the wellbore, the wax appearance temperature decreases and the depth of onset of wax formation in oil is from 300 to 400 m from the well-head.

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EXPERIMENTAL RESEARCH OF VERTICAL GAS-LIQUID FLOWS WITH A FOAMING AGENT

In the process of development of gas and gas condensate fields as depletion of deposits there are a number of related problems. One such problem is the accumulation of fluid at the bottom hole, which leads to a decrease of their production rates, or well shutdown. It should be noted that the problem occurs in almost all wells completed as high-permeability and low permeability reservoirs [1].As accumulating on the bottom hole of the well fluid can be condensation water is passed into the liquid phase in the upper parts of the wellbore, flowing down the tubing string coming from the reservoir brine of natural origin or technical water. These fluids can enter the well bottom hole at the same time in different quantities.Fluid accumulation occurs due to insufficient flow rate of gas-liquid mixture in the produc-tion string and tubing strings, including the perforated interval or filter. This problem may occur if the increase in the share of liquid extracted from the reservoir fluid. Large amounts entering the bottom hole fluid are not in time be brought to the surface at the same flow rates of gas in the wellbore. Emerging hydraulic resistance leads to a decrease of well production on the gas and the accumulation of fluid on the bottom hole with a gradual complete killing of well hydrostatic pressure. In addition, due to the flooding of the reservoir gas and gas flow rate fall as a result of decreasing gassy bulk of reservoir rock and reduce permeability of the reservoir gas during the growth of the share of the liquid in the reservoir formation. Another common reason for "self-kill" wells is a gradual decline in production rate (velocity) of gas due to the inability to further reduce bottom hole pressures after the natural decrease in pressure in the reservoir. To continue to further reduce the mouth of well and bottom hole pressure, mainly, does not allow the compressor equipment. As a result, even at a low concentration of liquid in gas (e.g., condensation water), it is not made from the well and gradually builds up, leading to a drop in the rate of gas production and well shutdown. Turning to the description of the problem of liquid loading at Russian fields, it should be noted that in recent years about 80% of natural gas is extracted from Cenomanian gas deposits in Russia [2]. Considerable part of the Cenomanian gas deposits are in the later phase of development, which leads to the manifestation of the described problems [3].

The choice of wellbore intervention (WI) to combat the accumulation of liquid is due to both the technological features of the production process at a particular field, and the economic efficiency of their application. In addition to the previously mentioned WI, the technology of introducing foaming surfactants into the well is widespread in the world, which is characterized by a relatively low level of capital investments and a high level of efficiency, including economic efficiency. Surfactants can be introduced into the well as solid rods or pumped as liquid solutions. With proper selection of the composition surfactants can be used to remove water (condensation and formation), gas condensate from both vertical and horizontal wells, at different pressures and temperatures (including high) [4]. In the Russian Federation considerable experience of application surfac-tant in various regions is accumulated: on fields of the North Caucasus, Krasnodar Krai, the Orenburg region, Far North (Yamburg, Urengoy, Bear, etc.). It should be noted that in the production of Cenomanian gas at the bottom of wells, only water accumulates mainly (more often condensation), which creates favorable conditions for the use of surfactants in such wells. As production technique of Cenomanian gas wells with introduction of a foaming agent is becoming more common it's necessary to take into account a differential pressure in well. To-day, in hydrodynamic simulation of gas field exploitation, the problem is the lack of multiparameter models (functional relations) describing the polyphase foamed flow in gas well with surfactants. These models represent multidimensional arrays (VFP-tables) and characterize differential pressures between the bottom and the mouth of well. The analysis of the results of best practices in the study of gas-liquid lifts, including foamer in the flow, showed that to be able to more accurately simulate pressure drop in the wellbore of a gas well working with surfactants, it is necessary to conduct experimental bench studies taking into account the characteristics of the physical parameters of specific conditions (pressure, temperature, gas-liquid ratio, etc.).

Based on the analysis, taking into account the specific features of the development of Cenomanian gas wells in the Russian Federation, as well as the relevance of the problem of their "self-kill", the authors of the article designed and implemented an "Experimental stand to simulate a gas-liquid mixture and dynamic processes in the gas well". With the help of the facility it is possible to conduct experiments related to the simulation of dynamic processes occurring in a gas well working with liquids, including those in interaction with surfactants and other non-aggressive chemicals, and to obtain digital data. Types of possible experimental studies: a) study of the processes of "self-kill" of the well with liquid; b) study of the processes of deliquification the well from the liquid gas flow; C) study of the processes of removal of liquid using liquid surfactants of different types and concentrations. It should be noted that with the help of the stand it is possible to reproduce physical conditions similar to the conditions of Cenomanian gas wells of fields with falling production: automatic keeping of pressure up to 1.5 MPa, temperature in the range of 15- 50 °C, water-gas ratio (including low WGR < 10−5). Experimental studies were conducted on gas-liquid flows with cationic, non-ionic, and amphoteric foaming agents in a wide range of flow parameters. Experimental correlations of the pressure gradient from the flow parameters are obtained. As part of the development of the work, it is planned to create a calculated model of the pressure gradient in a gas well under the foam flow.

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BENCH STUDY OF MULTI-STAGE CENTRIFUGAL PUMP CHARACTERISTICS FOR WATER ALTERNATING GAS INJECTION

In present time, growing an interest of use simultaneous water alternating gas (SWAG) to increase oil recovery. This method includes such positive aspects as the waterflooding for maintaining reservoir pressure and associated gas utilization. One of the perspective solution to increase oil recovery is using a pump-ejector system. The pump-ejector system for realizing of SWAG allows to prepare liquid-gas mixtures on the surface and injection into oil formations in wide range of flow rates and pressures and there is not required to create high-pressure gas pipeline and gas injection wells for well-head pressure and submersible equipments. Pump-ejector systems are simple, technological performance and has high economic benefit.

In the structure of the pump-ejector system [1] includes an ejector, pump and surface booster pump. During operation, pump injections water into nozzle of ejector and luquid-gas mixtures pumps into oil formation by surface booster pump. The surface booster pump is necessary due to the pressure limitation at the outlet of the ejector and the resulting mixture must squeezed to the desired values. In this reason, using of multistage centrifugal pumps.

One of the negative factors for the operation of surface booster pump is the presence of free gas in pumped injectant. An increase quantity of free gas in the liquid-gas mixtures leads to deterioration in the parameters of pumping equipment. When the gas content in the pumping liquid exceeds 30 %, it stops the operation of multistage centrifugal pump.

In [2], while conducting experimental studies, it found that the influence of gas on the characteristics of the surface booster pump reduced when salt added to water. With an increase in the limiting concentration of salt in the working fluid, it leads to complications of the booster pump and leads to premature equipment failure. At the oilfield Samodurovskoe , it was planned to add foaming surface-active substances (SAS) to prevent a pump starvation, but the pump-ejector system successfully worked on a water-gas mixture with mineralized water in this field, which led to cost savings.

In [3], it shown that in the case of unsuppressed coalescence of gas bubbles, a strong effect of free gas on the operation of a multistage centrifugal pump during the evacuation of water-gas mixtures observed. The experiments were carried out at absolute pressures at the pump inlet Pin = 0.3, 0.4, 0.5 MPa. The pressure at the intake ejector was close to atmospheric conditions. Similar studies of the effect of free gas on the operation of the booster pump carried out at elevated inlet pressures.

Experimental studies of the effect of free gas on the operation of the surface booster pump carried out at the stand proposed in [4]. This stand consists of the main components: a hydraulic accumulator, a power pump, an ejector, a booster pump and compressor. Also used a portable laser tachometer for measuring the frequency of rotation of the motor shaft. The gas content at the booster pump intake $\boldsymbol{\beta}_{\text{in}}$ was determined as

$$\beta_{in} = \frac{Q_{in}}{Q_{in} + Q_L}, (1)$$

where Q_{in}-the volume of free gas flow rate ender thermodynamic conditions at the pump intake; Q_L-the liquid in the same conditions.

The characteristics of surface booster pump during the evacuation of water-gas mixtures studied at various pressures at the inlet pressure of 0.2, 0.3, 0.4, 0.5, 0.6 MPa. Interval of supply

of working fluid 0.78 m3/h to 1.03 m3/h. The intake pressure at the ejector varied from 0.2 to 0.37 MPa.

Studies have shown that the negative effect of free gas on the operation of a multistage centrifugal pump at β_{in}> 8 % in the range of Pin = 0.2, 0.3, with Pin > 0.3 MPa, is observed to improve. At Pin = 0.4 - 0.6 MPa the pump pressure, practically does not change when the fluid supply is from 0.78— 1.03 m3 / h. With an increase in Pin, the influence of gas on the operation of the booster pump decreases, due to the suppression of the coalescence of gas bubbles.

At the same time, the previously established [5] was confirmed with an increase in pressure at the pump inlet and constant gas content, the pump parameters do not improve on the gas-water mixture.

Results:

1. Booster pump characteristics investigations during the pumping out of water-gas mixtures at elevated inlet pressures showed that the gas has a negative effect on the operation at P_{in} = 0.2, 0.3 MPa at β_{in}> 8%, and with the increase in pressure P_{in} > 0.3 MPa, the effect of gas on the characteristic the pump decreases with increased inlet pressures from 0.2 -0.37 MPa.

2. It found that with an increase in P_{in} and with a constant gas content, the operation of the booster pump improves.

3. Further investigation of the characteristics of the booster pump when pumping the water-gas mixture is need to using saline water at elevated inlet pressures.

ACKNOWLEDGMENTS

The publication has been prepared with the support of the «RUDN University Program 5-100».

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EXPERIMENTAL STUDY OF THE POSSIBILITY OF ACCELERATING THE PROCESS OF DEVELOPING GAS HYDRATE DEPOSITS BY THE REPLACEMENT METHOD

The relevance of the study of gas hydrates and technologies for developing gas hydrate deposits in the near future is becoming increasingly urgent in connection with the increase in human consumption of natural gas as the main source of energy. In 2018, consumption growth amounted to about 20%. [1] With these increases in consumption and depleting reserves of conventional gas fields, the issue of developing gas hydrate deposits will soon become an issue.

Among the proposed methods by world science for the development of gas hydrate deposits (decompression, heat supply and the injection of inhibitors), the substitution of methane in gas hydrates using carbon dioxide is also the most promising from an environmental point of view. In many modern works, there is a statement of the fact of an increase in the global temperature of the planet, thawing of glaciers in the Arctic zone and the displacement of warm ocean currents. Concerning these facts, for the next century, the technology of "substitution" may become the key, both from the point of view of the industrial "burial" of carbon dioxide emitted by civilization, and from the point of view of preventing the "shot of a hydrated gun" that will occur when the temperature of the oval deposits reaches the decomposition point methane hydrate.

The technology of developing gas hydrate deposits by replacing methane with carbon dioxide in hydrate is quite long in time. The main methods of intensification of this process are considered in the work, a number of unique laboratory experiments are carried out, some patterns are deduced.

A number of experiments were carried out on the formation of gas hydrates using various techniques, such as lowering the temperature and thermal stimulation. After calculating the amount of gas transferred to the hydrate, an increase of 43% was detected in the volume of the gas transferred to the hydrate form using thermal stimulation technology.

A series of experiments was carried out on the replacement of methane with carbon dioxide in gas hydrate using various intensifiers of the substitution process. Obtained data in previous work [2] was supplemented. When nitrogen was used as the gas of the intensifier of the substitution process, a growth of 15% in the volume of carbon dioxide substituted for methane was revealed at a ratio for the same period of time and the same experimental conditions. When atmospheric air was used as a gas intensifier for the substitution process, as a cheaper alternative component, a 36% increase was detected in the volume of carbon dioxide that replaced methane in a 30/70% ratio for the same period of time and the same experimental conditions. When applying thermal stimulation and substitution using preheated carbon dioxide, the growth was 44% and 52%, respectively. From the point of view of the mechanics of the process, substitution of methane with carbon dioxide in the hydrate is the most beneficial. However, the use of such a technology is not profitable from an economic point of view, as well as from an environmental point of view. The application of heat to the hydrated reservoir may cause an uncontrolled chain reaction of dissociation of methane hydrate.

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RESEARCH OF CONDITIONS FOR HYDRODYNAMIC SIMULATION OF INFLUXES

Oil and gas reserves are currently key assets of each oil and gas company. When designing a field development, a hydrodynamic and geological model of the field is built. gas. A geological model is necessary to get an idea of the structure of the resrvoir, the nature of the distribution of the parameters of the resvoir and fluid, the value of the hydrocarbon reserves that are in it. A hydrodynamic model is needed to simulate the oil and gas production process. The hydrodynamic model incorporates a model of fluid flow through the pore space. The rock

permeability coefficient is one of the key parameters in modeling the process of fluid movement in the pore space. This coefficient depends on various processes, including changes in the stress-strain behavior (SSB). VAT is associated with the following parameters:: 1. Physical and mechanical properties of rocks [1-4]. 2. Pore and confining pressure [5-6]. 3. The properties of saturating fluid, etc. [7].

To assess the effect of pore and confining pressures on rock permeability, laboratory studies were performed on sandstone from a resrvoir in Western Siberia. The sample was subjected to stepwise increase and decrease in confining pressure with a measurement of permeability.

Based on the results of the researches performed it may be concluded that: 1.In the course of the tests the decrease in the permeability of the rocks under the confining pressure increase was observed. In order to clarify the parameters and to determine the more accurate dependence between the confining pressure and the permeability it is required to prolong the duration of the test.2.The permeability decrease for fine- and medium-grained sandstone is non-linear. When the confining pressure is released the initial parameters of the specimen permeability are not recovered, this fact demonstrates that the formation of residual deformations of the rock began.3.Determination of qualitative criteria for the dependence between the rock permeability and the stress-strain behavior of the reservoir will allow to adjust the definition of ultimate oil recovery factor, which will affect the assessment of the profitability of developing an oil and gas field.

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COUPLING CORE FLOODING AND DIGITAL ROCK ANALYSIS TECHNIQUES FOR ROCK PROPERTIES CHARACTERIZATION

The evaluation of the rock properties is of paramount relevance for any field development plan of a petroleum and gas project. It is of vital importance for the energy company to understand, not only the physical properties of the rock, but also the capability of the porous medium to flow oil, gas, and water. This study encompasses the extensive investigation of two carbonate outcrops samples in terms of porosity, pore framework, and absolute permeability.

The pore space and the physical properties inherent to the fluid flow mechanism through the porous medium are the primary concern of this study. A holistic approach is utilized for this investigation integrating data from core flooding and digital rock fluids consistently.

Through direct measurements on core samples, rock properties are extracted and fluids predictive recovery efficiency may be projected. Coreflooding is a classical tool in this industry and becomes a determinant method to understand the fluid flow mechanism at a macroscopic dimension. Digital rock physics is becoming in recent years a vital tool to predictive studies. Digital rock physics gives insights about quantitative information of the rock topological and geological properties constrained at the microscopic level.

This paper evaluates two distinct outcrop carbonates, an oolitic and bioclastic calcarenite. Accordingly, this study has four key objectives. Firstly aims to estimate the permeability and porosity of the two outcrops, at micro and mesoscale. Secondly, evaluate the impacts of confining pressure in the pore framework. Thirdly attempts to assess the pore type and pore size distribution of each outcrop. Finally seeks to evaluate the effectiveness of integrating coreflooding and Digital Rock Physics (DRP).

A combination of laboratory work and simulation through computational fluid dynamics was computed in a coherent method.

The method applied to obtain laboratory porosity was the liquid saturation method. Moreover, permeability measurements were completed via the fallof method. Both of which recurring to the use of a coreholder.

Digital Rock Physics technique was accomplished by means of microtomography imaging. The imaging work was carried out at LAMPIST. A series of X-ray radiographs were taken to both rock specimens, such as oolitic and calcarenite carbonate. Providing a direct way to infer the rock skeleton as a volumetric representation. The image analysis through microtomographic scanning processes has conventionally grounded in five principal procedures, such as a) acquisition b) slice reconstruction c) rendering c) result analysis d) interpretation

The findings of this study suggest that the batonian oolitic has a lower permeability (>0.9 mD) and porosity ($\bar{x}$ 13%). Furthermore indicate that the Tortonian calcarenite, under ambient conditions, has interparticle porosity ($\bar{x}$ 25%) and is extremely permeable to water (>1000 mD). Nevertheless, under confining pressure (250 bar), the calcarenite modifies completely the pore structure (ϕ $\bar{x}$ 10%; k $\bar{x}$ 7 mD). This paper strengthens the idea that can be useful to the simultaneous integration of core analysis and digital rock physics data, enabling more accurately the characterization of the macroscopic and microscopic features of interest. Integration data coming from both sources are essential to minimize uncertainty and errors. Moreover, this paper critically analyses the pore size distribution of both samples. To the best of our knowledge, this is the first study of substantial extension, which examines the association between the fluid flow at the macroscale and the microscale of these two outcrops. These findings make several contributions to the current literature of these two specimens, in terms of fluid flow mechanism and rock topological features.

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NUMERICAL STUDY ON THE INFLUENCE OF THE DISPLACEMENT ANGLE IN OIL RECOVERY FOR SEVERAL VISCOSITY RATIOS IN COREFLOOD EXPERIMENTS

Oil companies are concerned with the efficiency of their operations to reduce costs, along with their social and environmental impact. One of the most significant issues is related to high water production in heavy oil and mature fields. The primary cause of this issue is a phenomenon called Viscous Fingering, one of the mechanisms that describe multiphase flow through porous media, where water moves through oil displacing its production dramatically, increasing especially the lifting costs [1]. Coreflood experiments are of significant importance for the oil reservoir characterization. Furthermore, these experiments are helpful in the study of oil recovery where breakthrough times, production profiles and sweep efficiencies can be measured.

However, research involving experimentation can be expensive due to the costs of materials and equipment. Therefore, numerical simulations can be a low-cost solution. Even more, they can show results that otherwise will require sophisticated experimental facilities. For example, the visualization of the movement of the fluids inside the porous media in 3D. In this study, a Computational Fluid Dynamic (CFD) model capable of describing the Viscous Fingering in coreflood experiments in 3D was developed and validated against experimental data. The model allowed the analysis of the effect of different viscosity ratios, and the effects of the coreflood inclination over the immiscible displacement of oil and water, and whether this affects production rates, as well as the recovery factor.

It was found that the model was capable of describing Viscous Fingering for three viscosity ratios and four coreflood inclinations, from vertical upward displacements to horizontal displacements showing gravity segregation. Moreover, it was found that the deviation against experimental data reported in the literature [2] for the vertical displacements was below 15%, showing fair agreement. Also, the results showed that as the viscosity of the oil increases, the oil recovery decreases. On the other hand, as the core gets inclined, the viscous fingering dynamics are affected. The results could be necessary for the understanding of the 3D Viscous Fingering in heavy oils and the design of water production solutions.

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LOG-BASED PORE PRESSURE PREDICTION IN GAS RESERVOIRS: CASE STUDY OF TWO SELECTED GAS RESERVOIRS, SOUTH IRAN

Pressure of the fluids trapped in porous rocks is known as the pore pressure (PP) in which a precise prediction of its magnitude is crucial in oil and gas industry. Specifically, a good understanding from the formation PP is determinant for safety and optimization of the drilling program [2].

Today, although several approaches exist for PP prediction but the associated difficulties and uncertainties in Carbonate formations persist mainly due to their significant multi-scale heterogeneities [2,3].

There are several conventional methods for determining the pore pressure in which calibration is needed for efficient and accurate prediction. The calibration is done empirically in most cases but in some cases, it is possible to rely on the drilling experience to provide calibration points. However, drilling operation is complicated and high pore pressure could cause some problems such as kicks or borehole breakouts, which in turn contributes to the non-accurate calibration points.

It has been shown that PP is foreseeable from variation in specific rock physics properties, such as, sonic velocity and electronic resistivity. However, the conventional PP prediction methods may not be reliable to be used for carbonate rocks mainly since at this type of rocks the porosity usually follows the effect of chemical process and cementation post diagenesis rather than the mechanical compaction [3,4].

Although significant work have been performed on PPP in oil reservoir there are still question regarding the possibility of such a prediction in gas reservoirs, specifically, the overpressure ones. The present research aims to fill the gaps in this regards through discussion on PPP in selected overpressure gas reservoirs in south Iran showing a range of porosity between 8 and 12%. Well A is currently producing at depth of 2841 meters and well B is producing at depth of 3085 meters.

In this work, collected data were processed using the well-known suggested models by Anselmati and Castagna (1993). The DT and RHOB logs as well as RFT data were used for predicting the pore pressure[1].

In summary, best fitted model was achieved from the Anselmati equation mainly due to the fact that apparently the Castagna model works effectively only for pure dolomite rocks and the samples from well A & B contains some other mixed lithology. However, it should be noted that there is a crucial condition for using the Anselmati model that is lack of siliciclastic content within the matrix of the target carbonate rock.

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SELECTION AND CALCULATION OF A DEVELOPMENT SYSTEM AN OIL FIELD, WHICH IS LOCATED IN THE ARCTIC SHELF OF RUSSIA

In the recent years, the Arctic region is entering a new stage of its development closely connected with the exploration of natural resources confined to the offshore areas. The development of the Arctic shelf zone oil fields is the strategic target for Russia. In long term they are to replenish the depleting onshore resources. The Pechora Sea is one of the richest in hydrocarbons areas of the Arctic shelf zone. Five oil and oil and gas fields have been discovered in its eastern part. They all have been ranked according to their development potential and the first on the list is the oil field under examination in this paper.

The oil field is in the eastern part of the Pechora Sea, 130 km to the south of the Novaya Zemlya archipelago, 80 km north of the mainland. Sea depths in the area vary between 25 and 45 metres [1]. The area is of severe weather and ice conditions. Average annual temperature is –2 degrees C, while in coldest months it can reach –40 degrees C. The strongest winds in the area are in November to February with the average monthly velocity being 8 metres per second. Maximum wind speed is up to 28 m/s gusting to 40 m/s. Ice cover season lasts from November to June. Ice thickness in the field area averages between 0,5 and 0,7 metres, with the thickest point of up to 1,2 metres [2,3].

The oil-bearing structure is a long and narrow anticlinal fold. Its size is estimated 45 km long, 2,0 – 2,5 km wide and 160 m high. The deposit is of massive type. Productive reservoir – bed is confined to the deposits of Serpukhov and Bashkir floors of the Lower Carboniferous period. The reservoir is mainly made up of grained, silt-grained, and low-permeable limestones. The reservoir is of fractured and porous type [4].

Since the field is located in the area under hard ice and weather conditions, the only feasible way of its development is to install a gravity based structure (GBS).

The rationale for the selection and oil field development system computation is an exceptionally hard scientific and technical task. Severe climate of the Arctic region, hard ice conditions remoteness from providing stations multiply the cost of projects. In addition, drilling limitations and slow rates of drilling create obstacles while designing the oil field development system [5].

To deal with these problems one needs to engineer oil field development systems which will ensure intensive oil production thus obtaining significant revenues to pay off the expenses. Hence, the main criterion for selecting a field development system in the Arctic shelf zone is the economic one. The number of wells projected is determined solely by profitability of drilling aimed at maximum well discharge acquisition.

The field development systems in the Arctic region are engineered using horizontal wells since only such systems with are capable of providing profitable oil production on the Arctic shelf zone due to the fast rate of the field development [6].

Having analyzed the oil field geological and physical data as well as considering the specificity of the field development and engineering, it was determined that the linear system of

horizontal wells will be the most favourable one for its exploitation. This system consists of one row of horizontal production wells placed centrally and lengthwise the oil-bearing structure and two rows of injection wells placed along the oil-bearing boundary from its southern and northern sides: 9 production and 9 injection wells in total. The proportion of production and injection wells is 1:1.

Because the main criterion for drilling wells on the Arctic shelf zone is its economic profitability, the calculation of the expected horizontal section length was made considering the accumulated discounted cash flow estimation.

Horizontal wells initial flow rate was calculated using Joshi method; horizontal wells critical flow rate – by Chaperson method [7]. Horizontal well breakthrough time was calculated using Papatzacos method [7]. To estimate pressure variations at the well drainage boundary during the oil field development Y. Zheltov method was used [8]. The main technological indicators of the field development were calculated using TatNIPIneft (Tatar Scientific Research and Design Institution) method for the model of a layer-by-layer and zonally heterogeneous in its reservoir properties bed [9].

Accumulated discounted cash flow and return index estimation has indicated that the field development project can be implemented with oil price being 110 dollars per barrel.

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MECHANISM EVALUATION OF RESERVOIRS SOURING, IN THE BEGINNING OR IN THE LENGTH OF OIL PRODUCTION PROCESS AND WATER INJECTION AND PRESENTATION OF SOLUTIONS FOR AGAINST HYDROGEN SULFIDE PRODUCTION IN ONE OF THE IRANIAN OFFSHORE OIL FIELDS

One of the most important challenges in industry world wide is the problem caused by hydrogen Sulfide or H2S. Further than being hyper toxic and dangerous for the employees who work on the field, its 'corrosives Will inflict significant costs to the industry. In this project, by studying the samples of injected water and Formation water from one of the fields with the use of Gas Chromatography (GC), Gas Chromatography-Mass Spectrometer (GC-MS). We tend to find the origin of creation and development of hydrogen sulfide in the field. By understanding the reasons, it can be Confronted easier, and proceeding to protected production and optimized utilization. In order to evaluate the origin of hydrogen Sulfide in the Hydrocarbon Reservoirs, we will study these elements in the reservoir: 1- Temperature of the reservoir is the most important element in evaluating the type of souring process. 2- Study the forms and distribution of Sulfate in reservoir, is essential in Thermochemical Sulfate Reduction (TSR), Bacterial Sulfate Reduction (BSR). 3- Study the microbiology of the produced water in order to evaluate the reservoir potential of Bacterial Sulfate Reduction.

The goals of this study:

1. formation evaluation and determine the regions with potential hydrogen Sulfide production in the field, and prepare the map of hydrogen Sulfide amount in each field;
2. study the origin and production mechanism of hydrogen Sulfide in the field;
3. determine the causes of volume increasing hydrogen Sulfide;
4. costs and difficulties reduction caused by high amounts of hydrogen sulfide in gas production and transfer.

Importance and necessity of research: By finding the reasons and origin of hydrogen Sulfide and determine the zones of hydrogen sulfide, the risk of exploration and production can be reduced. The ability to extend achieved science will clarify true value and importance of this study by applying them to other fields or regions. Hydrogen Sulfide is an undesirable compound that not only reduces the volume of economical value but also has toxic effects that corrode equipment's. Increased amount of hydrogen Sulfide leads to problems like environmental pollution in case of leakage, sweet reservoir pollution by the leakage from the sour reservoir and therefore increasing in costs of upgrading production utilities.

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SCIENTIFIC JUSTIFICATION AND TECHNOLOGY DEVELOPMENT OF ULTRASONIC AND MAGNETIC INFLUENCE FOR DESTRUCTION STABLE WATER-OIL EMULSIONS

Preparation of wells production to the requirements of the first quality group for the commercial purposes is becoming more relevant every year in the Perm region. Most operational facilities are in the final stages of development and are characterized by high water content of well products, which later leads to the formation of water-oil emulsions (WOE) during transportation and field preparation. Stable WOEs are poorly exposed to destruction when prepared by traditional methods, such as thermal and thermochemical gravity sedimentation. These preparing methods are easy to use, but do not always provide the expected result. In this regard, an urgent task is to find and apply new technologies for the preparation of hydrocarbons, which can be used separately from traditional methods, or in combination with them. These are methods of ultrasound and magnetic impact. [1,2]

The main purpose of this work is to determine the effectiveness of the application and selection of optimal conditions and operating modes of ultrasonic and pulsed-magnetic technology for the destruction stable water-oil emulsions. The authors of the article conducted pilot tests on the mobile well production preparing unit (MWPPU) with the use of ultrasonic and magnetic impact on stable WOEs. [3]. It should be noted that with the help of the MWPPU, various processes of oil and water preparing can be simulated at area facilities.

An example shows the comparative diagram (Figure1) of water content and salinity changes at the entrance (start mode) and output (end mode) installation. It can be seen that the combined effect leads to an increase the quality of WOE preparation.

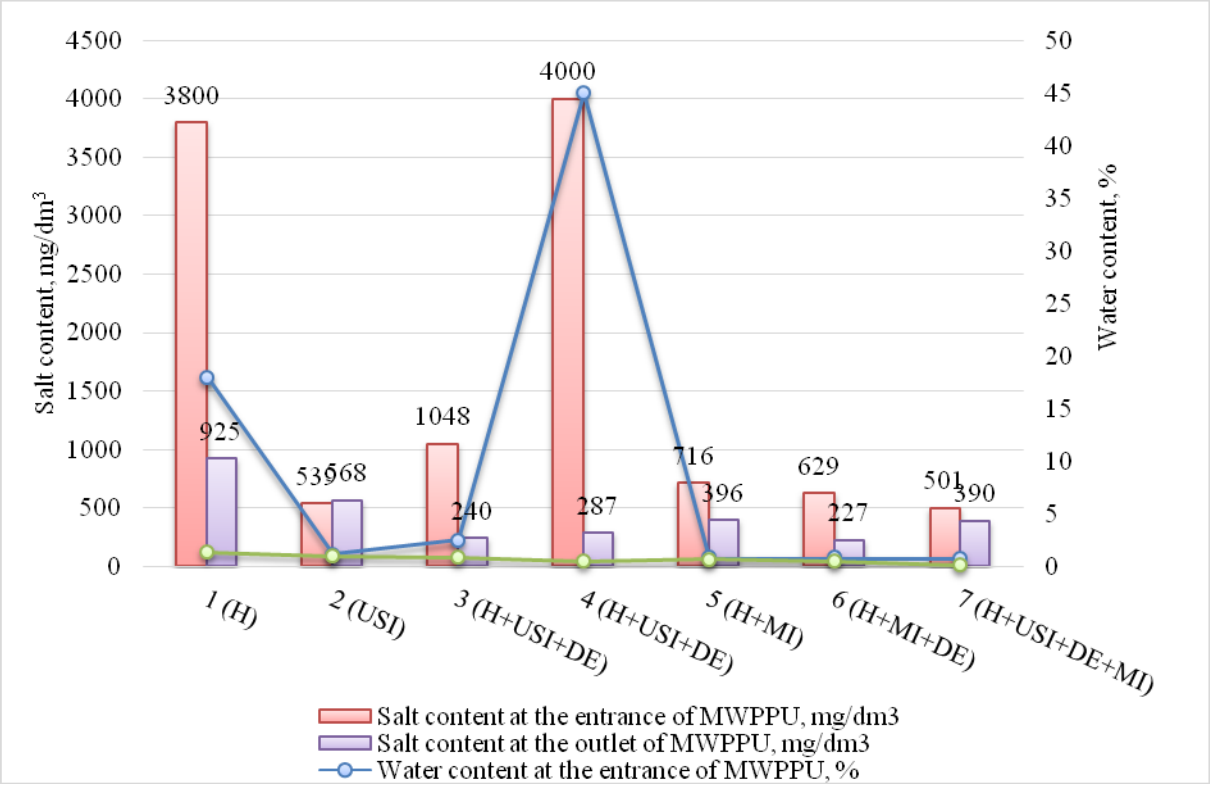

Figure 1 - Comparative characteristics of the complex impact effectiveness on the process of WOEs destruction. (H-heating up to 60^{o}C; USI-ultrasound impact; DE-demulsifier; MI-magnetic impact)

In the course of pilot tests and laboratory studies, it was possible to find the using limits of these methods for the water content of WOE, reduce the supply of demulsifier. The effectiveness of using magnetic preparing is justified by the presence of magnetic particles in the composition of water-oil emulsions is also shown. The effectiveness of ultrasonic and pulsed magnetic influence in combination with the thermochemical method has been demonstrated. It leads to the better destruction of stable water-oil emulsions and can increase the commercial oil quality due to the synergistic effect of the complex technologies.

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DEVELOPMENT OF GELLING COMPOSITION OF PROCESS FLUID FOR HYDRAULIC FRACTURING DURING DEVELOPMENT OF NON-TRADITIONAL OIL RESERVES

Deterioration in geological conditions of bedding of layers, difficulty of extraction of hydrocarbons from them in view of a number of factors, forces the oil and gas industry to improve constantly technologies of search, exploration and production of oil and gas. Hydraulic fracturing is currently one of the widely used methods for increasing well productivity in the oil and gas industry [1]. This article will discuss the features of bioxan-based gel-forming liquid "Bioxan-NT" for high-cost frac and compare it with other types of liquids. As well as the applicability of this system to increase the efficiency of oil flow intensification for hard-to-recover reserves on the example, Bazhenovsky whistle, Palyanovskaya Square.

Highlight the features of xanthan gum-based gel-forming compositions and justify applicability in order to improve the process of frac in conditions of difficult-to-recover oil reserves, as well as to create a branched crack system and increase the Stimulated Reservation Volume [2]. Materials and method: Considering the peculiarities of frac at the field with hard-to-recover reserves, the following factors can be identified:

- complex geology (faults, carbonate layers with sandstones);
- poor reservoir properties (ultra-low reservoir permeability and porosity);
- formation conditions (elevated temperatures, high depth, abnormal formation pressure) [3].

The main technological challenge is to create a common network of cracks to increase the stimulated volume of the formation. For this reason, the concept of stimulated reservoir/deposit volume (SRV) was introduced as a parameter for correlation of shale well productivity, and for evaluation of shale stimulation efficiency. SRV is complex and depends on many characteristics (proppant volume per stage, injection rate and mode, number of clusters, types of liquids). In the work in issue, the characteristic of the fluid type will be affected. On the basis of the selected parameter, key laboratory studies were carried out to assess the quality of gelling agent and the frac liquid derived therefrom. In addition to the experimental part, mathematical calculations are presented in the work.

Application of such technology as gel based on SI Bioxan will improve methods of developing collectors with weak clay barriers in the water-oil zone. High anti-sedimentation capacity will reduce the probability of STOP [2]. The high recovery rate allows reconstructing the gel structure after the perforation zone. This system is less dependent on water quality and reduces the time and cost of transportation and loading.

The use of xanthan-based formulations (SI Bioxan) in hard-to-recover conditions will be more efficient and rational.

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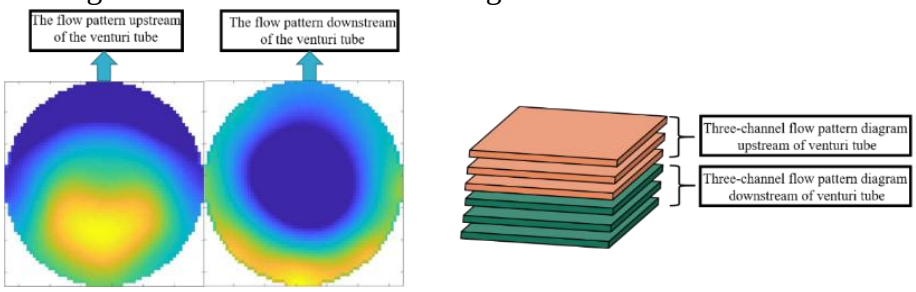
DUAL-ECT SENSORS AND VENTURI TUBE BASED ON DEEP LEARNING MODEL TO MEASURE OIL-GAS TWO PHASE FLOW PARAMETERS

In the field of petroleum multiphase flow research, the development of multiphase flowmeters to realize the real-time measurement of multiphase flow parameter processes is of great significance to the economic benefits, production management and process control of oil fields. The oil-gas two-phase flow is an important part of the field of multi-phase flow. At present, the main equipment used for the measurement of oil-gas two-phase flow parameters are high-speed cameras [1], gamma-ray sensors, optical fiber probe sensors [2], wire-mess sensors [3], acoustic emission detection sensors etc. Among them, the high-speed camera sensors, gamma-ray sensors, and optical fiber probe sensors are easily affected by the environment. And their operations are complicated and the maintenance costs are high. Although wire-mess sensors and acoustic emission detection sensors are inexpensive and easy to operate, their accuracy cannot meet the needs of the current market. Aiming at the above situation, this paper proposes a measuring device combining dual electrical capacitance tomography (ECT) sensor and venturi tube. The deep learning model is used to analyze the flow pattern changes upstream and downstream of the venturi tube under different oil and gas flow rate, so that the oil-gas two-phase flow parameters are measured based on the flow patterns upstream and downstream of the venturi tube.

This experiment is conducted on a semi-industrial multi-phase flow experimental measurement platform. The arrangement of sensors on the measuring pipeline is the upstream ECT sensor, venturi tube and downstream ECT sensor. In the experiment, the distribution of oil flow rate is $1\text{-}10 m^3/h$, the distribution of gas flow rate is $20\text{-}150 m^3/h$. The flow pattern is obtained by the LBP image reconstruction algorithm, and the flow pattern is used as the input of the convolutional neural network (CNN) model. In this paper, the Inception-V3 model in the CNN network is selected as the training model for this experiment. By analyzing the flow pattern changes upstream and downstream of the venturi tube, the flow pattern horizontal splicing model and the flow pattern channel superposition model are designed to predict the oil-gas two-phase flow parameters. Figure 1 shows the schematic diagram of the model structure.



(a) (b)

Figure 1 - The schematic diagram of horizontal splicing and channel superposition of flow patterns. (a) Horizontal splicing of the flow pattern (b) Channel superposition of the flow pattern

As shown in Figure 1, the flow pattern horizontal splicing model without taking into account the changing relationship between different corresponding location areas of the flow pattern. The flow pattern channel superposition model superimposes the flow patterns upstream and downstream of the venturi tube and inputs the superimposed flow pattern to the CNN network for training. This model can learn the change relationship between the flow patterns of the upstream and downstream of the venturi tube in the corresponding location area. In addition, this paper compares the training results of the single ECT sensor model with the training results of the double ECT sensor model. Highlight the superiority of the sensor structure and model

algorithm designed in this paper. The traditional ECT oil-gas two-phase flow parameter prediction model is based on ECT sensor raw capacitance data for prediction. Therefore, this paper compares the predicted results of the original capacitance value of ECT with other models. Table 1 shows the relative errors in the prediction of oil flow rate and gas flow rate of different measurement models.

Table 1 - Relative error of oil-gas two-phase flow parameter prediction

Parameter / Model	Oil flow rate	Gas flow rate
Original capacitance	32.1%	51.02%
Upstream ECT sensor flow pattern	7.02%	7.12%
Downstream ECT sensor flow pattern	7.03%	1.47%
Flow pattern horizontal splicing model	4.661%	1.433%
Flow pattern channel superposition model	3.406%	0.505%

As shown in Table 1, for the prediction accuracy of oil flow rate, the average prediction relative error of the flow pattern horizontal splicing and channel superposition model is less than 5%, and the prediction accuracy is high. For the prediction accuracy of gas flow rate, the prediction accuracy of the flow channel superposition model is significantly improved, and the average prediction relative error is less than 1%. It shows that the flow pattern upstream and downstream of the venturi tube have a change relationship in the same location area. The flow rate measurement model proposed in this paper is correct and reliable.

In this paper, a new oil-gas two-phase flow sensor structure and a new oil-gas two-phase flow parameter measurement algorithm are proposed. The flow pattern horizontal splicing model and the flow pattern channel superposition model are designed respectively to measure the oil-gas two-phase flow parameters based, and compared with the single ECT sensor flow pattern measurement results. The experimental results show that the flow pattern channel superposition model significantly improves the measurement accuracy of oil-gas two-phase flow parameters, indicating that the model assumptions mentioned in this paper are correct and feasible. In future research work, we will conduct further research and analysis on the characteristics of flow patterns, further improve the measurement model, and improve the measurement accuracy of the oil-gas two-phase flow.

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FLOW SIMULATION IN SHALE GAS RESERVOIRS

A higher energy demand in the last decades has played a substantial role in the insistent investigation and exploration of unconventional oil and gas resources. Shale gas reservoirs are amongst the major unconventional resources [1]. These resources defer from conventional ones in such a way that they cannot be produced and developed by conventional techniques relying

only on the pressure difference and other normal operations like pumping or compression. Technological advancement in both horizontal drilling and hydraulic fracturing methods have been the key to attain economical production rates and recovery factor from shale gas reservoirs [2]. Shale gas reservoirs have a relatively small permeability, in the range of 10^-4 mD, and are known for their complex gas transport mechanisms as well as the complex natural and induced hydraulic fracture geometries and network [3]. Typical shale gas production is composed mostly of two-phase flow of gas and water. However, suitable modeling of the two-phase behavior while also incorporating the much more complex fracture geometries and properties have been a challenge within the industry [4].

In this research, a 3D synthetic reservoir model is constructed using the commercial simulator Rubis by Kappa Engineering. Via the fluid flow numerical simulation approach, the effects of different levels of hydraulic as well as natural fracture complexities (considering geometry, network and petrophysical characteristics, both single and two-phase flow) were investigated in terms of the overall well performance and production, and, consequently, system recovery factor.

The model was built taking into account the geophysical as well as petrophysical properties of a typical shale gas reservoir. Two models were introduced, the Langmuir model as well as the Klinkenberg effect for proper gas flow modeling. This was then followed by the addition of one well in the reservoir. For the first 20 cases, only 1-phase has flow was modeled varying the total fracture length as well as geometry (fracture angle). The second more critical part, experimented with 2-phase gas and water flow starting from water injection until 10 years of well production. Each compared case had a different well geometry (planar, diagonal, scattered, network). A further analysis was then made on one of the complex cases, this time varying the water saturation at one time then the conductivity the second time keeping all other parameters constant. The last step was the introduction of natural fractures to the reservoir model. 4 cases were modeled; first varying the number (100 vs 1000 NFs) followed by varying the angle (planar vs cross sectional NFs).

On one hand, it was shown how both induced hydraulic and natural fracture geometries and distribution resulted in a different stimulated reservoir volume and thus affecting the final recovery mostly due to extent of interference between individual fractures. On the other hand, how much water injected before production, which was expressed in the relative permeability curves (Water Saturation) inside the fractures, reached a point where no further increase in recovery can be achieved. Furthermore, the fractures' conductivity affected production only after falling below 1 mD.ft.

The research results confirm the key role played by a proper modeling of the fracture network, and how much it can interfere with the results of gas and water production. Moreover, it displays a better understanding of the ideal water injection during the beginning of production to optimize the final recovery and avoid a high-water flow-back. In addition to explaining at what values the fracture conductivities and angles cause the highest disruption in production.

The future recommendations for such a study are to experiment with a more complex reservoir model instead of a simple rectangular reservoir used in this report. We can also vary the permeabilities and porosities across the reservoir's layers instead of having them constant all-through. Finally, the simulation process can start from the water injection process taking that into account as well for the proper geological mapping instead of setting time 0 as the start of production.

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BIOMIMETIC REVERSIBLE ADHESION PROPPANT

With the explosive growth of natural gas production, the development of shale gas has initiated a global revolution. Hydraulic fracturing (HF) is considered to be the main and effective method to improve oil and gas recovery [1]. In the process of hydraulic fracturing, in order to prevent the fracture from re-closing under formation closing pressure, proppants are required to support the fracture. At present, the proppants used in shale fracture supporting are mainly quartz sand, ceramic, and resin-coated proppants. Quartz sand is widely used in Shallow wells within 1500 m, but it starts to break at about 20MPa because compressive strength is low. Although ceramic proppants have larger strength, they have the disadvantages of high density, large cost, and big construction risk. The salient features of resin-coated proppants are low density, strong resistance to crushing, and embedding prevention.

Our group, inspired by gecko reversible adhesion toe pad and mussel underwater adhesion thread[2-3], have fabricated a self-suspension proppant with a "ceramic core-porous resin shell" structure (Figure 1a)[4]. Due to the high density, uncoated normal ceramic proppants supposed to sediment at the entrance of shale fracture (Figure 1b). The CPs supposed to go deeper inside the shale fracture, due to its self-suspension ability (Figure 1c).

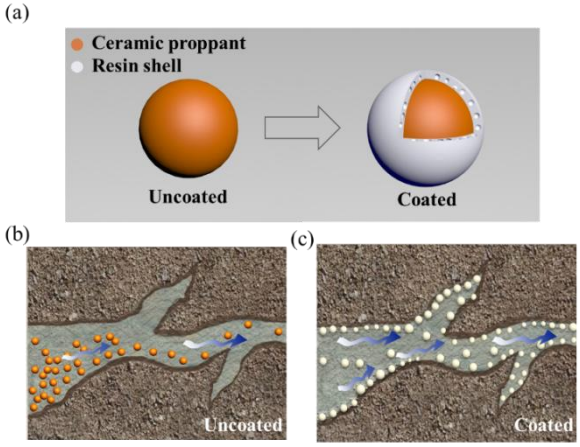

Figure 1 - Self-suspension properties and structure of coated proppant. (a) Film structure of proppant; (b) Schematic diagram of uncoated proppants in shale fractures; (c) Schematic diagram of CPs (coated) in shale fractures.

Figure 2a displays the liquid conductivity of the proppants under different effective closure stress changed from 6.9 to 27.6 MPa, while the proppants concentration and flow were fixed at 6 kg/m^2 and 3 mL/min. Although the conductivity of both proppants decreased with increasing closure stress, the coated proppants was higher than the uncoated proppants at lower closure pressure. The surface coating was able to improve liquid conductivity effectively and reduced the roughness of ceramic proppants. The adhesive ability of self-suspension proppants was conducted by atomic force microscopy (AFM). Figure 2b gives the variations of adhesion forces under different load force conditions, and the contact time was fixed at 0.1 s. With the increase of the load capacity, the adhesion of the two proppants showed the same trend,

indicating that the coating did not change the relationship between the proppant adhesion and the load capacity. But under the same conditions, the adhesion force of the CPs is higher than that of the uncoated proppants. The contact time versus adhesion force is shown in Figure 2c, where the contact time increased from 0.1 to 2.1 s. When the contact time was changed, there was no significant change in the adhesion force between proppants, but the adhesion of CPs is improved compared with uncoated proppants. The resin coating of the proppants coat increases the adhesion, and the proppants will more easily adhere to the surface of the fracture. At the same time, the resin coating will also cause the proppants to form inter-particle adhesion, thereby improving the fracture supporting ability.

The typical AFM force (known as force curve) is illustrated in Figure 2d, the adhesion force is determined by the difference of extended and retract force curves. CPs have higher adhesion force than uncoated proppants. Once proppants were coated, carbon element would have a free pair of electron pairs, which could form chemical bonds with oxygen on the fracture surface, including cohesive bonds and hydrogen bonds. Besides, as the temperature of underground rock fractures rises, force of chemical bond between carbon and oxygen further increases.The adhesion of the coated proppants has been increased and thus become higher than the uncoated proppants (Figure 2e). To test the self-suspension ability of the CPs, the sedimentation experiment was designed (Figure 2f). In the sedimentation experiment, the proppants were poured into guar gum solution (0.2 wt%. The self-suspending ability (proppant weight on the surface /proppant weight at the bottom) of the coated proppants and uncoated proppants is 0.466 and 0.088. The self-suspension ability of the coated proppants has reached nearly 11 times that of the uncoated proppants.

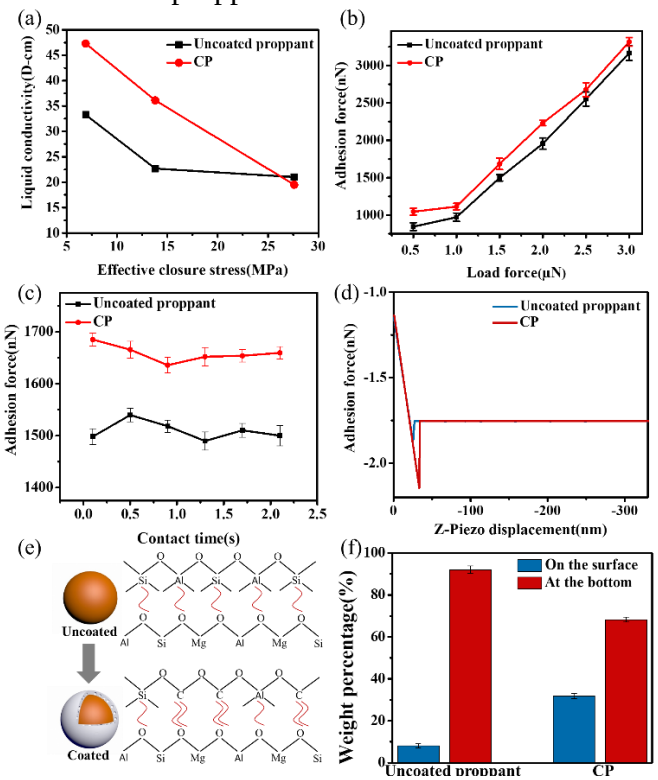

Figure 2 - (a) Liquid conductivity of the CPs and uncoated proppants under different closure pressure. (b) Adhesion performance of the CPs and the uncoated proppants surface of different load force. (c) Adhesion performance of the CPs and the uncoated proppants surface of different contact time. (d) Typical AFM force curve in adhesion measurement for a load force of 2 μN and a contact time of 0.1 s. (e) Mechanism diagram of adhesion force of the CPs and uncoated proppants. (f) Results of the CPs and uncoated proppants sedimentation experiment.

In conclusion, we have fabricated novel coated proppants, where the fabrication method is straight forward and easy to scale up. The self-suspension ability of the coated proppants is

nearly 11 times that of the uncoated proppants. In addition, the adhesion force of the proppants is also enhanced, it is easier to adhere to the fracture surface, which is more promising for fracture supporting usage to increase the liquid conductivity of oil and gas flow. CPs are able to go deeper into the fracture, which is due to its self-suspension ability. Our design is versatile and adaptable to a variety of proppants and expected to be applied to shale fractures.

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THE PROBLEM OF SUSTAINABLE DEVELOPMENT OF THE OIL INDUSTRY IN THE ARAB REGION

The oil system in arabic region faces a paradigmatic shift where, in addition to increased local traffic problems, climate change and depletion of fossil oil reserves will foster a successive transition to renewable fuels and a need for more resource-efficient mobility management and communication alternatives. Foresighted countries, cities or companies taking the lead in adapting to these tougher conditions might well not only solve those problems, but also turn the problems into business advantages. This thesis is based on six studies that attempt to develop future strategies based on rigorous principled emission and energy efficiency targets and to modulate the impact of travel policies, technical components and behaviours in economically advantageous ways. The modelling frameworks developed throughout the thesis build on a target-orientated approach called backcasting, where the following general components are applied: (1) target description at a conceptual level i.e. the potential for sustainable energy systems, emissions, costs, behavioural patterns, preferences, etc.; (2) mapping of the current situation in relation to target description; and (3) modelling of alternative sets of policies, technologies, behaviours and economic prerequisites to arrive at target achievement. Sustainable travel strategies are analysed from two main viewpoints. The first four studies focus on company travel planning, where behavioural modelling proved to be an important tool for deriving targetorientated travel policies consistent with employee preferences. The latter two studies focus on strategies and preconditions to meet future emission targets and energy efficiency requirements at a macroscopic regional level by 2030. Backcasting’s role as a generic methodology for effective strategic planning is discussed.

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EXPERIMENTAL RESEARCH OF THE EFFECT OF THE SHAFT SPEED ON THE EFFICIENCY OF HIGH-SPEED CENTRIFUGAL PUMP

Under the present conditions of oil and gas production, enhancement of company operations efficiency is becoming extremely crucial. The issue of maintaining energy efficiency of oil production is becoming more critical each year. Presently the total power consumption rate for fluid lifting for the Russian oil companies is 55-62% from the total energy consumption, while water injection consumption rate makes 22-30% and 8...23% for oil and gas treatment and transportation. The remaining oil production processes are less energy-consuming [1,2]. The present paper studies the methods of estimating energy efficiency of the ESP-operated low production rate wells (up to 100 m3/d).

Based on 2500 process modes data (actual production rate, average dynamic head, and energy consumption), the pump efficiency was calculated for various values of pump performance within the extended time scale (figure 1). The average efficiency value for high speed ESPs is higher by 12-17% in absolute value and by 40-68% in relative value than the efficiency of the pumps with the rated speed of 3000 rpm.

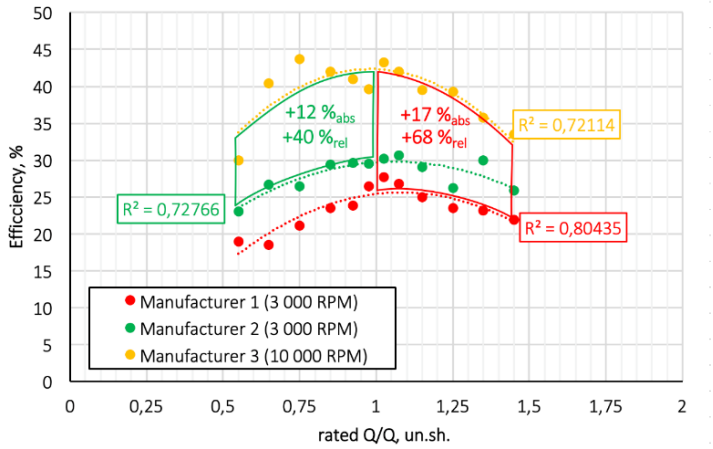

Figure 1 - Efficiency for ESPs of various manufacturers with the rated capacity of below 100 m^3/d

When operating at high shaft speeds of the pump, the foaming effect becomes significant. In the work [3] it has been established - the greatest effect on the behavior of the low foaming density of oil in the annular space its gas content and foaming value depends on the content of high molecular compounds (resins and asphaltenes) defining the oil viscosity. A foaminess coefficient, which characterizes the tendency of oils to dispersing and foaming was used as a stable and justified affinity coefficient for pumping gas-liquid mixtures in real conditions and in bench tests on model mixtures

The characteristic of the specific energy consumption (SEC) equal energy consumption in watts while recovering the fluid to a height of 1 m. From the analysis, it is clearly seen that the actual value of the SEC for high-speed ESP is higher by an average of 9 kWh/m^3. Thus allows us to recommend the equipment replacement in wells with stock ESP with the rated speed of 3000 rpm to high-speed pumping systems.

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IMPROVING THE EFFICIENCY OF HYDRAULIC FRACTURING WITH THE USE OF A NEW PROPPANT DEVELOPMENT

Currently fracturing is one of the most efficient methods to increase productivity of oil and gas wells. The most dangerous effect after fracturing is proppant entering the wellbore. Initially proppant places in the fractures, but it is taken out of cracks in the process of stimulation and exploitation. It causes reduction in the width of the cracks, decrease of a potential flowrate of the wells, formation of proppant plugs and a breakdown of electric-centrifugal pumps. Bottom-hole zone of the well after fracturing in the process of stimulation and exploitation is represented in Figure 1.

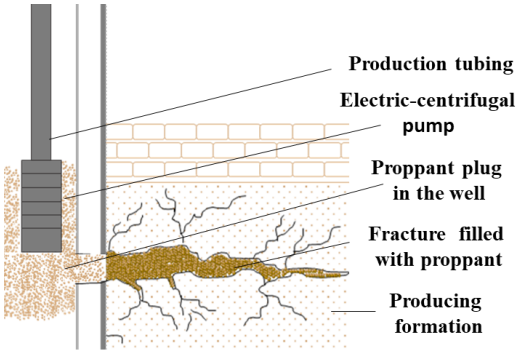

Figure1 – Bottom-hole zone of the well after fracturing in the process of stimulation and exploitation

The objective of the project is to find an optimal fracturing technology which reduces the amount of proppant entering the wellbore. To achieve this objective we need to solve the following tasks:

1. Firstly we need to give reasons for the application of the proposed technology;
2. Secondly we need to make up a research programme;
3. Thirdly we need to find analogues and compare our technology with them;
4. Fourthly we need to analyze market and calculate economic effect.

.In order to solve the problem we propose to use a new fusion of titanium and nickel in the ratio of 45% to 55% to prop the opened fractures in the reservoir. The name of this fusion is nitinol. Products that are made from this material can remember their shape.

For example if we take a product of a complex shape (for instance a simple clip) that is made from nitinol and heat it up to 400 degrees Celsius the clip will remember its shape. Then we can cool the clip to temperature of room conditions and deform it as we want. But if we heat it up to approximately 60 degrees Celsius again the clip will reconstruct its shape. The process of transformation of the nitinol clip under the action of temperature is represented in Figure 2.

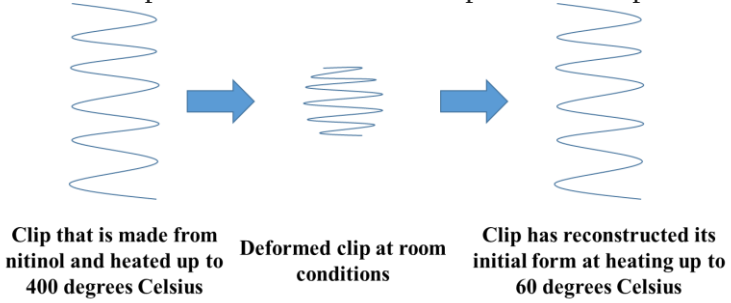

Figure 2 – The process of transformation of the nitinol clip under the action of temperature

On our technology at the first stage a peripheral part of the fracture is filled with a small fraction of ceramic proppant. Then proppant that is made from material with in-built intelligence (nitinol) is pumped down at the second stage to form a filtered layer in the crack of fracturing. The nitinol particles are pumped down in the shape of compressed springs. The compressed springs look like spheres. In fracture the springs release under the action of temperature of the producing zone and form the filtered layer that keeps proppant from entering the well. Disposition of ceramic proppant and nitinol proppant in the fracture is represented in Figure 3.

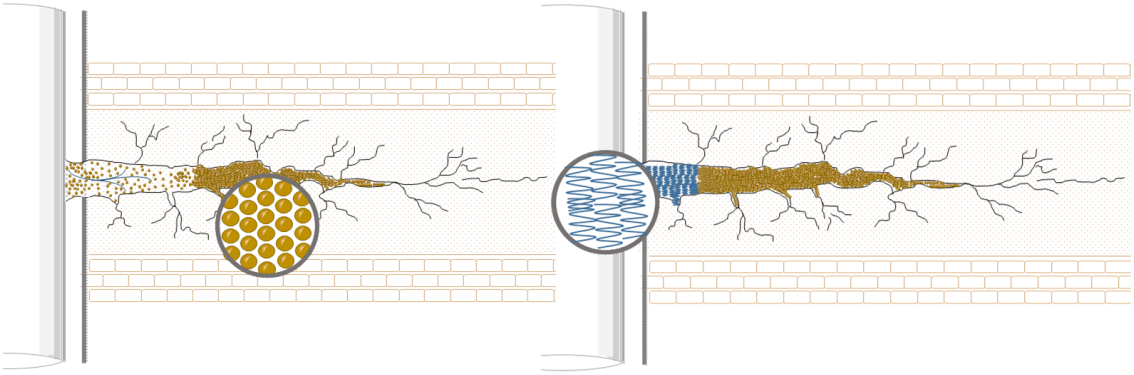

Figure 3 – Disposition of ceramic proppant and nitinol proppant in the fracture

As a result recovery factor and productivity of the reservoir increase and complications that are connected with electric-centrifugal pump and proppant sediments are prevented.

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Well Drilling

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A REVIEW ON STRESS CAGE TECHNOLOGY

Lost circulation, in which drilling fluid, or mud, flows partially or completely into a formation through areas known as thief zones is considered as one of the most important concerns in the oil and gas industry at different regions of the world. It is a common drilling problem and a major contributor to drilling NPT (Non-Productive Time). Economic losses caused by lost circulation may reach up to 25%–40% of total drilling costs [1].

Generally, lost circulation management methods are classified into two main categories, as shown in Aigure 1.

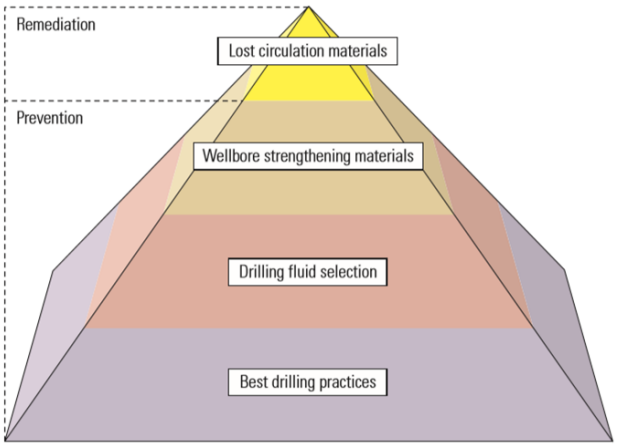

Figure 2 - Lost circulation management methods

Remedial methods are applied after diagnosis of lost circulation and their effectiveness is mainly controlled by the type and nature of the lost circulation materials (LCMs). Preventive methods are divided to the three main categories, as it can be seen in the figure 1.

Industrial researches show that prevention methods are much easier and cheaper to conduct, among which wellbore strengthening approach has been the subject of several recent researches. Methods of wellbore strengthening will help to maximize the wellbore pressure that formation can withstand before fracture initiation. Stress cage technology is the preventive mechanical method for wellbore wall strengthening while drilling [2].

Stress cage technology was firstly proposed by Aston M.S et al. This concept involves the control of lost circulation by adjusting hoop stress field and establishing the balance between wellbore fluid column pressure and formation stress field. In other words, in stress cage technology artificial shallow fractures are created at borehole wall and bridged at mouth of the fractures, which leads to hoop stress increase at or near wellbore wall. This increase of hoop stress will eventually lead to a rise in the fracture resistance of the rock at the wellbore wall, as shown in the Aigure 2. Therefore, less induced fractures are created, which in turn leads to less probability of lost circulation [3, 4].

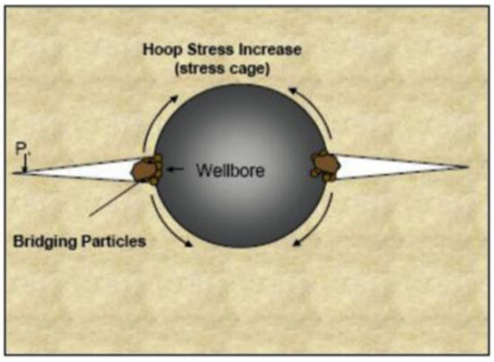

Figure 3 - Development of a stress cage by bridging a fracture

Various parameters affect effectiveness of stress cage technology. Some of these parameters are hole diameter, wellbore pressure, state of in situ stresses, formation pressure etc. Usually, graphite and calcium carbonate are used individually or in combination in order to seal and plug the fracture. It is very important that all parameters to be checked and determined to get the best results [3].

The importance of stress cage technology appears especially during drilling in formations with narrow mud weight window such as depleted reservoir and deepwater formations. By using this method, mud weight window can be widened by increasing fracture pressure gradient. This could better contribute to completion and drilling operations and in the best case it can reduce the number of casing strings, which leads to lower total cost.

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SUBSTANTIATION AND DEVELOPMENT OF DRILLING FLUID COMPOSITIONS TO IMPROVE THE QUALITY OF COMPLETION OF HORIZONTAL WELLS

The effectiveness of drilling wells, including horizontal wells, depends on subsequent operation. High quality drilling of wells depends not only on the used drilling tools, but also on the technology used, including the processes of removal of cuttings to the surface, which are closely related to the type and property of the selected drilling fluid. Therefore, the introduction and development of new systems of drilling and drilling fluids, with improved properties that ensure the safe conduct of horizontal wells and improve the quality of the initial opening of the reservoir is an important task.

Oil and gas companies need to constantly find and implement new concepts of oil and gas production organization, technical re-equipment of obsolete equipment, increase productivity, reduce operating costs of production [1].

In last years, active research has been conducted aimed at developing drilling fluids with the necessary technological properties when drilling wells in complicated conditions. Modern drilling fluids are characterized by various combinations of compositions, therefore, various properties and parameters. When preparing them, various aspects are taken into account, the most important of which is the quality of the liquid, as well as financial factors and other aspects. Of particular importance are properties such as mud density, filtration, viscosity, static shear stress and dynamic shear stress [2].

The properties of drilling fluids are controlled by the introduction of special additives and materials in order to improve quality and ensure maximum drilling efficiency. The drilling fluid, which is intended for the initial opening of the formation, must have the ability to form an impermeable and easily removable filter cake, to prevent the penetration of the filtrate into the reservoir, and such a composition of a dispersed liquid phase, allowing at the beginning of the well to eliminate the effects of the penetration of the filtrate into the bottom-hole zone of the formation without visible phenomena [3].

At present, hydrocarbon-based drilling fluids (HCBM) are more widely used for drilling oil and gas wells. Since they, in comparison with water-based fluids WBDs, have many factors, the most important of which is the conservation of reservoir properties. In addition, hydrocarbon-based solutions have unprecedented inhibitory and lubricating properties that cannot be achieved using WBDs. When drilling with extended reach drilling (ERD), hydrocarbon-based drilling fluids are the only options, as they ensure the stability of the wellbore and reduce the coefficient of friction, which in turn allows to control the drilling tools during drilling and make it possible to reuse them [4,5].

After analyzing the results of laboratory tests (Table 1,2), it can be confirmed and established that calcium carbonate (CaCO3), due to its properties and composition, had a significant impact on the technological properties of hydrocarbon-based drilling fluids, where it acted both as a good filler and as weighting agent. Significantly increased the density of the HCBM and lowered the filtration, while its colmatant penetrating into the reservoir layer is easily eliminated by acid treatment.

The biopolymer used also improved the properties of the HCBM, where it also lowered the filtration and increased its density to the required value. Therefore, it is recommended to use these two reagents when developing hydrocarbon-based drilling fluid systems.

Table 1 - The results of laboratory tests

The compositions of the studied fluids Component	№1	№2	№3
Base oil (Gazpromneft Drilline2),ml	557	557	557
NaOH		to pH=9,0-9,5	
Water, ml	248	248	248
CaCl2, g	87	87	87
Sulfonol, g	12	12	12
biopolymer-10 (OP), g	12	12	12
biopolymer, g	0	0	2
CaCO3, g	0	250	250

Table 2 - The results of laboratory tests

Result of the tests test parameters	Required Values	№1	№2	№3
Density ρ, g/cm3	1,13-1,15	0,97	1,13	1,15
Filtration, cm3/30 min	4-5	40	15	5
R6	>14	2	3,5	15
R3	>12	2	2	12
GEL 10сек, lbf/100ft²	8-12	2,134	2,134	12,804
GEL 10мин, lbf/100ft²	15-25	2,134	2,134	16,005
(YP) YP, lbf/100ft²	20-25	9	15	23

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ANALYSIS OF NATURAL NON-TOXIC COMPONENTS' INFLUENCE ON THE PHYSICAL AND CHEMICAL PARAMETERS OF DRILLING FLUIDS

Formulations of drilling fluids based on an organic primary components (plants) were considered in this work. Such reagents include peanut or corn oils, oleic acid ethyl ester. In the course of laboratory researches the basic physical parameters of drilling fluids were obtained. They are density, gel strength, water cut, plastic viscosity, etc.

The relevance of this topic is determined by the fact that drilling fluids are important components in the process of well construction. They perform a wide range of functions, from the removal of drilled rock to the surface and ending with the formation of a wall mud cake and lubrication of the drilling tool. In this regard, any drilling fluid must have an appropriate set of optimal indicators (parameters). In addition, in contact with rocks and the environment, modern drilling fluids must satisfy environmental safety requirements also they must not have a destructive effect on the ecosystem.

In the course of work on the basis of existing drilling fluid compositions, alternative formulations using non-toxic plant components were developed in this research work.

Currently, there are a large number of different compounds, esters and other biodegradable components that can be used as the basis for drilling fluid. All of them were developed with the purpose of replacing toxic drilling fluids created by using diesel fuel as a primary component. As a result of the extremely toxic effects on marine life, diesel fuel as the basis for drilling fluids was forbidden for exploitation in the Gulf of Mexico and the North Sea. Water-based drilling mud, although is non-toxic, biodegradable and relatively inexpensive, but it's not suitable for drilling complicated wells, especially in shale formations. Under such conditions, a synthetic-based drilling fluid is preferable for shale drilling because of its ability to stabilize clay, high lubricity, less corrosion, less formation damage, minimal temperature effect and lower cost.

As a result, based on research data on modern, low-toxic drilling fluids there were developed special formulations that included natural non-toxic components, as well as experiments were carried out that made it possible to determine the following key parameters of the drilling fluid:

1. density;
2. plastic viscosity;
3. yield point;
4. effective viscosity;
5. gel strength;
6. water cut;
7. mud cake thickness;
8. PH.

To determine the effect of low toxicity components on the physical and chemical parameters of drilling fluids, several formulations have been developed in which a variety of toxic components have been replaced. The formulation of the initial solution is shown in Table 1.

Table 1 - Hydrocarbon invert emulsion drilling fluid formulation

Compound	Component composition, mass %
Diesel fuel	37-39
Sulfonol	4-6
Mineralized water (60 % CaCl solution)	49-51
Clay powder	3-4
Calcium Oxide	3-4

In the formulation of the solution shown in Table 2, the hydrocarbon basic component was replaced with corn oil, as a natural non-toxic component, actively used and consumed by people in the process of cooking. The sulfonol emulsifier has a «hazard class 3» for exposure to the human body, work processes with this reagent should be carried out using personal protective equipment and in rooms provided with supply and exhaust ventilation. Therefore, it was replaced by a solid water-insoluble emulsifier prepared independently in the laboratory.

Table 2 - Corn oil invert emulsion drilling fluid formulation

Compound	Component composition, mass %
Mineralized water (15% NaCl solution)	29-29.5
Corn oil	69-69.5
Emulsifier (aluminum stearate)	0.2-0.4
Xanthan gum	0.5-1
Gelatin	0.3-0.6

To obtain a solid emulsifier, it is necessary to fill the crushed soap containing sodium stearate with water at t = 40-45 degrees Celsius and mix until foam is appeared, then add an aluminum sulfate $Al_2(SO_4)_3$, until the foam is extinguished. After that insoluble yellow-white flakes will be formed, this chemical compound is a required emulsifier.

Xanthan gum - food supplement E415, is a natural thickener, stabilizer and structure-forming agent. Gelatin is used as a gel-forming agent and forms a structure; it is a product of processing of connective tissue of animals, i.e. natural biopolymer. Mineralization of water occurs with the help of sodium chloride - table salt.

The process for preparing this drilling fluid consists of the following sequence:

1. Preparation of the water phase, its mineralization;
2. Preparation of the oil medium, dissolution of the emulsifier;
3. Adding a fluid structure builder to water phase;
4. Emulsification of phases;
5. Stabilization of the produced emulsion.

The process of preparing this drilling fluid consists of the following sequence:

1. Preparation of the water phase, its mineralization;
2. Preparation of the oil medium, dissolution of primary emulsifier;
3. Adding a fluid structure builder to water phase;
4. Emulsification of phases;
5. Dissolution of secondary emulsifier;
6. Stabilization of the produced emulsion.

The differences in the formulation of Table 3 are that two emulsifiers were used to obtain a more stable emulsion, a solid one, which was used in the previous formulation, and a liquid one, obtained by carrying out an esterification reaction between ethyl ether and oleic acid.

Table 3 - Inverted emulsified ester based corn oil invert emulsion drilling fluid formulation

Compound	Component composition, mass %
Mineralized water (15% NaCl solution)	38.7-39
Corn oil	58-58.9
Primary emulsifier (ethyl ester of oleic acid)	1.5-2
Secondary emulsifier (polyvalent soap)	0.1-0.3
Xanthan gum	0.5-1

The formulation in Table 4 differs from the others in that it is not an emulsion-based fluid, but a water-based fluid. A polysaccharide biopolymer is used as a structure-forming agent, crushed kelp (or Laminaria) is a source of alginic acid, a natural thickener and a gel-forming agent. Carboxymethyl cellulose (food supplement E469) was used to lower the filtration rate.

Table 4 - Clayless biopolymer drilling fluid with kelp (Laminaria) formulation

Compound	Component composition, mass %
Mineralized water (15% NaCl solution)	97.6-98.4
Biopolymer	1-1.5
Chopped kelp (Laminaria)	0.2-0.3
Carboxymethyl cellulose	0.2-0.3
Xanthan gum	0.2-0.3

The density of the drilling fluid is determined by measuring the mass of a certain volume of the fuild, or using special lever scales. The density of the fluid is presented in Figure 1.

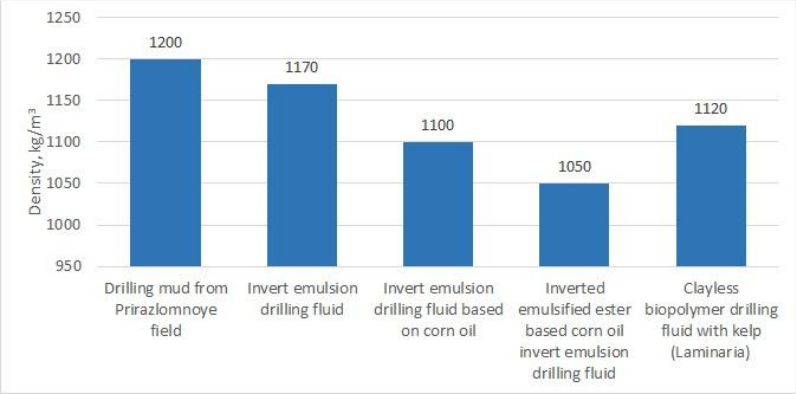

Figure 1 – Density

The plastic viscosity of drilling fluids was measured using an OFITE 800 8-Speed Electronic Viscometer. The viscometer readings were recorded, the plastic viscosity of the fluid is presented in Figure 2.

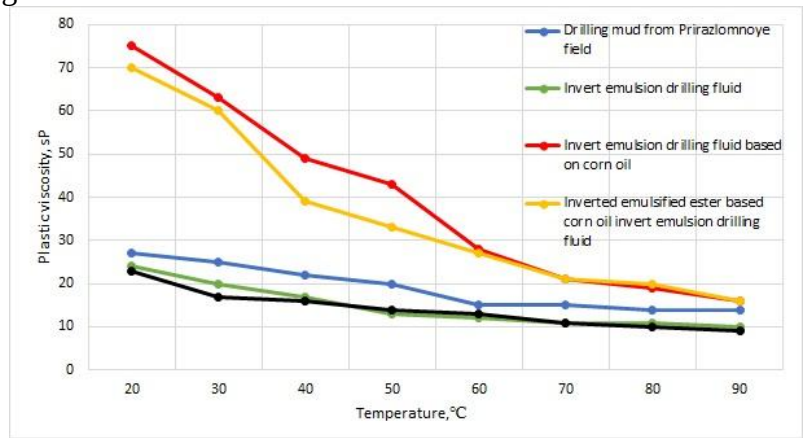

Figure 2 - Plastic viscosity

Yield point was measured using an OFITE 800 8-Speed Electronic Viscometer. The yield point of the fluid is presented in Figure 3.

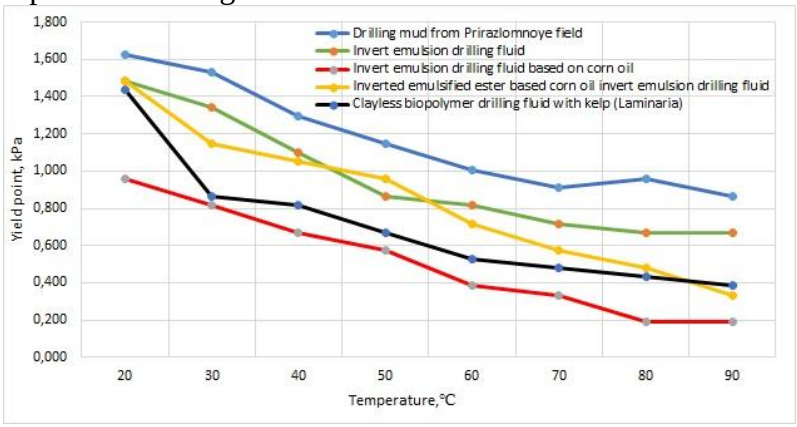

Figure 3 - Yield point

The effective (apparent) viscosity was measured using an OFITE 800 8-Speed Electronic Viscometer. The effective (apparent) viscosity of the fluid is presented in Figure 4.

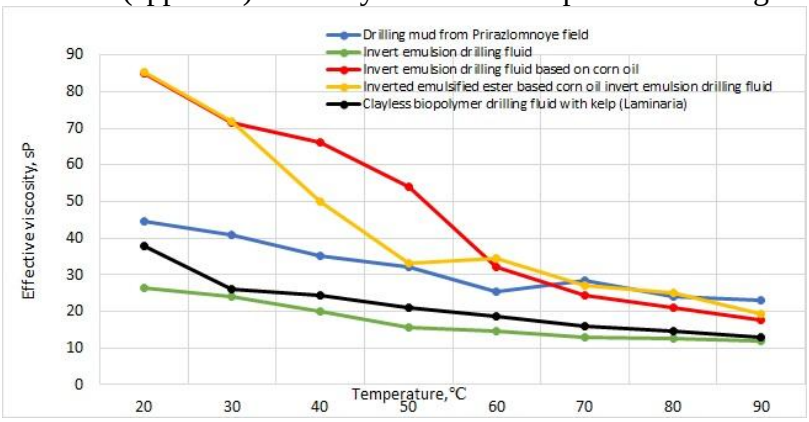

Figure 4 - Effective (apparent) viscosity

Gel strength is measured using the OFITE 800 8-Speed Electronic Viscometer. Gel strength of the fluid is shown in Figures 5 and 6. Measurements were carried out after 10 seconds and 10 minutes according to the measurement procedure.

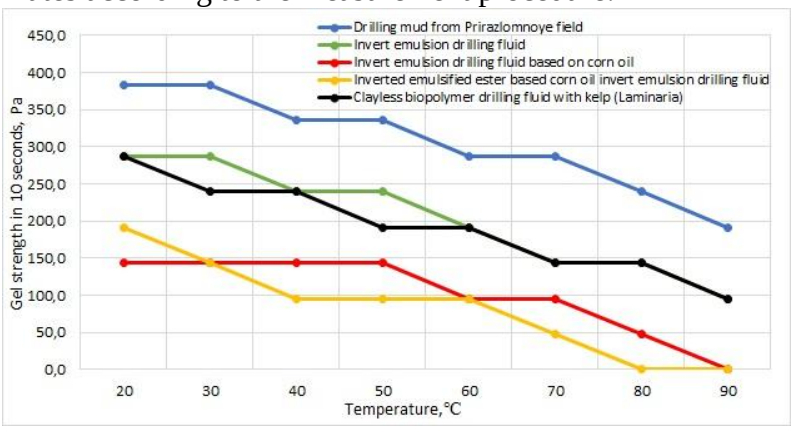

Figure 5 - Gel strength in 10 seconds

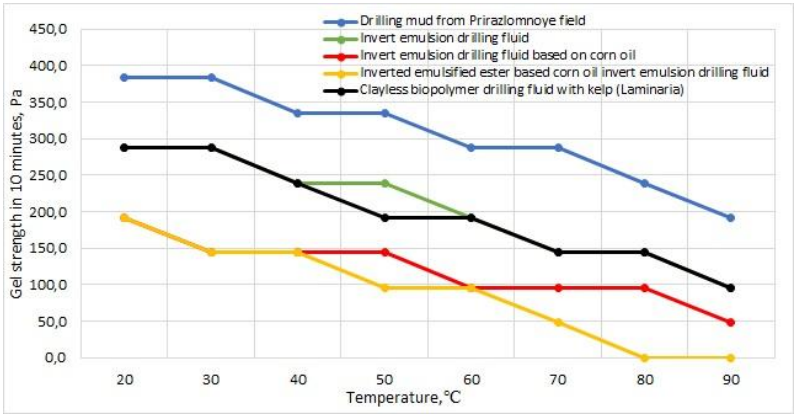

Figure 6 - Gel strength in 10 minutes

Water cut was determined using the OFITE filter press. The water cut of the fluid is in Figure 7. After this experiment, the thickness of the mud cake of each fluid was determined. The measurement results are shown in Figure 8.

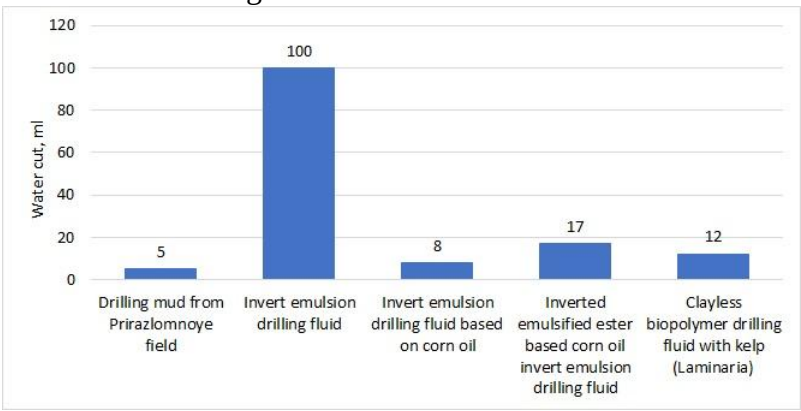

Figure 7 - Water cut

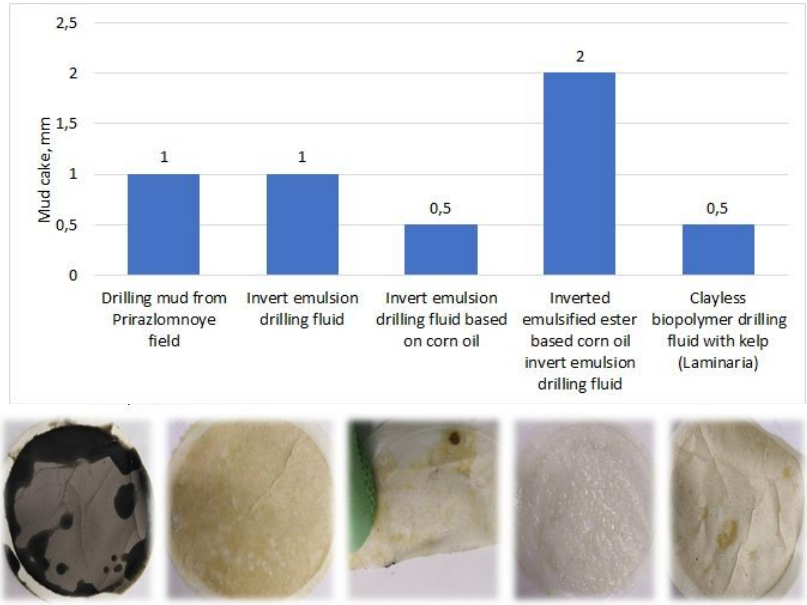

Figure 8 - Mud cake

When estimating the environmental impact of drilling fluids, one of the three most important indicators is the rate of biodegradation, i.e., the ability to decompose under natural conditions under the influence of microorganisms (the total amount of gases released during the decomposition; the rate of biodegradation, the rate of deposition).

Marine mussels of the mytilus edulis family, which live on the coast of the Barents Sea,

were chosen as indicators showing the degree of influence of fluids on the marine ecosystems. The research works were carried out as follows: several colonies of mussels in sea water were placed in a special cabinet that creates the temperature of sea water in the summer (approximately 5-7 degrees Celsius). Then, 10 ml of prepared solutions were added to each of the samples. Then, within a few days, deaths were recorded. The research results are presented in Figure 9.

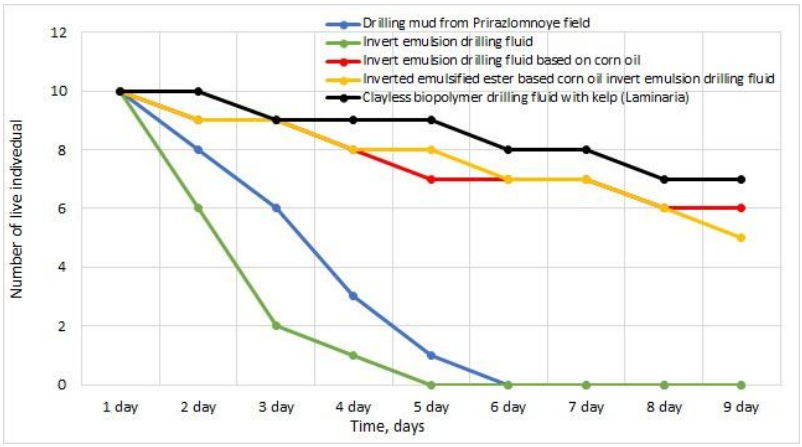

Figure 9 - Results of toxic effects on mussels of the mytilus edulis family

In the course of laboratory tests, a complex of studies of the qualimetric parameters of various drilling fluids formulations was carried out. As a result of the comparative analysis, the following conclusions were made:

1) Drilling fluid based on vegetable oils in terms of density is close to water-based fluids.

2) The plastic viscosity of the studied fluids based on oil is higher than the same indicator of the rest of the tested fluids in a wide temperature range. This fact favorably affects the amount of drill cuttings carried to the surface.

3) Oil-based drilling fluids have good lubricating properties, which, in turn, can ensure the longevity of the drilling tool.

4) The gel strength for a fluid based on corn oil has the lowest values from all tested samples. This parameter allows us to conclude that as a result of the start of the well exploitation, the circulation flow will create lower stresses on the drill string, which in turn will reduce the likelihood of accidents.

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A NOVEL APPROACH TO MODEL THE TRANSPORT OF WATER AND IONS THROUGH SHALE FORMATIONS

Transport of water and ions through shale is of significant importance in many scientific disciplines including wellbore stability in petroleum drilling and interpretation of geological surveys [1]. Since clay minerals have negative charge in their structure, they manifest semipermeable property with respect to anions while allowing water and cations to pass. Therefore a specific model for transport of water and ions through shale rocks can help to better simulate water and solute transport and hence wellbore stability. Conventional approaches to model and simulate water and ion transport through shale either doesn't take into account explicitly the microscopic mechanisms in shale [2], especially the double layer effect, or are involved in hardly-estimable parameters and complex procedures (such as "space-charge model" [3]). These approaches summarize the semipermeable characteristic of shale under a single constant parameter called membrane efficiency which should be found by pore pressure transmission test. However recent studies showed that this parameter is dependent to rock, fluid and solute properties (e.g. [4]).

In the current project, the matrix relating water, solute and electrical current fluxes to pressure, chemical potential and electrical potential gradients (the matrix L) was found by updating the model proposed by Revil [4] for multi-electrolytes and multivalent ions, where we assumed that concentration of cations in electrical double layer is greater than that in free fluid by a proportion which depends on shale's negative charge.

Then, the parameters used in solute and water mass conservation equations (namely, hydraulic mobility K_I, membrane efficiency K_{II}, and solute diffusion coefficient D) were found by the matrix L. By numerically solving the resultant PDE set with arbitrary initial and boundary conditions, pressure and concentration distributions in the domain (in linear or cylindrical mode) are found. The solver is molded to be capable of simulating a domain having chambers at either or both boundaries with stagnant or circulating fluids. Also the solver takes into account non-ideality of the pore fluid and variable parameters (e.g. K_I, K_{II} and D). We also analyzed effect of inhomogeneous rock properties on the three parameters (K_I, K_{II} and D) and also on pressure, concentration, and entropy generation rate profiles.

Finally, we proposed an inverse interpretation scheme, by calibrating rock properties and tuning parameters in order to match the PDE solution to data sets associated with laboratory and field tests.

In comparison to conventional approaches, the new approach has a superior capacity to interpret the laboratory and field test data. The model showed good matching by calibrating a few parameters. In fact, the new approach opens the black boxes called membrane efficiency and modified diffusion coefficient and makes it possible to find distribution of these parameters in the domain and to use vast amount of experimental and field data to predict osmotic property of shale formations. Future work should challenge other assumptions made by conventional approaches and the current approach, for example by taking into account anisotropy or temperature variations and also couple this transport model to well stability analysis models.

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THE DRILLING OF HORIZONTAL SMALL DIAMETER WELL IS DECISION FOR FURTHER DEVELOPMENT OF DEPLETED GAS LAYER

Today there are a lot of gas reservoirs which are depleted and their formation pressure is extremely low, however, they contain enough quantity of gas for further recovery. Thus, the solution of this problem is important for petroleum industry. Exploration maturity of topic is prevalent in foreign literature, abroad and native researchers create some engineering designs for this challenge.

The research work is based on creation of horizontal wells which have different diameters (114 mm and 60,3 mm) from the main vertical bore-hole which were drilled by conventional drilling rig and by coiled-tubing unit respectively. Petrel software was used for carrying out this investigation and creating the model of layer which has average porosity and permeability. The designed layer has real analog. The sizes of model were chosen to prevent the influence of boundary conditions to work of the wells [1]. As for drilling in such sophisticated conditions, mud can be changed to compressed air, so compression unit have to be applied. The diameter of coiled-tubing pipe for drilling horizontal well is 60,3 mm not coincidentally. This size is used more often in petroleum industry [2]. There are differences in completing of wells. The bore hole which diameter is 114 mm is cemented and perforated, however, other well has open hole. The work of wells is limited by some technological constraints. For example, bottom hole pressure is supported constantly – 0,15 MPa, because gas booster stations are installed. They allow to operate the wells when their well head pressure is 0,1 MPa.

Analysis lets to make some conclusions. The comparison of all features is done when bottom hole pressure of wells achieves 0,15 MPa. Firstly, the bottom hole pressure of the well with 114 mm diameter achieves this level in June 2018 and other bore hole in October 2018. Thus, coiled-tubing drilling lets to increase the running time of the latter. Secondly, gas production accumulation of well (60,3 mm) is higher by 21% (18 425 thous. m^3). Thirdly, gas production rate of the biggest well-bore is by 27% higher than the smallest one. Fourthly, the well with 60,3 mm diameter allows to diminish expenditures and to rise the income of a company.

To sum up, this investigation can be useful when decision about the method of further development of depleted gas reservoir is taken.

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INFLUENCE OF THE DRILL STRING SPATIAL FORM ON TRANSPORT OF CUTTINGS IN DIRECTIONAL WELLS

Every year the share of directional drilling grows to have risen nowadays as high as 80-90% of the whole industrial drilling. Drilling trajectories are getting more complex, not only in the number of sections with changing zenith and azimuth angles, but also in length. Complex drilling design increases possible problems and accidents that may emerge when a well is being cleaned from cuttings and «sludge pillows» [1].

Nowadays, drilling companies are trying to avoid buckling of a drill string. However, we suppose that controlled artificially created buckling can have a positive effect on sludge and cuttings removal from the well.

Full-scale laboratory modeling of drilling and flushing has long been an issue of interest for national and foreign scientists. For instance, among fundamental applied research works in drilling are experiments made by M-I SWACO, which became a part of fluids manuals for drilling engineers (2001) [2]. The researchers determined critical angles of a borehole when particles of destroyed rock are transported worst of all, analyzed factors that affect sludge and cuttings transport to the surface, and gave recommendations on directional wells drilling.

In 2016, scientists from the Iranian University of Amirkabir, Bekhnam Amanna and Mohammad R.K. Movaghar, published results of their experimental studies on how the flow rate of drilling fluid, zenith angle, rotation of a drill string and cuttings fractions affect well-cleaning [3].

At the end of 2019, a team of scientists from universities in the United States, Canada and Malaysia published results of studies on how drill string rotation influences well-cleaning with polypropylene particles in drilling fluid while flushing a well with various zenith angles [4].

All those studies confirmed and clarified critical zenith angles of a well, and influence of the flow rate and rheological properties of drilling fluid, or rotation rate of the drill string on the well-cleaning quality. However, none of the above studies dealt with effect of drill string buckling on transport of cuttings.

Influence of drill string buckling on the quality of well-cleaning from sludge and cuttings was studied on a test facility – an experimental non-standard equipment, which was built in the laboratory of the well drilling department, St. Petersburg Mining University. The test facility enables researchers to simulate the quality of sludge and cuttings transport depending on the rotation rate of the drill string, the number and length of half-waves in the drill string, the flow rate and rheological properties of drilling fluid, the zenith angle of the well and cuttings fractions.

The experimental test facility described above is an innovative solution in the study of flushing and hydraulic programs when drilling directional wells. Experiments confirmed effect of the number and length of half-waves in the drill string on the quality of well-cleaning from cuttings, taking into account drilling parameters, technological and rheological properties of drilling fluid.

When the drill string has 3 half-waves of 0.6 m long, cleaning of the well with zenith angle 35° is improved by 13÷82% at η=0.941 mPa·s and ρ=1000 kg/m^3, frequency 150 rpm; by 5÷21% at PV=40.283 mPa·s and ρ=1035 kg/m^3, frequency 100 rpm, and by 7÷15% at frequency of 150 rpm, depending on the flow rate of drilling fluid. It was also shown that when the drill

string rotates in a fluid with rheological properties, cuttings removal increases by 17÷37% (at Q=75 l/min, n=50÷150 rpm).

The data obtained speaks for necessity of further studies in this field of drilling science. Thanks to controlled bucking, drilling companies can improve the quality of well-cleaning and solve the issue of cutting beds with related problems and accidents.

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DEVELOPMENT OF A HARDWARE COMPLEX FOR INCREASING THE AMOUNT OF TRANSMITTED INFORMATION WHILE DRILLING USING A COMBINED COMMUNICATION CHANNEL AND TERNARY ENCODING

One of the primary guidelines for achieving the goals set for the oil and gas industry is to improve the technology for directional and horizontal wells in difficult geological conditions. To date, productive management of the drilling process is impossible without operational control of bottom-hole parameters that describe the flow of the drilling process [2]. Research and development of the communication channel between the bottom and the wellhead is of great importance, because at the moment there is no communication channel that provides reliable signal transmission during the drilling of ultra-deep wells. With the development of MWD&LWD systems, more and more data need to be transmitted, and with increasing depth of wells, signal attenuation becomes a clear problem [3].

The solution is to use a combined data transmission channel. Noting the trend of drilling ultra-deep wells, the hydraulic communication channel is widely used among all Telesystems, since it can be used at depths of more than 7 km. Another advantage of the hydraulic communication channel is that the communication channel is used as a column of drilling mud in the drill string, and therefore, no additional costs are required for the organization of the communication channel. The acoustic channel has a number of advantages: relatively high data transfer speed, simple implementation. It was suggested to use a combination of these communication channels. At the first stages, the use of an acoustic communication channel, at a relatively large depth-the use of a hydraulic channel with a hydraulic amplifier. The use of a ternary data encoding system transmits more information via the "bottom-to-wellhead" channel. This is effective at large depths, but at medium depths it is advisable to use an acoustic communication channel. Combining two channels in an acoustic Telesystem will increase the speed and quality of transmitted information, and installing repeaters along the wellbore will prevent signal attenuation.

Currently, interest in the ternary system in foreign scientific media has increased significantly. If you use a ternary number system for encoding and decoding the signal in telemetry, you can increase the speed by about 1.5 times [3]. Information transfer will be made in the tweet. Trit is a logarithmic unit of measurement in the data concept, the smallest single part of measuring the number of data keys with three equally probable messages. A data resource with three equally probable States has an entropy of 1 trit. In other words, according to the analogy with bit, which "reduces ignorance" about the subject under study by 2 times, trit "reduces ignorance" by 3 times. One trit is equal to log23 (approximately 1.58496) data bits. In the physiological implementation of the ternary functions in the ternary logic meet the ternary natural components, in the aggregate case is not necessarily electric. Schemes with 3-4-digit logic provide the probability to reduce the number of applied logical and memory components and inter-element combinations. Three-digit logic schemes are freely implemented in CMOS-technological processes. A three-digit pattern has a greater expressiveness than a two-digit one. When using the ternary number system, you can use 3 phase options: -1 – no phase shift; 0-phase shift by half; 1-phase shift by 180 degrees.

Demodulation occurs in several stages:

1. The Device sends data as a bit stream (0,1, -1).
2. A Group of several trits is called Word (word) or d-point (unit of data).
3. The word can be of different sizes (2-12 1-8 bit or trit)
4. A group of several words is called a Frame
5. At the beginning of Frame, there is always a special SyncWord and Frame Identification number (FID).

Transmitting information over a combined communication channel provides the following advantages over other communication channels. First, the accuracy of signal transmission from the face to the wellhead increases. Secondly, the frequency range of signal transmission is wider, and its upper limit is higher, which allows you to transmit data at a higher speed, and, consequently, more quickly manage the drilling process. Third, the conditions for receiving the signal at the channel output are facilitated. Fourth, it is possible to further increase the transmission distance to 9000 meters or more. At the moment, the team is building a mathematical model, but according to theoretical data, it has been proved that the development is suitable for wells of any information content and any length.

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UTILIZATION OF ABANDONED WELLS IN GEOTHERMAL ENERGY

Abandoned wells has been realized as one of the final points of life-cycle of wells in Oil and Gas sector. More often such aged wells require enormous stages of decommission processes: repair methods, plug settings, testing/monitoring and isolation. There are numerous literature around environmental risk assessments of abandoned wells as they draw attention from governmental authorities with respect to environmental impact. It goes without saying that it directly impacts Oil and Gas companies to seek for new developments and plan for other drilling projects. My thesis will reveal an alternative option for Oil and Gas companies to deal with wells

that are aged or depletion of oil resources by introducing utilization of wells to geothermal energy.

Wells depending on their drilling methods as well as overall drilling depth will have specific geothermal gradient. [1] This gradient reveals how much degree Celsius you have in the bottom of the well with respect to depth. Usually, most of the wells bottom temperature varies around 100-300 degrees. This range is more than enough to heat working (hot geothermal) fluid that will heat main pipe of water to a boiling point where steam forms and converts into electric energy through turbines.

Geothermal energy already being used in various countries such as Hungary, Ecuador, Iceland, Norway, New Zealand [2]. Their power supply to main electric grid is not as significant thermal electric stations. However, from facility point of view one abandoned well that generates electricity through geothermal energy can supply with electricity main villages or facility itself. Low-temperature geothermal energy resource can be harnessed to generate electricity using binary cycle electricity generating technology. [3]

Hot geothermal fluid is a byproduct of many oil and gas wells. Historically this hot water has been an inconvenience and a disposal issue. However, it can be looked at as a resource to produce electricity for field use or to be sold to the grid. These and other co-produced geothermal resources have the potential to produce significant amounts of baseload electricity at low costs and with near zero emissions. [4]

In the long run, Oil and Gas companies shall consider utilization of geothermal energy into their wells. For this reason, production of all aged wells eventually will come to an end which will open new doors to green energy that requires less of an investment to install and operate compare with drilling a new well. By taking into consideration that in Russia alone, there are more than 200 abandoned wells [5], each well can potentially generate from 50kW to 5MW of an electricity. Not only it will bring economical profit but also will create positive image in green energy from oil and gas companies.

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CHALLENGES OF SECTOR THE OIL AND GAS INDUSTRY

Hydrocarbons (mainly oil and gas) constitute the second largest reserve world energy, and are the main source of fuels today. In recent years, the demand for hydrocarbons has risen, so the need to develop techniques to overcome the challenges of the oil industry has been

growing. The present article will focus on the main challenges faced by the sector and also contribute with some recommendations or solutions.

The biggest challenge of any oil company today is to be able to adequately train its employees. As the market is very competitive and has a great turnover, it is through qualification that you can retain the professionals. Having a structured HR policy that invests in people is a key issue to keep them committed to the business.

There are other types of oil and gas called unconventional, such as oil shale. Their extraction is more difficult and requires a lot of technology, as they can be trapped in very permeable rocks or have very high viscosity.

Extraction of hydrocarbons can cause several environmental catastrophes, especially in case of leakage in the environment. Since most of the oil extraction platforms are located on the high seas, the environmental impacts caused by oil can take on overwhelming proportions.

The oil refining process works basically by raising its temperature (separating its molecules and increasing its degree of purity).The problem is that this procedure generates many toxic and flammable gases, which obligatorily requires the planning of an elaborate plumbing network, so that the gaseous fluids are properly processed and no leaks occur;

There are many activities in this work environment that are performed on the surface of the platform, or even in the sea itself. This may imply high sun exposure;

Since it is possible that there are problems with gas leaks, as well as the loss of control of the pressure of the piped fluid (be it the oil itself, be it the refining gas), the threat of explosion becomes imminent.

Increased cost of services is another huge challenge facing oil and gas. This increased cost cuts across the value chains from exploration to production as well as refining and transportation.

The oil and gas industry is one of the most important for human development. In order for the industry to progress, it is necessary to take into account these problems mentioned and among others, to ensure greater profitability**.**

According to experts, the key to reducing industrial accident rates in industries is awareness and prevention. It is extremely important that the management of the oil platform, before receiving employees, knows precisely what the present work risks are. This knowledge is only possible through the Preliminary Risk Analysis.

Investing in extraction techniques for unconventional reservoirs is a great opportunity for the countries, but it requires new regulations, investments and technology.

Encourage technical training and dissemination of training projects for engineers.

Research and development activities should not be left to universities and research institutions alone, but also to companies, which know the sector's problems and know where the biggest challenges are to be overcome

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3. Risk Analysis Applied To Work Safety In The Industry Of Oil And Gas, by E.J.P. Miranda Jr.

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PERFORMANCE OF A NOVEL GREEN SCALE INHIBITOR

Effective scale management is of great practical implication for oilfield development planning which would dominate the production viability [1]. The utilization of scale inhibitors (SI) in oilfields is generally common due to their impact on mitigation of scale formation as an efficient solution to enhance oil recovery (EOR) and prevent formation damage. In general, oil industry like other industries is suffering from environmental consequences of using hazardous chemical to inhibit scale formation. The selection of environmentally friendly inhibitors which should be non-toxic, biodegradable and shows no bioaccumulation [2], and appropriate dosage are two crucial factors to get the optimum inhibitory action which be achieved by simulating the well [3]. Although both types of phosphonate and polymeric SIs have been investigated, nevertheless, well-known polymeric environmentally friendly scale inhibitors like poly aspartic acid (PASP), polyepoxysuccenic acid (PESA), and carboxymethyl inulin (CMI) are gaining increased attention. In addition, natural organic molecules and plant extracts as green SIs [4] as in this study, the green materials are being assessed as a brand-new SI.

Formation damage has frequently been observed in various oil reservoirs as well as interconnected production equipment in Iranian oilfields, specifically near the wellbore. Employment of an efficient green SI would be a prevailing solution to overcome formation damage of various types as well as to safeguard the environment in water-flooding process. Therefore, scale potential and the SI's performance for a particular case study (Table 1) have been investigated through simulation by PHREEQC.

Table 1 - Ionic composition of investigated brines

Ion (ppm) / Brine	$[HCO_3^-]$	$[SO_4^{2-}]$	$[Cl^-]$	$[Ca^{2+}]$	$[Mg^{2+}]$	$[Na^+]$	$[K^+]$	pH
Formation water (F.W.)	2274	665	137114	14840	3086	67102	-	6
Seawater (S.W.)	183	2880	26625	750	1350	19550	410	7.5

Firstly, the critical mixing ratio of the two brines is examined to find out the maximum amount of precipitated particles at 90˚C. Secondly, the 50/50 mixing ratio as the critical point is conducted to evaluate the various dosage of the SI through incompatible mixing procedure. Finally, the impact of dolomite and calcite rock (10 gr) presence is investigated to determine the SI adsorption capacity for each rock.

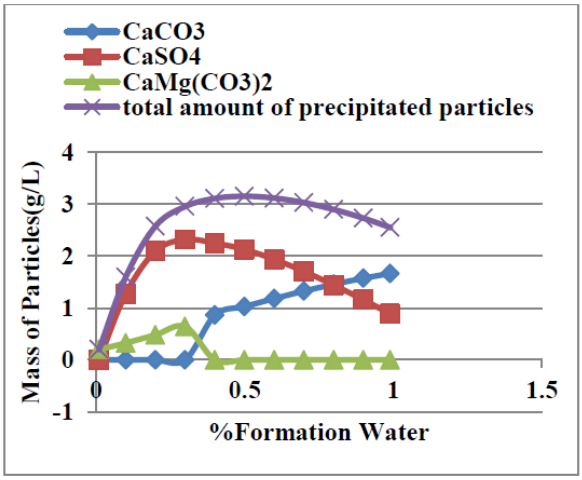

Figure 1 - scale potential determination

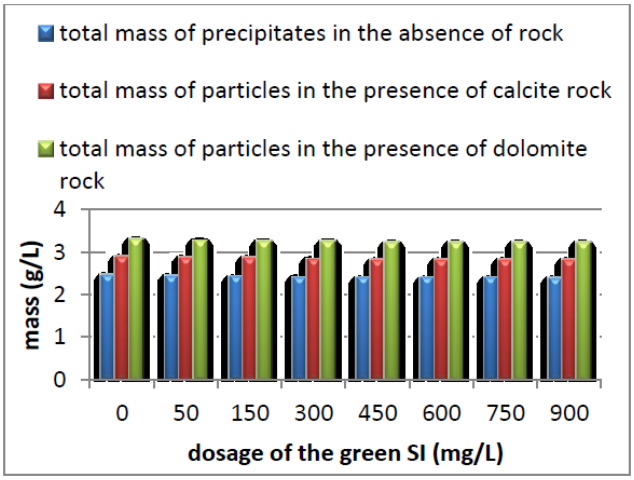

Figure 2 - Predicted mass of particles

Figure 1 demonstrates that the critical mixing ratio is 50/50 mixing ratio due to maximum amount of predicted precipitates including both carbonated and sulfated particles in the incompatible mixing process. Moreover, Figure 2 shows that the rock presence affects the SI's performance so that more particles would be formed in the presence of the rock, due to rock's dissolution mechanism. It seems that dolomite rock because of Mg^{2+} prevents the SI's adsorption compared to calcite. It would be worthwhile to investigate more about the predicted rocks' potentiality. Additionally, it can be concluded that 450 mg/L would be the appropriate dosage for utilization as optimum dosage of the SI in order to minimize the mass of particles.

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ENHANCEMENT OF ANNULAR SPACE INTEGRITY WITH ADDITION OF SWELLABLE AGENTS

Among the scientific and technical problems associated with the construction of wells, the task of creating high-quality cement sheath in the annulus of the well is the most responsible, as this ensures the reliability, tightness and environmental safety of the casing structure throughout the entire well service life [1]. Therefore, the development of self-healing cementing material that allows cement stone to self-repair is now a very promising area of activity. In this work, a study of water-swelling rubber particles and their self-healing ability was carried out. The feasibility of using rubber-swellable particles in water was investigated, as well as the

influence of these parts on the mechanical and rheological properties of cement slurry and stone. The self-healing ability of a cement stone with various percentages and particle sizes was quantified using a permeability test.

To develop a cement material capable to restore its tightness after mechanical damage, we chose a method for healing cracks and channels by blocking them with additives which are able to increase its volume [2]. Two types of swellable materials were chosen as objects of study: hydrocarbon swellable rubber (hereinafter referred to as HSR) and hybrid (hereinafter referred to as HR), swellable in a hydrocarbon medium and both in a hydrocarbon and in water, respectively.

The structure of the additives is pretty similar. It is a rubber porous matrix (frame), in the channels of which there is a composition of a vulcanizing agent, fillers and an absorbing active polymer. Due to the diffusion and porosity of the rubber carcass (in the form of a permeable membrane), the activator fluid entering the additive particles through cracks easily penetrates and interacts with the polymers, causing them to swell. Increasing in size, the polymer stretches in a radial direction the rubber frame, blocking the resulting cracks and channels. To qualitatively evaluate the performance of these modifying additives and their effect on the properties of cement slurry and stone, experiments were conducted in the laboratory of our university. After selecting the objects of study, it was necessary to conduct their preparation for the experiments [3].

For the experiments, a special installation was designed. To simulate cracks in the cylindrical pipe, used as a form for pouring, wires of the same diameter were attached at approximately the same distance [4]. Wires with a diameter of 0.3 0.5 and 0.7 mm were used, among which it was necessary to choose those which magnitude of error is the smallest.

This work made a significant contribution to the research for a material capable of partially or completely reducing the permeability of cement stone with a minimum decrease in mechanical properties. However, there is still a need to refine the new material. Firstly, it is necessary to slow down the rate of swelling of particles in the initial stages of hardening of cement stone and to increase the strength of swelling during the formation of cracks. It should be noted that during the study it was found out that the process of self-healing directly depends on the size of the cracks and the size of the rubber particles [5].

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TECHNOLOGY OF COMPLICATED WELLS DEVELOPMENT.

Most often oil and gas production companies use barite to weight the drilling fluid to lower abrasive properties and increase the density of the drilling mud. The use of barite is necessary for formation with abnormally high formation pressure, it also helps prevent complications connected with the damage of the integrity of the wellbore and possible oil-gas-water showings. Because of application of such drilling fluid, a colmatation cake containing barite and mud is formed, which results in reduced permeability, an increase in skin-effect and in diminished well performance in general. The following question is brewing as to how the colmatation cake should be removed from the wellbore wall?

This kind of problems can be solved by application the special chemical reagent called “RBS-3”. This reagent is a complex multicomponent organic product, which consist of chelate complexes and surfactants to increase the activity of the main active substance. Through the use of this reagent there is a possibility to dissolve barite and clay components of colmatation cake, that’s why the following parameters could be restored or even increased such as permeability, flowrate and injectability. [1]

“RBS-3” is intended for use as a destructor of salts of heavy metal, clays and polymers of drilling fluids, as well as resultants of reaction of hydrochloric acid with iron and rock in the oil and gas industry. There are some areas of application of the reagent such as in exploitation drilling for dispergation of drilling mud cake, drilling polymer-mud cake and barite. In Production well it helps with purification of downhole zone of the formation, inhibition of swelling of clayey substance of reservoir, recovery of permeability and removal of insoluble products of hydrochloric acid reaction with a rock. There are some advantages of using “RBS-3”: ability to dissolve heavy metal salts, efficient dispersion of a mud and the temperature resistance, low reaction rate with a carbonate rock, preventing the formation of a stable oil emulsions and low corrosion activity.

One of the most important things in oil and gas production is cost effectiveness, all companies make every effort to minimize the cost of extracting fossil fuels. When problems arise in the form of various deposits in wells that lead to decline in production, companies need to spend a large amount of money to solve these problems [3]. This paper presents and analyzes the innovative reagent for the removal of such deposits while being a cost-effective product.

Thus, the paper considers an effective and low-cost method of treating the bottom-hole formation zone and development of complicated wells, which will allow extracting the fluids from hard to recover reserves and restore the performance of old wells.

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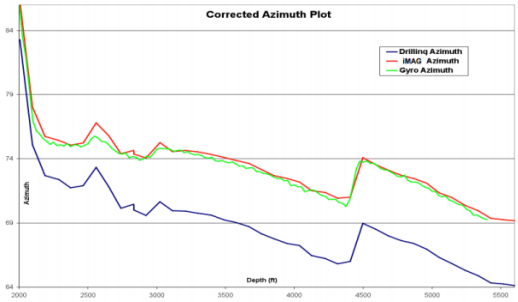
iMAG

The geomagnetic field of the Earth is a heterogeneous spatial structure and is characterized by a wide range of time variations. The main part of this field is created by sources inside the Earth. Additional sources of the magnetic field are located in the magnetosphere and ionosphere. Due to these additional sources, an external magnetic field of the Earth is created. Variations in the Earth's magnetic field are observed on its surface. A geomagnetic field spreads over all the spheres of the Earth: the lithosphere, hydrosphere and atmosphere, influencing geophysical, biophysical and technological processes. Often, magnetic navigation remains the necessary backup, the only possible and technologically justified method of orienting an object. Compass and magnetic declination data are widely used in aviation, geology, in the search for hydrocarbons and in drilling directional wells.

Directional drilling is determined by strict control of the orientation of the drill string below the ground. To measure the inclination angle and geographical azimuth, telemetric measuring systems based on magnetometry technology are used. This technology is more economical in comparison with the use of gyroscopes, since magnetic inclinometers are quite stable against mechanical stress and can be used as downhole navigation systems. A downhole magnetometer is part of a telemetry monitoring system called Measurements While Drilling (MWD) and is widely used in drilling and well construction in all geographic areas. However, with geomagnetic tracking of directional drilling of wells in the Arctic region, problems arise due to the structure of the Earth's magnetic field and the influence of solar activity factors on it. Powerful sporadic disturbances of the geomagnetic field associated with magnetospheric magnetic storms often occur at high latitudes of the Earth [4,5].

An important task of ensuring the specified parameters of the well is the stable following of the calculated direction of drilling and correction of deviations and verification of magnetometry data MWD. The reduction of errors associated with the Earth's magnetic field is achieved by applying modern models of the main magnetic field, models of local magnetic anomalies and aeromagnetic imaging. At high latitudes, it is also necessary to measure field variations on the Earth's surface directly in the area of work and to filter sporadic geomagnetic disturbances created by electric currents flowing in the ionized layers of the Earth's upper atmosphere (ionosphere). During magnetic storms in the polar ionosphere, jet currents elongated along parallels develop with electric capacities up to millions of amperes [1].

Using the methods used to calculate the actual profile of the wellbore [1], it is possible to assess the influence of sporadic disturbances of the magnetic field during a magnetic storm on deviations of the drilling path parameters of directional wells in the Arctic. These deviations, if they are not filtered out with the help of parallel measurements at the geomagnetic observatory, can lead to unacceptably large errors in the borehole inclinometric measurements by which underground navigation is carried out. Please take a look at our calculations at the graph below.



To determine the values of the main magnetic field at any given point on the earth, statistical models are used that assimilate data from ground-based observational and special magnetic satellite observations. Most oil and gas companies, in particular those operating in the North Sea and other subarctic regions, use the commercial model of the British geological

service BGGM (British Global Geomagnetic Model, British Global Geomagnetic Model) [3], which is updated annually.

During magnetic storms and other magnetospheric disturbances caused by solar activity, electrojets localized in the form of current jets flowing along latitudinal circles 65–75 ° in the northern and southern hemispheres develop in the Earth's high-latitude ionosphere. Electric currents flowing in near-Earth space create an external magnetic field of the Earth. The magnetic effect of near-Earth electric currents is observed on the Earth in the form of regular variations (daily, seasonal) and sporadic fluctuations on time scales from second to many-hour deviations from a calm level. At high latitudes, sporadic disturbances of an external magnetic field near the Earth's surface are determined mainly by ionospheric electric jets flowing along latitudinal circles in the auroral zone. Thus, in these areas, magnetometers record the most intense deviations in the horizontal component of the geomagnetic field. In addition, a rapidly changing external magnetic field excites telluric currents in the surface layers of the Earth with their own electrical conductivity. The magnetic field of these currents also introduces an additional error in determining the direction to the true north from the magnetic arrow [2].

The iMag software that we've developed with the introduction of machine learning will allow you to choose the necessary correction on the necessary parameter, to obtain the desired result. The main privilege of the software is the forecast of possible magnetic variations based on a prior data from magnetic observatories characteristic of the high-latitude region during magnetic storms. iMag software is a solution to an urgent problem in high latitudes and regions with a dislocation of more than 100 km from magnetic observatories. The software will serve as a domestic analogue for the import substitution program in a number of parameters, and will also provide the opportunity to adapt the latest additional features important for drilling in the Arctic region that have no analogues.

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DEVELOPMENT OF ARTIFICIAL NEURAL NETWORK FOR PREDICTING DRILL PIPE STICKING IN REAL-TIME DRILLING PROCESS

Predicting the drill string sticking is one of the most relevant topics in modern oil and gas drilling. Unfortunately, even when using modern technologies and equipment for the construction of wells, the practice of drilling oil and gas companies often faces such an accident as the sticking of drill string. According to drilling companies, the most common complication and accident during drilling is the stuck of the drilling tool [1-5]. The number of sticking of drill string every year remains high. Stuck accounts for 26% to 60% of the total number of

complications and accidents that occur during drilling operations, while 40% of wells where stuck occurred had to be liquidated or re-drilled [2]. The work is devoted to the developing neural network model for predicting drill pipe sticking in real-time drilling process, which allows the personnel of a drilling company to react promptly to the occurrence of stuck and eliminate them at an early stage. There is also a literature review of existing methods for predicting stuck.

The main part of the work deals with the quality of the data set, the formulation of the list of elements of input data, the primary processing (normalization) of data. Also, the paper discusses the method of sliding window with its main parameters (the dimensions of the window matrix). The choice of the neural network model and type, network architecture, network optimization and regularization, and network hyper-parameters are justified. Assessment of the quality of the network is made by the method of k-fold cross-validation. The test of the quality of the developed model is carried out on the real industrial data set of stuck (on the example of oil wells in the Tyumen region of the Russian Federation).

In conclusion, it should be noted that: the paper proposes a method for developing a model of a neural network with a sliding window for predicting drill pipe sticking; conducted experiments on real data that showed that the quality of the developed model exceeds the quality of previously existing models; the resulting prediction model can be used in the process of drilling wells, which will minimize the risk of stuck pipe; the developed model will allow to predict the occurrence pipe stuck (based on experimental data) with a prediction accuracy of 86%.

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HEAT TREATMENT OF PAY ZONE PARAFFIN OIL, IN A THE PROCESS OF DRILLING

A general problem in first opening of a pay zone is contamination of the pay zone. This problem is relevant to wells, when the pressure of a drill agent is bigger than the pressure inside the pay zone. One way to avoid contamination is drilling with controlled depression on a formation [1] this method based is on the special instruments. Other methods are based on drilling mud with silt or carbon components, etc. All these methods help to avoid pollution in the formation.

The main solution is forming crystals from oil [2] with drilling liquid which has a temperature lower than the temperature of the formation of paraffin crystals inside the pay zone. Paraffin crystals make a wall between the hole and formation, so it protects natural permeability. New methods to avoid the problem need a new technology of drilling. It is based on a period of heat treatment between the space around the bottom-hole and drilling liquid. When paraffin crystals are made inside this structure, then a bit can move to the pay zone which will be protected by the frozen paraffin structure.

Finally, my investigation showed that to form paraffin crystals, it helps to drill wells with less pollution in the pay zone. The next investigation has to show which width of wall from paraffin crystals helps to avoid pollution, and also which types of reservoir permeability work with it.

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DEVELOPMENT OF SUPRA-MOLECULAR SYSTEMS OF PROCESS FLUIDS FOR ADJUSTABLE CONTROL THEIR PROPERTIES TO PREVENT COMPLICATIONS DURING WELL DRILLING

Today, the market of chemical reagents, both foreign and domestic, offers a large list of polymer reagents whose nature, as well as their properties, are not fully understood.

On this basis, drilling manufacturers use a large number of polymer reagents as part of the recommended formulations of such solutions. In the formation of such formulations, the chemical structure of the macromolecules of polymer reagents, their mutual influence on the effectiveness of each of them during the interaction of the components of the drilling fluid and their influence on the components of the technological functions considering the composition and properties of rocks are not considered.

Polymeric reagents in the composition of drilling fluids should enhance the effect of each (synergistic effect) with a general positive effect in the implementation of a particular function of such fluids.

According to these problems we have analyzed the most widely used polymer chemical reagents that are the basis of polymer drilling fluids that are most widely used in drilling practice.

Today polymers are an integral part of almost all water-based drilling fluids. Some types of solutions are completely dependent on polymers; therefore, such solutions are often called "polymer". Currently, there is a huge variety of polymers. The unlimited potential of polymers makes them applicable for almost any tasks that drilling mud developers are called upon to solve. They can analyze the situation at the molecular level and design polymers with predetermined properties for solving various problems. Therefore, polymers have a great future in the mud industry.

The basis for the development of supramolecular drilling fluid systems we have obtained the basic laws of the formation of such systems [1]. When several polymeric substances are in an aqueous solution, they create associates of complementary molecular components connected by non-covalent interactions - that is, intermolecular interactions. The objects of such studies are supramolecular ensembles consisting of fragments of such systems having geometric and chemical correspondence.

These systems have the ability to spontaneously assemble complex spatial systems of polymer drilling fluids. The one of the objectives of our research is to study the patterns of formation of supramolecular polymer systems of drilling fluids, which determines the chemical properties, structure of macromolecules and the main functional groups of polymer reagents that are part of the supramolecular systems of drilling fluids and purposefully control their technological properties.

Establishing patterns of self-organization of supramolecular polymer drilling fluids makes it possible to obtain the dominant parameters of the membrane formation mechanism (MMO) when they interact with clay-producing rocks [2].

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THREADED LOCK CONIC CONNECTION OF DRILL PIPES AND METHOD FOR INCREASING ITS CARRYING ABILITY AND RESOURCE OF WORK

The practice of drilling oil and gas wells proved that threaded tool joints continue to remain the most vulnerable unit in the drill string assembly, perceiving complex alternating bending and tensile loads and having a tendency (with repeated acts of screwing and unscrewing pipes) to wear out the thread profile, with loss of sealing ability and mechanical strength, with an increase in the risk of their dismemberment and accident.

The proposed threaded connection for drill pipes is characterized by an increased service life and a high load-bearing capacity of the threaded connection in the conditions of drilling wells with complex spatial parameters, including when drilling sidetracks, horizontal and branched trunks of deep oil and gas wells.

A distinctive feature of the proposed threaded connection is that the full-sized threaded part of the nipple of a typical locking joint in accordance with GOST 28487 - 2018 is increased by a threadless conical extension. The linear size of the extension cord is in the range from 0.55 to 0.65 of the length of its threaded part. In the coupling part of the lock connection, after the end of the threaded type cutting, an internal conical bore (surface) is provided, congruent with a conical extension of the nipple part. An annular groove is provided on the conical surface, with a sealing ring located in it, while the end surfaces of the nipple and couplings are inclined to the axis of rotation at an angle of 105 ° to 120 ° (Figure 1).

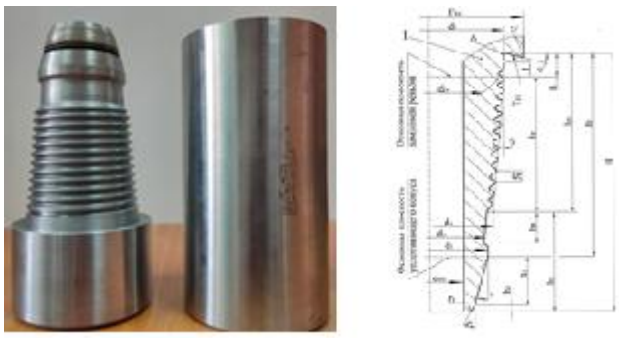

Figure 1 - Threaded Tool Tapered Drill Pipe Connection

The report will present the advantages of using the developed design of the threaded connection and prove the economic efficiency. For a complete understanding of the topic, done calculations, diagrams and a thread pattern will be presented.

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Midstream

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ANALYTICAL COMPUTATION OF LIGHTNING STRIKE PROBABILITY FOR FLOATING ROOF TANKS

Lightning creates a major challenge for oil and gas storage facilities due to the risk of lightning-induced fires [1]. To ensure rational use of natural resources, it is vital to eliminate or at least reduce sources of losses. Crude oil, gas condensate, and gasoline are typically stored in steel floating roof tanks (FRTs). FRT helps to stabilize the crude and limit vapour pressure, but FRTs are susceptible to lightning related fires, especially at the rim-seal region. A fire hazard study performed on 102 FRTs revealed that 65% of these fires were due to lightning strikes [2]. Currently, there is no air termination design for FRT in lightning protection standards. Designing a conventional lightning protection system (LPS) for FRT requires an adequate understanding of the variations in the exposure of various parts of a FRT to lightning strikes. This can be achieved by developing a simulation to analyse the probability of a direct strike to a FRT. The numerical simulation creates a challenge because it is slow, requiring days to compute in some cases, even on computers with good specification and this creates a heavy demand on computer resources [3]. This study presents an equivalent, accurate, and novel analytical computation resolved down to simple equations for determining the probability of a lightning strike to various parts of a FRT without the need for any slow and hard to model numerical simulation.

The numerical computation of the probability of a lightning strike to a FRT can be performed by applying the concept of dynamic electro-geometrical model (DEGM). In the DEGM model, the surface of the FRT, the ground and space area around the tank are discretized

into meshes for determining the probability of a strike to each meshed point using the lightning probability density function [3, 4]. This may require millions of iterations to compute in some cases, and this therefore makes it slow in generating results. Also, there is a need for a programming skill to implement the intricate model. Alternatively, a simplified analytical technique that is based on the dimension of the FRT and space points using increasing striking distance radius (*r*) can be developed.

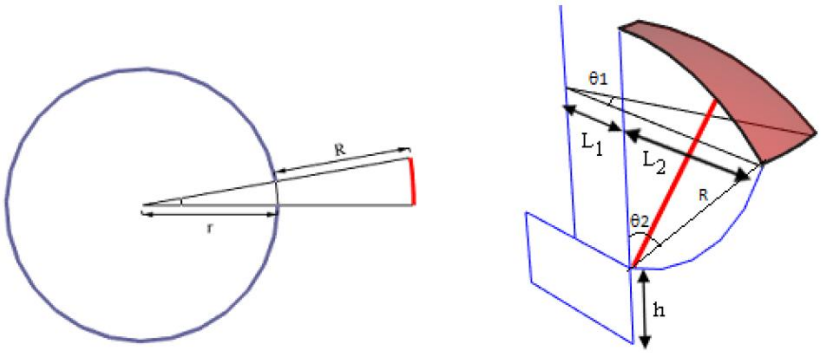

Figure 1 - Lightning strike collection area for the cylindrical wall and tank rim
(a) Side flash to unit section of the cylindrical FRT wall
(b) Space point surface area above a section of the tank rim edge

The surface of the FRT is classified into three i.e. the floating roof area (*Aroof*), the top rim-edge of the tank cylinder (*Arim*), and the cylindrical side wall (*Awall*). For the side wall and the rim edge, the computation was performed for a unit sectional area defined by a span O_1 of radians, where R is the radius of the FRT, and as such, the sectional result must be multiplied by the circumference of the cylinder. Analytical equations using concepts shown in Figure 1 (a) and 1 (b) were developed to describe these three surface areas, and these equations were incorporated into integral equations modulated by the lightning striking-distance probability density function PDF(*r*) to generate the probability modulated lightning collection volume (PMCV) defined in equations (1) to (3) for a FRT of height h.

$$PMCV_{roof} = \pi R^2 \int_{r=0}^{r\to\infty} PDF(r)\cdot A_{roof}\, d(r) \tag{1}$$

$$PMCV_{rim} = 2\pi R \int_{r=0}^{r\to\infty} PDF(r)\cdot A_{rim}\, d(r) \tag{2}$$

$$PMCV_{wall} = 2\pi R \int_{r=0}^{r=h} PDF(r)\cdot A_{wall}\, d(r) \tag{3}$$

Floating roof tanks are generally about 10 m to 20 m in height. To provide an extended range, the analytical computation was developed for various FRT heights ranging from 1 m to 40 m. Using the results of the analytical computation, data fitting technique was applied to the resulting dataset, and simple equations for the PMCVs as a function of FRT height (h) was developed.

The performance of the analytical model was verified by carrying out DEGM numerical simulations for various FRT height (*h*) and radius (*R*) for a direct comparison. The analytical equations performed accurately well for the cases considered with a maximum variation of 2.058 in value for the sectional rim edge, giving an accuracy of 97.97% as compared to the numerical result. Due to typical errors associated with numerical simulations, as they are often an approximation of the true result, the analytical model may even be more correct than the numerical result obtained from DEGM. Hence, a simple, easy to use and accurate equations are now available for estimating the probability of a lightning strike to various parts of a cylindrical tank, towards enabling the design and implementation of a safe and effective lightning protection system.

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NETWORK OF MARINE GAS PIPELINES ON THE ARCTIC SHELF

The main oil and gas reserves are located in Siberia and the Arctic shelf. In the water territories, half of the Russian gas lies with a quarter of the oil. Most of the gas is concentrated in the Barents Sea (approximately 49%) in small and medium fields [1]. The main purpose of this article is to derive and analyze new ways to optimize the laying of offshore pipelines in severe arctic conditions. The global goal of this scientific work is to identify possible ways to sell deposits on the Russian Arctic shelf. Choose the optimal method for the development and subsequent transportation of produced hydrocarbons. Estimate recoverable reserves. Highlight existing problems and possible solutions. Carry out hydraulic and economic calculations. Prove the chosen transportation method.

To consider the long-term prospect of developing large fields, the gas pipeline will be a rational method from the point of view of economics and technical equipment [2]. Development of large and medium fields - a network of gas pipelines; small - CNG gas carriers. Based on the location of the fields, a route was chosen (Figure 1). It is planned to create a number of key platforms that can be installed in the fields: Ludovskoye, Shtokmanovskoye, Murmanskoye, Ledovoye, North Kildinskoye [3]. Moreover, the latter two can not only maintain pressure for gas transportation, but also serve as terminals for CNG vessels. Upon the expiration of hydrocarbon deposits of key platforms, the commissioning of medium and small fields is possible. The development and supply of gas to the key platform will be carried out underwater using underwater compressor stations and drilling facilities. The initial data for the calculation were selected on the basis of the pumping indicators of the existing Portovaya compressor station. The costs and diameters of pipelines are calculated based on the thermobaric conditions of the region[4].

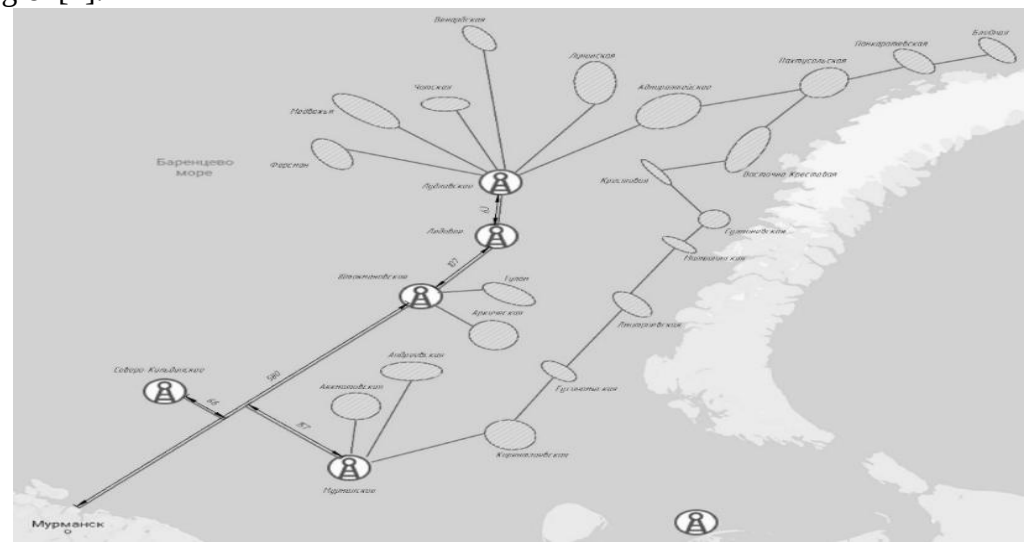

Figure 1 - Project gas pipeline route

As a result of the calculations, the following values were obtained in Table 2.

Table 2 - Hydraulic calculation of losses in 3 sections of the pipeline

Track / Parameter	L, km	D, m	$\rho_{0,}$ kg/m^3	$Q_{0,}$ m^3/h	Re*10	λ	ΔP, MPa
Ludlovskoye - Ledovoe	69,3	1,42	0,7	625000	38,9	0,03	0,891
Ledovoe - Shtokman	117,7	1,42		1666667	10,4	0,03	0,310
Shtokman - Murmansk	638	1,42		2916667	18,2	0,03	1,262

The problem of most deposits is the evaporation of interlayers of gas hydrates at a depth of 10-15 meters, as a result of which the pressure in the reservoir rises abnormally. For the exploitation of small and medium deposits, this can be both an advantage and a disadvantage. Saving energy for production can result in a catastrophic fracture. A thorough preliminary assessment of the state of the formation is necessary. Also, as a prevention of possible adverse pressure surges, there are projects to develop such deposits by injecting liquid nitrogen. However, this method has never been used in practice.

In the process of simplified economic calculation, the profitability of the project was calculated, which is positive. The main buyers of Russian gas transported through the pipeline will be the countries of Western Europe. The main buyers of CNG delivered by gas carriers on the Northern Sea Route are Asian countries. The optimal route for transporting gas to Europe was compiled, a hydraulic and economic calculation of the project was carried out, a scheme for the development of small and medium fields was proposed. The pressure loss on the route will be no more than 2 MPa. With constant supplies, using only three sections, the profit will be about 324 billion rubles. per year with an initial investment of 707 billion rubles.

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EMERGENCY RESOURCE RESERVES OPTIMIZATION FOR RESCUE POINTS OF LONG-DISTANCE OIL AND GAS PIPELINES

When long-distance oil and gas pipeline's accidents outbreaks, emergency resources such as personnel and materials should be obtained from the nearest rescue point in time to minimize direct and indirect losses. Under the presumption that the rescue points along the pipeline have been established and the total cost of the emergency resources invested is certain, the way to allocate the various emergency resource reserves of each rescue point, that ensure the emergency resource requirements for accidents at any location of the pipeline and minimize the repairing time of emergency resource distribution is about to be established[1]. In general emergency resource allocation issue such as earthquakes, fires, and urban pipeline networks, etc.[2], the resource distribution process is regarded as equal weights network connection[3]。 However, as long-distance oil and gas pipelines distributed along the route, field geographical environmental factors and traffic conditions have direct impacts on resource distribution efficiency. In addition, the corresponding accident probability and severity of different pipeline sections are variable [4]. Therefore, on the basis of the general resource allocation problem, the above two points should be combined and optimized.

According to the characteristics of long-distance oil and gas pipelines, a mathematical model for optimizing the resource reserve of rescue points was established.

Model preparation The emergency resources are divided into categories according to personnel, emergency equipment, emergency appliances and spare materials. The range of factors that may affect the efficiency of emergency resource transportation is also defined.

Model assumption Since most of the long-distance pipelines are routed in desolated areas such as mountains, deserts, tunnels, and wastelands, the public security rescue force can be used little. Therefore, no other emergency forces shall be considered except the known emergency rescue points established by the pipeline company.

Model composition a) For different emergency rescue points, the location and traffic centrality of the point in the resource allocation network should be considered. For example, if the location centrality of emergency rescue points to the pipeline is the same, prioritize the allocation of emergency resources to the point which has the biggest traffic centrality. b) For a single rescue point, the cost of resource purchase, the particularity of reserves and the necessity of resources should be considered. For example, for a rescue point with the same resource necessities but higher personnel placement costs, it is better to increase the material reserves and reduce personnel distribution. c) The conception of risk degree of different pipeline segments is introduced to modify the resource reserves of each rescue point.

Model solution Establish the emergency resource factor index (ERF) to measure the emergency resource capacity of oil and gas pipelines. Regard emergency resource factor of the overall pipeline system as the objective function and Greedy Algorithm as the method. In the way above, search the various emergency resource reserves of each emergency rescue point under certain cost, which is, the corresponding emergency resource reserve optimal plan.

Regarding the resource reserve plan of the long-distance pipeline, on the basis of the ideal resource allocation network, the actual environment and the risk of the pipeline sections are modified to make the emergency reserve plan more realistic. With the digitalization of the full-cycle management of oil and gas pipelines, some constant parameters in the original emergency resource reserve optimization model will be replaced with dynamic real-time parameters, which will make the mathematical solution results of resource reserve optimization more practical and contribute to decision-making.

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SYSTEM OF INDEPENDENT EXPERT EVALUATION OF VAPOR RECOVERY TECHNOLOGY OF OIL ON THE MARINE TERMINAL

A steady increase in the volume of transshipment of oil and oil products through the marine terminals is observed not only in the Russian Federation but also throughout the world. An increase in the volumes of loading oil and oil products is naturally associated with an increase in environmental risks. It is possible to reduce these risks in terms of air pollution to an acceptable level by the rational use of vapor recovery technologies [1].

A large number of different technologies for trapping vapors of oil and oil products are presented on the world market: adsorption, absorption, membrane, catalytic oxidation, cryogenic, etc. [2,3]. More countries follow the path of introducing the best available technologies. Equipment manufacturers are commercially interested participants in the process and often deliberately keep silent or distort the information provided on possible problems when introducing a particular technology.

For example, membrane installations are extremely unstable to the effects of mechanical impurities the use of cryogenic plants is associated with significant energy consumption and the operation of widespread adsorption plants faces serious problems in the hydrogen sulfide vapor.

Based on a synthesis of experience in using such equipment a solution is proposed for an independent expert evaluation of vapor recovery technologies based on experiments at a specially developed stand. The concept of the stand provides for an assessment of the parameters of the process as a whole (specific energy consumption per 1 kg of captured product, efficiency). As a result of a review of vapor recovery technologies and a critical analysis of data from equipment manufacturers was established that marine terminals need a system of independent expert evaluation of vapor recovery systems.

The proposed method for solving the problem is the assessment and comparison in laboratory conditions of individual technological processes and materials involved in the vapor recovery. The project evaluation system based solely on a comparison of the technical and economic offers from suppliers is incorrect and can lead to significant unnecessary material costs.

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EFFECTIVE TECHNOLOGIES FOR TRANSPORTING OIL AND NATURAL GAS

Modern progress is unthinkable without natural gas, oil and its refined products. The effective work of industrial enterprises in almost any national economic sector is directly dependent on the timely supply of energy carriers, as a result of which the transportation of oil and gas as well as their processed products is of great economic importance.

Hydrocarbons can be transported in the following ways:

- tank wagons;
- oil tankers;
- tank trucks;
- pipelines.

As a rule, transport and storage of oil is carried out using a system of pipelines and oil depots.

Pipeline transportation is the cheapest way to transport and transit petroleum products. All pipelines are arranged according to one principle - the main pipe, a complex of pumping stations and auxiliary facilities (power lines, corrosion protection systems etc.).

Pumping stations are the most complex part of pipeline structures. Pumping stations are equipped with powerful pumps and a complex energy system, the capacity of which reaches several thousand kilowatts.

The density and viscosity of the oil change depending on the temperature. Density and viscosity of oil significantly affect operating costs and reliability of transportation[3]. The volume of oil products formed on the walls of pipelines during pumping is 0.5 - 1% of the pipeline volume. Currently, significant amounts of oil are produced that have a high viscosity at ordinary temperatures or contain a large amount of paraffin and, as a result, congeal at relatively high temperatures. Pumping such oil through pipelines is difficult.

To solve these problems, it is proposed to apply a composition comprising a fluorinated surfactant and a solvent to the surface of the pipeline. When applied to a surface, the solvent evaporates, and the surfactant forms a monomolecular film on the surface, which in turn significantly changes the energy state of it [4]. This allows you to give the surface the following properties:

- hydrophobicity and oleophobicity;
- antiadhesion properties;
- thermal stability up to 400 ℃;
- indelibility from the surface by oil products;
- chemical inertness;
- reduction of hydrodynamic friction.

An experiment was conducted to determine the free flow time of transmission oil through a capillary glass viscometer using a thermostat.

At the first stage, the measurements were carried out on a viscometer in the temperature range 20 – 70 ℃, the free flow time was recorded every 10℃. At the second stage, the viscometer was treated with a surfactant solution, and measurements were carried out with the same oil in the temperature range 20 – 70 ℃.

The research result showed that in the processed viscometer, the free flow time had decreased by 15% over the entire temperature range.

Nanocoating based on fluorinated surfactants significantly changes the functional characteristics of the surfaces of objects, and in addition to them it changes the nature of the processes occurring on the surface. That is, the formation of a layer of oil products on the surface is excluded and the hydrodynamic resistance during pumping of oil products is reduced, and, as a result, the energy consumption at pumping stations becomes lower.[1-2]

The technology of applying a surfactant molecular layer to a surface can be implemented in two ways:

1. Spraying fluorinated surfactant solution (0,03 ~ 3,0%) on pipe surface.
2. Introduction of 0,03% surfactants into the oil during pumping.

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CIVIL LAW NATURE OF THE TRANSPORTATION OF GAS AND OIL THROUGH PIPELINES

The legal regulation of oil and gas transportation through the use of pipeline transport includes a set of regulatory legal acts relating to various branches of law. First of all, the question arises, to what extent the legal relations under consideration are civil law. To answer this question, it is necessary to determine what features from the point of view of civil law they possess.

The following features are characteristic of gas and oil transportation relations. Property isolation of participants, as gas and oil companies independently participate in these relations and are liable with their property. Equivalently paid nature, because the execution of all oil and gas transportation operations using a pipe system is the usual commercial activity of legal entities. Participants in the above-mentioned relations are equal and independent in relation to each other, and are also not under administrative subordination, being independent separate entities.

For civil law, the conclusion of a model civil law contract is typical. In relations for the transportation of gas and oil, the conclusion of a set of contracts is available in cash. They clearly define the persons between whom civil rights and obligations are established. These persons, in this case, legal, are authorized to perform certain actions within their competence.

The system of contractual relations includes two interdependent parts. The purpose of oil as fuel and material for the manufacture of petroleum products indicates what the first part of the system will be, as a result of which oil should be delivered from oil production facilities to oil refineries in the domestic market or to specialized oil loading sea ports, i.e. in case of further export of energy.

To achieve the desired result in the production process, civil contracts act as intermediaries. Such a role of contracts can be observed in the case of oil transportation through the pipeline and during oil transshipment in the seaport. The contract for the performance of work and the provision of services for the preparation and delivery of oil at an oil production facility will mediate on-site transportation and delivery of oil through the producer’s metering unit to the main oil pipeline system. An agreement on the provision of oil transportation services via trunk pipelines determines the procedure for delivering oil from oil production facilities to metering stations of Russian oil refineries, i.e. to the domestic market, as well as to seaports for export. An agreement on the provision of oil transshipment services at the seaport regulates the transshipment of energy resources to the final points of transport systems for oil supplies outside Russia. The oil supply agreement through the main oil pipeline system mediates the transfer of oil to oil refineries for the production of petroleum products. Contracts from the second part of the system mediate the circulation of petroleum products in the retail and wholesale markets.

The legal nature of the relations regulated by the gas and oil transportation agreement is controversial. On the one hand, the civil law relations for the transportation of energy resources by pipeline cannot be qualified as transportation or delivery of goods. They should be drawn up in the form of an agreement on the provision of services for the transportation of oil or gas. On the other hand, it is impossible to mix the two types of delivery and transportation obligations. This is due to the emergence of two different kinds of obligations during the transportation of oil and gas: transportation obligations and delivery obligations. However, in the scientific literature, these types of obligations are also related to the provision of services.

We believe that the contract for the transportation of gas and oil through the pipeline should be classified as different from all the above types of contracts. The gas of one owner, moving through pipes, is mixed with the gas of another, as a result of which its qualities change, which makes it impossible to identify a specific owner of the energy resource. Organizations transporting gas (oil) cannot be called suppliers or recipients of products, which does not allow the procedure of transportation to be attributed to a delivery obligation. It is more difficult to separate the oil and gas transportation agreement from the transportation agreement. The transportation of goods and goods is carried out only with the help of "classical modes of transport": railway, water (sea and river), automobile and air. The transportation of oil and gas in

the case we are considering is realized through a system of pipes. Pipeline transport does not belong to any of the above types due to its inherent properties.

The main difference between pipeline transport from other modes of transport is its immobility and the inadmissibility of leakage and damage to goods. By means of pipeline transport it is possible to transport an unlimited amount of oil and gas. The quality and quantity of cargo does not change due to the good sealing of pipes and stations. Pipeline transport is characterized by a high level of automation of operations and a relatively low cost. That is why we consider it necessary to single out gas and oil transportation relations as separate from other similar types of civil law relations and to prescribe their terms in a new type of agreement.

The agreement on the transportation of oil and gas by pipeline establishes important conditions for the parties to provide services for the transportation of energy resources through oil and gas pipelines, focusing on the fact that the legal relations settled by him are of a commercial nature. The contract is long-term, i.e. The deadline is one calendar year.

The subject of the contract is cargo - oil and gas. Oil deserves special attention. One of the mandatory conditions of the oil transportation agreement is its stay with the consignor on the basis of ownership or on any other legal basis, including in the mixture with oil of other consignors. As an important point, the definition of the owner of the energy resource located in the pipes should be recognized. During the process of moving oil through pipelines, the oil of one particular owner (shipper) is mixed with the oil of other shippers. As a result, the depersonalization of oil takes place, its de-individualization, which means that the ownership of it is lost.

There are two points of view regarding the resolution of the existing dividend. The first of them says that mixing in the oil pipes of different owners leads to the emergence of a common ownership regime for each of them. In our opinion, this is not a completely correct resolution of this dispute, because there will be problems with the disposal of transported oil. So, the owner of a certain share will not be able to transport it without informing the co-owners about their intentions and without knowing the consent of the latter to this. If other participants in the joint shared ownership refuse, the owner of the share of oil that is in the pipeline and is already transported will not be able to separate it from the shares owned by other persons. According to the second idea, which is true in our opinion, being in the pipeline system and transported oil is recognized as the property of only the consignor with whom an agreement has been concluded for the provision of transportation services.

Relations on the transportation of oil and gas through the use of the pipeline are quite justifiable civil law, as evidenced by their specificity and their attributes. Thus, we got a completely new relationship, thanks to which all modern states are provided with oil and gas.

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COMPARISON OF THE TRANSPORTATION COST OF LNG AND CNG FROM FIELDS OF THE BARENTS SEA TO CENTRAL EUROPE

In connection with the development of natural gas production from the fields of the Arctic continental shelf an urgent problem becomes the choice of the most economically and environmentally advantageous type of transportation. Currently, there are two types of marine transportation of natural gas: liquefied natural gas (LNG) and compressed natural gas (CNG) [1]. One of the most promising areas of the Arctic continental shelf for natural gas production is the

territory of the Barents Sea with the Shtokmanovskoye, Ludlovskoye and Ledovoye fields. The main consumer is expected to be Central Europe.

To make a decision on choosing the most profitable technology for transporting natural gas from fields of the Barents Sea to Central Europe, it is necessary to fulfill the goal of the work: to compare the cost of transporting LNG and CNG. To achieve this goal, the following tasks should be performed: 1) Compare LNG and CNG transportation technologies in Arctic conditions. 2) Using the methodology presented in the publication [1], calculate the required number of ships and voyages for both types of transportation with the same volume of natural gas from fields of the Barents Sea to the port of Rotterdam. 3) Evaluate the cost of fuel for the transportation of LNG and CNG. Research method: comparative analysis of existing projects and research of natural gas transportation by LNG and CNG technologies. As a result of the calculations, the following values were obtained in the Table 1.

Table 1 - Calculation results for the transportation of 5.475 bn m^3/year of natural gas from fields of the Barents Sea to the port of Rotterdam

Parameter	**LNG**	**CNG**
The estimated number of the carrier ships	2	8
The cost of fuel for one voyage	96444 Euros	41072,56 Euros
The estimated number of the voyages	56	160
The estimated annual fuel cost	5400864 Euros	6571610 Euros

According to calculations, it will take 2 vessels to transport LNG from the port of Murmansk to the port of Rotterdam, and 8 vessels for CNG, but it is worth considering that the cost of one LNG tanker is higher due to a complex construction. Despite the fact that the fuel consumption and cost per 1 voyage for CNG tankers is lower than for LNG, for the transportation of the same volume of natural gas, the cost of fuel per year for CNG tankers is 21% higher due to the greater number of voyages. In addition, it should be taken into account that for LNG transportation 65% of the costs are spent on liquefaction, storage and regasification at the LNG plant [2]. At the same time, CNG vessels can receive and return gas independently, the process does not require pre-treatment, filters and compressors are placed on the ship [3]. This advantage will save on infrastructure costs typical for LNG transportation. From an environmental point of view, the use of CNG technology is more preferable due to low gas losses during transportation [4].

Thus, in order to make a final choice between LNG and CNG technologies for transporting natural gas from fields of the Barents Sea to the European market, it is necessary to continue researching this issue and complete the economic calculation, taking into account depreciation, operating and freight costs, port charges and customs duties.

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RISK ASSESSMENT AND RANKING AFTER DESIGN IMPROVEMENT OF THE GAS TRANSMISSION SYSTEM

Pipelines are constructed and operated for one function that is to move hazardous substance from one site to another. To accomplish this aim, the gas transmission system must be built and operated in compliance with relevant requirements and best practices ensuring that its design is acceptable, and that its operation is performed to keep it running according to the design conditions. Safety while undertaking a potentially hazardous activity means the identification and management of risks.

Control of the risk has become an integral part of pipeline transportation. Risk assessments of pipelines are very useful for recognizing the real extent of threats posed by pipelines carrying dangerous materials to the public and service staff in the environment and pipeline operations.

Gas pipelines be hazardous production facilities are situated in a continuously evolving natural environment. Though conceptually simple, they are in fact complex, dynamic systems, operating in often challenging environments and subject to a vast and varied array of threats to integrity. Accurate estimation of the service lives of pipelines is important in the management of pipeline assets to maximize maintenance and rehabilitation strategies. The basis for making accurate estimates of structures' operational life is to consider the dynamics, and kinetics of various cycles of structural decay, whether they are steel, concrete, or other materials. Thus, hazards need to be detected in an extremely structured manner following well-established protocols and practices being effectively managed. They to be identified include anything that could potentially cause harm to personnel, the environment or assets, or any possible events and conditions that could cause emergency situations.

Effective risk evaluation is an investigation into the complexity; offering an open, understandable, manageable integration of the potentially pipeline-acting physical processes: external forces, deterioration, cracking, human mistakes, material changes, etc. The impact of such hazardous events is defined as the type and extent of the hazardous impact that results from those events [1]. An occurrence usually refers to events (or accidents) that lead to dangerous circumstances, such as flammable material leakage that ignites and exposes workers to fire / thermal hazards that result within injury or death. Assessment of these effects are performed to estimate the extent and magnitude of the threat (e.g. the amount of people to be affected and their likelihood to be injured or killed).

The effects and frequency of the different dangerous incidents must be measured to assess the danger associated with a facility or an operation. The best approach in risk evaluation is to determine major risk variables by analyzing and integrating several minor variables, usually accessible from reports of the operator or databases on the public domain. The key problem that is continuously manifesting itself is the lack of reliable data that allow for proper evaluation of possible release of hazardous material from these pipelines and evaluation of the pipeline risk [2]. Risk is measured by combining impact and frequency of various hazards. To quantify the overall risk, the calculated risk is aggregated for different incidents. Risks are usually measured around the pipeline facilities for staff and public services, the company losses, and the atmosphere. Risk is estimated quantitatively using comprehensive frequency and effect analyses, where data are available, and where the sophistication of the method demands the information. Quantitative risk assessment uses a systematic mathematical approach to predict risk from

hazard sources regarding impacts and frequencies. To decide whether the risk is appropriate, the results of the risk must be compared with defined parameters that define appropriate levels of risk.

The algorithm development for risk analysis and monitoring, as well as the development of ad-verse situations scenarios, is carried out from functioning parameters calculation of the hazardous production facilities. In general, the calculation sequence is as follows: 'strength $R_\sigma(\tau)$ – rigidity $R_\delta(\tau)$ – stability $R_\lambda(\tau)$ – resource $R_{N\tau}(\tau)$ – reliability $P_{QR}(\tau)$ – survivability $L_{ld}(\tau)$ – safety $S(\tau)$ – risk $R(\tau)$ – protectability $Z_\kappa(\tau)$'. All parameters are functions of time τ, at all stages of their life cycle [3].

Pipeline failure modes and integrity assessment are key components in maintaining the safety of the pipeline and managing its risk. Well-maintained and operated gas transmission systems can be safer and have less of an impact on the environment than other modes of transportation only if proper process management system for the pipeline will be implemented that based on international best practices ensuring protection and risk control.

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RATIONALE FOR USING A LIQUID-GAS EJECTOR IN LIQUEFIED NATURAL GAS (LNG) STORAGE SYSTEMS

Storage of liquefied natural gas is a complex system that ensures that the fuel temperature is kept low. This increases the cost of capital and operating expenses for the construction of tank fields. LNG storage systems are equipped for safety with devices that ensure the discharge of vapors from the storage when there is an excess of them in emergency or periodic situations. Such discharges are burned in the system's flare, which leads to the loss of expensive fuel, or if there is a technological binding, they are taken away by a compressor, the use of which requires additional energy consumption [3].

Sampling of liquefied natural gas (LNG) is also a necessary part of the fuel liquefaction, storage, and transportation processes. Using a compressor to feed regasified liquefied natural gas to the sampler may result in a change in the component composition of the sample due to the ingress of the device's lubricating oils. In addition to changing the quality characteristics, the use of a compressor requires additional capital and energy costs when completing and operating the system, respectively [2].

Based on the above disadvantages of the compressor's applicability for storage of liquefied natural gas and sampling, the goal is to develop ways to reduce energy costs during storage of LNG and improve the quality of samples.

As an alternative to traditional methods of control and discharge, it is proposed to use a liquid-gas ejector (LGE) [1]:

- including liquid-gas ejector in the technological strapping of the tank to maintain the working pressure by dumping fuel into the separator due to the energy of a high-pressure flow of the gas phase;

- including liquid-gas ejector in the periodic sampling system in which regasified LNG, after passing a gas chromatograph, is pumped into the sampler using an ejector.

To justify the efficiency of using a liquid-gas ejector, the main indicators of its efficiency were calculated, according to which the most productive aerodynamic scheme was selected. For a visual analysis of the results obtained, the dependences of the mixture pressure at the outlet of the ejector, the reduced power and the efficiency coefficient on the ejection coefficient were constructed. In accordance with the selected scheme, the pressure characteristic of the device operating at optimal, stall and limit modes was constructed. The geometric dimensions of the flow part of the ejector were calculated and its design scheme was presented. The obtained results are confirmed by modeling the process in the ANSYS software package.

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TECHNOLOGY FOR TRANSPORTING OF HIGH-VISCOSITY AND HIGH-PARAFFINIC OILS MIXTURE USING DEPRESSANT AND ANTI-TURBULENCE ADDITIVES

The "Usa – Ukhta" and "Ukhta – Yaroslavl" oil main pipelines pump a mixture of crude oils from fields and deposits in the Northern part of the Timan-Pechora oil and gas province. The composition and properties of the pumped oil mixture change throughout the entire period of operation of the pipeline. The pumped oils are of various types and have a wide range of physical, chemical and rheological properties. As a rule they have different abnorbal non-Newtonian properties. Thus, high-paraffin oil from the Kyrtayel field, which pumped to the main oil pipeline at the Chikshino oil pumping station, has a high positive pour point, whereas heavy oil from the Yarega field added to the basic flow at the Ukhta-1 station is characterized by high viscosity and density. At temperatures close to or below the pour point, high-paraffin oils are able to form a volumetric spatial structure of high-molecular compounds that determines the behavior of oils during pumping. When pumping of such oil is stopped, thixotropic hardening of the spatial structure can lead to gel formation and "freezing" of the pipeline. Transportation of high-viscosity oils is associated with significant power consumption. Therefore, transportation of such oil via the main oil pipeline requires special pumping technologies.

For this reason, the main oil pipelines "Usa – Ukhta" and "Ukhta – Yaroslavl" transport oils of various component composition in a mixture with pre- and track heating at the stations "Chikshino", "Ukhta-1"and "Privodino". One of the ways to reduce the cost of electricity, technical service and repairs in the pipeline transport of oil is the use of anti-turbulence additives, i.e. drug reducing agents (DRA). Five DRA entry points have been installed on the Ukhta-Yaroslavl oil pipeline. Pumping of oil with an anti-turbulence additives through the Ukhta-Yaroslavl oil pipeline is complicated due to pumping of high-viscosity oil from the Yarega field at the Ukhta-1 station. The present paper considers the influence of high-viscosity oil on the main rheological parameters of the pumped mixture. To prevent problems associated with pipeline shutdown, oil is pumped in winter with the addition of a depressant additive. The use of a depressor additive at the head station allows to reduce the pour point by 10-15 °C, to reduce viscosity and yield stress at low temperatures, which allows increasing the safe stop time of the Usa – Ukhta oil pipeline by an average of 20 hours.

When conducting the research and solving the set tasks, a comprehensive approach was used, including theoretical and experimental research methods. The theoretical method is based on the analysis and generalization of existing information about technologies for pumping paraffin oil through pipelines. The experimental research method includes laboratory experiments and pilot tests of depressant and anti-turbulence additives, processing the results and obtaining empirical dependencies. Possible factors for reducing the effectiveness of the depressant additive on the transported oil pour point have been studied. Among them are the following: the time of oil transport through the pipeline, the "life" time of the additive, the action of centrifugal pumps, the turbulent flow of oil, reheating of oil at the heating point. Laboratory experiments were carried out on processing the oil mixture from the output of the Usa station with a depressor additive at different concentrations to assess the effect of the additive on the pour point, dynamic viscosity and static shear stress. The time of "aging" of the additive action was studied. The main rheological characteristics of point samples of oil from the same batch at the stations "Usa", "Chikshino" and "Ukhta-1" at different times of the year were selected and measured. As a result of the analysis of monthly monitoring data, it was found that pumping of high-paraffinic oil at "Chikshino" station increases the pour point, dynamic viscosity and yield stress of basic oil flow from the "Usa" station, while the density of the oil mixture at the "Chikshino" outlet decreases. Laboratory studies of the effect of high-paraffinic oil pumping and heating of the entire oil flow at the Chikshino station on the pour point of model oil mixtures composed similarly to real mixtures at the Chikshino station exit were conducted. In addition the results of joint pumping of oils mixture with depressant and drug reducing agents are presented.

The results of the experiments allowed to determine the main factor of the reducing of depressor additive effectiveness along the pipeline length, as well as to identify the main features of pumping a mixture of abnormal oils with an anti-turbulence additive. It was found experimentally that the decrease in the effectiveness of the DPN-1 depressor additive is mainly determined by pumping of 10% of the high-yield oil from the Kyrtayelskoye field. The high content of paraffins and high-molecular paraffins, in particular, in this pumped oil determines the high pour point and strong spatial structure of the gel formed by these hydrocarbons at lower temperatures.

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EFFICIENCY OF TRANSPORTING RUSSIAN LNG AND CNG IN THE ASIAN DIRECTION THROUGH THE NORTHERN SEA ROUTE

Currently, the Arctic region is a strategic direction of state policy and a growing emphasis on the development of the hydrocarbon fields in the Arctic and methods of transporting energy produced there. The presidential decree "On state policy of the Russian Federation in the Arctic

for the period up to 2035 year" represents the national interests of Russia in the region, reinforcing the decisive role of the mineral complex in the development of the Arctic territories. Problems of development of the Arctic, the geopolitical interests in the region, advantages and disadvantages of different methods and directions of the energy transportation dedicated a lot of work (Cherepovitsyn A.U., Petrakov D.G., Buslaev, G.V., Kunshin A.A., Dvoynikov, M.V., Yakovlev O.N., Streltsov D.V., etc.). However, the potential of the Northern sea route (NSR) in the strengthening of international relations and Russia's geopolitical position in the Asian direction has not been studied. NSR is a major transportation artery, the political, geographical and economic importance of which is extremely large for Russia and for other States. A feature of this work is to offer transportation of liquefied and compressed gas in the direction of Asia directly to China. The aim of this work is to identify the characteristics and role of NSR in the Russian economy; the positions of countries in the region export and import of gas; a substantiation of economic efficiency and environmental friendliness of gas transportation via the Northern sea route; identifying promising areas of Russian-Chinese cooperation in the field of energy supply.

Economic efficiency of oil and gas fields depends not only on the cost of the search and production risks and time spent on development of fields, processing and transportation of raw materials, but is largely determined by transport costs, alternative options of logistics. Therefore, the possibility of transporting LNG and CNG is directly connected with the development potential of NSR. For the realization of their own interests in the Arctic region of Russia is developing a fleet of nuclear-powered icebreakers, special tankers for liquefied gas of the Arctic class. In the total volume of investments in Arctic projects, about 15% is natural gas production and supply via pipelines to the LNG plant; 40% for the preparation of gas liquefaction (cleaning, drying) on the LNG plant, natural gas liquefaction, storage and shipment of LNG to tankers for shipment to consumers; 20% - transportation of LNG by tankers from the plant to the receiving terminal; a 25% unloading of LNG at the receiving terminal, storage and distribution [1]. By 2030, the flow of Russian cargoes in the waters of the Northern seas will reach about 80 million tons per year. The disadvantages of the NSR are still the complexity of the passage in winter, lack of infrastructure, lack of icebreakers. The main challenges of the project activity in the Arctic region are the remoteness of the fields from the mainland, high cost of organization and operation, special requirements for the protection of labor and environment, increasingly sophisticated and technologically advanced wells. One of the important parameters of selection scheme of transportation of Arctic oil and gas using tankers is the priority issues for the protection of the environment, the complexity of the elimination of possible oil spills in the conditions of heavy ice conditions on the sea. The main environmental threat to the Arctic ocean is the contamination of spent fuel. During the construction of the gas wells should be implemented technological scheme of processing of drilling wastes by solidification to obtain construction material [2].

Already the first projects for the delivery of LNG to China via the Northern sea route have changed the geopolitical situation in the world. Working on the North Sea shelf not only contribute to the development of these territories, but also affect the geopolitical strategy of Russia. According to experts, in the next 5 years China will need more than 170 billion m^3 of gas [3], so LNG supplies will play a crucial role in the Chinese market. The overall focus of the interests of Russia and China is helping States to find solutions to the problems that arise during an already existing cooperation. A new supply of fuel from Russia is now expanding. Thus, the NSR is one of the promising directions of development of Intercontinental energy relations between Russia and China. To summarize, it is important to note that in relation to the development of the Arctic region for Russia it is important to maintain the Arctic as a territory of peace, stable and mutually beneficial partnerships; to develop the territory as a strategic resource base; use it to accelerate the economic growth of the Russian Federation; to develop the Northern sea route as a globally competitive national transport communications.

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DEVELOPMENT OF FASTENERS FOR THE ROBOTIC QUALITY CONTROL COMPLEX OF THE WELDED JOINT

18% of accidents at main oil pipelines are due to weld defects, that can be eliminated before they occur. The solution to this problem is the quality control of the weld. The project under development is intended to automate the solution of this problem, by developing a robotic system for monitoring the quality of the weld. This paper presents the development of the first stage of creating an automated system; determining the method of mounting to the metal pipe and the method of weld recognition using technical vision. The calculation of the required magnetic force to hold the robotic system on a metal pipe is performed. Experiments were carried out, in which the calculations were confirmed and graphs were made. To enhance the magnetic force, the method of installing an additional metal plate was used, which increases the attraction by 30%.

Main oil pipelines are designed for oil transportation, and are by far the most economically convenient mode of transport, even though it is a complex system with liquid substance in it. Worldwide experience in operating mail oil pipelines shows that, despite the significant advantages in the constructional design and the operation of mail oil pipelines, accidents cannot be completely eliminated, leading to environmental pollution, fires, and destruction of buildings, deaths, significant losses of material assets. An analysis was carried out, during which the causes of accidents on the oil wire were established. One of the main reasons for the formation of defects in the weld, about 40%, are organizational reasons. In this regard, when constructing a pipeline, it is required to carry out quality control of the weld. The first stage of the implementation of this project is the retention of the robotic system on a steel pipe in various positions. To solve this problem, various options were considered. The magnetic confinement method was proven to be more optimal and suitable.

Fastening the robotic system with neodymium magnets is the most optimal way. The location of the magnets on the body is strictly proportional and uniform, this is required due to the fact that with an uneven distribution and weakening of one of the sides, the entire structure will detach from the pipe surface under the action of gravity. Calculating the force of attraction of magnets to a metal pipe with an air gap is essential, in order to know what magnetic force neodymium magnets should have. The mathematical calculation of magnetic force with an air gap is presented below in formula 1.

$$Y=(Br/\pi)*[arctg((W*H)/2*Z*(((W^2)+(H^2)+4*(Z^2))^(1/2))-(arctg((W*H)/2*Z*(((W^2)+(H^2)+4*(Z-L))^(1/2))], \quad (1)$$

where, Y- Residual magnetic force; L, W, H - the magnet parameters; length, width and height, respectively; Z- air gap; Br- residual magnetic induction.

After calculating the magnetic induction, it is required to know the force of attraction of the magnet to the metal, this formula is presented below on formula 2.

$$F=(B^2*S)/ (2*\mu 0), \quad (2)$$

where F – Force; B – residual magnetic induction; S – magnet area: μ0 – magnetic vacuum permeability.

To confirm the calculations, experiments were conducted with a decrease in the distance from 6mm up to 4mm. The distance was reduced with metal plates and a ring spacer, with thicknesses 0.5 mm and 1mm, respectively. all elements were securely fixed to the body, the weight increased until the moment of separation.

During the experiment, the calculations were confirmed. When using metal plates to reduce the distance, the magnetic force increased by 25-30%. Theoretical and experimental data are represented in a graphically shown in Figure 1, which verifies the inverse proportionality; the magnetic force increases with the decrease in the distance to the metal surface.

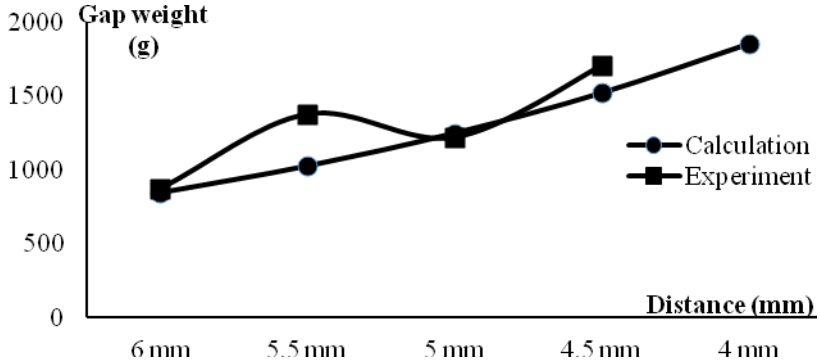

Figure 1 - Comparison of experimental data with calculations

It has become clear that it is vitally important to develop a robotic system for monitoring the quality of welds based on research for the causes of main oil pipeline accidents.

Calculations have been carried out to calculate the required magnetic force for mount-ing the robotic system on a metal pipe. When making calculations in educational materials, it was found that the fields formed by the paths that make up the scattering fluxes in real magnet designs, cannot be mathematically described. However, taking into account that the scattering flux is usually substantially less than the working flux. A simplified repre-sentation of the pattern of the scattering flux distribution is quite acceptable in order to fa-cilitate the calculation of magnetic circuits. Therefore, errors in the calculations may oc-cur.

Theoretical and experimental studies of magnet retention of a robotic system have been carried out and it has been concluded that the addition of metal plates increases magnetic induction. The maximum weight of the robotic system has been calculated, despite the fact that it is a difficult task, due to the fact that the different magnetic strength of each batch influences the magnetic force and therefore an experimental study was required, the results of which confirmed the calculations and studies conducted earlier on the complexi-ty of accurate calculations of magnets.

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UNDERGROUND GAS PIPELINE LAYING IN FROZEN SOILS WITH POINT FIXING ANCHOR SUPPORTS

Permafrost soils are widespread in the northern regions of Russia. These soils are very sensitive to temperature and change their bearing capacity depending on the temperature. In the frozen state, they serve as a reliable foundation, but after thawing they turn into swamp slurry, in which pipelines may rise, have transverse displacement and deformation. The construction and operation of pipeline systems in these conditions is a complex engineering task and require a special approach for each specific case [1].

In the course of the study, a review of literature on operating experience and regulatory and technical documents on the requirements for the design of trunk pipelines laid in areas of permafrost and seasonal melting soils was conducted. Based on the example of existing Russian and foreign pipeline systems, a comparative analysis of the applicable design and technological solutions is carried out, their advantages and disadvantages are given [2]. The main risks associated with the uncertainty at the design stage of pipelines in the presence of zones of permafrost are considered, possible solutions are proposed. In particular, an underground laying method has been proposed for areas of small length with point fixing by underground anchor supports at the intersection of solid ice lenses and formed heaving tubercles; its advantages are substantiated. In order to assess the stress-strain state and determine the spacing of the proposed type of supports, a finite element model was developed for calculation in the ANSYS software environment. The results obtained made it possible to determine the locations of dangerous sections and the predicted values of stresses depending on various scenarios of thawing of the base soil and loss of stability. The inappropriateness of the use of thermal insulation has been proved, leading to an increase in loads, both during ascent and sagging sections of the pipeline. The developed model allows you to determine the acceptable step for the safe placement of anchor supports for attaching underground sections when there is a risk of thawing soils, and with appropriate refinement, it can be effectively used in the design of underground sections of trunk pipelines [3].

To determine the best technical solution for fixing underground pipeline sections in frozen soils, an analysis of existing design solutions was carried out. It was found that none of the structures would prevent both the ascent and subsidence of the pipeline with different options for thawing the trench. A new support design was proposed, which does not have this drawback, which is characteristic of analogues. For support, a patent of the Russian Federation for an invention was obtained [4]. In addition, to ensure the operability of the support in weakly bearing soils, two more modernizations were proposed, for which patents of the Russian Federation for utility model were obtained.

To confirm the operability of the developed model the ANSYS software package and verify the operability of the design of the new support, a test facility was designed and built. After the experiments, the experimental data were highly converged with the results of analytical calculations and calculations in the ANSYS finite element model.

Thus, the study made it possible to establish that the proposed construction of the support [4] allows for efficient underground fixing of pipeline sections. The use of the proposed construction of supports for fixing sections of the gas pipeline eliminates the need for expensive elevated laying in cases where the permafrost sections are intermittent or insular in nature, which significantly reduces the cost of construction and subsequent operation costs.

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IMPROVING THE ENERGY EFFICIENCY OF THE COMPRESSOR STATION BY GENERATING ELECTRICITY

Oil and gas industry enterprises receive electricity from both the main suppliers of the power grid network and from their own power plants. Improving the energy efficiency of compressor stations is an important issue, since gas compression is the most energy-intensive heat and power process in the main hydrocarbon transport. A detailed analyse of transition from central power supply to power plants of own needs can be found in works of A. N. Nazarov [1] and L.V Bulygina. [2] In this regard, it should be noted that the uninterrupted supply of compressor stations with electricity is a key factor both for the overall integrity of the system and for the industry as a whole. The program of switching compressor stations to receive electricity from centralized sources adopted in the last century has shown its inefficiency. Such reasons as the wear and tear of power lines, unexpected outages due to outdated equipment, as well as rising prices for electricity tariffs do not allow to ensure uninterrupted power supply to enterprises. This trend is expected to continue for many years to come. High electricity prices mainly affect the profitability of production enterprises such as «Gazprom» and «Surgutneftegas» as they increase the cost of gas production and transportation. These circumstances confirm the necessity to search for new energy-saving technologies to reduce energy production costs.

For compressor stations, the key factors in the choice of power supply schemes are the territory where the facility is located and its climate conditions. The main sources of power supply are power lines from the power system, gas turbine power plants running on gas and diesel fuel and power plants for own needs. [3] It is worth saying that most of the damages in the electrical networks are caused by bad weather conditions. It is therefore impossible to predict exactly when and where disturbances occur. Distribution stations and electrical installations that transmit electricity are the most frequently affected. This leads to disruption of compressor stations and in some cases to their complete shutdown.

Uninterrupted work to provide compressor stations of gas main pipelines with electricity is possible in case of the following:

1. The power supply must be provided from two independent mutually redundant power sources, which ensures the highest reliability of the power supply
2. Reserve sources are used – for example captive power plants, capable to work in case of an accident up to several days until failures in the system are eliminated
3. Emergency source - power stations with diesel drives, which provide voltage recovery in 1 minute
4. As the source of temporary power supply can be accumulator batteries, charged either from a compressor station or from non-renewable energy sources, ensuring stable operation of all equipment under emergency conditions in the power supply system [4]

Compressor station №7 of the "Surgutneftegas" company was chosen as the object for research. The aim of the work was to determine the most advantageous source of power generation both from the technical and economic sides. For this purpose, the theoretical capacity of turboexpander, gas turbine unit (GTU) and combined cycle gas turbine unit (CCGT) were

calculated. As a result of the thermodynamic calculations of three different power generating units it was obtained that the combined cycle gas turbine has a capacity of 13.67 MW while GTU and turboexpander are 7.5 MW and 4.37 MW respectively. However, in a view of impossibility to operate CCGT in the conditions of the extreme north it is offered to use combination of gas turbine unit with turboexpander. Economic calculations approved that the project is interesting to invest as the net present value (NPV) and productivity index (PI) are positive values. Therefore, it can be stated, that in 8 years investments will return money that exceeds the investment by 17.7%.

To sum up, it should be said that measures aimed at improving energy efficiency of oil and gas companies make it possible to use hydrocarbons more rationally, which on the one hand leads to higher incomes of both organizations and employees, and on the other hand improves the environmental condition of the planet. For future researchers it is recommended to perform a technical and economic analysis, where the refrigerant in combined cycle gas turbines is used as a working fluid. This will make it possible to use the CCGT in the extreme north and generate as much electricity as possible. It is also recommended to review existing technologies to reduce emissions of carbon dioxide, carbon oxide and other harmful substances and to carry out the analysis of electric power losses both on power lines, and on power stations of own needs. These measures will provide more accurate data for further studies.

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REGULATION OF GAS PRESSURE AT SMALL REDUCTION POINTS USING EXPANDER-GENERATOR UNITS

This topic is actual according to several reasons. The most important of them - Russian energetic strategy (Governmental order from 13.11.2009 N 1715-p) according to witch energetic natural resources should be used effectively. Usage of regulative expander generator unit allows to produce energy on the reduction line.

The advantage of this aggregate is possibility to work in the networks of average and low pressure, considering that existing recycling energy tools of gas stream are using generally in the networks of high pressure. Moreover, considering development of gas-spreading networks, which leads to increasing amount of reduction points, this invention will be actual nowadays.

This work represent development and explain the usage of regulative expander generator unit, depict the work principle of the invention, which can be referred to the gas industrial area and can be used for regulating natural gas pressure on the reduction line.

Technical result is the possibility to regulate natural gas on the reduction line and energy production on the expander generator unit, which can be applied to provide gas distribution station and other energy-intensive resources with energy.

Result is reached with usage if asynchronous generator, advantages of which are based on the work. Generator is connected to the administrating system. Administrating system monitor

numbers from pressure sensor and regulates the generator parameter by changing the additional resistances in the rotor circuit. The other part of administrating system is necessary to provide acceptable quality of electricity transmitted from the generator to consumers.

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PREDICTIVE MAINTENANCE PROGRAM FOR OBSTRUCTED WELLS OR PIPELINES

Flow assurance problems, namely the formation of deposits, are some of the most challenging operational issues in the oil & gas industry [1], both in production and transport stages. A preventive maintenance program is a key factor for a well-suited management plan. Due to the fact of not being practical to inspect the tubing through a closed-circuit television system, an indirect method should be used to predict the blockage's magnitude [2]. Predicting when the mitigation measures must be applied for unclogging the pipe is essential to avoid pump damage and subsequent operational issues. A major achievement would be evaluating the risk of blockage and accounting for real field data uncertainties while guaranteeing the best economical maintenance plan. Thus, the preventive maintenance program's goal is to assess the overall system condition in order to establish the proper type of maintenance routine. The preventive maintenance program provides part of the asset management framework required to operate and maintain the infrastructures at its optimal level of performance.

The proposed methodology to define the predictive maintenance program, either for wells or pipelines, is presented in Figure 1.

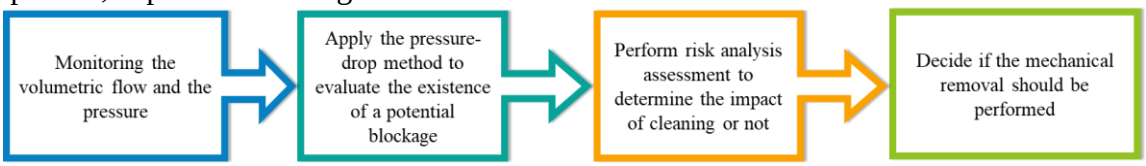

Figure 1 - Methodology to establish the predictive maintenance program

The pressure drop along the pipe, due to friction, can be calculated by Eq. (1), according to the Darcy-Weisbach equation, which is an empirical relation for pipe-flow resistance:

$$\Delta P = 0.5 f_D L D^{-1} \rho V^2 \quad (1)$$

Where ΔP is the pressure drop (Pa), f_D is the Darcy friction factor (-), L is the length of the pipe (m), D is the inner diameter (m), ρ is the density of the fluid (kg/m^3), and V is the velocity of the fluid (m/s). The Darcy friction factor depends on the type of flow regime. If a laminar flow occurs, the viscous forces will be dominant, and the Reynolds numbers will be low ($Re < 2000$). Otherwise, if turbulent flow happens, the Reynolds number will be higher ($4\,000 < Re < 100\,000$). For the laminar flow regime, Eq. (1) can be rewritten as Eq. (2), where μ is the dynamic viscosity of the fluid ($Pa.s$):

$$\Delta P = 64 \times 0.5 \times (\rho V D)^{-1} \mu L D^{-1} \rho V^2 \Rightarrow \Delta P = 32 \mu L D^{-2} V \Rightarrow \quad (2)$$

When deposition occurs, the pipe radius decreases as a function of time (r_t), and the velocity also varies (V_t). The volumetric flow rate is given by Eq. (3):

$$Q = A \cdot V_t = \pi \cdot r_t{}^2 \cdot V_t \quad (3)$$

Rearranging the Eq. (2), it is possible to establish a linear relationship between the flow rate and the pressure drop, applying the $K_{laminar}$ factor, for a laminar flow regime:

$$\Delta P = 32 \mu L Q (4 \pi r_t^4)^{-1} \Rightarrow Q = 0.392699 \cdot \mu^{-1} \cdot L^{-1} \cdot r_t^4 \cdot \Delta P \Rightarrow Q = K_{laminar} \cdot \Delta P \Rightarrow$$
$$K_{laminar} = Q.\Delta P^{-1} = 0.392699 \cdot \mu^{-1} \cdot L^{-1} \cdot r_t^4 \quad (4)$$

For turbulent flow, and hydraulically smooth pipes ($\epsilon = 0$) such as glass, copper, and plastic tubing, in turbulent flow, the Blasius equation [3] can be used. Eq. (5) allows the determination of the pressure drop for a turbulent flow regime:

$$\Delta P = 0.3164 \times 0.5 \times (\rho V D)^{-0.25} \mu^{0.25} L D^{-1} \rho V^2 = 0.158 \rho^{0.75} \mu^{0.25} V^{1.75} L D^{-1.25} \quad (5)$$

Rewriting the Eq. (5) to consider the effect of deposition in time, in a turbulent flow regime, it is possible to obtain the $K_{turbulent}$ factor, according to Eq. (6):

$$Q = (111.5945 \cdot \rho^{-0.75} \cdot \mu^{-0.25} \cdot L^{-1} \cdot r_t{}^{4.75})^{\frac{1}{1.75}} \Delta P^{\frac{1}{1.75}} \Rightarrow Q = K_{turbulent} \cdot \Delta P^{\frac{1}{1.75}}$$
$$\Rightarrow K_{turbulent} = Q.\Delta P^{-\frac{1}{1.75}} = (111.5945 \cdot \rho^{-0.75} \cdot \mu^{-0.25} \cdot L^{-1} \cdot r_t{}^{4.75})^{\frac{1}{1.75}} \quad (6)$$

Both Eq. (4) and (6) shown that K factor decreases as the pressure drop increases for a certain flow rate, which means that K factor decreases when the deposit grows.

Using this K factor methodology, one will attain not only an initial K_0 value for the ideal pipe or well conditions without deposition, but also a continuous set of K values. Absolute $|K-K_0|/K_0$ and relative $\Delta K_{t=i \text{ to } t=j}$ values can be employed to assess the likelihood for sectional blockage and, therefore, the need for maintenance. However, real field data is likely to yield sensible variations in the computed K. This is due not only to high-frequency measurements of a complex flow but also to the uncertainties of real data. Under these circumstances, and to allow a robust and applicable methodology, there is the need for determining uncertainty measures for K values. For such an end is possible to perform a risk assessment attributing density probability functions to the historical data. In this manner, rather than attaining a deterministic K value at each moment, one will compute an expected K value and an uncertainty measure. Furthermore, instead of prescribing maintenance interventions when $|K-K_0|/K_0$ or $\Delta K_{t=i \text{ to } t=j}$ values exceed certain thresholds, we will be able to probabilistically assess the uncertainty of such command, highlighting or waiving the urgency of the intervention.

This study summarizes the methodology to perform a predictive maintenance program for obstructed wells or pipelines while addressing the uncertainty associated with the field measurements.

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INFLUENCE OF STABILITY OF RESIDUAL FUELS ON SEDIMENTATION WHEN STORING IN TANKS

During the operation of oil depots, fuel terminals, and in maritime transport, the problem of active sedimentation of residual fuels and fuels blend is observed with increasing frequency. According to the quality requirements of fuels set out in ISO 8217, the content of total sediments should not exceed 0.1%, which means that sedimentation should be at a low level. However, in practice, the problem of stability loss and active sedimentation caused due to the manifestation of

fuel incompatibility during blending is observed rather often. The manifestation of incompatibility in the blending of residual fuels is associated with the emergence of strong intermolecular interactions caused by a change in the structural and group composition, as well as the mutual ratio of the concentrations of high-molecular weight compounds of petroleum products, which leads to the formation of molecular associates, bulk colloidal particles of various shapes and structures, which leads to loss of fuel quality and accumulation of sediments in the tanks and storages. Since in recent years a trend has been established for the production of heavier oil and its deeper processing, it leads to an increase in the fraction of asphaltenes and heavy components in fuels

The blending of fuels in tank farms, barges and storage tanks takes place for various reasons. Firstly, due to the lack of free tanks and time to clean the tanks, it is necessary to drain a new batch of fuels into the tank with the residues. It is worth noting that there are risks of manifesting incompatibilities even when blending the fuels of the same brand due to differences in composition. Secondly, different types of fuels are deliberately blended in order to obtain the required quality indicators that correspond to a specific brand of marine fuels. This blends fuels preparation procedure is actively used to obtain marine fuels at fuel terminals and tank farms.

The risks associated with the loss of stability and manifestations of fuel incompatibility are increasing in connection with the implementation by the international maritime organization in Annex VI of MARPOL 73/78 to the International Convention for the Prevention of Pollution from Ships of the restrictions on emissions of sulfur oxides, nitrogen, volatile organic compounds, and ozone-depleting substances. According to the Convention, the sulfur content for marine fuel used in all areas of the oceans should not exceed 0.5% wt. from January 1, 2020. Therefore, the proportion of blended fuels will increase, while the risks of manifesting fuel incompatibilities will increase.

Today, the process of sedimentation is poorly studied, there are no exact dependencies and methods that would theoretically determine the possibility of manifestation of incompatibility of fuel blends. There are a number of laboratory methods for determining the compatibility of residual fuels before blending, namely the spot method according to GOST 33365 and ASTM D 4740, the determination of xylene and toluene equivalent according to GOST 33288 and GOST 33296, the methods for determining the stability of fuels according to RF patent No. 2305836 , also RF patent No. 2444005 and international application No. WO2018185520, however, these techniques and methods have a high error and low accuracy, therefore, have not been widely used in practice. All these factors contribute to the manifestation of incompatibility and active sedimentation during storage of blended residual fuels.

To conduct laboratory tests to determine the compatibility and quantitative characteristics of sedimentation of residual fuels, an algorithm for testing based on GOST 33360, IP 375 and IP 390 has been developed. Thanks to this method, it becomes possible to accurately determine the compatibility and stability of fuels, as well as trapping the sediments formed.

Among a number of different types of fuels studied for compatibility, incompatible blends of residual fuels were determined. Laboratory studies were carried out, based on the method set out in GOST 33360, according to which, the thermal aging of the sample required its exposure at 100°C for 24 hours. For the experiments, the main quality indicators of 2 samples taken in accordance with GOST 2517-2012 were studied and determined on calibrated laboratory instruments and equipment following reference methods. The samples are blended in a 1:1 ratio, namely the sample (RMG-380), (type I STO 00148725-004-2011 with measurements 1-5) and sample No. 2, compound of lubricating oils, grade A type 1. (STO 11605031-088-2015). The filters after laboratory experiments to determine the total sediments show a negative effect of fuel incompatibility, namely a sharp increase in the amount of total sediments (Figure 1).

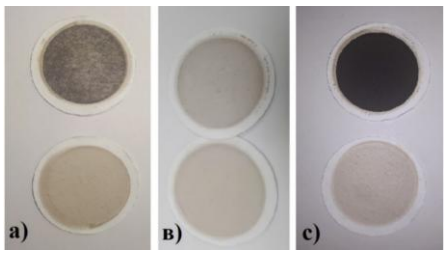

Figure 1 - Filters after filtration and determination of the total sediment content:
a) sample No.1; c) sample No.2; c) a mixture of samples No.1 and No.2.

Studies have shown the importance of this problem for tank farms for storing residual fuels at tank farms and terminals. For a more detailed study of this issue, the influence of storage conditions on sedimentation in tanks, namely the influence of temperature and storage time, is considered. It should be noted that active sedimentation during the manifestation of fuel incompatibility is already observed at 40 ° C and above, these temperature values are working during transport and storage of residual fuels. Experimental studies were also carried out to determine the effect of the ratio of the incompatible mixture, where it was determined that even 5% of the fuel adversely affects sedimentation.

To increase the efficiency of the transport system, namely storage facilities, a more detailed study of the manifestation of the "incompatibility" of ship, residual, mixed fuels is necessary, since this directly affects the quality of petroleum products and the efficiency in the operation of fuel storage facilities.

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STUDY ON SAFETY EVALUATION OF LNG UNLOADING SYSTEM

As a clean energy source with high calorific value, low carbon and easy storage and transportation, LNG has obvious advantages over other traditional fossil energy sources and is increasingly favored by countries all over the world. The global LNG transaction volume has increased year by year, the LNG industry has developed rapidly, and more and more LNG receiving stations have gradually been built and put into production. The unloading system is the transition unit between the LNG ship and the receiving station. On the one hand, the unloading conditions involve intensive processes, mechanical equipment, and personnel operations; on the other hand, when operating at sea, the unloading equipment is affected by the wind and waves, and the workers are highly mobile on the unloading platform. These characteristics determine the safety risk of the unloading system in the LNG receiving station. At present, China's LNG industry is in the development stage, and safety management has also achieved gradual results. Helong Wang [1],Jingjing Yue [2] et al. applied Fuzzy - AHP in the risk evaluation of LNG receiving station, determined the risk index weight vector and Fuzzy evaluation matrix, and

realized the ranking of risk factors to achieve the purpose of risk identification. Yanyan Chu [3] and others established a fire risk early warning model for LNG receiving stations based on the theory of information diffusion. Using the fuzzy mathematical method of information diffusion, the warning signal vector was output to obtain the early warning assessment of the risk of the station and the fire risk. Yuanling Song et al. [4] applied hazard analysis and operability analysis methods in the evaluation, and put forward suggestions to mitigate the consequences; Yunqing Qi [5] used the fault tree to identify the main risk factors, used multi-level composite element extension analysis to analyze the failure probability of each block of the LNG receiving station, and combined the static and dynamic evaluation process to analyze the development trend of the failure possibility.

After continuous development of the safety evaluation of LNG receiving station, it is found that the existing safety evaluation methods have some limitations in the implementation. Due to many safety evaluation system indicators, it is difficult for personnel to make an objective evaluation during the evaluation, and experts' experience is not easy to be preserved. In recent years, "smart LNG station" requires the LNG industry to develop in the direction of intelligence. As the representative of integrated learning, the XGBoost method proposed by Chen Tianqi has advantages in processing large-scale sparse data. Now researchers have applied it to ultra-short-term load forecasting of power systems, transformer fault diagnosis, laboratory safety risk prediction and network security In areas such as risk assessment.

The author proposed by this paper is based on the eXtreme Gradient gain (eXtreme Gradient Boosting, XGBoost) algorithm, to build LNG receiving station preliminary build LNG unloading system security evaluation, in combination with a domestic terminal 12 months of the discharging system index table and the overall rating, establish evaluation model, for LNG unloading system security risk level is more objective and scientific evaluation. At the same time, the theory of set pairs is applied to the risk evaluation, and a risk comprehensive evaluation model based on multiple connection Numbers based on set pair analysis is proposed. The correlation degree is calculated by matter-element theory as the basic reliability allocation, and the final safety state is obtained by fusion based on evidence theory, and the sensitivity factors are determined based on Monte Carlo principle.

The experimental results show that XGBoost-based LNG unloading safety evaluation model can be used for risk identification, and the accuracy rate of safety level prediction is over 95%, which provides a reliable basis for reducing the risk of LNG unloading system. Based on the Monte Carlo method, the important influencing factors are pointed out, and from the sensitivity analysis results, the risk factors of the unloading system at the LNG receiving station are determined, which provides a reliable basis for the risk reduction of the LNG unloading system.

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Session 2. TECHNOLOGIES OF INTEGRATED PROCESSING OF MINERAL RAW MATERIALS WITH FURTHER PRODUCTION OF NEW GENERATION MATERIALS

Chemical Engineering in Natural Energy Carriers, Carbon Materials and Inorganic Substances

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POLYANILINE COATED GOLD-ARYL NANOPARTICLES: ELECTROCHEMICAL SYNTHESIS AND EFFICIENCY IN DYES REMOVAL

Methylene blue (MB) is a common synthetic dye in textile industry which implicates several health complications such as breathing difficulty, methemoglobinemia-like syndromes, chest pain, severe headache and mental confusion. Chemical, adsorption and catalytic routes have been used to eliminate MB from the environment and wastewater. The adverse effects of adding more chemicals to the environment has motivated many research laboratories to apply chemicals-free approaches such as sunlight, green synthesized catalysts and adsorption. We present our results on the fabrication of PANI coated gold-carbon nanocomposites by "green" and efficient electrochemical reduction of $[HOOC\text{-}4\text{-}C_6H_4N{\equiv}N]AuCl_4$ salt and their applications in MB adsorption.

Synthesis of gold-carbon □-bond nanoparticles was achieved by the electrochemical reduction of aryldiazonium tetrachloroaurate(III) salt $[HOOC\text{-}4\text{-}C_6H_4N{\equiv}N]AuCl_4$ in the presence of polyaniline (PANI) emeraldine salt. The electrochemical deposition of PANI coated Au-COOH NPs was efficient in KNO_3 supporting electrolyte at different potential values using two electrodes cell in the presence of PANI. The deposition potential was determined from the cyclic voltammetry study of aryldiazonium gold(III) salt. The nanocomposites were characterized with transmission electron microscopy (TEM), X-ray photoelectron spectroscopy (XPS) and thermal gravimetric analysis (TGA). The multi-branched nanoparticles display the strongest diffraction peak in the direction of (111) which implies the deposition occurred preferentially along this highly energetic facet. The results concluded the thermal stability of the gold nanocomposites and the gold percentage in the range 5-23 wt.% depending on the added mass of PANI. Selected area electron diffraction pattern (SAED) analysis displayed typical rings of face centered cubic structure of crystalline gold(0) nanoparticles. Raman analysis supported the completeness of the reduction of the aryldiazonium cation and gold(III) supported by the absence of the diazonium and $[AuCl_4]^-$ vibrations and the presence of the gold-carbon peak. Emeraldine coated gold-carbon nanoparticles soaked to nanosand showed high adsorption capacity for methylene blue. It indicates that the prepared materials could be used to remove synthetic dyes in textile wastewater treatment like methylene blue.

Nanosand was used as adsorption surface in the removal of methylene blue, the adsorption ability was enhanced by Au-COOH/PANI nanocomposites, in which nanosand was soaked in two systems for comparison which are Au-COOH NPs and Au-COOH/PANI nanocomposites. Nanosand was soaked in these two systems, and then the adsorption study of methylene blue was performed. The adsorption kinetics was monitored using UV-Vis instrument for 30 minutes period. The comparison was done by comparing the adsorption capacity and removal rate of nanosand in these two systems and for nanosand alone without any material on it. Au-COOH/PANI nanocomposites showed the higher maximum adsorption capacity and removal rate to be 4.96 $mg.g^{-1}$ and 87.0%, respectively, While Au-COOH NPs onto nanosand showed 4.28 $mg.g^{-1}$ and 76.0%, respectively, nanosand alone showed removal rate of 65.0%.

The adsorption kinetics fits pseudo-second order reaction with correlation factor equal to 1 for the Au-COOH/PANI nanocomposites.

SEM-EDS and FT-IR were used to confirm the presence of Au-COOH/PANI nanocomposites after the adsorption of methylene blue, the percentage of Au in the samples was consistent with percentage before the adsorption confirming no leatching of the nanocomposite to the adsorbent. FT-IR showed a decrease in the Si-O peak from the nanosand due to the adsorption of methylene blue on it.

Au-COOH/PANI nanocomposites was achieved by the electrochemical reduction of aryldiazonium tetrachloroaurate(III) salt [HOOC-4-$C_6H_4N{\equiv}N$]$AuCl_4$ in the presence of polyaniline (PANI) emeraldine salt. It enhanced the adsorption of methylene blue on nanosand following pseudo-second order reaction mechanism. Our Au-COOH/PANI nanocomposites while adsorbed onto nanosand avoid the complications in using homogenous catalysts and chemical reducing agents. It is to be used in the removal of other different dyes found in wastewater and in the environment in general.

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THERMODYNAMIC ANALYSIS OF SULPHUR-CONTAINING COMPOUNDS' REACTIONS IN THE VACUUM DISTILLATE HYDROTREATING

Trends in intellectualization and digitalization lead to the development and implement mathematical models of chemical processes and software products to production management. The introduction of modern intelligent technologies to existing oil refineries is associated with the growing demand for fuel products and adaptation of existing and introduction of new technologies for processing heavy oil feedstock containing a significant amount of sulfur and metal compounds. Heavy oil pre-refining is forced by all these circumstances in order to be able to process large volumes. This complex problem is solved by oil feedstock hydroprocessing [1]. Research and improvement of the current technology efficiency is carried out experimentally on industrial installations, namely, by "intuitive" selection of technological parameters depending on the properties and ratios of the streams number involved in processing. This method is quite expensive and not always effective. To solve the problems of increasing production efficiency and product quality, the method of mathematical modeling is used [2], which allows to predict

the optimal technological parameters of the industrial process without significant material and time expenditures.

The purpose of this work is to develop a mathematical model of the vacuum gasoil hydrotreating process that is suitable for raw materials of the catalytic cracking process composition and properties predicting. It is necessary to establish and analyze the main physical and chemical relationships of the industrial hydroprocessing and perform thermodynamic calculations to achieve this goal. First of all, it is necessary to determine the list of reactions and compounds involved in the chemical transformations of a particular process to create a mathematical model of a chemical-technological process. Due to the complexity of the oil refining processes chemistry, as well as the large number of individual components of the reaction mixture and reactions, their complete kinetic models are very cumbersome, so various simplifications are used based on combining reagents and reactions into pseudo-reagents and group reactions, respectively [1]. The literature data analysis showed that typical sulfur - and nitrogen-containing compounds representatives of high-boiling oil fractions are benzothiophene and dibenzothiophene, pyridine, indole, and carbazole, for which calculations were performed with the thermodynamic parameters determination, confirming the reactions possibility in the industrial hydrotreating process conditions.

The Gaussian program was used to calculate the thermodynamic parameters of the hydrotreating process (Enthalpy, Gibbs energy, and Entropy). The DFT – Density Functional Theory method is chosen as the calculation method. The quantum chemical calculations results of thermodynamic parameters of vacuum gas oil sulfur-containing compounds are presented in the table.

Table 1 - Thermodynamic parameters values of sulfur compounds hydrogenation reactions (at 350°C and 4 MPa)

Sulphurous and nitrogenous compounds group	**Reaction**	**ΔH, kJ/mol**	**ΔG, kJ/mol**
Benzothiophene	$C_{15}H_{20}S+3H_2 \rightarrow C_{15}H_{24}+H_2S$	-190,97	-112,82
Dibenzothiophene	$C_{15}H_{14}S+2H_2 \rightarrow C_{15}H_{16}+H_2S$	-54,96	-25,29
Pyridine	$C_{15}H_{25}N+5H_2 \rightarrow C_{15}H_{32}+NH_3$	-325,84	-109,18
Indole	$C_{15}H_{21}N+3H_2 \rightarrow C_{15}H_{24}+NH_3$	-152,71	-72,85
Carbazole	$C_{15}H_{15}N+2H_2 \rightarrow C_{15}H_{16}+NH_3$	-32,47	-5,16

The Gibbs energy of the benzothiophene hydrogenation reaction to hydrocarbons is -112,82 kJ/mol. Dibenzothiophene hydrodesulfurization occurs with high selectivity to diphenyl [2] with a Gibbs energy of -25,29 kJ/mol. The reactivity decreases with the molecule complexity, which can be seen from the values of the Gibbs energy change. The observed trend is fully correlated with the literature data on vacuum distillate hydrotreating [2, 3].

Thus, within the framework of the work, heterogeneous pseudocomponents groups embedded in the reaction network of the vacuum gas oil hydrotreatment process were determined, and their reactivity was evaluated using quantum-chemical calculation methods. The mathematical modeling method will allow to obtain results for the analysis and synthesis of highly efficient chemical and technological systems, as well as the prediction of their optimal behavior over a long time and the rationalization of the natural resources use.

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DEVELOPMENT PROPERTIES OF ALUMINUM METAL MATRIX COMPOSITES REINFORCED BY PARTICLES OF BORON CARBIDE USING POWDER METALLURGY

Metal composite materials are an important class of economical structural materials with unique properties that expand the field of engineering applications in various industries. One of the highly interested metal composite materials are with low cost of reinforcement and accessibility for serial production. Currently, the production of high-strength aluminum alloys with composite compounds with improved mechanical properties at a given level of ductility is being actively developed. A composite material is a combination of two or more materials that results in better properties than those of the individual components used alone [1].

In contrast to metallic alloys, each material retains its separate chemical, physical, and mechanical properties. The main advantages of composite materials are their high strength and stiffness, combined with low density, when compared with bulk materials, allowing for a weight reduction in the finished part, it had been used for wide range of applications such as sporting goods, electronic packaging, amours, nuclear, biotechnology, aerospace, marine, automotive and transport industries [2].

Furthermore, the advantages of Al and its alloys over other composite matrices are its high specific strength and stiffness, good damping capacities, dimensional stability and good machinability. To strengthen the metal matrix, it has become an interest to use nano-sized ceramic particles, while maintaining good ductility, high temperature creep resistance and better fatigue [3].

Existing technologies for modifying alloys with ceramic materials such as B4C, provide the necessary performance characteristics for casted and especially rolled billets. However, the high level of segregation of particles in the aluminum matrix, the heterogeneity of the surface of the composite particles during rolling, their low wettability sharply worsen the quality of the work pieces and as a result leads to a decrease in yield.

Composite materials of B4C solid particles create a rigid reinforcing frame in the matrix, which gives the aluminum alloy unique properties (stiffness, strength, thermo physical and electrical properties) after the introduction of copper powder, allowing it to be used with Al-Cu-B4C alloy for the production of rolled products [4].

The purpose of this research boron carbide (B_4C) is reinforced in the aluminum matrix composites to increase the more conductivity and characterized for their mechanical properties such as hardness and tensile strength.

Al-5%Cu aluminum alloy metal matrix composites will be reinforced with Boron Carbide (B_4C) particles up to 2, 5 and 7 % was produced by stir casting. Particulates may subsequently add using the squeeze casting process. The squeeze casting technique decreased the porosity of the final composites.

In this research, the following composites will be evaluated and tested experimentally. They are tensile strength, hardness, improved stiffness, reduced density (weight), improved high temperature properties, controlled thermal expansion coefficient, thermal/heat management, enhanced and tailored electrical performance, improved abrasion and wear resistance, control of mass (especially in reciprocating applications) and improve damping capabilities.

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CHARACTERIZATION, DETERMINATION AND ELIMINATION TECHNOLOGIES FOR SULFUR FROM PETROLEUM TOWARD CLEANER FUEL AND A SAFE ENVIRONMENT

Sulfur-containing compounds are the most abundant compounds in crude oil. Sulfur in liquid fuel oil leads to the emission of sulfur oxides and sulfate particulate matter which not only endangers health and community property but also reduces the life of the catalysts and engines due to corrosion. Various methods, with a high level of precision and sensitivity, have been developed to analyze sulfur-containing. The petroleum consists of carbon, hydrogen, and heteroatoms like sulfur, nitrogen, oxygen, metals, etc. Among heteroatom, sulfur is the most abundant with around 0.03 to 6 wt% in natural gas and crude oils. When the total amount of sulfur is <0.42%, it is called sweet crude oil, while when the amount of sulfur is more than around 0.42%, it is called sour crude oil. Sulfur-containing compounds are classified into different types (i) elemental sulfur, (ii) hydrogen sulfide (H2S), mercaptans (thiols), sulfides (acyclic and cyclic), polysulfides (disulfides, trisulfides, etc.), thiophenes and others Sulfur compounds are recommended to be removed in the refining process as they cause the deactivate of the catalysts used in crude oil processing and corrosion problems in pipelines, pumping, and refining equipment. From an environmental point of view, the sulfur left in fuels may case the emission of toxic gases that react with water and cause acid rain [1]. Therefore, there is a need for bomb the determination of the amount of sulfur in oil and for methods to remove sulfur. It should be noted that assessing the refining value of crude oil requires a full description of the crude oil and its components, involving scores of properties. Nevertheless, two properties, i.e. API gravity (a measure of density) and sulfur content are important for quickly classifying comparing crude oils [2].

Sulfur, oxygen, and nitrogen are associated with carbon atoms in various structural forms, and these are the building blocks of the whole molecular structure of kerogen. Sulfur-containing compounds have an adverse influence on the oils used as transport fuels. In addition, the combustion of sulfur-cop taming compounds leads to the emission of SOx which is an important source of air pollution and acid rain. Several techniques for qualitative characterization and quantitative determination of sulfur in fuels have been developed and applied. Sulphur is analyze d by the bomb method (ASTM D129) [3]. However, due to some limitations, it is preferable to use the Microwave induced combustion (MIC) method for preparing samples. Additionally, high temperatures can be utilized to prepare samples of oils as per ASTM D1552 and ASTM D4239. Then, pyrohydrolysis was used to overcome the limitations. Other methods such as wavelength dispersive X-ray fluorescence spectrometry (WDXRF) and Energy-dispersive X-ray fluorescence spectrometry (EDXRF) were used as standard test methods to analyze a sample without the sample being treated prior to analysis, i.e. direct analysis. Other methods are also

used including gas chromatography coupled with sulfur chemiluminescence detector (GC-SCD), inductively coupled plasma optical emission spectrometry (ICP-OES), inductively coupled plasma-mass spectrometry (ICP-MS), laser ablation-inductively coupled plasma-mass spectrometry (LA-ICP-MS), electrothermal vaporization inductively coupled plasma spectrometry (ETV-ICP-MS), ion chromatography (IC), high-performance liquid chromatography (HPLC), high resolution-continuum source-molecular absorption spectrometry (HR-CS-MAS), ion-selective electrode (ISE), and x-ray fluorescence spectrometry (XRF) [3].

Methods for analyzing sulfur compounds can be divided into two classes based on the type of samples; nonvolatile and volatile samples. For the nonvolatile samples, the molecular characterization of sulfur can be performed using HPLC or direct liquid infusion and its combination with mass spectrometry (LC- MS), like Fourier-transform ion cyclotron resonance mass spectrometry (FT-ICR MS) and Orbit rap MS, associated with various atmospheric ionization techniques including atmospheric pressure chemical ionization (APCI). The use of surface desorption ionization techniques, direct electrospray ionization (DSEI) and desorption atmospheric chemical ionization (DAPCI), for the molecular characterization of insoluble kerogens that has been characterized by x-ray near edge structure spectroscopy (XANES) and x-ray photoelectron spectroscopy (XPS) remain to be explored [2].

Gas chromatography (GC) is a common and efficient separation technique for sulfur compound mixture analysis. Examples of GC based methods are mentioned briefly. These include (i) flame photometric detectors (FPD) which make use of the specific emission spectrum of excited sulfur molecules to achieve selective detection. When crud with GC. for the analysis of SCCs, AED atomizes components eluted and separated by GC into excited states using microwave- induced plasma. (ii) Sulfur chemiluminescent detector (SCD) converts sulfur-containing compounds from oxidative/reductive zones the ozone to form SO2 in an excited state (SO2*) and detects its specific chemiluminescent ' spectrum while quenching to ground state. It is a selective detector because it eliminates the signals of many other compounds that may interfere with sulfur detection. (iii) Mass spectrometry (MS) is another preferred detector for the characterization of sulfur compounds based on fragmentation patterns that enhance the selectivity.

Characterization and analysis of sulfur compounds is a critical element in petroleum science since it allows for better evaluation of the refinery process. With regards to sulfur detection, several merits are to be considered when selecting a method of sulfur-containing compounds analysis including precision, accuracy, sensitivity linearity, and stability with long-term rep-Auc/Aity. In addition, the data processing, sample preparation and pretreatment, simplicity of the method, interference, cost of analysis, and suitability for routine analysis are also t > be considered. Sulfur removal from oils is an essential step to protect refinery equipment and catalysts and to produce clean low-sulfur fuels and products [1]. Hydrodesulfurization remains a powerful sulfur removal technology in the refinery, however, more desulfurization technologies such as oxidation, absorption and biodesulfurization are emerging. A combine don of these tools may contribute to the current practice of hydrodesulfurization. This may resolve the involvement of severe conditions for its reaction. The study of thiophene hydrodesulfurization remains an area of interest for researchers to provide the best suitable c Alyst and kinetic design. Another challenging area of research for hydrodesulfurization processes is operation at mild conditions in an optimal reactor [2]. The development of technology, the upgrading of equipment, and the innovation of detection and molecular characterization methods; deepened our understanding of sulfur compounds in oils, which can, in turn, monitor effective exploration/production in upstream and processing in downstream, along with lowering environmental risk. Consequently, these approaches still need further research, especially in the area of designing appropriate selective methods [3].

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GASIFICATION PROCCES AS AN ALTERNATIVE TO COMBUSTION

The relevance of this topic is due to the search for the most rational ways to use both natural solid fuels and alternative raw materials that can be used as fuel, particularly industrial waste and waste consumption. The purpose of this work is to analyze the gasification process and find the advantages of this process as compared to the full oxidation (combustion) process.

Currently, the following methods are used for disposal of solid industrial and consumption waste (packaging materials, waste paper, waste carbonation, crop production waste): landfill disposal, recycling, composting, incineration and gasification [1]. Incineration of solid waste on an industrial scale was introduced in the 1960s in Japan, and in the UK, for example, the issue of waste reduction was raised even earlier - in the middle of the XIX century. As time passed, the negative impact of emissions on the environment and on human health from this technology was revealed. Despite these facts, waste incineration is also being implemented, for example, in Europe and Central Asia about 17.8 per cent of all solid domestic waste was incinerated in 2018 [2].

Due to the active development of the oil refinery industry, gasification stopped being explored and developed everywhere. Nevertheless, gas generators, which were previously used also for fuel supply to transport, can still be successfully used today. The use of the gasification process to convert solid fuels into gas can be justified by the fact that gaseous fuels have a number of advantages, including ease of transportation and distribution between consumers, as well as less negative impact on the environment.

The problem with the combustion process from an environmental point of view is the release of dioxins, the strongest synthetic poisons. During the gasification process, if properly organized, dioxin emissions are greatly reduced, the figures for combustion may be in the order of 3 mg/Nm3, while for gasification the dioxin concentration may be 0.2-0.5 mg/Nm3. Lower emissions of nitrogen oxides should also be noted, 350 mg/Nm3 for the combustion process and 150 mg/Nm3 for gasification [3,4]. Therefore, it is immediately possible to declare the reduction of costs for waste gas purification. In addition to its environmental advantage, gasification has a wider range of application possibilities for process products, especially when natural energy sources are used as a raw material. In the gasification process, due to the possibility of varying the oxidants, which can be air, steam, oxygen, carbon dioxide and their numerous combinations in different proportions, it is possible to obtain a gas mixture suitable for further chemical synthesis, such as Fischer-Tropsch synthesis, ammonia synthesis and methanol synthesis.

In summary, the gasification process of fuels, both natural and non-natural, is a profitable alternative to the full oxidation process and has environmental and economic advantages. And the one of the ways to minimalize the environment impact of emissions of process is to use gasification instead of the combustion. When it comes to the natural fuels it is even possible to produce the gas for further synthesis.

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METHOD OF GYPSUM HYDROPHOBIZATION WITH PEAT BITUMEN

Gypsum binder (gypsum hemihydrate), used in the construction industry, is a fine powder obtained from natural gypsum dihydrate by heat treatment in the temperature range 140-190°C. Gypsum dihydrate refers to quick-setting and quick-hardening miner binding materials. One of the main issues of using gypsum binder is its activity reduction over time. This is due to its hygroscopicity. The intensity of the absorption of water from the atmosphere depends on the humidity and ambient temperature. This leads to a gradual transformation of gypsum hemihydrate into the dihydrate one during storage, and reduces its activity upon setting and hardening. The longest storage life is considered to be three months – during this period the activity of gypsum binder reduces on average by 30-50% [1, 2]. There are several established methods for the protection from exposure to moisture and water vapor. For example, hygroscopic materials can be stored in dry places in an airtight plastic container. Another method is the processing of their particles with isolating coatings or their powdering with flowing agents. The use of this method prevents or hinders the access of water molecules to the protected particles. In this case an isolating protective film, liquid or solid flowing agent should possess a high water-repellant property – hydrophobicity. Peat is one of the natural organic materials, which can be used as a raw material for obtaining hydrophobic coatings. Its known reserves in the Russian Federation are about 186 billion tons (37% of global reserves). The natural hydrophobicity of peat can be decreased or increased by deep processing. When heated to temperatures above 150-180°C (in the absence or lack of oxygen) the peat begins to manifest the characteristic property of all biofuels – thermal instability. Its organic matter undergoes a complex transformation, the complex of which is called thermal decomposition, resulting in formation of solid, liquid and gaseous products [3, 4]. It was established that by setting up certain parameters it is possible to obtain the maximum amount of thermal bitumen, which possess high hydrophobic characteristics. This gives the possibility to extract these products and further apply them as a coating film on an insulated material [4]. Thus, the aim of the study is to develop a method for hydrophobization of gypsum binder by organic components extracted from peat raw materials. The idea of the method consists in combining of two stages in the technological process of gypsum binder production: gypsum dehydrate calcination with simultaneous application of nano-films from peat bitumen onto the surface of its particles, which further isolates it from moisture.

In industry, the thermal treatment on the dihydrate gypsum is performed for 1-2 hours in special boilers with constant stirring. Generally, the maximum temperature of the material at the time of discharge from the boiler, depending on properties of raw materials and requirements to mineral binder, is in the range of 140-180°C. The process is divided into three stages. The first phase lasts about 20 minutes. During this time the temperature slowly increases from 80 to 120 °

C, which corresponds heating of the powder from the temperature at charging stage to the temperature of the beginning of intensive dehydration of gypsum. In the second stage the powder is kept for 30 minutes at the temperature of 120°C. This stage is characterized by intensive occurring of material dehydration with the removal of crystallization water. In the final third stage, the duration of which is 35-40 minutes, the temperature rapidly rises to 180°C. Dehydration intensity is lowered at the same time. After cooling, a ready-to-use material, semi-aquatic (building) gypsum, is produced.

Based on the analysis of different methods for obtaining hydrophobic additives based on organic and mineral materials, there was developed a method for a water repellent processing of mineral binding powders by an organic peat-based additive. The method of the hydrophobic modification of mineral dispersed materials by native and thermogenic bitumens, extracted from peat, was developed in relation to cement. Cement is mixed with a semi-finished peat additive with particle size of about 20-70 microns. Bog and mud peat with a medium decomposition level is used as an organic raw material. Preference is given to bituminous types of peat. Use of the method in the presented way in cement industry is extremely problematic due to a number of technological and economic issues. It requires adaptation to existing processes, or their minimal change. At the same time, the developed method can be well adapted to the process of production of gypsum binder. Basic parameters (temperature, time, presence of oxidation agents, etc.) of gypsum calcination technology meet the basic parameters of the hydrophobic modification process.

Experiments on calcination of gypsum dihydrate with peat hydrophobizers at T = 180-200°C completely confirm this assumption. Optimization of the quantitative composition of peat additives allowed getting hydrophobically modified gypsum binder with low sorption capacity for water vapor and high strength.Simulation of experimental gypsum binder storage under 100% relative humidity indicates that at a concentration of 0.5-1% additive there is a decrease in water vapor absorption of the modified materials by 2 times [4]. Moreover, increasing of the additive concentration does not result in a proportional decrease of water vapor absorption. This confirms the hypothesis that a protective barrier for the water molecules is a continuous bitumen film released during thermolysis of organic matter of peat and applied to the surface of the gypsum. Under these processing conditions the gypsum particles may keep per unit area of only the amount of bitumen which is determined by the energy of its interaction with the mineral surface. Most probably, the numerical value of the film thickness of the modified gypsum particles surface will be in the same range as that of the previously set for cement (11-22 nm). Proceeding from this it is possible to create building materials and constructions based on gypsum binder hydrophobically modified by peat additives the strength of which will not be lower than the one of control samples. However, it should be kept in mind that high strength properties can be achieved only by optimization of particles size, concentration of the hydrophobically modifying component and suppressing air entrapment. In this case, there will be achieved a high hydrophobicity of the material that will not lower its strength. For example, for Portland cement, use of mud-peat as a basic raw material for obtaining hydrophobic additives shows that there is a significant decrease in the strength of the samples only with the concentration of more than 2% of the mass of mineral binder. At a concentration of the peat hydrophobizing additive of 0.5-1% there is no critical decrease in strength characteristics as well as there is no increase in the setting time of gypsum samples.

Thus, the results of the study allow to develop a technology for the production of gypsum binder hydrophobically modified by peat additives. The proposed method is completely adapted to the processes currently used in the production and do not require any technological equipment changes. Its use in the proposed form would not lead to an increase in the modify product cost, as the price of the semi-finished hydrophobic peat product equals to the cost of the source raw gypsum.

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TO INVESTIGATE THE EFFECTS OF DEMULSIFIERS ON DEEMULSIFICATION OF LOCAL WATER-OIL EMULSIONS

Today, one of the most common problems that exists in the oil industry is the fight against the formation of persistent oil-water emulsions. These phenomena significantly complicate oil preparation and negatively affect the operation of oil production equipment and pipeline communications.

However, until now, the main condition for the necessary effectiveness of demulsifiers was considered to be the selection of specific fields for oil. Moreover, this selection is carried out mainly only empirically: by searching possible variants of mixtures of several reagents and checking their effect on certain water-oil emulsions. Due to the lack of scientific bases for obtaining composite demulsifiers, there has not been a significant increase in their efficiency over the past half-century, while most other technologies have undergone a radical change.

Pumping even 1-2 % of water together with oil in the form of emulsified globules contributes to more intensive corrosion wear of equipment, reduces the throughput capacity of the pipeline and increases the probability of pipe breakage. Currently, the water content of oil wells in most oil fields reaches 90 % or more. Therefore, oil production and refining is impossible without the use of special chemical reagents, primarily demulsifiers, which provide rapid, at minimal energy costs, water release without adversely affecting the physical and chemical properties of oil. To intensify the destruction of oil emulsions, unimpeded coalescence of water globules should be provided[1].

The mechanism of action of demulsifiers is to destroy the armor shells and reduce the surface tension at the oil-water border.

At the same time, it is necessary to optimize the choice of rational feed points and the volume of dosage of the demulsifier.

It is known that deemulsifiers are imported mainly from abroad, entering into the range of reagents used to bring oil into the commodity state. This, in turn, increases the cost of preparing oil. The issues of identifying and applying an effective deemulgator, as well as identifying its alternative or reducing its cost, remain relevant. A number of works are carried out in this regard in cooperation with production enterprises by a number of scientists of our republic.

The application of deemulsants as chemical reagents is mainly aimed at exposure at the second main stage. In this case, the properties of surface active substances are manifested. All types of deemulsifiers are surface active substances (SAS) and have a molecular asymmetric structure consisting of single or multiple hydrophilic groups and hydrophobic radicals.

The purpose of this work is to develop a methodology for accounting for the effect of demulsifier concentration on surface tension, develop an algorithm, a block of the calculation program, and conduct research using a mathematical model. In [2], the dependence of the surface tension on the concentration of the supplied demulsifier is shown (Figure 1).

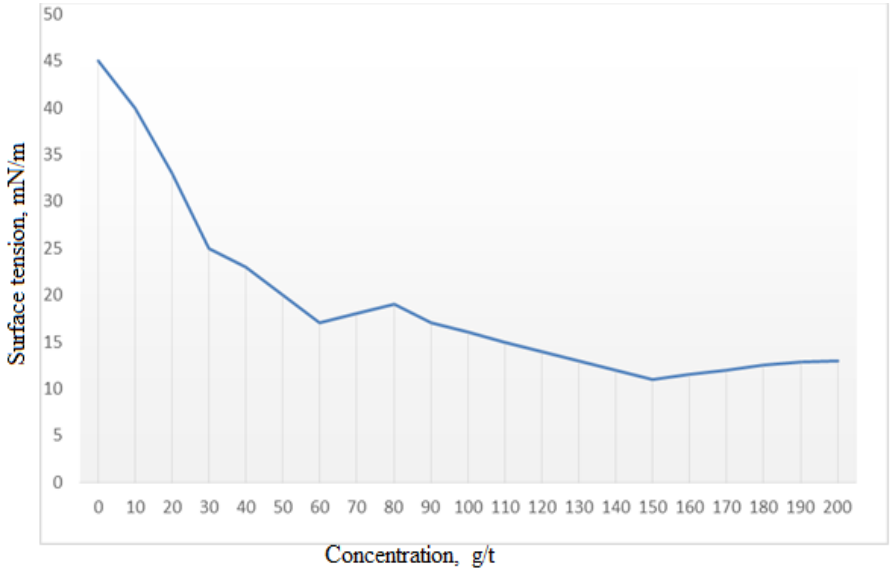

Figure 1 - The dependence of the surface tension on the concentration of the demulsifier

Based on experimental data, the theoretical dependence of the surface tension at the interface on the concentration of the chemical reagent is obtained.

Taking into account the obtained equation, an algorithm and a block of the calculation program were developed, which is included in the mathematical model of the droplet formation process[3].

The developed dependence will allow us to take into account the effect of the concentration of demulsifier on the size of droplets formed in the flow of oil-water emulsion.

The research carried out using a mathematical model will allow us to find the most effective technological modes of the process of droplet formation during field oil preparation.

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KINETICS OF ADSORPTION AND DESORPTION OF WATER VAPORS ON GRANULATED BINDER-FREE LOW-MODULE ZEOLITES

Zeolites have a unique crystalline structure. The presence of cavities with sizes from 0.3 to 0.45 and mobile cations in their frameworks make it possible to use zeolites in the oil refining industry and in relation to the purification of natural and other process gases [1]. In the last years as an intensify method of heterophase processes, ultrasonic treatment presents great interest to researchers [2]. Ultrasonic treatment allows essentially reducing the time of crystallization of various zeolites types and duration of aging the reaction mixtures as well as to increase the crystallinity degree of zeolites.

In the present work, for the synthesis of low-modulus zeolites, ultrasonic treatment of a suspension of metakaolin, alumina, and sodium hydroxide followed by the formation of samples

was used. Further, the thermal treatment of the granules at 600 ° C and hydrothermal activation in NaOH solutions with a concentration of 2-6 mol / L were carried out.

It was determined LTA zeolite particles have a cube shape with a size of ~2 μm, SOD particles have an irregular shape with a size of 0.5–1 μm. The dimension of the coherent scattering region was calculated to be 760 nm for LTA and 453 nm for SOD. The specific surface area of LTA is 115 m2·g–1 and SOD is 141 m2·g–1. isotherms of water vapor on zeolites have been obtained and it has been found that the curves are of type IV, and the maximum amount of absorbed water vapor for LTA was ~30 wt.% And for SOD ~20 wt.% [3]. Tests of zeolites in a flow-through setup have been showed that LTA zeolite provides adsorption of water from the gas phase to a dew point of –50°C, and SOD zeolite only up to –9°C. The values of the apparent activation energy of the adsorption process were calculated for both zeolites, which amounted to about 50 kJ·mol–1. By methods of synchronous thermal analysis, it has been shown that for LTA zeolite, water desorption occurs up to 275.5°C, and for SOD zeolite, adsorbed water is removed up to 304°C. It has been found that these processes proceed in two stages.

The apparent activation energy for water desorption on zeolites has been calculated By Friedman, OFW, and KAS analyzes. It has been shown that all three analyzes give similar results. It has been found that, with conversion extent, the activation energy values are no more than 60 kJ·mol–1, which corresponds to the desorption of physically bound water. An increase in activation values to 110 kJ·mol–1 (for SOD) and to 80 kJ·mol–1 (for LTA) is associated with the removal of water from the α- and β-cages of zeolites.

This work was supported by the Ministry of Science and Higher Education of the Russian Fed-eration (Project № FZZW-2020-0010)

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CLAY-BASED FUNCTIONAL COMPOSITES FOR PHOSPHATE REMOVAL FROM WASTEWATER

Eutrophication, a global problem, threatens the ecology of freshwater bodies and marine environments. In this situation, the discharge standard of total phosphorus has been set, such as 0.05 mg/L for the United States Environmental Protection Agency (U.S. EPA) [1] and 0.5 mg/L for the Chinese government (GB 8978-2002) [2]. Achieving low levels of phosphate concentration to prevent eutrophication is one of the important goals of wastewater engineering and surface water management. However, the control of phosphate in water bodies and contaminated sediments poses major technical and economic challenges [3]. Today, various attempts have been made to investigate a cost-effective way to have phosphate control. Among the various techniques applied to remove phosphate, the process of adsorption has drawn great attention due to its low cost, ease of operation, and simplicity of design [4]. Another attractive

feature of adsorption is the usage of nutrient-loaded adsorbents, which can be used as a phosphate fertilizer and a soil conditioner in agriculture. In this regard, many different types of chemicals with various structures have been synthesized and applied for the capture of phosphate from water [5]. Clay minerals are the most commonly tested adsorbents for environmental remediation because of their higher adsorption capacity by virtue of its large specific surface area, having attracted much attention for highly efficient phosphate removal from wastewater.

To enhance the adsorption capacity, clay minerals have been subjected to array of treatments. In this paper we have provided an overview of progress in researching phosphate removal from wastewater by clay-based functional composites. Firstly, the physico-chemical characteristics and commonly used modification methods of different mineral materials have been briefly considered. Then, experimental results for raw and modified clay-based functional composites have been summarised, and influencing factors highlighted, followed by elucidation of possible reaction mechanisms which transpire in the various mineral adsorbents phosphate removal processes. The regeneration of used adsorbents are examined. Correspondingly, interaction mechanisms between the phosphate and adsorbent are categorized as ligand exchange, electrostatic attraction, complexation, and precipitation [6,7]. Through economic viability analysis, we conclude with the suggestion that future research should focus on developing new clay-based functional composites for phosphate removal from wastewater, which exhibits significant performance and good stability.

Metal (hydr)oxides loaded clay minerals have been widely researched. Additional modifying of material characteristics such as improving porosity and surface area, the stability and potential risks of clay-based functional composites in complex conditions, and their efficient separation and regeneration should be taken into consideration in further studies. So we synthesize La-modified rectorite composites for highly efficient phosphate removal from wastewater. Rectorite is a rare variety of clay minerals with a 2:1 layer structure. It is a regularly interstratified clay mineral of the dioctahedral mica layer and dioctahedral montmorillonite layer in a 1:1 ratio. Rectorite was used as the support of lanthanum to improve the usage efficiency of lanthanum by achieving the dispersion of active lanthanum species and exposing more adsorption sites for phosphate. The experimental results further confirmed that clay-based functional composites can serve as superior adsorbents for phosphate adsorption.

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UNDERSTANDING THE GROUND SURFACE DAMAGE FORMATION OF SINTERED SILICON CARBIDE IN SINGLE DIAMOND ABRASIVE GRINDING FROM A MICROSTRUCTURE PERSPECTIVE

KEYWORDS: Microstructure, Damage formation, Grain boundary, Dislocation pileup, Crack initiation, Surface/subsurface morphology.

This study demonstrated the surface and subsurface damage formation mechanism in SSiC from a microstructure perspective. A single diamond abrasive grinding experiment was performed to understand the ground surface damage formation in grinding of sintered silicon carbide (SSiC). The surface and subsurface morphologies of the grinding groove were examined by scanning electron microscopy (SEM) and transmission electron microscopy (TEM), respectively. With the increase of the undeformed chip thickness, a transition of four material removal modes: purely ductile, primarily ductile, primarily brittle and purely brittle, was demonstrated. In the primarily ductile mode, intragranular, intergranular, semi-transgranular, lateral, and median, five types of cracks were observed. The cracks and plastic deformation occurred primarily among the top layer of grains underneath the ground surface, showing the effect of grain boundary in dissipating strain energy and inhibiting crack and stress transgranular propagation. The intergranular and semi-transgranular cracks were aligned in the direction of the slip bands due to the initiation mechanism: pile-up of the dislocation.

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PRODUCTION OF CO_x-FREE HYDROGEN FROM NATURAL GAS ON ORDERED Fe/Al_2O_3 MESOPOROUS CATALYSTS

Nowadays, hydrogen is considered as a clean, renewable and cost-efficient energy carrier to complement depleting carbon-based resources for a sustainable future. The industrial production of H_2 is based on natural gas resources and achieved via catalytically-assisted steam reforming of

methane (SRM, $CH_4 + H_2O \leftrightarrow CO + 3H_2$) to synthesis gas (syngas, H_2 and CO mixtures). Currently, catalytic decomposition of methane(CDM, $CH_4 \leftrightarrow C_{(s)} + 2H_2$) is rising as a competitive H_2-production path owing to several advantageous principally: the generation of CO_x-free hydrogen gases along with carbon, having various commercial interests, as a solid by-product [1]. The design of a stable yet cheap catalyst for CDM is one of the drawbacks limiting the industrialization of this process. Several catalysts have been already reported in literature as promising and economically attractive especially those based on Ni (transition metal) as active site, Ni-doped noble metals (small contents for promotion purposes), carbonaceous materials and, Fe-based ones. From both cost and environmental perspectives, Fe-based catalysts appear as most advantageous for scaling-up considerations. One particular catalytic combination with good outcomes in CDM is Fe species supported on (standard) non-porous Al_2O_3 oxide [2]. Nevertheless, using an ordered mesoporous Fe/Al_2O_3 catalyst could lead to special performances owing to the porous structure of Al_2O_3, shown beneficial in promoting intrinsic activity as well as in maintaining stable reactivity in reforming reactions under similar endothermic conditions ($T\geq$ 700°C) as CDM [3]. The aim of the present work is to synthesize, evaluate and understand the role of mesoporous alumina on the performance of Fe species in catalyzing hydrogen production via CDM. To the best of our knowledge, such an approach has not been yet considered in literature. For comparison purposes, several non-transition metals (Ni, Co and Cu) were also studied.

In this work, 20 wt% Ni, Cu, Co and Fe loaded in Al_2O_3 catalysts (noted as $Metal_{20\%}Al_2O_3$) were prepared (along a 50 wt% Fe-containing sample) by adopting a "one pot" inspired evaporation induced self-assembly method, used in our previous works for synthesis of stable nickel and/or iron based-catalysts for methane reforming reactions [3,4]. Synthesized materials were characterized by N_2 sorption, X-Ray diffraction and, temperature programmed reduction/desorption (TPR/D). After *in situ* pretreatment (H_2/Ar, 700 °C/2 h), methane decomposition tests were performed at T= 700 °C, P= 1 atm and for a gas-hourly space velocity (GHSV) of 12 L g_{cat}^{-1} hr^{-1}. Carbonaceous species over spent catalysts were characterized by thermal gravimetric analysis (TGA) coupled to differential scanning calorimetry (DSC).

N_2-sorption results reveal the successful synthesis of well-defined mesoporous structures over both $Fe_{20\%}$-and $Fe_{50\%}Al_2O_3$ samples as attested by the sharp increase in adsorbed N_2 amounts within the 0.25-0.60 relative pressure (P/P_0) range. Isotherm shapes, specific surface area (range: 161-108 m^2 g^{-1}) and porous volume (range: 0.33-0.29 cm^3 g^{-1}) values were in line with those found over similarly synthesized mesoporous materials [3,4]. Regarding reducibility behaviors, one main reduction peak over $Fe_{20\%}Al_2O_3$ at circa 445 °C is indicative of Fe_2O_3 reduction into partially oxidized Fe_3O_4 rather than Fe^0 species (catalytically active). On the other hand, metals of Ni, Cu and Co were generated upon reducing samples till 900 °C. Such an incomplete reduction of iron could affect reactivity since methane is mainly activated over reduced metallic surfaces. H_2- reduction followed by desorption measurements over $Fe_{20\%}Al_2O_3$ showed several families of iron sites depending on their desorption temperatures. The origin of peaks centered at high temperature ($T\geq$ 600 °C) are iron species with low H_2-releasing potentials whereas, those at lower temperature are the result of active iron sites with an ease in H_2-release. The latter family of species are extremely interesting for catalysis as they show high C-H activation barriers [3]. Alike $Fe_{20\%}Al_2O_3$, low temperature H_2-desorption peaks were observed over $Co_{20\%}Al_2O_3$.

Methane decomposition results (in terms of methane conversion and H_2 yield) show that $Ni_{20\%}$-and $Co_{20\%}Al_2O_3$ have high intrinsic activity levels however, they deactivate drastically with time-on-stream. As for $Cu_{20\%}Al_2O_3$, low initial performances were noted along with complete deactivation after just 40 min of catalysis. Regarding $Fe_{20\%}Al_2O_3$, initial methane conversion and H_2 yield were lower than those over $Ni_{20\%}Al_2O_3$ yet, an increasing trend in the performance was observed as reaction proceeds. This could be the result of an *in situ* reduction of (incompletely reduced) Fe_3O_4 into catalytically active metallic sites. A similar trend along with a relatively stable performance were noted over $Fe_{50\%}Al_2O_3$, for the entire test duration, with methane conversion

being close to the maximum thermodynamic expected one. X-Ray diffractograms confirm the presence of reduced Fe^0 phases over spent samples justifying the stable reactivity resulting from the continuous *in situ* reduction of iron species. With respect to carbon production, TGA/DSC data were in complete accordance with catalysis as higher conversion led to higher amounts of, selectively formed, carbon nanotubes over spent $Fe_{50\%}Al_2O_3$ as compared to $Fe_{20\%}Al_2O_3$.

In this work, a series of "one-pot" synthesized transition-metal based catalysts (metal loading of 20 and 50 wt%) were synthesized and tested for hydrogen and carbon productions via methane decomposition. Screening of the various metals showed that iron stands as an economically and environmentally attractive active site for this reaction. Lower initial reactivity levels are noted over iron as compared to Ni and Co yet, non-deactivating trends are only observed over $Fe_{20\%}Al_2O_3$. Methane conversion is shown to increase significantly upon increasing Fe loading while preserving the mesoporous arrangement. The presence of the mesoporous structure is shown beneficial in preserving Fe dispersion against potential sintering while allowing the continuous accessibility of methane towards iron sites for selective generation of (non- deactivating) carbon nanotube species.

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THE ADDITION OF DIOCTYLTEREPHTHALATE TO ENERGY-SAVING ENGINE OILS TO INCREASE THE RESISTANCE OF POLYMER ADDITIVES TO MECHANICAL DESTRUCTION

Rising of fuel efficiency of internal-combustion engine is highly dedicated to constant trying to increase compressive ratio, which leads to heating up inside of an engine. That is why tough requirements to construction materials and engine oils quality are raised, especially to those called 'energy-saving'. The production of updated high-quality off-season lube oil demands injection of thickening additives to base oil. The result is a good pumping quality in low temperature and high viscosity while critical engine heating.

The aim of the work was to analyze the effect of the dioctylterephthalate ester (DOTP) on the resistance to mechanical destruction of polymer thickening additives in paraffin-naphthenic oil VHVI-4.

Thickening additives such as PIB (polyisobutylenes) trademarks P-118 and P-155 – 1% and such as PMA (polymethacrylate) trademarks PARATON 8900 – 1%, dissolved in the base oil VHVI-4 were used in a current work. Viscosity was measured at 40 and 100 degrees, and based on that, the viscosity index was calculated and the thickening ability of the PIB and PMA was studied. The resistance of the samples of thickened oil to the destruction of the polymer additive was evaluated by treating the samples with ultrasound on the UZDN-2T device.

Based on the analysis of the obtained results, it was concluded that polymethacrylates undergo mechanical destruction slightly less than high-molecular polyisobutylenes. It was suggested to add ester of a branched structure with concentrations of 3, 5 and 10 per cent to increase the resistance of the mechanical destruction additive.

Table 1 - The results of testing the PIB for mechanical destruction

PIB 118 (1%) + VHVI-4 (99%)			
Before UZDN		After UZDN	
40°	100°	40°	100°
40,75	8,5	28,46	6,01
Viscosity Index = 193		Viscosity Index = 165	
PIB 155 (1%) + VHVI-4 (99%)			
Before UZDN		After UZDN	
40°	100°	40°	100°
41,83	8,68	30,7	6,35
Viscosity Index = 193		Viscosity Index = 165	

Table 2 - The results of testing the PMA for mechanical destruction

PMA (1 %) + VHVI-4 (99 %)			
Before UZDN		After UZDN	
40°	100°	40°	100°
39,81892	8,427731	37,0159	7,91216
Viscosity Index = 196		Viscosity Index = 193	

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LAMINAR BURNING VELOCITY AND EXTINCTION STRAIN RATES OF H2/CH4/O2/N2 IN FLAT FLAMES

KEYWORDS: Hydrogen, Methane, Laminar burning velocity, Extinction strain rate, Heatflux burner, Counterflow burner.

In this paper the extinction behavior of laminar non-premixed and the laminar burning velocity (LBV) of premixed methane and hydrogen flames are evaluated. The aim of the work is a better understanding of fuel components in interaction with inert gases and oxygen reduced air. For these gas mixtures, the extinction rates and LBV as two important physical-chemical properties were investigated. These properties are basic values for validation of reaction mechanisms and the specific design of burner systems.

For this purpose, an experimental setup with a counter-flow and a Heatflux burner was used. The extinction limits and strain rates of the counter-flow for non-premixed $H_2/CH_4/O_2/N_2$ flames at atmospheric pressure are experimentally determined. Furthermore, the detailed flame structure and the extinction limits are visualized by using a high-speed- and an OH* - chemiluminescence camera system. The results pointed out that the blow-off limits are enhanced

with higher fuel substitution in the flames. In addition, it could be shown that more distance between the nozzles have a dramatic impact on the strain rate whereas the OH* detection allows for the detection of the flame position relative to the nozzles.

Furthermore, the Heatflux burner method [1,2] was applied to measure LBV of hydrogen containing fuel blends. Therefore, different hydrogen containing fuels were tested within a range of equivalence ratios between 0.7 and 1.6 and for a gas mixture with lower and higher oxygen partial pressure from Y_{O2}=0.14 to Y_{O2}=0.21. Initial temperatures of 298 K up to 378 K were tested for atmospheric conditions. In addition, it could be shown that the LBV reduction is significant influenced by the oxygen content. With these results, the lack of data for hydrogen containing gases could be partly closed and helps to validate reaction mechanisms for better simulation of internal combustion with exhaust gas recirculation (EGR) or oxygen enriched atmosphere for special combustion systems.

The focus of this experimental study was to determine the extinction strain rate for C1-C3 fuel and the impact of oxygen reduction. Extinction strain rates were measured for non-premixed flames stabilized in a counter-flow burner. The critical conditions of strain rate were measured for varied mass fractions of the fuel streams and stoichiometric mixture fraction chosen. The strain rate at extinction was found to increase with increasing amounts of fuel in all tested combustible mixture. It could also be concluded that with a lower oxygen mass ratio in the oxidizer stream, the strain rate decreases. Secondly, the impact of the nozzle distance to non-premixed methane/air flames was determined. The current results show that with higher distance the extinction strain rate decreases nonlinear. Furthermore, the influence of oxygen reduction on premixed laminar flames stabilized on a Heatflux burner was investigated. Likewise, the influence of hydrogen addition to these mixtures. It could be shown that the reduction of oxygen reduces the laminar burning velocity and on the other hand, the addition of hydrogen increases the burning velocity. The measurements will be compared to different reaction mechanisms to shown their possibility to predict laminar burning velocities and temperature levels for exhaust gas recirculation and combustion with lower oxygen ratio in the oxidizer flow. Furthermore, experiments for different temperatures and pressures will follow.

Figure 4 - Stabilized methane flame in counterflow burner (left, Zst=0.1) and in heat flux burner (right, ϕ=0.9)

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CALCULATION OF OIL HYDROCARBONS ACTIVITY COEFFICIENTS USING UNIFAC MODEL

The content of isomeric and unsaturated hydrocarbons is an important indicator of the quality of diesel fuel, however, there are difficulties in identifying these types of hydrocarbons even by the chromato-mass spectrometric method. This is due to overlapping peaks with n-alkanes (the main components of diesel fuel) and the similarity in the structure of isomeric hydrocarbons. Therefore, for a qualitative and quantitative description of diesel fuels, an additional identification feature is needed; as such a parameter can be used the distribution coefficient of hydrocarbons between two immiscible phases.

The distribution coefficient is a parameter sensitive to the structure of the substance and is defined as the ratio of the concentrations of the component in two immiscible phases. In the case of a dilute solution, the distribution coefficient can be calculated through the limiting activity coefficient [1]. Thus, comparing the calculated and experimental distribution coefficient, it is possible to identify the components. For calculations, there are a large number of models: UNIFAC, UNIQUAC, NRTL [2, 3].

The UNIFAC and NRTL models allow to describe with great accuracy various types of equilibria (liquid-liquid, liquid-gas). However, to describe multicomponent systems, it is necessary to know the interaction parameters for all binary subsystems, which greatly complicates the calculations. In addition, the NTRL model requires an additional system parameter, which is set empirically. To predict the properties of a wide range of systems, group solution models have found application.

In systems consisting of organic components, the UNIFAC model is most often used. Its main advantage can be called the ability to calculate the properties of the system without studying the properties of specific substances. The main point of the UNIFAC model is the representation of molecules as a set of certain chemical groups, which are supposed to make additive contributions to the properties of the system. For example, ethanol can be represented as a combination of groups: OH, CH_3 and CH_2. Hexane: four CH_2 groups and two CH_3 groups. The attractiveness of group models is that the properties of a huge variety of organic compounds can be determined through a limited number of parameters characterizing the contributions of individual groups.

It is proposed to use diesel fuel itself as the first immiscible phase, and acetonitrile as the second. It was experimentally shown that more polar substances — alkenes and arenes — mainly pass into the acetonitrile phase, which allows using acetonitrile extraction to preferentially extract these classes of hydrocarbons from diesel fuels for subsequent analysis [4]. In addition to eliminating the problem of overlapping peaks, extraction concentration of these components also occurs, which also facilitates their analysis. It is also possible to use more available polar solvents instead of acetonitrile - ethanol, propanol, isopropanol.

As part of this work, a set of programs for calculating the thermodynamic parameters of fuel systems was developed. On industrial diesel fuels, the process of extraction of the components with acetonitrile and other organic solvents was studied. Based on the data obtained, a method was proposed to improve the quality of identification of diesel fuel components in gas chromatography. Subsequently, on the basis of this method, it is possible to develop an accelerated method for assessing fuel quality, which is important in the conditions of continuously operating enterprises with high productivity.

The work was performed on the basis of Centre of collective usage of St. Petersburg Mining University.

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PREPARATION AND APPLICATIONS OF GEOPOLYMER AND GEOPOLYMER BASED COMPOSITES

Geopolymer, named by Joseph Davidovits in 1970s, is a new class of three-dimensional (3D) inorganic materials formed by alkali activation of aluminosilicates with significantly reduced greenhouse gas emission during its production [1]. Mineral and industrial waste with abundant Si and Al including metakaolin (MK), fly ash or blast furnace slags have been used to prepare geopolymers as source materials [2,3]. Compared with ordinary Portland cement (OPC) as construction materials, geopolymers exhibit advantages including low cost [4], stronger early compressive strength [5], better acid resistance [6,7], fire resistance [8,9], and eco-friendly[10]. Hence, geopolymers have attracted lots of attention from civil engineers and materials scientists.

Since the crucial factors in influencing compressive strength are including Si/Al ratio [11,12], hydroxide concentration [11], alkali cation used [13], and curing condition [14,15]. To improve the mechanical properties of geopolymers, several studies have been conducted by focusing on these factors as mentioned. For example, we found the compressive strength of MK based geopolymers using Na^+ was higher than that of those using K^+ under the same Si/Al ratio and alkali cation concentration [16]. A high compressive strength up to ~40.1 MPa was achieved from a system by using 12 M of Na^+ with Si/Al ratio of 1.9:1 where a continuous monolithic microstructure was observed [16]. This was attributed to the difference in dissolution tendency between Na^+ and K^+ resulting in different morphologies, which further affected the compressive strength [16]. To overcome intrinsic brittleness and enhance fracture toughness of geopolymers, geopolymer based composites with highly porous melamine foam as the 3D skeleton have been prepared [17]. Compared with pure geopolymer, fracture toughness and work of fracture of geopolymer composites with as low as 2.5 wt% elastomer increased by 258% and 654%, respectively [17]. This can be explained by a transition of fracture behavior from brittle failure mode to a more ductile one when introducing the 3D skeleton [17].

To enable the various applications of geopolymer and geopolymer based composites, geopolymer based syntactic foams have been made by introducing K15 glass microspheres and Phenoset BJO-0930 phenolic microspheres into geopolymer matrix [18]. The obtained unique

interfacial bonding between the microspheres and the matrix pronouncedly contributed to the compressive strength of the geopolymer based composites under a high temperature of 500 °C, which is lacking in polymer composite or foam systems [18]. Besides the fire resistance application, geopolymer composites with ultrahigh self-sensing performance as construction materials have been prepared based on the unique behaviors of SiO2 coating on CNTs (SiO2@CNTs) in the geopolymer matrix [19]. High gauge factor up to 663.5 and 724.6 can be achieved under the individual compressive and flexural loading for geopolymer composites with the addition of only 0.25 vol% SiO2-CNTs [19]. In summary, geopolymer and geopolymer based composites show their great potential as green structural materials.

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A STUDY ON THE POSSIBILITY OF DESULFURIZATION OF LIQUID PRODUCTS OF THE PYROLYSIS OF ESTONIAN OIL SHALE

Shale liquid fuels are characterized by low sulfur content. This value falls in the range from 0,4 to 1,4 wt. %. The actual sulfur content in shale gasoline is 1,2 wt.%, in wide fraction of shale oil from 0,7 to 0,8 wt. %. The main problems of the qualified use of shale oil: high content of oxygen compounds; high content of unsaturated compounds; easy oxidability; thermal instability (tendency to polymerization). As of 1 January 2020, new emission standards are enforced for fuel oil used by ships, in a rule known as IMO 2020. The global sulphur limit (outside SECA's) dropped from an allowed 3.5 wt. % sulphur in marine fuels to 0.5wt. %. [1]

There are many methods in use for sulfur removing from liquid fuels/oils, such as: adsorptive desulfurization; oxidative desulfurization ODS; hydro-desulfurization (HDS); desulfurization by extraction; microbe desulfurization (MDS); supercritical treatment and others. [2] In this work, to reduce sulfur in liquid pyrolysis products of Baltic oil shale – Kukersite, some of above mentioned methods were used (HDS, oxidative desulfurization, extractive distillation, formation of insoluble complexes and adsorption). There are similar patents for all of the above-mentioned method exists, however their applicability for shale oil produced from kukersite oil shale is not studied.

Experiments on wide fraction of shale oil were conducted at different pressures 50 and 100 bar and temperature range 350 – 450 ^{0}C. In experiments was used NiMo catalyst for hydrotreating on Al_2O_3 base. The flows of hydrogen was 3 l/min and for oil – 5 ml/min respectively. Time of experiments was 1 hour. The work carried out showed that fully sulfur reduction (up to 0.003 wt.%) may be achieved only by HDS method.

Formation of insoluble complexes and adsorption allows reducing sulfur up to 1/3. The method involves combining a liquid fuel and at least one metal acetate, nitrate, salt or metal oxide to form a thiophene/metal. A thiophene concentration in a liqued fuel is reduced by formation of insoluble complex, which can be removed by, for example, decantation, filtration or centrifugation. Carried experiments with complexation with silver nitrate, tin tetrachloride and others allow to reduce sulphur by a third. There also a trend is observed with a different complexing agent/oil ratio. However, these methods are expensive for industry.

Extractive distillation method allows concentrating some sulfur compounds. Experiments shows that slightly more sulphur in shale gasoline is concentrated in fractions with boiling range 110-117 °C and 135-142 °C, which correspond to 2-methylthiophene and 2,5 dimethylthiophene, but total sulfur decline not significantly, due to their low concentration in the initial sample. In experiments was used high efficiency mini distillation system with 200 theoretical plates. A significant reduction in sulphur can be achieved only by eliminating the above-mentioned fractions and the bottom residue, which in turn carries a loss in the product of up to 40 vol. %. [3]

Oxidative desulfurization of Estonian shale oil carries some difficulties. One of them, that presented organic sulfur compounds are difficult to oxidize and second, due to high content of oxygen compounds (phenols, ketons, etc.) with high polarity extraction of oxidized compounds is practically impossible.

Thermal treatment and adsorption experiments showed that addition of Ca consisted adsorbents with high specific surface area and active metals allows to reduce sulphur up to 25

wt. %. Unfortunately, with such processing, losses amount up to 15 volume percent due to the formation of gas and coke.

Liquid products of thermal treatment of oil shale contain the major part of the sulfur contained in organic sulfur compounds such as thiols or mercaptans, cyclic sulfur compounds, thiophenes, sulphides, disulfides. Desulfurization of aromatic sulfur compounds much complicated as compare with desulfurization of aliphatic sulfur compounds. It is highly necessary to explore the exact composition of shale oil, to develop methods for its cleaning in order to solve these complex problems.

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OBTAINING PETROLEUM COKING ADDITIVE FROM VARIOUS RAW MATERIALS

The refining industry development and improvement of the refinery's economic efficiency are directly connected with the increasing depth of petroleum processing. Ltd Kinef was commissioned in 1966 and since then has been the main supplier of oil products for Northwest Russia. Since 2013, company has already put into operation a hydrocracking complex, which contribute to deeper oil refining and significantly increase the output of light petroleum products. However, for further increasing in depth of refining and, as a consequence, producing more high-value light oil products (motor fuel components), it is necessary to include processes of heavy oil residues deep refining into the technological scheme of the plant.

One of the consider options for increasing oil refining depth at Ltd Kinef is the construction of UZK unit and petroleum coking additive (PCA) production. This type of carbon products in accordance with TU 0258-22900190437-2008 [1] should have high volatiles content - from 15 to 25 wt. %.

The main purpose of petroleum coking additive is using it instead of deficient coking coals of K, KO and OS grades as a charge component to produce quality coal coke. The need for coal coke in the long term will remain, as the main consumer of coal coke is blast-furnace production, which is the main process of iron, and steel production in the world. Petroleum coking additive has low ash content (up to 0.3 % against the ash content of coals more than 2-30 %) it leads to improvement of quality and increase of coal coke yield, and also reduces specific coke consumption for smelting copper, pig iron and nickel [2,3].

Technology for producing petroleum cocking additive at UZK is carried out at a milder temperature regime (450-465 °C), in comparison with the ordinary process of obtaining petroleum coke, which allows to produce a carbon material with high values of volatile matter content [4]. The oil products industrial samples of Ltd Kinef. have served as raw material for produsing PCA, in particular: tar derived from the atmospheric-vacuum distillation unit (VR1),

tar derived from the vacuum distillation unit C-1000 (VR2), visbreaking residue derived from the visbreaking unit (light thermal cracking) S-3000 (VR3).

Technological parameters in the course of experimental research were the following: coking overpressure is 0.35 MPa; final temperature of coking layer inside the reactor equals 455-460 °C; heating time to the final temperature 345-360 minutes and holding in isothermal mode - 60 minutes; mass of raw materials is 0.25 kg.

The main physical and chemical characteristics of PSA have been determined by means of X-ray diffraction and thermal gravimetric analysis. In the course of the study, PCA of the required quality was obtained from three types of raw materials. The highest yield of PCA was obtained the coking of visbreaking residue, as the visbreaking residue has already been thermally activated and contains more coke substances. Moreover, the coking rate of visbreaking residue is the highest.

ACKNOWLEDGMENTS

This work was carried out as part of the State Assignment “Development of scientific foundations of innovative technologies for processing heavy hydrocarbon raw materials into environmentally friendly motor fuels and new carbon materials with controlled macro- and microstructural organization of mesophase”. Study was conducted with involvement of laboratory base of Center for collective use of Saint Petersburg Mining University.

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PROSPECTS FOR ALTERNATIVE USE OF ALUMINA PRODUCTS

Today aluminium hydroxide is in wide demand in different areas of the national economy. The bulk of aluminum hydroxide (gibbsite) is used for the production of aluminum metal. Also, aluminum hydroxide (boehmite, bayerite, pseudoboehmite) is widely used in the production of adsorbents, catalyst supports, and ceramics [1].

The gibbsite of non-metallurgical consumption is obtained by Bayer method by precipitation (carbonisation) from an aluminate solution obtained by leaching bauxite or nepheline sinters with limestone. Precipitation conduct at pH $\leq$ 12 and T=50-60 °C . In the catalyst industry, gibbsite is used to prepare an aluminate solution. The aluminate solution is

obtained by dissolving the gibbsite at 85-90 ° C. Industrial precipitation is carried out using nitric or sulfuric acids [2]. Active aluminium hydroxide is obtained during precipitation.

Many studies were carried out on the effect of the nature of the precipitator on the phase composition of the hydroxide precipitates. Methods for producing aluminum hydroxide pseudobumite and other phases have also been patented. The patents propose to use ethylene chlorohydrin, aluminium salts, Na_2CO_3 solution and others as precipitators [3, 4].

In recent years, there has been an increase in scientific publications in the field of the use of industrial aluminate solutions of alumina production of the Bayer cycle in the process of precipitation of active aluminium hydroxide of the hemite and pseudobumite structure. This direction is very promising, as the issue of excluding the process of precipitation of gibbsite is under consideration.

In this regard, the authors consider the study of precipitation of active aluminium hydroxide using industrial aluminate solutions of Russian alumina plants and solutions of aluminium salts to be relevant today. They are planning experimental work in this direction.

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ADSORBENTS BASED ON SILICON OXYCARBIDE COMPOSITES

Silicon oxycarbide composites are usually considered as materials based on silicon oxycarbides (SiOC), which formally can be described as products of carbon incorporation into the network structure of silicates. The structure of silicon oxycarbides is mixed network of silicon atoms tetrahedrally bonded to oxygen and carbon atoms [1]. Currently, silicon oxycarbides are prepared from organosilicon polymers as raw materials, polyorganosiloxanes in particular. In addition to the structural units mentioned above, there is also a phase of segregated sp^2-hybridized carbon in silicon oxycarbides. This carbon is a highly disordered, and turbostratic. Unique structure of silicon oxycarbides determines all their properties, for example high strength, chemical and thermal stability. SiOC is used to produce a large number of different types of materials, in particular coatings, tubes, fibers, etc. [2]. The most interesting are porous structures. Such composites are well suited as carriers of Ni, Co and Pt for instance [3]. At the same time, silicon oxycarbide composites that do not possess significant specific surface area may still act as adsorbents [4]. For example, they were used for wastewater treatment. Despite all the advantages of silicon oxycarbides and composites based on them, the key disadvantage is high cost of their production. Firstly, this is due to expensive raw materials, and, secondly, to pyrolysis at high temperatures as the only synthesis method. In this regard, one of the aims of this work was to search for another method for producing of silicon oxycarbides, and mechanochemical synthesis could potentially be the one. Another objective of the work was to study adsorption activity of silicon oxycarbide composites obtained mechanochemically.

Activated carbon (AC) and silica (S) were chosen as raw materials for mechanochemical synthesis of silicon oxycarbide composites. These materials are cheaper than organosilicon polymers. Mechanochemical synthesis was carried out in a roller ring vibratory mill VM-4. Several mixtures of AC and S with various mass ratios of the components were subjected to mechanical treatment for 15 min. The samples were analyzed using various experimental methods. The structure was investigated via powder X-ray diffraction. Both the raw materials and the samples obtained have a large number of different types of functional groups, which were characterized via IR Fourier spectroscopy. Concentration of various surface functional groups was determined potentiometrically. Adsorption activity was determined using fluoride ions and methyl orange as compounds to be adsorbed. Adsorption capacity for fluoride ions was measured potentiometrically, and that for methyl orange was measured photometrically.

The process of silicon oxycarbides synthesis is quite complicated, because many chemical reactions proceed. The mechanism of SiOC formation and resulting product composition differ depending on raw materials and synthesis method used. So, pyrolysis of organosilicon polymers is carried out in inert medium. The product contains much more silicon and oxygen than carbon in this case. Mechanochemical synthesis in the vast majority of cases implies air medium, in which oxygen is presented. The presence of the oxidizing agent doesn't allow silicon and carbon to bind directly to form silicon carbide that could occur during pyrolysis in inert medium. Therefore, silicon and carbon are most likely to be bonded only through an oxygen bridge. This is possible due to presence of various functional groups, in particular phenols, carboxyls, silanols, etc.

Mechanochemical synthesis of SiOC composites proceeds together with oxidation of activated carbon, which results in increase of concentration of various functional groups, in particular phenolic and carboxylic ones. Probably, formation of Si-O-C bonds occurs due to these groups. Structure of the composites obtained varies depending on the initial mixture composition. In fact, the larger the proportion of silica, the more Si-O-C bonds could form. This trend is observed in absolute terms. However, degree of binding of AC and S decreases, since silica excess overlaps network structure of silicon oxycarbides by crosslinking of Si-OH bonds to form Si-O-Si. From this point of view, a small concentration of S in the initial mixture is required in order to achieve a high degree of binding of AC and S. Assessing adsorption properties of the obtained composites, it should be noted that role of silicon oxycarbides in sorption processes is not fully revealed. Decrease in specific surface area was observed with addition of S to AC. Nevertheless, specific surface area of even pure AC under mechanical impact would decrease due to destruction of its porous structure. This decrease of specific surface are is responsible for reduction of adsorption capacity for methyl orange. At the same time, it was observed that adsorption capacity for fluoride ions significantly increased. It can be assumed that synthesized silicon oxycarbide composites are more effective as ion exchangers. However, further studies are needed to confirm this.

Thus, mechanochemical synthesis is effective, because mechanical impact could make chemical reactions, which aren't possible at standard conditions, to occur. A process like this is production of silicon oxycarbides that requires high temperatures, as well as expensive organosilicon polymers as raw materials. In this work, it was shown that intensive supply of mechanical energy allows one to obtain silicon oxycarbides even from activated carbon and silica. However, in this case, silicon oxycarbides are actually intermediate phase between AC and S. Therefore, it is possible to mechanochemically produce exactly silicon oxycarbide composites, which, upon further processing, could be converted directly to silicon oxycarbides themselves. This may be useful if a specific composition of silicon oxycarbides is required. Besides, it was shown that silicon oxycarbide composites could act as highly efficient adsorbents for fluorine removal.

This work was supported by the Ministry of Science and Higher Education of the Russian Federation (Project № FZZW-2020-0010). Equipment of the Center of Collective Use of Ivanovo State University of Chemistry and Technology was used when carrying out the research.

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PREPARATION OF MODIFIED MAGNETIC CNTS ADSORBENT AND STUDY ON THE TREATMENT OF LANTHANUM IONS IN WATER

KEYWORDS: thiol group, modified magnetic carbon nanotubes, adsorption, response surface, lanthanum ion.

Ionic rare earth ore is an internationally recognized strategic resource and an indispensable mineral raw material in the future production of new materials. Due to in-situ leaching, precipitation and filtration processes for extraction and recovery, there are problems like ammonia nitrogen pollution, low recovery rate and low separation efficiency. That efficiently recovering rare earth ions from the leaching solution has become a key technology. In this paper, a new type of highly efficient adsorbent-thiol- modified magnetic carbon nanotubes is used to recover rare earth La3+ from the ionic rare earth ore leaching solution. The research shows that it is convenient and of fast reaction rate. Through quadratic multiple regression model equation, variance analysis and three-dimensional response surface diagram in response surface method, data were obtained. The results show that the order of influence of various factors on adsorption effect is adsorbent dosage > pH > initial solution concentration > adsorption time. The optimal adsorption conditions are initial solution concentration of 100mg/L, pH value of 7, adsorbent dosage of 0.02g and adsorption time of 180min. On this condition, the maximum adsorption capacity of magnetic carbon nanotube adsorbent reaches 99.72mg/g, and the rare earth La3+ is well recovered. In this paper, great values have been found in the integrated processing of rare earth materials and the treatment of its wastewater with further production.

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DEVELOPMENT OF GREEN CONCRETE WITH "0%" CEMENT

Concrete is one of the most common building materials used in the construction of buildings, bridges, and infrastructure around the world. Its major constituents include Portland cement and aggregates, which are which mixed with water to achieve the desired strength properties. Nevertheless, the production of Portland cement is very polluting, energy intensive, and requires large amounts of non-renewable raw materials. On average, the production of 1 ton of cement releases 1 ton of CO_2 into the atmosphere; about 8% of global greenhouse gases generated by human activities originates from cement production.

The green concrete made with "0%" Portland cement invoked particular interest and numerous studies around the world. This new type of environmentally-friendly concrete is made by mixing aggregates, supplementary cementitious materials (instead of Portland cement), and caustic activators (instead of water). The supplementary materials are typically aluminate and silicate-based obtained from natural sources or as waste by-products such as fly ash, silica fume, and blast furnace slag. Over the past few years, investigations conducted by various universities and countries across the globe have shown that performance characteristics of green concrete are comparable, even better, than conventional concrete prepared with Portland cement. For example, green concrete gains its full strength (curing process) much faster, shrinks less than standard concrete, possesses higher compressive and tensile strengths, and is more resistant to corrosion and fire.

In Lebanon, almost no efforts and attempts have been made by the construction industry to develop and use green concrete made with "0%" Portland cement. In this context, the Civil & Environmental Engineering Department in the University of Balamand (UoB), under the auspices of UNESCO, aims to spread and introduce such eco-concrete practices to the Lebanese contractors and consultants. Students and research professors in UoB laboratory will seek to investigate a variety of green concrete mixtures made using local supplementary materials and tailored to meet the challenging production, performance, and environmental constraints of the building and transportation infrastructure sectors. This project would be of great interest to the construction industry in Lebanon and neighbouring countries that are facing construction growth opportunities and rising environmental constraints associated with cement production.

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STUDY OF THE COMPOSITION OF SHALE OIL COMPONENTS IN THE SOLID HEAT CARRIER PROCESS

In recent years, the issue of refusing to use kukersit oil shale has been increasingly raised. Burning or processing oil shale to produce boiler and marine fuels is probably not the best way to use oil shale today. Shale processing enterprises need to improve the quality of liquid fuels to be used as automobile fuels, as well as to find the possibility of developing shale chemistry. The refining of shale oil can help improve the quality of shale fuels by lowering sulfur content, stabilizing fuel and improving its consumer properties, thereby increasing added value. The refining process occurs at high hydrogen pressure on the hydrogenation catalysts. The selection of catalysts and the life of the catalysts directly depends on the composition of the hydrogenated feed. The development of shale chemistry is based on knowledge of the chemical composition of

shale resin. The main problem of studying the composition of even narrow fractions of resins is a large number of components with their low relative content. However, in spite of all the difficulties, about 400 individual chemical compounds were previously identified, which accounted for 70-80% of the light-middle shale resin of kukersite. The high-boiling part of the shale oil remains virtually unexplored [1].

The main problems of the qualified use of shale oil: high content of oxygen compounds; high content of unsaturated compounds; easy oxidability; thermal instability (tendency to polymerization) [2]. It is highly necessary to explore the exact composition of shale oil, to develop methods for its cleaning in order to solve these complex problems. Group composition most fully shows the properties of shale oil. However, it is not always possible to determine it correctly, since the main methods for determining the composition of liquid fuels have been developed for fuels derived from petroleum.

The purpose of this work was to study the component and group composition of a wide fraction of shale oil from an installation with a solid heat carrier. The study was conducted in the research and testing laboratory of fuels technology at the Virumaa College of TUT. The research work consisted of several stages. At the first stage of the work, an analysis of the literature was conducted to study the already existing methods for determining the group composition of shale oil.

The second stage of the work was experimental in nature and was conducted in the laboratory:

- the physicochemical properties of the original shale oil and the oil obtained after dephenolation were determined;
- was chosen the method of separation of the shale oil according to the group composition by using adsorption column chromatography;
- a filler (adsorbent) and solvents were selected for the chosen separation method;
- was studied the effect of the column length/diameter ratio and the amount of adsorbent on the separation of the shale oil;
- fractions of the main groups of compounds were obtained: aliphatic and aromatic hydrocarbons and oxygen compounds;
- the obtained fractions were analyzed by the GC / MS method to determine the individual component composition.

The data obtained were analyzed, the identified components were grouped by type of compounds and the number of carbon atoms. The results of the research are presented in this work in the form of summary tables, chromatograms, and graphs of group composition. The data on individual components and their content in shale oil, obtained in experiments, are given in the appendices.

The hydrocarbon part of the shale oil is characterized by a high content of unsaturated compounds, and oxygen-containing compounds are represented mainly by ketones and phenols, which causes thermal instability. Therefore, the accepted methods of fractionation by distillation are not very suitable. The results of the experiments show that the column chromatography method used (cold fractionation) gave good results. It was possible to concentrate the compounds in groups, the separation was accurate, which allowed a qualitative and quantitative assessment of the content of components in each of the selected fractions using the GC/MS method more reliably [3].

Shale oil is a multicomponent mixture. Each of the compounds in its composition contributes to the performance of this fuel. Annually tougher requirements for the quality of motor fuel. To clean it, inevitably to consider and study new methods, and for this need to know a more accurate component composition of the shale oil. Also, a detailed study of the component composition is important when exploring the possibilities of using shale oil, not only as fuel but also as a source of valuable chemical products.

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LIGNIN-BASED RESINS: RENEWABLE MATERIALS FOR 3D PRINTING

Photopolymerization is an established process which is used in various application fields, such as electronics, optics, biomedical engineering or dental materials. 3D printing based on photopolymers, also known as lithography-based additive manufacturing technologies (L-AMTs), is a powerful tool to create complex parts. [1] Commercially available photopolymer resins are primarily based on petrochemical products with a very low sustainability. A promising candidate for the development of renewable photopolymers is lignin. It's the second most abundant natural polymer and is present in wood and plants. Natural resources of lignin are estimated at 300 billion tons. In pulp and paper industry 50 million tons of lignin are produced annually. Modification and application of lignin was studied by several groups in the past. [2] However, a major part of this low-value product is used for energetic purposes, although lignin has the potential for application as upcycling product in various field.

In this work, wheat straw soda lignin was modified in a two-step procedure to obtain photo-curable polymers for L-AMTs. First, lignin was liquefied through an oxyalkylation reaction with propylene oxide under alkaline conditions in a solvent free procedure. The propoxylated lignin was further modified with different reactive compounds, e.g. methacrylates or vinyl esters [3], to convert the lignopolyol into a photopolymerizable macromonomer. Characterization of modified lignin products was performed via qualitative and quantitative methods.

Oxyalkylation of lignin improves the solubility, decreases the viscosity, increases the reactivity and homogenizes the different functional groups of the polymer, resulting in better processability for 3D printing. Due to their radical inhibition capacity, the transformation of phenolic hydroxyl (OH) groups is of particular importance. With viscosities below 20 Pa·s, the synthesized propoxylated lignin samples fulfilled the requirements for 3D printing trials. Functional OH groups of lignopolyols are converted into reactive double bonds via transesterification reaction. Modification with methacrylate compounds was studied intensively, because methacrylates are the most important building blocks for production of reactive monomers, oligomers and polymers. Methacrylated lignin-based samples were obtained in good yields and the viscosity was decreased even further.

Real time-NIR photorheology experiments were performed to evaluate the efficiency of modified lignin in radical photopolymerization. [4] The successful one-layer photopolymerization of methacrylated lignin was the starting point for 3D printing trials. Several modified lignin samples had to be unified, to generate the large amount of needed material.

Introducing new materials in 3D printing requires extensive tests to adjust all necessary parameters. However, finally it was possible to print different methacrylated lignin specimens with a commercial stereolithography printer. To achieve a bio-based, sustainable material, the formulation just contained the lignin resin and a photoinitiator. As known from previous work it is also possible to use methacrylated lignin as an additive for commercially available photopolymer resins. [5]

Wheat straw soda lignin was used for the development of a photopolymerizable macromonomer. Advanced characterization with several methods was performed to evaluate the efficiency in photopolymerization. To the best of the authors knowledge, it was possible for the very first time to print a methacrylate lignin-based resin as a pure component by stereolithography. This motivating proof of concept shows the huge potential of bio-based precursors as an alternative to non-renewable derivatives for 3D printing. It is also a promising starting point for further modification of wheat straw soda lignin with less toxic vinyl ester compounds.

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INVESTIGATION OF MATERIAL PROPERTIES USING DATA-DRIVEN APPROACH

Materials engineering has always been the state of the art in designing, modelling and manufacturing efficient machines. The smart societies today rely hugely on this field for its innovative approach in rendering material properties according to the consumer's needs. With the digitization taking its contour over every sphere of life, there is a huge demand for its application into the materials domain. Although the invocation of informatics has kick-started to engineer the material properties, yet there is extensive need for data mining in the investigation of material properties.

Application of Neural Networks, Machine Learning, Data Mining approaches in the field of material mechanics have enabled, accelerated and simplified the process of discovering and developing material characteristics. Numerous deep – learning methods have already been employed successfully in the field of continuum mechanics, pertaining to tasks that are descriptive, predictive, etc.,

My current work is based on describing the yield potential of material based on its stress state, strain history, etc, using Neural Networks (NN). With the induction of genetic algorithms and data acquired through experiments, a prediction on the material capabilities i.e., strength, liability to fracture and evolution of stress states can be made with ease.

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PLASTIC PROPERTIES OF POLYMER-BITUMINOUS BINDERS BASED ON PETROCHEMICAL POLYMERS

In the modern world, roads are the main component of the country's infrastructure, and the load on them is increasing every day. However, about 50% of Federal roads have unsatisfactory road surface strength [1], due to the fact that the road surface can not perform its functions in full, in conditions of cracks, holes and ruts. In order to improve the quality of the roadbed, complex solutions are being taken, one of which is the development of polymer-bituminous binder (PBB). It makes it possible to form a strong, stable structure of asphalt concrete, which allows you to resist unsatisfactory weather conditions, as well as improve the plastic properties, which provides greater resistance to loads.

Main goal of work was investigate the plastic properties of polymer-bituminous binders (PBB) based on styrene-butadiene-styrene polymers of linear and branched structure. As initial bitumens two brands of oil road bitumen were selected: BND 70/100 produced by JSC Gazprom-Moscow oil refinery and BND 90/130 produced by LLC LUKOIL-Nizhegorodnefteorgsintez. Well known, that the mechanism of action of polymers consists in the fact that upon contact with bitumen, elastomeric blocks of polybutadienes swell, absorbing a significant proportion of aromatic hydrocarbons. At the same time, polystyrene blocks that are less compatible with bitumen are separated, forming a spatial grid with cross-links [2].

The influence of different polymer concentrations (1-4%) on the main properties of PBB was studied. These include the softening temperature, which increases with increasing content of polymers of each type in the environment of the initial bitumen, which is related to increase system rigidity due to the formation of spatial polymer grid [3]. In turn, the penetration at 0˚C and 25ºC decreases with increasing polymer content. The reduction occurs with the transfer of the original bitumen to a more consistent brand, which is due to the high oil content in the original bitumen, which contributes to better polymer dissolution and formation of PBB structure.

The use of polymers for the preparation of PBB transfers bitumen to the property of elasticity, which characterizes the ability of the binder to reversible, elastic deformations. According to experimental data, we can conclude that addition to bitumen 4 wt. % of linear or branched polymers, elasticity increases by 80% and 60% relative to the initial bitumen properties at 25 ° C and 0 ° C, respectively..

The difference in the structure of a styrene-butadiene-styrene polymer does not significantly affect the mechanism of its interaction with the initial bitumen. In the course of research, PBB compositions with similar properties were obtained.

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IMPLEMENTATION OF POLY(ALKYL ACRYLATE)S AS AN ANTISTATIC AGENT FOR ULTRA-LOW SULFUR FUELS

Currently, synthetic liquid fuels produced by GTL technology have been utilized as a fuel for internal combustion engines throughout the World. In near future the fuels are being manufactured in the Republic of Uzbekistan as well [1]. They are considered one of the most propitious clean alternative fuel for the diesel engines. The incentive to use the fuels is their less negative effect to the environment. Using the GTL fuels as alternatives to the diesel resulted in a significant decrease in engine CO, NO_x, and SO_2 emissions [2]. However, as sulfur levels in diesel are reduced, the risk of static charging during pumping has increased significantly. Ultra-low sulfur diesel (50 mg/kg sulfur, and lower) with a low aromatic content has poor lubricity and electrical conductivity. Highly refined petroleum products, like jet fuels and ultra-low sulfur diesel fuels, have very low electrical conductivity since the conducing ionic species are removed during the intensive refining processes [3].

Under turbulent flow the generated static electricity cannot be dissipated by fuels having low electrical conductivity. When a fuel of low electrical conductivity flows through a pipe, a separation of electrical charges can occur and the static charge is built up in the liquid. This charge separation can lead to high voltages with the possibility of spark discharges that can ignite the fuel vapor. The charge generation is increased by high pumping rates or by the fuel vapor and also by contact with the equipment having a high surface area, such as water separators and fuel filters. The filter separators and splash loading can also increase the charge considerably. Several reports of road tanker explosions in Europe followed the introduction of ultra-low sulfur diesel (ULSD), despite the use of grounding leads. Truck explosions in Europe were also reported in several publications around the same time. The cause was traced to a static charge induced spark ignition of the fuel vapor during the fuel transfer operations. It is therefore necessary to treat such diesel fuel with an additive to restore electrical conductivity. This is especially important for aviation fuel. The minimum and maximum fuel conductivity requirements for brand jet kerosene fuels such as Def Stan 91–91 and JP-8 are 50 – 450 pS/m [4].

In this work terpolymers of acrylic monomers, which were synthesized with different loading modes but with the quantitatively same chemical content (decyl acrylate: butyl acrylate:methyl acrylate with ratio 3:1:1 respectively) have been evaluated as a static dissipator additive for GTL diesel to eliminate the risks mentioned above. Moreover, their low temperature and lubricity properties in GTL diesel have been also given.

Table 1 - Low temperature, lubricating and electrical conductivity values of GTL (synthetic) diesel dosed with terpolymers

No	**Denomination**	**C, %**	**Wear trace diameter, (mm)**	**Wear resistance increment %**	**Electrical conductivity, pSm/m**	**t_c**	**t_s**
1	GTL diesel	0	0.59	-	3	-6	-15
2	PDBMA1 in GTL diesel	0.1	0.55	7	212	-7	-15
3	PDBMA in GTL diesel	0.1	0.55	7	187	-6	-17
4	Keroflux6100 in GTL diesel	0.1	0.55	7	-	-7	-26
5	Keroflux6100+PDBMA 1 in GTL diesel	0.1+ 0.1	-	-	-	-7	-30

6	Keroflux 6100 + PDBMA in GTL diesel	0.1+ 0.1	-	-	-	-5	-28

Seeing the results one can conclude, the enhancement of wear resistance was negligible, however, electrical conductivity increased considerably. Terpolymer PDBMA1 with more finely dispersed short chain radical content and low molecular weight than the one PDBMA resulted in more conductivity.

They have almost no effect to decrease the pour point of the diesel, don't mentioning the negligible 2 ^{o}C decrease when PDMBA used in GTL diesel. However, when they are exploited with brand additive Keroflux 6100, they show synergetic effect. As the synthesized polymers are amorphic, they cannot co-crystallize themselves with the paraffins of liquid hydrocarbons and eventually stop the augmentation of paraffins' volume at low temperatures. But when they are used with other depressors they postpone the increment of paraffin crystals with their polarity, decreasing intermolecular forces of paraffins at low temperature, helping to function the depressor, i.e. when the polar acrylate polymer and depressor come together to stop crystal augmentation they work more effectively.

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CALCIUM PHOSPHATES BY DIRECT ACIDULATION OF PHOSPHATE ROCK

In Uzbekistan, the phosphorites of the Central Kyzylkum are the main phosphate raw material for obtaining phosphorus-containing fertilizers. It is a phosphorus-poor raw material, which also contains a large amount of undesirable impurities, in particular, carbonates and chlorine [1]. Such raw materials are not suitable for direct production of highly concentrated phosphorus-containing fertilizers, i.e. it must first be enriched. Therefore, a multi-stage enrichment was carried out at the Kyzylkum Phosphorite Plant (KFP): crushing, dry enrichment to obtain ordinary phosphorite flour, washing away from chlorine, roasting to remove CO_2 [2].

At present, KFP produces three types of phosphate raw materials: washed burned concentrate (P_2O_5 – 27-29%, Cl<0.04%) in the volume of 400 thousand tons per year; washed dried concentrate (P_2O_5 – 18-19%) in the amount of 200 thousand tons per year; ordinary phosphorite flour (P_2O_5 – 16-18%) in the amount of 200 thousand tons per year.

It should be noted that when enriching the phosphorites of the Central Kyzylkum, carried out at the KFP, a large amount of waste is produced (off-balance ore). As a result, the sorting of phosphorite ore with a P_2O_5 content of less than 12-15%, performed directly in the process of extraction, a large amount of it is stored as a waste, unsuitable for fertilizer production. To date, the volume of this waste is more than 6 million tons, and the number of such unused substandard phosphorites is growing from year to year. These wastes are stored up to future times, i.e. until the time when an acceptable technology for their processing is found.

In this regard, we considered it legitimate to conduct studies on the decomposition of off-

balance ores of Kyzylkum phosphorites with an incomplete rate of hydrochloric acid. We know that in recent years, the equivalence in efficiency of partially decomposed phosphates and standard traditional fertilizers, ammophos and simple superphosphate, has been proved in agricultural practice both in Russia and abroad [3].

To carry out laboratory experiments, we took the phosphate raw material of Tashkura from Jeroy-Sardara deposit, having the following composition, mass%: P_2O_5 – 12.98; CaO – 39.95; Al_2O_3 – 1.17; Fe_2O_3 – 1.37; MgO – 0.53; F – 1.85; CO_2 – 12,01 and 32% hydrochloric acid. The norm of hydrochloric acid was varied in the range 10-50% of the stoichiometry for CaO [4].

The decomposition of phosphorite with hydrochloric acid was carried out on a laboratory unit consisting of a tubular glass reactor equipped with a stirrer with an electric drive and placed in an aqueous thermostat. The speed of rotation of the stirrer was regulated by a rheostatic device and measured with a TM-3M tachometer using a D-1MM sensor. The temperature in the thermostat was maintained using a TK-300I thermometer and an RT-230U electronic relay. In all experiments it was constant and equal to 400 °C.

After cessation of the reaction, a certain amount of water was added to the resulting dough-like mass in order to obtain a normally flowing pulp. Preliminary experiments have shown that decomposition products having a pH of less than 3.5 due to high acidity are poorly dried. Therefore, the resulting acidic pulps were ammoniated with gaseous ammonia to pH values of 3.42-4.10. Ammonized pulps have good rheological properties, which allow their drying and granulation in such active industrial units as a drum granulator-dryer. Then the ammoniated pulps were dried at a temperature of 95-100 °C, and the resulting fertilizers were analyzed for the content of the main components by standard methods.

Analysis of the square diagram of the CaO – P_2O_5 – HCl – H_2O [$(Ca_3(PO_4)_2$ – $CaCl_2$ – 6HCl –$H_6(PO_4)_2$ – H_2O)] system shows that when the phosphate raw material is decomposed with the calcium modulus equal to 3.08 32% an acid taken in an amount of 10 and 50% of the stoichiometric norm, the figurative point of the system is outside the square of the system. The liquid phase of the system consists of a solution of $CaCl_2$, and a solid phase of tricalcium phosphate under-decomposed phosphorite. The hydrochloric acid formed during decomposition of the mineralized mass has a pH range of 3.5-5.5.

The results of determining the composition of fertilizers are given in the table. From the data it can be seen that the content of the assimilated form of P_2O_5 significantly depends on the norm of hydrochloric acid. An increase in the rate of hydrochloric acid from 10 to 50% leads to an increase in $P_2O_{5\ assim.}$ in citric acid and EDTA from 2.4 to 7.26% and from 2.01 to 4.20%, respectively. At the same time, the degree of decarbonization of the initial phosphorite is from 25.12 to 82.23%. The content of total phosphorus and calcium in the fertilizers obtained, depending on the experimental conditions, is 11.29 - 12.55% and 34.8 - 38.24%, respectively.

The dependence of the change in the assimilable forms of P_2O_5 on EDTA and the 2% solution of citric acid shows a changes in the relative content of assimilable forms of phosphorus from the initial rate of hydrochloric acid. An increase in the rate of hydrochloric acid in CaO from stoichiometry from 10 to 50% contributes to an increase in the relative content of the assimilated form of phosphorus in EDTA and a 2% solution of citric acid from 16.01 to 37.20 and from 19.12 to 64.30%. The relative content of assimilable calcium fluctuates within the range 54.73-76.18%.

Thus, the resulted results of laboratory researches testify that by carrying out the process of decomposition of off-balance ore of Kyzylkum phosphorites with an incomplete norm of hydrochloric acid, there is a principal possibility of obtaining phosphoric calcium fertilizers with different content of assimilable forms of phosphorus and calcium.

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IDENTIFICATION OF PHASE COMPOSITION HYDROXIDEALUMINUM RAW MATERIAL AND ITS TEMPERATURE MODIFICATIONS IN THE PRODUCTION OF Al_2O_3-CATALYSTS

To create effective catalysts for various processes of refining petroleum products (hydrogenation, cracking, hydro-desulfurization, etc.), Al_2O_3-carriers with different phase compositions (γ–, δ -, n -, χ -) and textural properties are required, which are formed depending on the Genesis of the initial aluminum hydroxide used for the preparation of the carrier and the final processing temperature of the carrier, usually within 500-800°C.

The phase compositions of pure aluminum hydroxides and the routes of their polymorphic transformations under the influence of up to 1200°C have been studied fundamentally. However, industrial types of GOA raw materials, as a rule, have a mixed phase composition, the definition of which, and, accordingly, the choice of raw materials for the production of the carrier causes difficulties. They are compounded by the fact that during the years of perestroika, not only the geography of industrial production of the usual quality of GOA raw materials has changed (some disappeared, others appeared as new, imported products appeared), but also the technology of its production, which leads to a shift in the quality of the final carrier products.

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STUDYING THE POSSIBILITY OF USING «GREEN DIESEL» FUEL MIXED WITH HYDROTREATMENT PRODUCTS OF DIESEL FRACTIONS

Every year there is a tightening of environmental requirements for diesel fuel in terms of such indicators as lubricity, sulfur content, the number of emissions of carbon oxides and dioxides, sulfur oxides and nitrogen oxides in the fuel. In this regard, there is a need to develop a product that meets these requirements and is not inferior in other indicators, such as low-temperature properties, namely, cold filter plugging point and pour point.

As a raw material for the production of "Green diesel" fuel, a crop from the cabbage family, namely, Camelina, was used. Multicomponent mixtures of environmentally friendly diesel fuel were obtained, including "Green diesel" fuel, hydrotreated diesel fuel and a bio-additive. The additive was obtained by transesterification of Camelina oil with diatomic alcohol [1].

This work is aimed at improving such indicators as pour point, cold filter plugging point, fuel lubricity, and others.

A decrease in the sulfur content as a result of the Hydrotreating process leads to a significant deterioration in the lubricating properties of the fuel. Since heteroatomic compounds in the fuel play the role of a natural additive, that prevents wear of engine parts.

The action of anti-wear additives consists in the formation of a modified metal layer that provides uniform load distribution and reduces wear, as a result of the chemical interaction of the surfactant of the additive with metal oxides on the rubbing surfaces [2].

The increased pour point of diesel fuels can be caused by the presence of paraffins in their composition, they are the first to form crystals at low temperatures. To prevent their formation and further growth, depressant-dispersing additives are introduced into the fuel.

This type of additive is a composition. It includes components that perform various functions. The depressor component leads to a decrease in the cold filter plugging point and the pour point of diesel fuel. The dispersing component prevents agglomeration of paraffins that crystallize in the fuel at negative temperatures into large aggregates and thus ensures the stability of the fuel at low temperatures [3].

During the work, nine types of mixtures of environmentally friendly diesel fuel were compiled. The composition includes diesel fuel from the Hydrotreating plant (the content in the mixture is from 40 to 95 %)," Green diesel" (the content is from 50 to 70%), as well as a bio-additive obtained by transesterification of oils, the percentage of which varies from 5 to 20 % [2].

After receiving the mixtures was carried out the improvement of indicators such as pour point, cold filter plugging point, lubricity, and others. The corresponding experiments were carried out, as a result of which the pour point fell to -30 °C, and the maximum filterability temperature to -20 °C.

The essence of the method for determining the pour point consists in a sequence of the following actions: preheating the sample, then lowering the temperature to the one at which the sample passes into a stationary state. This method was performed in accordance with GOST 20287-91.

Special attention is paid to the low-temperature properties of environmentally friendly diesel fuels. Because various climatic conditions occur on the territory of Russia, in some of them the ambient temperature can reach up to -50 °C.

The results of this work identified that the introduction of 10 % Supplement to environmental mixtures of diesel fuel lubricity characteristics - corrected wear scar diameter decreases to 233 μm (the value according to GOST 52368 not more than 460 microns). In addition, when mixing the "Green diesel" fuel with hydrotreated diesel fuel, the pour point decreases compared to the pure component.

“Development of scientific foundations of innovative technologies for processing heavy hydrocarbon raw materials into environmentally friendly motor fuels and new carbon materials with controlled macro- and microstructural organization of mesophase”.

Study was conducted with involvement of laboratory base of Center for collective use of Saint Petersburg Mining University.

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PUT INTO INDUSTRIAL PRODUCTION DIFFICULTIES OF NOVEL EFFECTIVE HYDRODESULFURIZATION-CATALYSTS IN RUSSIAN FEDERATION

Currently the extensive researches were executed in order to optimize supports properties, active phase chemical and weight composition and main technological parameters of initial components conversion into active six-sided MoS_2 groups, which are decorated by CoS_2 molecules, involving sulfurization stages of catalyst oxide forms [1].

For effective the catalytic process flow, it is desirable to develop the number of active centers, dispersion of active phases, and transport access of organic molecules to them. The implementation of the last two conditions is achieved by using a support that allows reducing the content of active components to an optimal minimum due to the thin-layer distribution of Mo (W) - Ni(Co) metals and the necessary porous structure formation that would completely eliminate or minimize diffusion inhibition during reagents transferring to the active centers of the catalyst [2].

The complexity of choosing aluminum hydroxide as a raw material for multi-tonnage production of the support, in addition to the demand to obtain the specified high structural characteristics, depends on its binding properties and formability. To increase the geometric contact surface of liquid hydrocarbons with the catalyst surface, different forms of single granules were produced as follows: spheres, cylinders, rings, extrudates of complex shape with low bulk density [2,3].

On the Department of Chemical Technology and Processing of Utilities of the St. Petersburg Mining University, an optimal formulation of the support is developing, with a complicated profile form extrudates (three-or four-lobe, diameter equals 1.59 mm). In this case, there is an effect of catalyst the geometric surface area increasing the with a minimum strength properties loss.

A preliminary analysis of the feedstock phase composition made allows to optimize the finely fraction support forming technology. This provides effectively select a peptizing agent, depending on the aluminum hydroxide genesis.

It was also revealed that the use of similar origin co-former (similar technology for producing aluminum hydroxide) positively affects both the formability and strength properties of the final porous anhydrous Al_2O_3 structure. The addition of pore-forming additives based on ammonium salts and amides during the support preparation stage modified the pore distribution: from the monodisperse to the bidispersed. Along with that, the increasing of calcination temperature limits of the support granules towards the θ-Al_2O_3 phase formation allows increasing thermal stability and also changes structure.

Further research in this area will be focused on investigating of active components implementation methods: during support preparation stage and final granules impregnation. It is also desirable to carry out deeper research regarding heat treatment conditions modification of aluminum hydroxide into anhydrous porous systems and determine their potential competitiveness and the ability to act as supports of new hydrotreatment catalysts with improved textural and acid-base properties.

ACKNOWLEDGMENTS

This work was carried out as part of the State Assignment “Development of scientific foundations of innovative technologies for processing heavy hydrocarbon raw materials into environmentally friendly motor fuels and new carbon materials with controlled macro- and

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COORDINATION OF HYDROCYCLONE PARAMETERS WITH FORCED FLOW ROTATION

Parameters and results of technological processes of petroleum refining and petrochemistry are determined by the quality of raw materials, which is received for processing, which in turn depends directly on the efficiency of the methods used for its preparation and purification. The current stage of development of chemistry and technology of hydrocarbons is characterized by a progressive deterioration of the properties and quality of petroleum due to the increase in water content, corrosive aggressiveness, sulfur content, salts, etc. Therefore, reducing the impact of these negative factors on the separation and transformation of hydrocarbons is one of the priority areas of science and technology.

Formation water coming from wells of different fields can differ significantly in the composition and concentration of the mineral salts dissolved in them and the gas content. When extracted with formation water, an emulsion is formed, which should be considered as a mechanical mixture of two insoluble liquids (oil and water), one of which is distributed in the volume of the other in the form of droplets of different sizes. The presence of water in oil leads to a rise in the price of transport due to the increasing volumes of transported fluid and an increase in its viscosity. Based on experience, the water content of oil should not exceed 10-50 ‰. With a higher content of water in the oil entering the processing, the technological mode of operation is broken, the pressure in the apparatus is increased, the micro-explosions begin, the productivity of the distillation column and the heat exchangers is reduced, as well as the additional amount of heat is expended for heating the oil[1].

To calculate the velocity of motion of particles in the field of centrifugal forces use the same positions as in the process of deposition under the action of gravity, replacing the gravity by centrifugal force or their ratio.

The dependencies obtained are valid for the deposition of a single particle and for dispersed systems with a low concentration of suspended particles, that is, when the deposition of particles does not cause their interaction: collisions, motions of one particle after another. At high concentration of the deposited particles, it is necessary to take into account their mutual influence. The deposition of particles in an environment with high concentration of them is characterized by phenomena that contribute to increasing or slowing the deposition rate. For example, particle collisions may be accompanied by their agglomeration, which increases the rate of deposition; the movement of one particle after another also increases the deposition rate;

the collision of the settling particles causes the action of additional friction forces, which slow down the deposition. To account for the phenomena described, it is necessary to consider the change in the properties of the medium in the direction of motion of the particle.

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INFLUENCE OF LEACHING PARAMETERS ON THE VANADIUM EXTRACTION PROCESS FROM PETROLEUM COKE

In connection with the depletion of light oil reserves, the question arose of the processing of heavy metal oils. However, the metals are contained in oils adversely affect the quality of the obtained products, deactivate catalysts for oil refining processes and cause corrosion of equipment. At the same time, trace elements are contained in oils are valuable incidental components, of which vanadium is an important strategic metal, due to it use as an alloying additive to high-strength steel, a cathode for lithium-ion batteries, catalysts, etc. About 95% of all vanadium is concentrated in petroleum coke during coking process [1], so it a promising raw material for the recovery of vanadium. Spent catalysts and ash from boilers of thermoelectric power plants using fuel oil and petroleum coke can also serve as raw materials for vanadium recovery. A large number of studies about vanadium extraction are carried out using ash from the thermal power plants as the feedstock [2] and few research is devoted the study of coke as a raw material for the recovery of vanadium [3].

Therefore, in this work, we studied the efficiency of extracting vanadium from petroleum coke by the leaching method and the effect of parameters of process on the efficiency vanadium recovery such as the ratio of liquid and solid phases, the duration of the process and the leaching agent.

The experiments on leaching vanadium from petroleum coke were carried out in stainless steel reactors with a height of 60 mm and a diameter of 40×30 mm. 1 g of petroleum coke (particle size of about 0.1 mm) and the necessary amount (1:2, 1:3, 1:4) of leaching agent (NaOH 12 % or H_2SO_4 10 %) were placed in each reactor. Then the reactors were placed in a drying oven and kept at the temperature of 100 ℃ from 0.5 to 2,5 hours.

A photometric analysis of the solutions after leaching was performed to determine the degree of vanadium recovery. 40 ml of the solution after leaching, 2 ml of diluted sulfuric acid 1:1, 5 ml of diluted phosphoric acid and 2.5 ml of sodium tungstate solution were placed in a 100 ml beaker. After adding each reagent, the contents of the beaker were mixed by shaking. The resulting solution was heated to 40–70 ℃ and cooled to room temperature. Then the solution was quantitatively transferred into a 50 ml volumetric flask and adjusted to the mark with distilled water. The solution was left for 60 minutes [4].

The composition and structure of the solid residue after leaching was studied by X-ray fluorescence and X-ray diffraction analysis, thermogravimetry and differential scanning calorimetry.

It was shown that the recovery of vanadium is higher when using sulfuric acid as the leaching agent, however, the sulfur content in the solid residue after leaching for these samples

increases. The content of aluminum and calcium is higher in samples obtained using sodium hydroxide, so alkali has a higher selectivity for vanadium extraction compared to acid. The recovery of vanadium increases with increasing ratio of solid and liquid phases and the duration of the process. The highest yield of 80% is observed during the process in the presence of sulfuric acid for 1.5 hours with a phase ratio of 1:4. It was also shown that the crystals of the coke have a turbostract oblate structure, because of the thermobaric conditions for the formation of petroleum coke.

ACKNOWLEDGMENTS

This work was carried out as part of the State Assignment “Development of scientific foundations of innovative technologies for processing heavy hydrocarbon raw materials into environmentally friendly motor fuels and new carbon materials with controlled macro- and microstructural organization of mesophase”. Study was conducted with involvement of laboratory base of Center for collective use of Saint Petersburg Mining University.

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SIZE AND INNER-DIAMETER CONTROL FOR EXPLORATION IN BIOLOGIC EFFECTS OF HALLOYSITE NANOTUBES

Natural halloysite nanotubes (HNTs) are ideal carriers for drugs and bioactive molecules due to its nano-scale lumens, high length-to-diameter ratio, abundant surface hydroxyl groups and good biocompatibility [1]. Here, the work explores the size and inner diameter regulation and related biological effects by outside nano-processing and inner structure modification, aiming to build an efficient nano-carrier material.

The effect of the drug was largely determined by the cellular uptake efficiency. By studying the interfacial effect between halloysite with different sizes and colon cancer cells, the size-dependent mechanism was explored. The results showed that the process of the uptake of halloysite was first endocytosis and exocytosis, and then the balance was reached. In particular, for the small size of the halloysite tubes, the intake and uptake efficiency were faster. Halloysite nanotube with 650 nm and 250 nm length did not exhibit cytotoxicity to colon cancer cells due to the smallest size halloysite nanotubes engulfed by colon cancer cells and accumulated mostly in lysosomes while that of larger size are extremely block to outside. While halloysite nanotube with 400 nm length shows very low cytotoxic to colon cancer cells due to the cancer cells skewed, lead to inflammation, DNA damage and cell death [2-4]. It is speculated that halloysite (~250 nm), due to the increased on the exposed end surface of positive charge, with a relatively large potential value is more prone to electrostatic adsorption on the negatively charged cell membrane, which tends to accumulate near the cell membrane and promote internalization.

Besides the work mentioned-above, expanding the loading space of halloysite might be of great significance. The inner-diameter and specific surface area of halloysite by acid etching were significant increased. The loading and release effects of halloysite with different inner lumen diameters were investigated by loading of insoluble antitumor drug molecules paclitaxel (PTX). The results showed that the load capacity and drug release efficiency were greatly improved. With the increase of the inner diameter, the drug sustained release effect was more significant, the improved performance was attributed to the blocking effect of nanotube structure since the diffusion of paclitaxel drug molecules in the lumen was slower. The cell uptake of halloysite increased with the increase of surface charge. The cytotoxic effect of halloysite with different inner lumen diameters on HT-29 cells was also verified.

Based on the control of tubular structure, the groups, surface charges and pore structure characteristics in regards to the changed sizes and inner diameter of halloysite on HT-29 in colon cancer cells were further discussed to evaluate the effects on the inhibition and uptake efficiency with the help of toxicity test (MTT), fluorescence confocal microscopy (CLSM) and flow cytometry (FCM). It aims at solving the problems of low uptake efficiency and poor drug effects caused by different sizes and limited load activity of natural clay materials, thus providing the experimental evidence and rational design to enhance the efficacy for cancer therapy.

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NOVEL DOPED PEROVSKITES CATALYSTS FOR METHANE DRY REFORMING – ENHANCING CATALYTIC ACTIVITY BY TAILORED EXSOLUTION OF NANOPARTICLES

Perovskite-type oxides are a large class of materials with many interesting properties, including mixed ionic-electronic conductivity and high catalytic activity. Their general chemical formula is ABO_3, where both cation sites A and B can be occupied by one or more elements. The high versatility of the material class is due to the possibility of adjusting the properties by choosing different elements for the cations and by doping either of the cation sites, thus opening up a large matrix for materials design. In terms of catalysis, a recently shown outstanding property of perovskites is the exsolution of metal nanoparticles under reducing conditions [1].

This surface modification (by migration of cations to the surface) can change the catalytic activity and selectivity of the perovskite surface completely and is the core topic of our ERC project. Advantages over other preparation techniques for nanoparticle decorated surfaces (e.g. deposition or impregnation) include a very homogeneous distribution [1], an improved sintering stability during catalytic reaction [2] and the possibility of easy catalyst regeneration by oxidation- reduction-cycles [3]. One possible reaction, for which perovskite catalysts are an interesting alternative, is methane dry reforming. This reaction takes the two greenhouse gases methane and carbon dioxide and transforms them into useful synthesis gas. Thus, it is very interesting for the processing of natural gas.

Several perovskite-type oxides (e.g. $La_xCa_{1-x}FeO_3$ or $Nd_xCa_{1-x}FeO_3$), that are promising catalyst materials, were synthesised and subsequently characterised. In addition, in some of the samples the B-site was doped with different catalytically active elements, e.g. Co or Ni. The techniques for characterisation included X-ray diffraction (XRD), X-ray photoelectron spectroscopy (XPS), scanning electron microscopy (SEM), transmission electron microscopy (TEM) and energy-dispersive X-ray spectroscopy (EDX). Using different reducing conditions, the stability and reducibility of the synthesized perovskites were investigated. Also, catalytic testing

was performed for methane dry reforming. To correlate the material properties with the catalytic performance, *in situ* and *operando* XRD and XPS experiments were conducted.

Tailored exsolution of metal nanoparticles from a stable perovskite backbone was achieved upon reduction of the materials. This was visible in the diffraction patterns, XPS spectra and SEM images after reduction. The exsolution behavior (e.g. size and composition of the resulting particles) can be controlled by the design of the materials and the exsolution conditions. Doping with Co or Ni facilitates the exsolution process. In this case, the resulting nanoparticles have diameters of 30-40 nm and are homogeneously distributed on the material surface. They consist predominantly of the catalytically active elements Co or Ni, respectively. The catalytic testing showed that exsolution strongly enhances the catalytic activity of the materials for methane dry reforming. The nanoparticles can be either exsolved during a pretreatment step or even *in situ* during the reaction and promoted by electrical polarisation (shown with *operando* techniques).

The study showed that the novel perovskites are very promising catalyst material for methane dry reforming due to their structural stability even at high temperatures and their ability to exsolve metal nanoparticles, which enhance catalytic activity. These particles are relatively resistant towards sintering and coking and allow for a stable operation. Especially the Ni doped material is a promising candidate for a high performance catalyst, because the exsolved Ni is catalytically highly active for dry reforming.

ACKNOWLEDGEMENTS

This project has received funding from the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme (grant agreement n° 755744 / ERC - Starting Grant TUCAS).

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CHARACTERISTICS OF SEMI-COKING PRODUCTS OF OIL SHALE AND BROWN COAL

Recently, there has been a growing global interest in processing low-grade types of solid fuels: brown coal and oil shales. In the near future, the role of solid fuels in the fuel and energy balance of the country is expected to increase, which is primarily due to their large reserves [1-3].

The semi-coking process is a type of solid fuel pyrolysis, but occurs at lower temperatures: the optimal temperature range is (450 ÷ 550) ℃. This process is mainly used to produce synthetic fuels (liquid, gaseous and solid) from low-grade coals, oil shale and peat. Apart from semi-coke, there are also resin and gas as products that are formed as a result of primary coking reactions [1-3].

The main purpose of this work is analyze the process of semi-coking of oil shale and brown coal on a laboratory installation with a closed system for the gas treatment. Comparative analysis of properties (density, ash content, yield of volatile substances, humidity, porosity), as well as thermogravimetric analysis of the obtained oil shale and brown-coal semi-cokes.

Parameters of the process of semi-coking of low-grade types of solid fuels:

- raw materials – oil shale, brown coal fraction (2 ÷ 4) mm;
- the sample mass is 20 g. (provides filling of 2/3 of the reactor);
- hold up time – 3, 5, 8 hours;
- operating temperature – (450÷470) ℃ (mode I) and (510÷520) ℃ (mode II);
- the rate of heating muffle furnace - 4,76 ℃ / min.;
- the reactor heating rate is 6,11 ℃ / min.

Table 1 shows an example of the obtained physical and chemical properties of a shale semi-coke.

Table 1 - Characteristics of the oil shale semi-coke

Raw material for the process		Characteristics					
		W, %	V, %	A, %	ρ, г/см^3	d, г/см^3	П, %
Oil shale		2,00	41,43	50,50	1,64	1,24	24,34
Mode I (450÷470) ℃	3 hours	1,15	41,50	46,30	1,71	1,39	18,50
	5 hours	0,81	38,09	54,20	1,94	1,52	21,65
	8 hours	0,78	37,05	57,56	1,98	1,53	22,91
Mode II (510÷520) ℃	3 hours	1,08	42,80	51,56	1,71	1,39	18,67
	5 hours	0,99	40,59	52,60	1,96	1,49	23,67
	8 hours	0,98	38,98	53,95	1,99	1,53	22,78

An example of the results of thermogravimetric analysis of the obtained semi-coking products is shown in Figure 1.

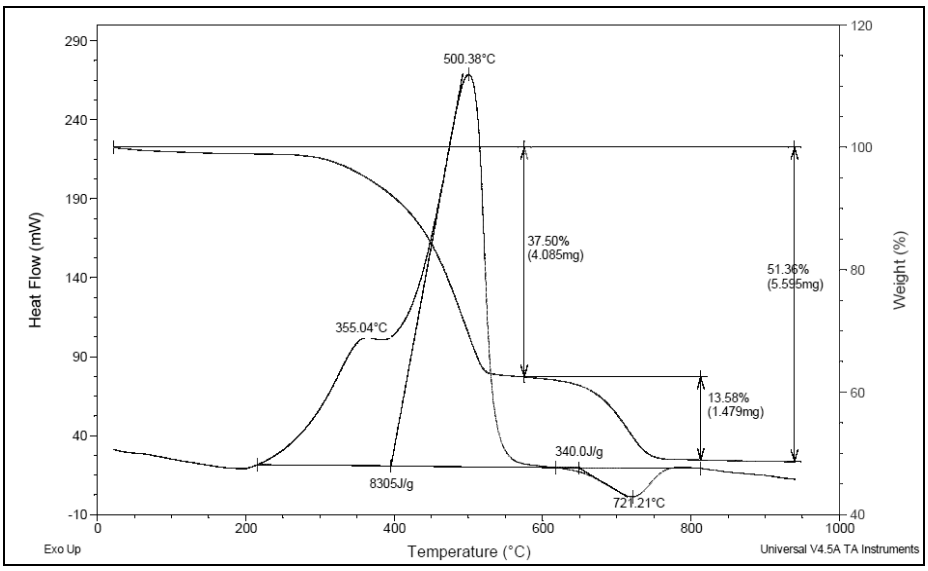

Figure 1 - Thermogravimetric analysis of shale semi-coke obtained at a temperature (450÷470)°C. Hold up time is 5 hours.

Nowadays the quality of coal used to produce coke is declining, but in the future will be possible to replace high grade coal coke with semi-coke which will be made of brown coal and oil shale for use in industries.

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HIERARCHICAL POROUS CARBON RICH IN UNIFORM MICRON-SIZED, BUBBLE-LIKE PORES CONTROLLING BY CALCINATION TEMPERATURE FOR PREPARED SUPERCAPACITOR ELECTRODE MATERIALS

Supercapacitors effectively exhibit electrochemical performance of electrode materials because of their unique characteristics, such as fast charging and discharging, high power densities, and great cycling stabilities [1]. To obtain excellent storage performance, the advanced supercapacitor electrode materials should possess several characteristics, such as, large surface area, good electrical conductivity and low production costs. It has been mentioned in our previous reports that micron-sized, bubble-like pores structure can disturb ions of electrolyte, thus increasing the probability of ions entering micropores and improving the utilization of micropores [2]. However, the three-dimensional structure with strong network connectivity is affected by many factors. In this paper, we prepared it by simple temperature control. The most

excellent morphology and structure of carbon materials were prepared by the simplest method. Finally, excellent electrochemical properties were prepared.

Hierarchical porous carbons were prepared at 1:1:5 mass ratio of loose medium component (LMC) to KH_2PO_4 and KOH at activation temperatures of 650 ℃, 750 ℃ and 850 ℃. They were named AC-650, AC-750 and AC-850, respectively. LMC was one of the products of coal extraction and anti-extraction. All the carbon materials were prepared under the protection of N_2, the heating rate of 5 ^{o}C/min was increased to the corresponding activation temperature, and the temperature was constant for 2 h.

Figure1 (a) shows the SEM diagram of AC-650. Due to insufficient activation temperature, the pore structure on the surface of carbon materials is not dense. Most of the pore structures on these surfaces are uniform micron-sized, bubble-like pore size. Some micron-sized, bubble-like pore structures have large or small pore size, which may be caused by the uneven distribution of KOH during activation. When the activation temperature is further raised to 750 ℃, the micron-sized, bubble-like pore structure on the surface of carbon materials is uniform and the pore size is more uniform, which is smaller than that of AC-650 (Figure1 (b)). Although the surface pore structure of Figure 1 (c) is rich, the pore size is not uniform and the micron-sized, bubble-like pore structure is not obvious when the activation temperature is raised to 850 ℃.

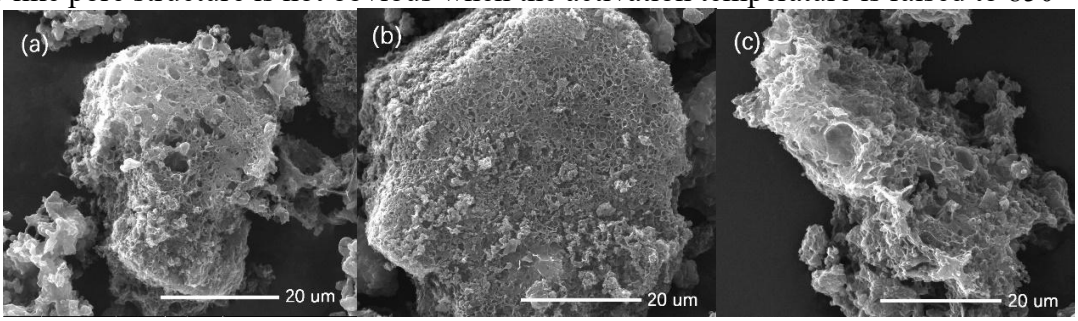

Figure 1 - The SEM images of AC-650(a), AC-750 (b), and AC-850(c)

In order to better understand the effect of activation temperature on the evolution of micron-sized, bubble-like pore structure, we have drawn Figure 2 for detailed explanation. As we have explained in previous studies, KH_2PO_4 is fused to $(KPO_3)_n$ as template, KOH as activator, and KOH follows the normal activation process. At the final activation temperature of 650 °C (Figure 2 (a)): In the first stage, LMC, KH_2PO_4 and KOH are mixed in powder form when the temperature is less than 400 °C during the heating process; in the second stage, KH_2PO_4 is melted and dehydrated $(KPO_3)_n$ when the temperature is 400 °C during the calcining process; in the third stage, at 450 °C, LMC is melted and tightly encapsulates KOH and $(KPO_3)_n$ molecules; in the fourth stage, KOH is completely decomposed into K_2CO_3 at 650 °C, and is in close contact with $(KPO_3)_n$. After the final activation, KH_2PO_4 is washed and the by-products of calcination are removed, resulting in relatively uniform micron-sized, bubble-like pore structure. However, due to the low activation temperature, the activation process of KOH is not completely realized, so the pore structure activated is less. Figure 2 (b) is the evolution process at the final activation temperature of 750 ℃: the activation process from stage 1 to stage 4 (from room temperature to 650 ℃) is completely consistent with Figure 2 (a); in stage 5, when the activation temperature reaches 750 ℃, part of K_2CO_3 is decomposed into K_2O, and then continues to be activated with C at a temperature higher than 700 ℃. After the final activation is completed, the by-products washed and calcined are removed to obtain uniform micron-sized, bubble-like pore structure. Since the size of K_2O molecule is smaller than that of K_2CO_3 molecule, the micron-sized, bubble-like pore size produced with the molecule of template $(KPO_3)_n$ is smaller than that produced with the molecule n of K_2CO_3 and template $(KPO_3)_n$, thus not only more micron-sized, bubble-like pore structures are produced, but also in a hierarchical manner. Figure 2 (c) is the evolution process at the final activation temperature of 850 ℃: the activation process from the first stage to the fifth stage (from room temperature to 750 ℃) is consistent with Figure 2 (b); in the sixth stage, when the temperature is raised to 850 ℃, K_2CO_3 is completely decomposed into

K_2O and continues to be activated with C. After activation, the by-products are washed and calcined to obtain the micron-sized, bubble-like pore structure. Due to the complete decomposition of K_2CO_3 into K_2O, more micron-sized, bubble-like pore are generated in close contact with the template $(KPO_3)_n$. The content of K_2O also increased compared with 650 ℃ and 750 ℃, and the pore structure increased to a great extent. When the pore structure increases sharply, the pore and the pore will appear the phenomenon of two into one, the pore diameter obviously increases, even causes the pore collapse the situation. Therefore, the pore size of AC-850 is obviously enlarged and the pore collapses, which leads to the inconspicuous micron-sized, bubble-like pore structure.

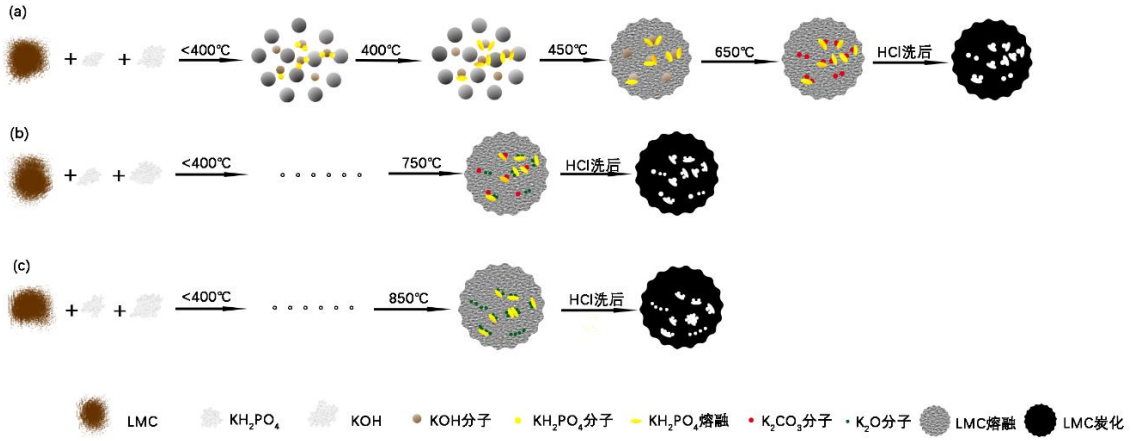

Figure2 - Effect of activation temperature (AC-650(a), AC-750 (b), and AC-850(c)) on the evolution of micron-size, bubble-like pores structure

When the activation temperature is 650 ℃, 750 ℃ and 850 ℃ respectively, the carbon material of AC-750 prepared at 750 ℃ has more micron-sized, bubble-like pore structure with relatively uniform pore size and pore distribution. The results show that the chemical properties of carbon materials with uniform micron-sized, bubble-like pore structure are much better than that of carbon materials without obvious microcellular structure. It is shown that the disturbance of micron-sized, bubble-like pore plays an important role in charge storage.

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ENERGY INDUSTRY WASTE PROCESSING METHODS

The basis of this work was chosen an article from the codex of the Republic of Kazakhstan on subsoil and subsoil use (with changes on December 30, 2019) - Technogenic mineral formations, rights to technogenic mineral formations. Technogenic mineral formations of energy production include solid waste generated as a result of fuel combustion during the production of electric and (or) thermal energy by generating units (ash and ash and slag). The main consumer of primary energy resources in Kazakhstan is the sector of electricity and heat production (about 50% of the consumed fuel). The total capacity of electricity generating sources in the Republic of Kazakhstan is more than 18 thousand MW. The basis of generating capacities is thermal power plants - about 87%, hydroelectric power plants - about 12%, others - 1%. About 38% of the total generating capacity (6.7 thousand MW) is made up of combined heat and power

plants with combined heat and power. The main technogenic waste from thermal power plants and state district power plants are ash and slag and flue gases. For the sale of fly ash and slag as raw materials, for the safe storage and use of ash and slag in the national economy, in various industries, it is necessary to have basic information on their properties and characteristics: chemical composition, physical properties, mineralogical composition, physicochemical properties, environmental characteristics, including radioactivity and toxicity. The use of ash-slag waste (ASW) of thermal power plants brings the thermal power plant technology closer to wasteless by 80%. Thus, ash is a product of fuel combustion, which is carried out by flue gases from the furnace of the boiler and is captured by ash collectors. Slag is a material that accumulates as fuel burns in slag collectors. Ash is mainly represented by a fraction of 0.01 - 0.1 mm with a maximum particle size of not more than 1-2 mm. Slag is mainly represented by fractions of 0.1 - 20 mm with a maximum particle size of 40 - 60 mm and a minimum of 0.04 mm. Ash is a finely divided mineral powder from light gray to dark gray, slag has a similar color, but differs from the ash in larger size [2].

Physical characteristics of ash and slag waste: - bulk density in the range of 700-900 kg/m^3; - specific surface within 4000-6700 cm^3/g; - the content of unburnt particles from 16 to 25%; - humidity from 2 to 15%; - coefficient of porosity of 1.03-1.44 with a porosity of 50.1-58.9%. The maximum grain size of ash and slag grains is 1.0-2.5 mm. The amount of pulverulent fractions in stocked ash and slag varies from 15 to 95% depending on the removal of the product sampling point on the crest of the ash dump dam. The granulometric composition and specific surface area of the ash disposal plant depend on the place of sampling: the minimum specific surface characterizes the samples taken at points directly adjacent to the place of discharge of the pulp from the slurry pipeline. As the sampling points move away from the discharge point, the specific surface of the material increases, reaching 6500 cm^2/g in the settling pond. Table 1 shows the averaged chemical composition (macrocomponents) of ash and slag waste obtained from the burning of coal from some deposits at Kazakhstan's TPPs.

Table 1 - The chemical composition of the ash (microcomponents)

Name of deposits and TPS	Contents%								
	SiO_3	Al_2O_3	Fe_2O_3	CaO	MgO	TiO_2	SO_3	K_2O	NaO
Semipalatinsk TPS Kuznetsk coal	55.3	17.3	3.2	3.03	1.86	1.4	0.29	1.86	0.72
Ust-Kamenogorsk TPS Kuznetsk Coal	56.9	18.8	3.2	3,59	2.12	1.44	0.37	2.6	0.3
Ekibastuz coal 1	52.3	25.7	5.26	1.53	0.4	-	1.68	0,03	0.6
Ekibastuz coal 2	57	22	2,8	1,6	0.9	-	1.72	0.3	0.2
Pavlodar TPS Ekibastuz coal	54.14	28.3	7.47	1.14	0.55	1.48	0.62	0.4	0.2
Karaganda TPS Karaganda coal	60,2	25.5	5.85	3.65	1.05	0.95		1.65	1.06

In addition to the macronutrients that make up the bulk of the waste, ash and slag waste contains trace elements such as zinc, lead, chromium, manganese, cobalt, nickel, mercury, arsenic, antimony, vanadium, strontium, thallium, germanium, boron, beryllium, fluorine, etc.

Ash from Ekibastuz coal contains up to 30% alumina [3]. Only with ash from Ekibastuz state district power plants annually about 6 million tons are dumped aluminum oxide. Consequently, the ashes of Ekibastuz coal are actually an inexhaustible source of raw materials for the production of alumina. In addition, other microelements, such as vanadium, are also contained in the ash.

The use of waste- slag waste (ASW) of thermal power plants brings the thermal power plant technology closer to wasteless by 80%.

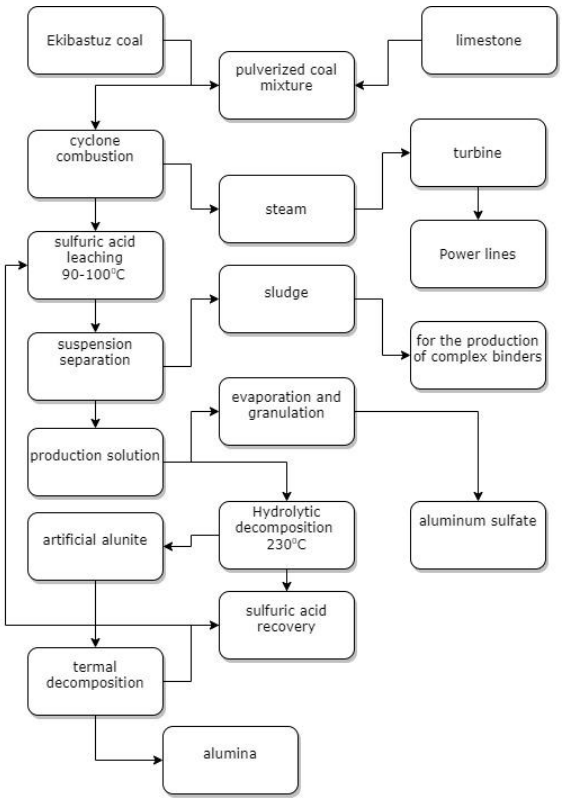

Figure 1 - Technological scheme for producing $Al_2(SO_4)_3$ from energy slags

When coal is burned in the Ekibastuz deposit, about 40-50% of silicon ash is formed. Alumina can be obtained from this ash, and cement from waste from alumina production.

Concrete based on this cement has high performance, it is gaining brand strength in just one day. Wastes from this production can be used for laying coal mines with the possibility of subsequent recycling.

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METHODS FOR OIL DEHYDRATION USING DEMULSIFIERS

This article describes the existing methods of oil dehydration and desalting, which can reduce the cost of oil transportation and processing. These methods produce a good effect of oil dehydration and desalting when used together. The article considers in depth the effect from the use of demulsifiers in the process of oil dehydration, their selection, and it substantiates the selection of the optimal ones using which an oil sample with a residual water content of 0.1% mass was obtained. It is shown that the most effective separation occurs upon preliminary

heating of the oil emulsion, because when the emulgated oil is heated, its viscosity decreases, the emulsifier film expands and collapses, and the droplets of the liquid merge with each other.

The liquid extracted from oil wells is a complex mixture consisting of oil, gas, mechanical impurities, water and salts dissolved in it. The main stage of field oil treatment before transportation is its dehydration.

Water and the salts dissolved in it form a stable emulsion, which is dispersed in the oil medium in the form of tiny drops.

There are several main ways of oil dehydration and desalting:

- mechanical (or the process of gravitational settling);
- electric;
- in the ultrasonic field;
- use of special devices;
- with the use of demulsifiers.

Gravitational settling is the simplest method because the tanks are filled with the original oil and left for a certain time (2 days or more). During this time, the water drops coagulate, and under the action of gravity the large water drops gravitate to the bottom. But this method of cold oil settling has low productivity and is not effective enough [1].

The electric method of dewatering is fairly known and widely used at fields and plants. When combined with other methods (thermal, with the use of a demulsifier), it produces a good effect with the right mode selected and when applied for emulsions of almost any type. By the nature of the electric field they distinguish the following methods: with the use of alternating and direct currents of power and high frequency; but it was found that the effect of oil demulsification in an electric field of alternating current is higher than the one in an electric field of direct current.

The paper [2] presents a review of scientific papers using ultrasound and ultrasonic devices. Crude oil was sonicated for 30 seconds. with the addition of an oxidizer (0.5 - 1% sulfuric acid solution). The analyzed results revealed that the content of salt and sulfur in oil decreased, but with ultrasonic exposure, partial cracking and fractionation of the oil product occurred, and in the lower layer there was an accumulation of heavy fractions and oxidation products of the extracted sulfur and water.

The paper [3] studies the effect of ultrasonic exposure on the oil viscosity decrease during its pipeline transportation. The studies revealed that the effect of ultrasonic treatment:
- is higher for oils of heavy fractional composition than for light oils;
- is more effective as compared to thermal treatment.

The paper [4] considers the use of static mixers with vortex devices in the process of oil desalting and dehydration prior to its processing, where the effectiveness of this process at oil treatment plants directly depends on the degree of its mixing with water and demulsifiers. These devices have passed industrial testing.

To simplify the technological process of oil treatment and reduce the cost of treatment, it is necessary to use effective demulsifiers.

The paper [5] introduces the results of a laboratory study of dehydration of an oil emulsion (with 24% water cut) using demulsifiers.

In this work, the fastest method for comparative evaluation of the chemical reagent's demulsifying activity was used - the Bottle test [6]. The unbiased evaluation of the demulsifying properties of the reagent involves the determination of its activity, both at low and high temperatures.

The temperature of the emulsion in the pipelines and field gathering systems is within 5-15°C, in the preliminary dehydration units at oil treatment facilities – is within 20-25°C, in the deep dehydration units – is within 50-60°C.

The settling time is assumed to be 1-5 hours, depending on the emulsion stability and the water separation dynamics, but the first 2 hours are significant, when the dehydration depth close to the maximum is reached at the right flow rate and temperature.

Measured amounts of demulsifier (20 g/t, 40 g/t, 60 g/t) were injected into each cylinder. The samples were manually mixed for at least 200 swings in order to completely dissolve the demulsifiers. The test tubes with the studied emulsion were left for a couple of hours, while recording the amount of the separated aqueous phase every 30 minutes, measuring the height of the water layer. The demulsifier flowrate depends on the water content of the oil and can range ~ from 40 to 200 g/t.

There are various ways of oil dehydration and desalting, but combining these methods is more effective for increasing the dehydration depth. Oil emulsions are stable systems and they do not completely separate under gravity only.

Therefore, to speed up the process of the oil-water emulsion separation during settling, it is also subjected to other treatments (addition of demulsifiers, heating), which are aimed at enlarging water droplets, reducing the oil viscosity and increasing the density difference. In the conducted laboratory experiments, demulsifiers were injected into the oil-water emulsion, heating was carried out, and centrifugation was used.

It is shown that during separation the greatest effect is created upon preliminary heating of the oil emulsion using demulsifiers and with vigorous stirring before settling.

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IMPROVING THE EFFECTIVENESS OF DEPRESSANT ADDITIVES FOR DIESEL FUEL BY ADDING HEAVY N-PARAFFINS

The climate of the main Russian Federation territory determine the high level of demand for diesel fuel of winter and arctic brands. A promising direction in the production of low-freezing diesel fuels is the use of depressant additives, the effectiveness of which largely depends on the composition of the fuel. The presence of n-paraffins in the composition of straight-run diesel fuels significantly deteriorate their low-temperature properties, however, formation of the first n-paraffins crystals triggers the action of depressant additives [1].

The aim of this work is to study the effect of adding heavy n-paraffins on the effectiveness of the depressant additive.

The object of research in this work is a straight-run diesel fuel sample (DT), heavy n-paraffins (P), separated from vacuum gas oil by freezing, and commercial depressant additive. The depressant additive was used at a concentration of 0.26 ml per 100 ml of diesel fuel (the concentration recommended by the manufacturer). The characteristics of straight run diesel fuel sample are presented in Table 1 (ρ is the density at 20 ° C; ν_d is the dynamic viscosity at 20°C; ν_k is the kinematic viscosity at 20°C; T10%, T50%, T95% - distillation temperature 10, 50, 90% vol.; CFPP – cold filter plugging point; T_p— pour point).

Table 1 – Characteristics of straight run diesel fuel sample

ρ, kg /m^3	ν_d, mPa · s	ν_{to}, mm^2/s	Sulfur content, mg /kg	Fractional composition, °C			Low temperature properties, °C	
				$T_{10\%}$	$T_{50\%}$	$T_{95\%}$	CFPP	T_p
833.0	3.4553	4.1480	3911	183	263	348	-5	-16

At the next step, the blends of DT / heavy n-paraffins (DF + P) and the blends of DT / heavy n-paraffins / depressant additive (DF + P + Ad), were prepared. Heavy n-paraffins were used in concentrations of 0.05% wt., 0.10% wt., 0.25% wt.

Figure 1 shows the hydrocarbon composition of the used heavy n-paraffins, which had been determined by gas-liquid chromatography method using a Chromatec-Crystal 2000 unit.

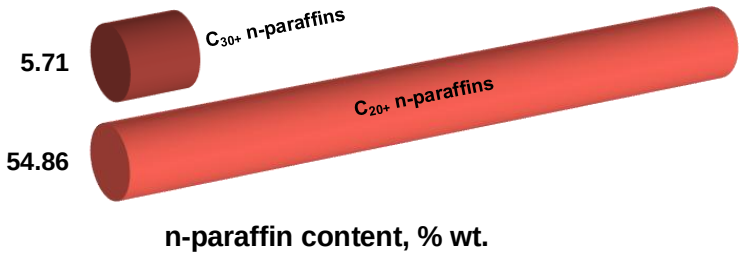

Figure 1 – The hydrocarbon composition of heavy n-paraffins

Figure 2 presents the results of determining the low-temperature properties of the studied blends.

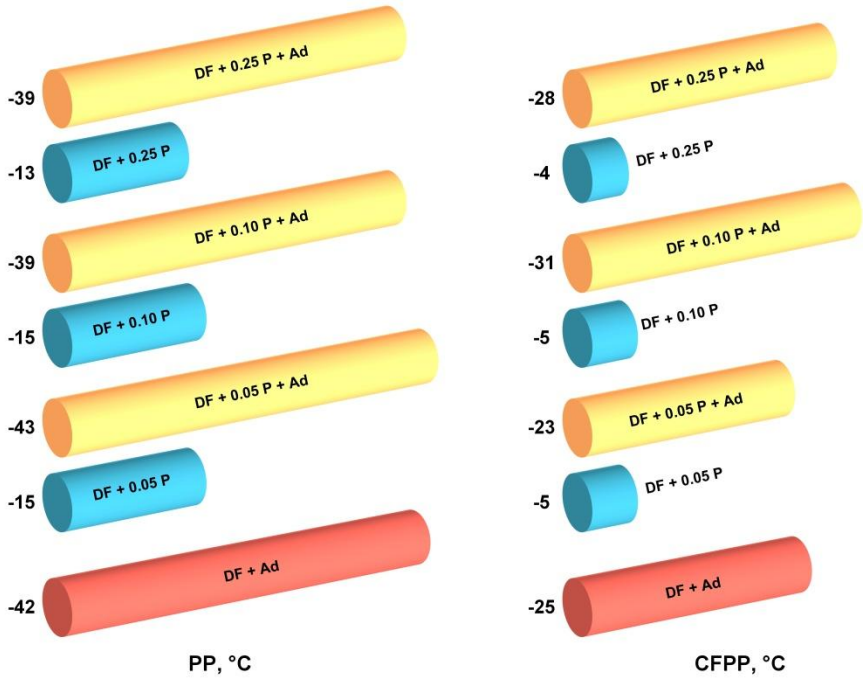

Figure 2 – Low temperature properties of the studied blends

As can be seen from the data, presented in Figure 2, the addition of a small amount (0.25-0.10% wt.) of heavy n-paraffins increases the effectiveness of the depressant additive in relation to CFPP (by 3 °C and 6 °C, respectively). Thus, the addition of heavy n-paraffins is a promising way to produce the low-freezing brands of diesel fuel.

The reported study was funded by RFBR and Tomsk region according to the research project No. 19-48-703025.

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EXPERIMENTAL RESEARCH OF ANTHRACITE PROPERTIES CHANGE DURING ITS HEAT PROCESSING

Anthracite is a valuable raw material for the production of carbon materials for various purposes. However, nowadays it is consumed mainly as fuel in the energy sector and only about 5% are processed, while oil products used for production of carbon materials or finished products are purchased abroad. The development of various industrial technologies requires the production of an increasing number of carbon and carbon-containing products, a significant part of which can be obtained on the basis of anthracite; there is a serious danger of falling behind the world level in this industry and the substitution of domestic products by import. In this regard, the Donetsk coal basin, which is represented by all brands of coal, including anthracite - the final product of coal metamorphism, is of great interest.

The variety of properties of anthracites determines the relevance of not only the tasks of their study, but also a variety of technological uses. In turn, the uniqueness of the properties of carbon-containing products sets the task of improving existing and creating new technologies for the production of such products, as well as technologies for processing anthracites and preparing, on their basis, products with desired properties, such as thermoanthracite, carbonizer, carbon material, carburizer, hydroanthracite and filtrant. During heat processing, the properties of carbon materials are stabilized, moisture and volatile substances are removed. The observed manifestations of complex transformations during heat processing are the release of volatile substances and material shrinkage, while the density, mechanical strength and electrical conductivity of the materials increase. During heat processing occurs the ordering of carbon structure - the growth of flat hexagonal carbon lattices. Some aspects of the physicochemical regularities of anthracites heat processing has not been fully studied, they are very diverse, cover a wide range of problems from different areas of technological science. For this reason laboratory tests for the heat processing of anthracite were carried out in Donetsk national technical university.

The indicators that characterize the quality of heat processed anthracite are - mass fraction of total moisture (W_t), mass fraction of hygroscopic moisture ($W_{ги}$), ash content (A^d), volatile yield (V^{daf}), total sulfur (S_t^d), carbon content ($C_0{}^{daf}$), net calorific value (low $Q^{daf}{}_s$), size class. Initially, these characteristics were controlled for the feedstock, and then for the products obtained after a series of experiments.

After processing the received data of the specified values for a certain number of points, a graphical dependence was obtained - a thermogram. On the obtained thermogram characteristic areas are identified and studied: removal of adsorption (external) moisture; distillation of internal moisture (hygroscopic, molecular), accompanied by the opening of capillary pores; removal of some sorption gases - O_2; N_2; CO_2 and volatile emission in the form of organic components; physical changes in the structure of anthracite with the formation of micro- and macropores as a result of sublimation of volatile and sulfur; intensive opening of pores; hydrogen evolution, change in surface porosity; volume expansion and change of the crystal lattice.

It was found that after heat processing there is a change in electrical properties (conductivity improves and electrical resistivity decreases). Petrographic destruction of a part of the volume of the processed material due to increasing fracturing and mechanical and thermal tensions of the remaining part of the material is also observed.

The obtained results are the basis for determining the technological parameters for real processes intended for production of the entire spectrum of carbon-containing materials from Donetsk anthracites.

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FEATURES OF THE TECHNOLOGY OF THE CARBON COMPOSITE SG-P AND ITS NEW OPPORTUNITIES

The manufacturing technology of carbon composites of the SG-P type (pressed siliconized graphite) allows to obtain a wide range of materials with different phase composition and physico-mechanical properties [1]. These materials are used as the basis for abrasive, refractory, constructive, electrical, semiconductor, attrition-resisting, heat-resistant, radiation-hard, rust resisting products and many others. The analysis of the literature data showed that the problem of production of SG-P carbon composite with specified properties in the conditions of instability of the properties of raw materials (silicon, coke, pitch) is insufficiently studied and requires further research.

Features of the SG-P production technology make it possible to vary the properties of carbon-carbide-silicon materials within a single technological cycle. The technology consists of the following sequence: the artificial graphite received by the enterprise is crushed and dispersed into narrow fractions on industrial sieves [2], then the fractions are mixed in a certain ratio. Next, a binder is dosed into the resulting powder, mixed and pressed, then subjected to firing with polymerization. Then siliconization is carried out: impregnation of the preforms with a molten silicon with subsequent heat treatment to carbide formation. The final stage is mechanical processing of the resulting composite. For effective impregnation, the optimal ratio of the rate of impregnation and carbide formation, which is determined by the temperature and time of impregnation, heating rate, and exposure time at maximum temperature, is necessary.

A graphitized filler, coke from a binder and silicon, each of which contains a significant amount of impurities that significantly affect thermal, chemical and kinetic phenomena, are involved in the process of silicification. In addition, the reactivity with respect to silicon for a graphitized filler and coke from a binder is different [3], as it is different for carbon basal and prismatic planes in a graphite crystal, but an increase in temperature to 2000 ° C accelerates carbide formation in all cases. It is noted that the greater the porosity of the initial graphite, the more silicon carbide is formed at the same time. The porosity of the carbon material before silicification affects not only the average density and chemical composition of siliconized graphite, but also the distribution of density and phase composition (Si, SiC, C) in microvolumes of siliconized graphite.

The main distinguishing feature of SGP-0.5 siliconized graphite is that it becomes possible to create large-sized products with sizes up to 400 mm. However, increasing the size of parts requires careful research in this direction for each individual product dimension. [4]

Thus, the production technology of the carbon composite type SG-P allows you to get materials with different properties, changing the raw material and its composition, varying technological factors and methods of conducting individual stages of production. The resulting composites are in demand in various industries. Silicon graphite is characterized by low friction and wear. It should be noted that products made of silicified graphite have "self-lubrication", that is, a graphite film is formed on the metal surface, and a shiny layer of oriented graphite crystals is formed on the parts made of SG-P. Due to this property, a stable sliding mode and a low coefficient of friction are ensured. These materials are most in demand in the oil, chemical and nuclear industries for the manufacture of pump bearings operating at high temperatures, as well as in chemically aggressive environments. The use of thin-walled protective tips made of silicon graphite made it possible to ensure a long thermocouple life and sufficient accuracy when measuring the temperature of cast iron and slag.

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PRODUCTION TECHNOLOGY OF STABLE LOW-SULFUR MARINE FUEL

Since 01.01.2020, the International Maritime Organization has tightened requirements for the content of sulfur compounds in marine fuel to 0.5% mass. This sulfur content can be achieved in two ways: direct hydrogenation of oil residues and indirect hydrogenation. Indirect hydrogenation is the production of marine fuel by compounding distillates of hydrogenation processes and residual fractions. In this paper, we consider a method for producing marine fuel by indirect hydrogenation, since it is the simplest method that does not require large capital investments [1, 2].

High-sulfur and low-sulfur components of marine fuel were selected and analyzed from oil refineries. Using the obtained data on the properties of the components of marine fuel, 12 samples of marine residual fuel were obtained. Physicochemical and operational characteristics of the obtained samples were determined and analyzed for compliance with the requirements of ISO 8217:2010 «Marine fuels. Technical conditions.». Some samples do not meet the requirements of ISO in terms of total sediment after aging, which characterizes the stability of marine fuel. The stability of the fuel system can be controlled by adjusting the hydrocarbon composition of the fuel.

To determine the optimal ratio of components and the stability area of the marine fuel, it was decided to consider three three-component diagrams. One of the components is the residual fraction, which contains asphaltenes (visberker residue, asphalt), the second is the fraction, which contains predominantly paraffin-naphthenic hydrocarbons (hydrotreated straight-run diesel fraction), and the third of the components is the fraction, which contains predominantly aromatic hydrocarbons (light gas oil delayed coking and light gas oil catalytic creaking). Samples of marine fuel were prepared with different ratios of these components in increments of 10% of the mass. After that, the total precipitate after aging was determined according to GOST R ISO 10307-1:2009 for the samples obtained. The data obtained are presented in the form of three three-component phase diagrams. The diagrams highlight the stability region of marine fuel (when the total sediment after aging indicator meets the requirements of ISO 8217:2010) [3].

Thus, by the method of indirect hydrogenation, samples of marine residual fuel with improved environmental properties that meet the requirements of the standards were obtained. Three three-component phase diagrams were obtained, showing the stability region of marine fuel with various component and hydrocarbon composition, allowing to choose the optimal ratio of marine fuel components.

ACKNOWLEDGMENTS

This work was carried out as part of the State Assignment “Development of scientific foundations of innovative technologies for processing heavy hydrocarbon raw materials into environmentally friendly motor fuels and new carbon materials with controlled macro- and microstructural organization of mesophase”. Study was conducted with involvement of laboratory base of Center for collective use of Saint Petersburg Mining University.

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INVESTIGATION ON NATURAL MINERALS FOR ULCERATIVE COLITIS THERAPY

Ulcerative colitis (UC), a common chronic inflammatory bowel disease, has features of diarrhea, rectal bleeding and inflammation in colon, which affects millions of people worldwide and causes risk of cancer increasing [1]. The therapeutic efficiency is associated with serious

side effects due to high doses and long-term administration. Therefore, there is an urgent need for effective drug with high therapeutic efficiency and low side effect for UC therapy. Natural minerals are widely known as kaolinite (Kaol), halloysite (Hal), diatomite (Dia), montmorillonite (Mt), palygorskite (Pal) and talc, etc. In ancient times, natural minerals were recorded in Compendium of Material Medica by Shizhen Li since Ming Dynasty, and they were of great significance in medicine not only for external use to diminish inflammation or inhibit hemorrhage, but also administered orally for therapeutic purpose [2]. Nowadays, natural minerals also emerge to delivery drug, gene, protein, and serve as bioactive scaffolds in biological fields.

Due to the outstanding properties and applications of natural minerals, in the current study, five typical natural minerals (Kaol, Hal, Dia, Mt and Pal) were chosen and investigated for UC treatment. Properties including morphology, distribution of particle size, surface charge of five typical minerals (Kaol, Hal, Dia, Mt and Pal) were characterized first, and then in vivo experiments were conducted by using dextran sulfate sodium (DSS)-induced UC mice model. Change of body weight, colon weight and disease activity index, damage in the mucosa, blood hematologic analysis, hematoxylin and eosin (H&E) staining of colon were analyzed to evaluate the therapeutic efficiency of natural minerals on UC.

Moreover, gut flora contributes to human health and metabolism, which is a main reason that leads to inflammatory bowel disease in the condition of disordered [3]. The balance of gut flora is influenced by many factors, for instance age, diet and antibiotic. Common gut flora species in the colon were studied to understand the relationship between microflora and UC. DSS-induced UC was accompanied with disorder of gut flora, and mainly showed a severe elevation of pathogens like Enterococcus and Enterobacterium and reduction of probiotics like Bifidobacterium and Lactobacillus. While treatment with natural minerals decreased the number of anaerobe, as well as Enterococcus and Enterobacterium, and increased the relative abundance of Bifidobacterium and Lactobacillus.

In summary, typical natural minerals (Kaol, Hal, Dia, Mt and Pal) had various morphologies, centered size distribution, and negative charge in the surface. In vivo studies showed that minerals exhibited a quicker upward tendency and regained UC mice body weight fastly, as well as decreased white blood cell significantly, alleviated the inflammation in the colon of DSS-induced colitis obviously. Furthermore, we found that natural minerals could restore the balance of gut flora in UC mice by decreasing the number of pathogens and increasing the number of probiotics. Besides, Kaol showed the best effect on UC synthetically compared with other minerals. Our results collectively suggested that natural minerals exhibited excellent therapeutic efficiency on the DSS-induced UC, and could be used as effective drug and may serve as drug carrier to attain synergistic effects with other drugs for UC therapy.

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ANALYSIS OF METHODS FOR PROCESSING SOLID DOMESTIC WASTE ON A POLYMER BASIS

In all developed countries, there are and are very significant problems associated with an increase in the amount of municipal solid waste. Various types of plastic waste, car tires, and other polymer-based materials belonging to the category of secondary raw materials poison the air, soil, and water bodies of cities. As the main method of processing such waste, it is customary to use recycling in the form of incineration or burial.

The environmental situation in the world requires the search for effective ways of both recycling and recycling household waste. One of such methods may be our proposed method of processing waste to obtain, in the form of a final product, an energy carrier from plastic.

Plastic is, first of all, garbage, and environmentally harmful and practically unrecyclable for a long time. In some industrialized countries, technologies for recycling plastic waste have already been introduced.

Regarding the Russian Federation, the level of use of polymeric materials in Russia is one of the highest around the world, and the degree of utilization and processing of such materials is low. It follows that the problem of environmental pollution by waste from polymer materials is much more acute than in other developed countries.

Interest in the processing of municipal solid waste, primarily by processing enterprises, is evaluated in terms of the economic benefits of the process. Specialists determine the price of secondary raw materials on the basis of the following features, such as the degree of processing of raw materials and the color of plastic materials. Natural and white material is rated much higher than color. In addition, the type of material affects the cost - the pressed form, crushed, agglomerate and in the form of granules. The cost of granular raw materials is much higher than other types.

Recently, in our country, the problem of disposal and recycling of municipal solid waste has been given more attention by the state. It is worth noting that only focusing on this issue by the state will make it possible to effectively develop the processes of disposal and processing of solid waste.

Based on the studies, it can be concluded that the most promising, at this stage of industrial development, are optical waste sorting methods. In Russia, since there is no separate collection of garbage, the issue of using such technology for mixed solid waste is relevant. Another research task that can be solved using optical-mechanical sorting lines is the study of the composition of plastic waste. The availability of data on the component composition of municipal solid waste, for each region taken separately, makes it possible to assess the promising volumes of recovery of secondary raw materials. There is also the opportunity to make a preliminary assessment of the quality of secondary raw materials expected to be obtained in the course of waste processing [1].

The use of automatic selective waste sorting using optical recognition elements in our country is constrained by a number of factors. First of all, these are the distinctive features of the materials in chemical composition produced in our country in comparison with their foreign counterparts. This leads to the fact that optical sensors are not programmed to recognize such materials. Secondly, the technology of selective selection of materials from the general stream of

mixed solid waste, typical for the settlements of our country, has not yet been developed. Along with these factors, unfortunately, industrial methods of processing solid waste with the subsequent receipt of secondary raw materials are still not being introduced. All interest in such processes is based on the interests of individual researchers or a group of enthusiasts who are engaged in obtaining secondary raw materials from polyethylene, plastic, used car tires and other raw materials. There are many facts of the processing of plastic bottles and other waste in Russia, with the subsequent receipt of products for further processing.

Based on the facts that there are mountains of waste, and only a few are engaged in the processing of waste into useful raw materials, it is quite reasonable to show interest in the type of fuel obtained from waste.

The authors propose a method for processing municipal solid waste with the subsequent production of so-called synthetic oil.

The technological process of obtaining the product is as follows:

recyclable plastic, rubber, synthetic materials, etc. are loaded into the tank After that, the loading container is tightly closed. The condensing system must be filled with the required volume of coolant. The gas filter is also filled to a certain level with water. Stop valves at the beginning of the process must be closed, except for the valve for the passage of vapor into the cooling system. The start of the process is carried out with the supply of additional energy. Combustible gas or electric current can be used as an energy carrier. In the tank, the loaded material gradually as a result of heating passes into a viscous flowing and gaseous state. Next, the gas-vapor mixture enters the cooling system, where it decomposes into a gaseous and liquid phase. The liquid component flows into the container of the final product, and the gas mixture, passing the purification filter, is fed to the gas burner and the valve on the inlet of the additional energy carrier is closed. Further, the system completely switches to a closed cycle. The final product is a flammable, dark greenish liquid. This liquid without further processing can be used as fuel for heating furnaces, after additional processing for internal combustion engines.

In our opinion, this form of disposal of rubber and plastic waste would be the solution to several problems. Firstly, the elimination of plastic and rubber wastes, and secondly, the production of a useful product, in particular synthetic oil, which can be processed into commercial fuel for internal combustion engines.

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CHANGING THE ORGANIC MATTER IN HYDROTHERMAL PROCESSES

This work appeals to a continuation of previous researches [1-4] directed to the catalytic hydrothermal process of heavy crude oil in the presence of supercritical water, coal-like compounds and transition metals oxides. The issue is to gain new experimental data on superviscous oil hydrocarbons and carbonaceous substances conversions in supercritical water in a presence of rock forming minerals.

A series of experiments of heavy oil thermolysis in supercritical water is carried out. The reaction systems consist of heavy oil, carbonaceous substances and catalytically active rock-

forming minerals. In the 1st experiment, the initial reaction mixture contains heavy oil and water in a ratio of 2:1 and 3 wt. % of coal. In the 2nd experiment, the mixture is characterized with heavy oil to water ratio of 2:1 and 3 wt. % of charcoal. In the 3rd experiment, the mixture is the same, as in the 1st one, but with the addition of 2.3 wt.% of iron oxides. In the 4th experiment, the mixture contains 2.5 wt. % of Al_2O_3 and 2.5 wt.% of Ni and Cu carbonates with the oil to water ratio of 2:1. The hydrothermal initial mixtures transformation is carried out in a supercritical water medium under subduction zones conditions.

The data of the converted oils fractional distillation indicates the presence of supercritical water in the hydrothermal medium leading to the light fractions b.p.-200°C formation. They exist in a small quantity in the original oil. Thereby, the content of compounds b.p.- 200°C and 200-350°C in 4th experiment product (385°C, 23 MPa) refers to 19.1 wt. % and 24.5 wt. %, respectively, whereas the corresponding data of the original oil equal 9.8 wt. % and 16.1 wt. %. A multidirectional change of the boiling point is typical for the converted oil during the 3rd experiment (375°C, 22.5 MPa) with the participation of iron oxides. The initial boiling point decreases to 83°C, whereas it increases from 91°C to 99°C for the product of the 2nd experiment (375°C, 23 MPa). A temperature effect on the formation of low-boiling compounds is mostly observed under the conditions of hydrothermal heavy oil transformation in a supercritical water medium.

The asphaltenes amount increases from 7.7 wt.% to 9.9 wt. % and 9.2 wt.%, respectively in the products of heavy oil transformation in the presence of a carbonaceous anthracene substance during experiments 1 and 3 (375°C, 22.5 MPa). Obviously, the compounds formed during the oxidation of caustobiolite in the course of its surface interaction with supercritical water provide hydrocarbon radicals which react further participating in asphaltenes polycondensation reactions. Thereby, the products of the reactions proceeding on the carbonaceous substance surface increase their quantitative content. A significant decrease of the resin content is also detected what can be explained by the fact that the resins are not only the source of hydrocarbons and aromatic structures, but they also react with asphaltenes.

An inverse dependence of the composition change of the converted oil is observed in the 2nd experiment (375°C, 23 MPa) occurred in a presence of a microporous high carbon compound with a developed specific surface. The asphaltenes content decreases from 7.7 wt. % to 5.5 wt.%.

The oil converted in a supercritical water medium is characterized by an increase of the saturated hydrocarbons content from 40.8 wt. % to 53.5 wt. % - 76.2 wt. %. There is a simultaneous decrease of aromatic and resinous substances content. The product of 4th experiment (385°C, 23 MPa) carried out in presence of a carbonaceous anthracene substance, Al_2O_3 and Ni and Cu carbonates is characterized by a decrease of the aromatic hydrocarbons content from 13.7 wt. % to 4.1 wt. % and that of the resin content from 37.8 wt. % to 13.1 wt. %.

It is also detected that a high-molecular components destruction proceeds leading to the formation of normal and branched structure alkanes almost absent in the original oil. The immature organic substance is shown to undergo catagenetic maturation as a result of the aquothermolysis.

ACKNOWLEDGEMENTS

This work is supported by the Russian Science Foundation under grant № 18-77-10023.

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METHOD FOR OBTAINING RAW MATERIAL FOR THE PRODUCTION OF CARBON FIBERS

There are several high-tech unique products, including those that have no analogues on the Russian market, in the production of which pitch is the most important raw material component [1]. One of the most promising materials is carbon fiber from coal tar pitch. Another promising direction that is developing in China is the production of carbon fibers from coal tar pitch (pitch-based carbon fibers). Pitch-based carbon fibers, in comparison with PAN-fibers, are characterized by a high modulus of elasticity, resistance to oxidation, and higher thermal conductivity [2]. The main source of pich is coal tar, a by-product of coking coal. However, pitch and coal tar are characterized by increased environmental hazards due to their high content of polycyclic aromatic hydrocarbons, including Benz[a]pyrene, which are carcinogens. Therefore, the development of alternative methods for producing a binder with less environmental hazard is of big importance [3, 4].

Due to the urgency of the problem of shortage of high-quality raw materials for the production of carbon fibers in Laboratory research at PJSC Koks together with the Department of solid fuel chemical technology of the Institute of chemical and oil and gas technologies permits the production of an alternative binder by the solution of coal in anthracene oil. The thermal solution of coal is undertaken in experimental apparatus with a sealed reactor, in which the temperature and the heating rate may be adjusted. The raw materials in the research are anthracene oil and G, GZh, and Zh coal concentrates used in coking batch at PJSC Koks.

The key issue in obtaining high-quality fibers is the presence of mesophase in the sand or its ability to transition to the state of mesophase pitch [5]. To determine the presence of mesophase in the resulting product, studies of its optical activity were performed using a MIN-8 polarization microscope. Figure 1 shows a photo of the peck film in passing ordinary light, and Figure 4 shows it in polarized light. From the analysis of microphotography (Figure 2), it can be seen that the pitch obtained by thermal dissolution of coals is capable of forming a mesophase, but its amount is small. To increase the amount of mesophase, the resulting pitch must be subjected to heat treatment.

As a result of research, it was found that the optimal conditions for obtaining a thermosolution product with a low softening temperature are the ratio of solvent/coal – 70/30, the temperature in the reactor – 390-400 °C. This pitch is characterized by the lowest ash content and the lowest content of α and α_1 fractions. However, in this case, the softening temperature does not correspond to this indicator for fiber-forming pitches, so it is necessary to further process it in order to increase the softening temperature and reduce the yield of volatile substances.

To obtain a product with a high softening temperature, the optimal conditions are the ratio of solvent/coal – 60/40, the temperature in the reactor – 370 °C. However, even in this case, further processing is necessary in order to increase the softening temperature and reduce the yield of volatile substances.

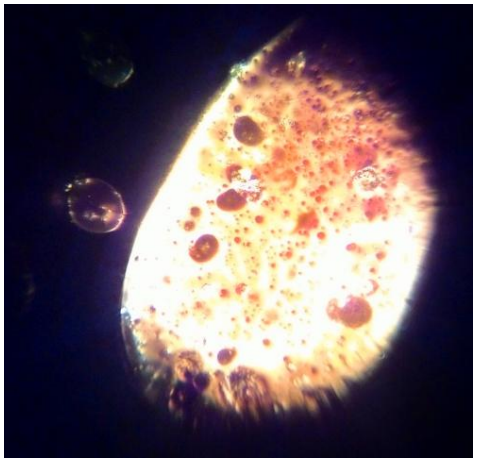

Figure 1. Appearance of the pitch film in passing ordinary ligh.

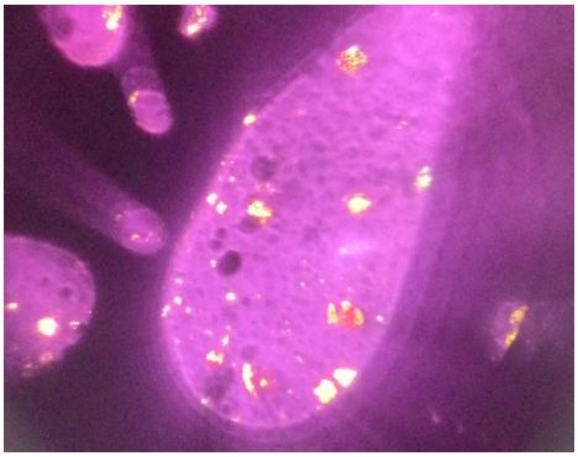

Figure 2. Appearance of extractive pitch film in polarized light.

It is particularly worth noting the high ash content of samples, which determines a separate layer of research to reduce this indicator.

Thus, for use as a raw material for the production of carbon fiber, the resulting pecopadobny product must be subjected to additional cleaning to reduce ash content and additional processing to increase the softening temperature. However, a peak with a reduced content of polycyclic aromatic hydrocarbons without additional purification can be in demand even now in technologies that do not impose high requirements for ash content (for example, the production of carbon refractories and refractory masses).

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A GEOCHEMICAL METHOD IN BIOMEDICINE: APPLICATION OF CLAY TO COMBAT ANTIBIOTIC RESISTANCE

Designing a new mineral-based antibacterial material based on the mechanism of geological mineral-bacterial surface interaction is a geochemical method, which could combat pathogenic microorganism pollution and antibiotic resistance that threaten human health. It provides a new design idea and theoretical guidance for the preparation of new antibacterial disinfection materials. The misuse of antibiotics leads to the production and spread of drug-

resistant bacteria. Infectious diseases induced by bacteria become one fatal and serious health problem for human beings worldwide currently [1]. To protect the public health effects, the traditional drugs or materials, such as metal ions, quaternary ammonium compounds, and antibiotics, have been developed and widely used in daily life. In addition to the traditional drugs or materials, antibacterial materials including carbon nanotubes, metal oxide, silver particles, or their composites, functionalized polymers etc., have been exploited to deal with infectious diseases recently [2]. However, the above antibacterial materials suffer concerns and drawbacks associated with antibiotic resistance, environmental safety, commercial and industrial applications. There has been the increasing resistance of bacteria including Escherichia coli attributed to antibiotics use.

Moreover, the above materials inevitably face and overcome the disadvantages of toxicity on human health and complex chemical synthesis of high cost [3].

Since the emergence of life on earth, the geological environment and bacteria have been interacting, and finally formed the earth ecosystem. The interaction between bacteria and geological minerals is closely related to the biogeochemical cycle of the earth, and participates in the nutrition and energy transfer between the geology, hydrology, and atmosphere, and affects the evolution of life and the ecological environment of the surface. In the process of bacteria-mineral interface interaction, the crystal structure, chemical composition, surface interface properties and hydration of the mineral affect the biochemical and physical properties such as the formation, permeability and metabolism of the bacterial membrane, and form a unique bacterial-mineral fingerprint.

Clay minerals, as a type with high surface activity have a natural antibacterial effect against pathogenic bacteria. Pathogenic microorganism pollution and antibiotic resistance threaten human health worldwide. In order to combat the threats of microorganism and antibiotic resistance, we modified the surface of natural mineral materials, the interactional energy and the smallest energy barrier between mineral materials and bacteria was calculated based on DLVO theory, and van Oss

- Chaudhury - Good was applied to calculate the surface free energy of calcined kaolinite. In order to study the effect of the adjustment strategy of interaction on the antibacterial activity, the equilibrium adhesion isotherms of *E.coli* to kaolinite were investigated because the adhesion plays important roles during the direct interactions [4].

The results show that surface-modified kaolinite could interact with bacterial membrane more easily. By modifying the surface of natural mineral materials, kaolinite acquired the lowest total interactional energy and the smallest energy barrier between mineral materials and bacteria, indicating kaolinite could easily adhere to the surface of bacteria through long-range force. The total surface free energy and polar surface free energy of modified kaolinite were largest, implying it is easier to interact with the bacterial membrane via hydrogen bonding, which could lead to a rapid collapse of the bacterial metabolism and improve the antibacterial activity of mineral materials effectively. Antibacterial experiments and adsorption experiments show that the bactericidal efficiency of modified kaolinite increased, and the adsorption capacity of it to bacteria is 10 times as larger as raw kaolin. The interaction alters the structure of the bacterial membrane lipid bilayer and rigidifying the lipid chain vibrational dynamics, eventually killing bacteria. Regulatory interfacial interactions via adjusting the surface properties of kaolinite could enhance the antibacterial activity of clay. Surface modification of kaolinite is a geochemical method to combat bacterial infection and antibiotic resistance.

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INTERFACIAL CHARACTERISTICS BETWEEN MINERAL FILLERS AND PHENOLIC RESIN IN FRICTION MATERIALS

KEYWORDS: Mineral filler; Properties; Phenolic resin; Interfacial characteristics.

Mineral fillers are indispensable constituent part of friction materials, which are capable of improving and stabilizing coefficient of friction, decreasing wear, enhancing thermal conductivity and reducing costs of friction materials, in addition, decreasing the noise in brake application. Based on their role in the friction material, mineral fillers are classified into abrasives, lubricants, functional fillers, and space fillers. According to this, four typical commercial mineral fillers, namely quartz, graphite, expanded vermiculite, and barite were studied for revealing their effects on the performance of friction materials in this paper. The composition, thermal stability, textural properties such as surface area, pore volume, and pore size distribution, and thermal conductivity of these mineral fillers were investigated mainly by X-ray diffraction (XRD), differential scanning calorimetry and thermogravimetry (DSC-TG), N_2 adsorption-desorption isotherms, and thermal conductivity tester. Moreover, in order to illustrate the interfacial characteristics of mineral-based in friction materials, four ideal brake pads only consisting of mineral filler, $BaSO_4$ and phenolic resin were prepared. Microstructure and combination of mineral fillers and phenolic resin were investigated by scanning electron microscopy (SEM), polarizing microscope, and Fourier transformation infrared spectroscopy (FTIR). The results showed that different types of material fillers have special functions for friction materials, and they combined with phenolic resin mainly in a physical way.

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THE EVOLUTION OF STRUCTURE AND PROPERTIES OF RECTORITE DURING CALCINATION AND ITS APPLICATION IN FLAME RETARDANT MATERIALS

Generally, energy-efficient buildings require materials with low thermal conductivity and high flame retardancy. Flame-retardant treatments on flammable materials that can delay ignition time and hinder flame propagation are consequently necessary to reduce the risk of fire. Unfortunately, many of the commonly used organic flame retardants are halogenated or phosphorus compounds with negative environmental and health impacts [1], while inorganic flame retardants represented by graphene, carbon nanotubes, and fullerenes are usually

expensive and difficult to achieve large-scale applications. Recent work has shown that the flame retardancy of organic-inorganic composites can be significantly improved by the addition of well-distributed inorganic fillers such as carbon nanotubes, silica, layered montmorillonite (MMT), needle-like sepiolite and metal oxides or hydroxides (e.g. MgO or LDHs) [2, 3]. However, addition of inorganic fillers to an organic material increase the density and can make the hybrid more fragile. Poor compatibility between the inorganic fillers and the polymer matrix can also result in catastrophic disintegration during combustion and fail to prevent thermally induced collapse of the building [1].

Nanoclay, compared with other inorganic filler, such carbon nanotubes, graphene, is inexpensive, widely exists in nature, and shows superior biocompatibility and biodegradability. The most attractive feature of clay nanosheets as flame retardants is that they have a certain aspect ratio and are impermeable to heat and gas molecule, which can lengthen the heat propagation path. Recently, MMT has been widely used to improve the rigidity and flame retardancy of polymers because of its excellent thermal stability and gas barrier properties [4]. Rectorite (REC), another two-dimensional (2D) layered materials, is composed of dioctahedral mica layers and dioctahedral MMT layers stacked in a ratio of 1:1. Since the mica layer is included between the interlayers, the REC has excellent thermal stability, and its fire resistance temperature (i.e., melting point) can reach up to 1660 °C. Therefore, the REC has higher flame retardancy than MMT. However, there are few studies on the application of rectorite in flame retardant materials.

Therefore, the understanding of the structural and compositional evolution of rectorite (REC) during the progressive calcination at elevated temperatures is essential to promote its use as flame retardant. In this work, we present in-situ X-ray diffraction (XRD), in-situ FTIR, thermogravimetry/differential scanning calorimetry (TG/DSC) and multinuclear NMR data to investigate the thermal evolution of rectorite in the temperature range of 25-1200 ºC, with the aim for laying a profound background for the full use of rectorite mineral and applying it to materials in flame retardant field. The results show that rectorite has gone through the following four stages after heat treatment: dehydration at room temperature to 300 ºC, dehydroxylation at 500-700 ºC, structure collapse at 1000 ºC, and formation of a new phase above 1100 ºC, and SiO_4 tetrahedral units and AlO_6 octahedral units in rectorite were distorted around 1000 ºC, so that the maximum contents of active SiO_2 and Al_2O_3 could be simultaneously obtained, showing excellent thermal stability.

Furthermore, a novel waterborne intumescent fire retardant coating (IFR-Na-REC) containing sodium-modified rectorite (Na-REC) was synthesized and characterized. The flame retardancy, morphology, structure, chemical composition and mechanical property of the intumescent coating were in detail investigated. The results showed that Na-REC could greatly improve the flame retardancy and heat insulation effect of waterborne intumescent coatings. The fire test shown that the 10wt% of the Na-REC enhanced the heat insulation effect and recorded the temperature of the backside of steel plate 218°C after 90min of fire test, lowered by 62°C relative to the control coating, and the fire retardant time reached 119min.Thermogravimetric analysis (TGA) demonstrated that addition of 10wt% Na-REC increased residual mass of the char by 18.89%. These may be due to the fact that the Na-REC could enhance the adhesion of the coating to the substrate and, during combustion, form a ceramic-like protective layer (TiP_2O_7、 SiP_2O_7 and $Al(PO_3)_3$) between rectorite and components in intumescent coating, on the surface of the coating, acting as a fire barrier to protect the internal matrix. The results obtained here will enlarge the application of rectorite in flame retardant, which is of great practical significance.

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EFFLUENTS TREATMENT GENERATED BY BIOLIXIVIATION IN THE EXTRACTION OF PRECIOUS METALS THROUGH SELECTIVE RECOVERY OF IRON, COPPER AND ZINC

In the mining districts, the gold deposits contain metal sulfides such as pyrite, chalcopyrite, arsenopyrite, galena and sphalerite, and when exposed to the action of air and water they undergo throw a series of physical, chemical and biological phenomena. This produces the oxidation of sulphides to sulphates by the catalytic action of bacteria such as Thiobacillus Ferrooxidans, T. Thiooxidans, T. Sulfooxidans, and T. Thioparus, in addition to the production of sulfuric acid that dissolves heavy metals such as iron, copper and zinc; process called bioleaching [1]. These solutions, with a high level of acidity, pH around 2, are dragged by water currents or runoff, constituting a powerful water and soil pollutant [2]. The main sources producing acid solutions in mining operations are drainages from underground mines, runoff in open-pit mining and leachate from tailings and mining waste [3]. These acidic solutions, with a high content of heavy metals in solution, are called “acid mine drainage” (DAM) [4]. DAM contains heavy metals such as lead, mercury, iron, copper and zinc, which are toxic in small concentrations (LD10 for lead, 1470 µg/kg, LD50 for mercury, 30-50 mg/kg, LD50 for iron, 600 mg/kg; LD50 for copper, 50-500 mg/kg, and, LD50 for zinc, 180 mg/kg) and tend to bioaccumulate. The aim of this study is to use selective precipitation, in order to recover iron, copper and zinc from acid solutions produced by bioleaching during the extraction of precious metals at a laboratory scale and from natural acid mine drainage [5, 6]. The results were obtained using volumetric analysis methods for the determination of Fe^{2+}, Fe^{3+}, total Fe, SO_4^{2-}, Cu^{2+} and Zn^{2+}.

The product of solubility (Ks) makes it possible to calculate the pH value at which the precipitation of a hydroxide begins and ends. For copper hydroxide, iron hydroxide and zinc hydroxide, after dissociation, the Ks and the hydroxide concentration [OH] are calculated with:

$$Ks = \left[Cu^{2+}\right]\left[OH^{-}\right]^{2} = 2.2 \times 10^{-20} \quad \text{and} \quad [OH] = \sqrt[2]{\frac{K_s}{[Cu^{2+}]}}$$

$$Ks = \left[Fe^{3+}\right]\left[OH^{-}\right]^{3} = 4.0 \times 10^{-38} \quad \text{and} \quad [OH] = \sqrt[3]{\frac{K_s}{[Fe^{3+}]}}$$

$$Ks = \left[Zn^{2+}\right]\left[OH^{-}\right]^{2} = 1.8 \times 10^{-14} \quad \text{and} \quad [OH] = \sqrt[2]{\frac{K_s}{[Zn^{2+}]}}$$

Bioleaching tests were conducted in four tanks with agitation and continuous aeration for six months. Each of the tanks contained acid drainage from a natural mine, K9 nutrient medium,

gold ore and sulfuric acid to maintain a low pH. The methods to characterize the samples were: analytical methods for the determination of Fe^{2+} and SO_4^{2-} in solution and atomic absorption, with hydrochloric acid matrix. For the selective precipitation of iron, copper and zinc, from the bioleaching solutions prepared with acid drainage from natural ore and gold ore, six different tests were performed. Each test follows a logical order for the sequential separation (by stages) of heavy metals and, by means of atomic absorption method, both for the filtrates and for the precipitates (partial and final precipitates), the percentages of recovery were determined.

It was verified that it is possible to determine the presence of copper, iron, lead and zinc in a solution without interference between the ions to be analyzed. The metal solutions were prepared with lead acetate and with copper, iron and zinc sulfates. Results of the characterization of the three samples of bioleaching solutions in Table 1. The characteristics of the solutions generated by a controlled bioleaching process in the laboratory are similar to those of the natural bioleaching solution, Orenas. Results show that iron is the predominant component of the solutions, but it was found as Fe^{2+} and Fe^{3+}. As the precipitation pH of Fe^{2+} is very close to the precipitation pH of Cu^{2+}, an oxidant was used to oxidize $Fe^{2+}$to $Fe^{3+}$and allow the range of precipitation between copper and iron to be wider.

Table 1 - Solutions characteristics

Solution (Bioleaching)	**Initial pH**	**Volume (l)**	**Sulfates (g/l)**	**Fe^{2+} (mg/l)**	**Fe^{3+} (mg/l)**	**Total Fe (mg/l)**	**Copper (mg/l)**	**Zinc (mg/l)**
Orenas	1.92	14	60.98	55.84	12660.2	12716	108.8	464.0
SOLBIO 1	1.68	14	54.35	1563.52	10290.5	11854	71.8	301.2
SOLBIO 2	2.54	14	53.89	1072.13	9323.9	10396	108.4	381.8

The validation of the methods of analysis allowed to demonstrate that the presence of copper, iron, lead and zinc in a solution can be determined by means of simple methods of analysis. The methods used are feasible to use in the field since only glass material and chemical reagents are needed. All the selective precipitation tests carried out allowed the heavy metals to be completely eliminated from the solution or left at concentrations lower than the maximum permissible limit so that they can be discharged to a body of water or to the public sewage system. In this way it was proved that the variation of pH is an effective, easy to use and inexpensive method, feasible to be used in the purification of waters that have been polluted with heavy metals. Bioleaching solutions were prepared with similar characteristics to the acid drainage of natural mines to carry out the tests of selective precipitation of heavy metals in solution. Pure metal hydroxides were precipitated from natural acid main drainage and form the bioleaching solutions generated under controlled processes in the laboratory. Results show that the process proposed in the present study for iron, copper and zinc recovery has a potential industrial application.

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THE THEORETICAL BASIS FOR THE DEHYDRATION OF OIL

Oil is a greasy, flammable liquid with a characteristic smell, dark brown-black color, sometimes light yellow. Its color depends on the content of chemical elements. Prepared for processing in two stages – at the oil field and at the refinery. The task of preparing for processing at both stages is to separate the oil from the impurities that come out of the wells with it, associated gas, mechanical impurities, water and mineral salts. At the stage of field preparation of oil (see figure 1), the main amount of associated gas is separated from the oil for further processing. The associated gas is separated in high-and low-pressure separators by gravity separation. Complete separation is not possible, and approximately 0.5-1.5% of hydrocarbons up to and including butane remain in the oil in the dissolved state. This part is extracted after separation of the remaining impurities in the field at the stage of oil stabilization, promotion of methods for minimizing the sulfur content in oil, analysis of sulfur compounds in oil, revealing the importance of oil dewatering. Its color depends on the content of chemical elements.

Depending on the chemical composition, oil is a complex mixture of two main elements – carbon C (82-87 %) and hydrogen H2 (11-14%). It is called hydrocarbons. Oil contains other chemical elements that do not contain large amounts: O2, N, S and SL, U.

The reactive method is a technologically complex process, when oil becomes heavy, its catalytic treatment becomes heavy and expensive. Crude oil is bound to sulfur by the introduction of catalysts or adsorbents, in some cases micro-organisms. The process of catalytic hydrogen purification involves selective disconnection of sulfur compounds by molecular binding of hydrogen sulfide to hydrogen sulfide. At the next stage of the process, hydrogen sulfide was separated from the refined raw material, and then extracted again and formed into hydrogen and sulfur.

The biosulfarization method is relatively the most advantageous of "soft" selective dewatering, which can be used to distinguish sulfur compounds without causing damage to other components of the oil.

Chemical separation methods are based on various reaction properties of components in the reactions of hydrogen, serenium, isomerization, halogenation, etc.

The reaction of catalytic hydrogen has analytical significance for heteroatomic compounds in relatively easier to analyze hydrocarbons.

ρ =935,5 kg / m^3,

T_3=-10 °C,

* ν =116mm^2/c 20°C temperatured, p content=11.3%, total sulfur content 2.45%;

Table 1 - Electric pulse discharge of zhalgyztobinsk oil results in the process of processing

Oil zhalghyztobe	t (c)	ρ (sq)	Percentage of sulfur (%)
1 example	30	15	2,20
2 example	60	15	1,96
3 example	60	20	1,47
4 example	90	25	0,92
5 example	120	25	0,72

When analyzing the project options, various technologies are considered, based on changes in the duration of the process, the volume of allowable pressure.

In turn, hydrogen leads to a reduction in material and energy losses during processing, without the use of hydrogen-containing gases, pressure and expensive catalysts;

The analysis of physical and physico-chemical effects resulting from the discharge of an electric pulse allowed us to determine the General patterns of their manifestation.

During many experiments on processing electric pulse discharges of high-viscosity oil, it became known that intensive dewatering of oil raw materials, resulting in improved geological properties of oil.

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PORE RECONSTRUCTED KAOLINITE BASED COMPOSITE FORM-STABLE PHASE CHANGE MATERIALS WITH HIGH PERFORMANCE FOR THERMAL ENERGY STORAGE

With the developing economy and improving living stands, the demand for energy has increased dramatically in recent years, which has led to a variety of problems that include the exhaustion of fossil fuels, environmental pollution, and increasing levels of carbon dioxide emissions. Therefore, improving energy-use efficiency and environmental protection are important issues. Thermal energy storage (TES), which includes sensible heat storage, latent heat storage, and thermo-chemical storage, is considered to be one of the most effective methods for improving energy efficiency. Compared with other methods, latent heat storage is a more-promising heat-storage technology by virtue of the advantages associated with phase change materials (PCMs), which have high energy-storage densities and isothermal characteristics. However, the disadvantages of their low thermal conductivities and the leakage of organic PCMs during the phase change process have limited their applications. To overcome the two problems, considerable efforts have been devoted to developing form-stable composite PCMs without leakage and with high conductivity [1-2].

Kaolinite is a widely studied and applied class of phyllosilicate minerals. Because of its specific physical and chemical properties, it has been used as a pigment for coatings, a filler for paper and polymers, an extender for water-based paints and inks, and a significant component of ceramics [3]. In recent years, a new application that uses kaolinite as a support matrix for PCMs has been explored [4]. However, the low loading mass of phase change materials in the composites restricts its application.

It is well known that a high specific surface area for porous materials is beneficial to encapsulate more PCMs. To improve the thermal performance of kaolinite-based form stable PCMs, two methods were used to reconstruct the pore structure of kaolinite.

The hierarchical porous materials can be incorporated with phase change materials (PCM) to overcome the leakage issue of phase change materials during phase transition due to their outstanding properties such as high surface area, unique porous structure, and excellent adsorption capacity. For the intention, an aminofunctional modification of hierarchical porous nanosheets (NH_2-HPNT), which was prepared by template-free structural reorganization method and modification with (3-aminopropyl) triethoxysilane (APTES), has been used as the stearic acid (SA) supporting materials. Meanwhile, the effects of modification on the microstructure of HPNT and thermal properties of composite PCMs were studied. The results showed that the loading mass of SA in the composite PCMs increased by up to 63.5%. Also, the thermal conductivity of NH2- HPNT/SA is higher than the raw SA. After 200 thermal cycles, the reliability of the prepared samples significantly improved. Above all the results can be

concluded that NH2-HPNT could be a promising supporting material for application in thermal energy storage.

Carbon-coated halloysite-like supporting materials (CHL) were prepared via intercalation-exfoliation and in-situ intercalator carbonization. The composite FSPCMs were subsequently developed via incorporation of paraffin within the prepared supporting material. TEM and N_2 absorption-desorption analysis indicated that the pore properties of the exfoliated and carbonized Kaol significantly increased, which was beneficial to the high loading and leakage-proof. In detail, the BET specific area is about 170 m^2/g. The effect of the carbonization temperature on the thermal performance of composite FSPCMs was investigated. The maximum paraffin content of composite FSPCMs without leakage is 60.63 %, 63.14 %, and 59.99 % while calcination at 600 ℃, 700 ℃, and 800 ℃, respectively. The paraffin/CHL composite FSPCMs have the phase temperatures of 51-58 ℃ and high latent heat of 123 -142 J/g. Compared with pure paraffin, the thermal conductivities of paraffin/CHL composite FSPCMs are increased by 1.98, 1.92, and 2.01 times for calcination at 600 ℃, 700 ℃, and 800 ℃, respectively. The composite FSPCMs exhibited excellent thermal and chemical stability after 1000 thermal cycling tests, indicating that paraffin/CHL composite FSPCMs have exceptional promise in the solar energy storage and conversion system.

Therefore, the pore reconstruction of kaolinite is a promising candidate method to improve the thermal performance of kaolinite based composite form-stable PCMs. With the advantages of abundant resources reserves and low cost, kaolinite has excellent potential in the filed form-stable phase change materials for thermal energy storage.

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Technologies and equipment for ore processing and metallurgy, their physics and chemistry

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POSSIBILITY OF COMPLETE PROCESSING OF COPPER SLAGS AND OBTAINING OF DEMANDED PRODUCTS

Over 140 million tons of slag which contains about 40% or more than 55 million tons of iron has been accumulated in the dumps of copper smelting enterprises in the Russian Federation [1]. In addition to iron and copper, slag also contains sulfur, zinc, selenium, arsenic and some other elements. Considering the quantity, iron has the highest cost in the slag. Extraction of iron by pyrometallurgical method from the waste of copper-smelting production would make it possible to obtain not only metal, but also oxide residue (slag) with lower density, suitable for use as a concrete aggregate. Thus, it is possible to dispose a huge amount of stored waste reducing the environmental issue and obtaining the demanded products [2]. Therefore, the

development of methods for the effective use of sludge and slag from the copper smelting production is an urgent economic and environmental challenge.

The aim of the work was to develop methods for the complete recycling of copper sludge with production of demanded products.

The object of the study was copper smelting sludge. The metal particles containing copper, iron, antimony and tin are present in the sludge. The oxide phase is represented by iron spinel particles and complex silicates containing iron. The spinel contains relatively high sulfur content and non-ferrous metal impurities in the silicate phase. According to the X-ray structural analysis, the major phases of the sludge are fayalite 2FeO • SiO2, magnetite Fe3O4 and pyroxene CaFeSi2O6 .

As a result of the solid-phase reduction and liquid-phase separation the following products were obtained: cast-iron grinding balls, zinc oxide concentrate, proppants (ceramic bodies for filling of fractures in oil wells) and construction sand with satisfactory quality [3].

Figure 1 - Cast Iron Grinding Balls

Figure 2 - Propants with diameter of 0.6 - 1.0

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THERMAL-ALKALI FERTILIZERS BY LOW-GRADE PHOSPHATE MINERAL PROCESSING

Central Kyzylkum phosphorites - a low grade raw material on phosphorus and rich in carbonate and chlorine [1]. Such raw material is not suitable for acid processing. To obtain high-quality phosphate fertilizers from raw materials, it must be pre-enriched. In the Kyzylkum Phosphate Plant (KPP) carried multistage enrichment: crushing, dry dressing, washing from

chlorine, sintering to remove CO_2 [2]. Technology of washing and enrichment of phosphate rock of the Central Kyzylkum includes the following operations:

- Wet disintegration of the original ore;
- Wet screening;
- Dechlorination (by washing) and filtering;

Currently KPP produces three types of phosphate materials: Washed-sintered concentrate (27-29% P_2O_5; C1 <0.04%) in the amount of 400 thousand tons per year; washed dried concentrate (18-19% P_2O_5) in the amount of 200 thousand tons per year; phosphorite meal (P_2O_5 – 16-18%) in the amount of 200 thousand tons per year. It should be noted that the enrichment of phosphate Central Kyzylkum, carried out on the KPP, with a large amount of waste.

One of the perspective directions of the processing such type phosphate raw material is a thermal treatment, which based in destruction of unassimilable by plants the crystalline structure of mineral under thermal activation. [3].

Laboratory experiments was held on study of the thermal activations of Central Kyzylkum's phosphate sample (16,53 % P_2O_5; 46,65 % CaO;15,3) with SiO_2xH_2O (chemically pure) and soda ash (99 % Na_2CO_3) in different weight ratio. In the beginning weighted components carefully mixed and sifted, after prepared tablets in diameter 50 mm and height 10-15 mm in hydraulic laboratory press at pressure of the pressing 35-40 kgs/sm^2. Prepared laboratory samples were dried at room temperature 25-30 ^{0}C within day. Afterwards tablets dried at the temperature 105-110^{0}C during 2 hours.

Dried samples were sintered in muffle furnace for 2 hours under different temperature (900 - 1250^{0}C) and after rapidly quenched. Fast cooling sample is saved amorphous structure that soluble in 2% citric acid and EDTA. Cooled samples analyzed for different forms of phosphorus and calcium (total, water-soluble and assimilable).

Results of investigation follows that, sintered mixture component (phosphate sample, Na_2CO_3 and SiO_2xH_2O) at the temperature 900^{0}C occurs the activation (the translation unassimilable into assimilable form by plants) phosphate raw material. Obtained product contains 17,06-17,35% P_2O_5 total, 45,8-49,84% CaO total.

But increasing of the temperature up to 1250^{0}C also promotes significant increase assimilable forms of phosphorus and calcium.

Thus, experiments shows, the possibility thermal activation of low grade Central Kyzylkum phosphates with alkali metal salts in destination to obtain thermal-phosphate fertilizers. Fertilizers are not hygroscopic, do not caked.

The total content of nutrients in thermal-phosphate fertilizers, ranges from 57-58% (P_2O_5 total. + CaO assim.) this salt is not water soluble. High level of solubility at 2 % Citric acid and at EDTA means that phosphate fertilizer components promotes the use of phosphorus by plants of any types of soil and is associated with a decrease retrogradation process. Being slightly alkaline thermos phosphates can be used both independently and as part of mixed fertilizers.

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DESIGN FEATURES OF DUST COLLECTING DEVICES IN METALLURGY

The technological process of obtaining steel in converters with oxygen supply from above is associated with the formation of Converter gases containing highly dispersed Converter dust, mainly iron oxide. Process dust, consisting of small iron-containing particles, is removed from the Converter to the gas-dust removal path, gas-dust collecting centrifugal devices of cyclonic action, for neutralization and purification of carbon oxides, nitrogen oxides, sulfur dioxide and dust capture. The efficiency of dust collecting devices is estimated by the concentration of dust in the purified air or gas 1,2.

Dust is a dispersed system with a gaseous dispersion medium and a solid dispersion phase consisting of particles from quasi-molecular to microscopic sizes.

Powder, powdery material - a fine-grained solid whose particle size is within the same limits as the size of dust particles.

An aerosol is a dispersed system with a gaseous dispersed medium and solid or liquid dispersed doses, whose particles can remain suspended indefinitely. The thinnest aerosol particles are close in size to the largest molecules, and the size of the largest reaches from 0.1-1.0 microns.

Aerogel - a gaseous medium with floating in it solid particles larger than 0.1 microns, which is usually called the word dust.

The use of well-known formulas is recommended to describe the particle size distribution. It is shown that the empirical formulas of Avdeev, Svensov, and Shidorin are three-parameter expressions that can be used to approximate the most common distributions of single-component polydisperse materials by particle sizes 2.

More comfortable one - and two-parameter formula of Hodaka-Andreev and Rosica of Ramler as they are universal. The most common and convenient is the Godek-Andreev formula, which describes the mass distribution of crushed materials in the following form:

$$D(\delta) = A\delta=(80/\delta')\delta', \quad (1)$$

where A and ℓ are constants; δ' is a characteristic minimum size of the particles.

At the heat and power enterprises of the CIS - West Siberian, Kuznetsk, Cherepovets, Chelyabinsk, Magnitogorsk, Nizhny Tagil, etc. various cyclone designs are installed: centrifugal and inertial.

At JSC "ArcelorMittal Temirtau" conical cyclones of Niiogaz design were installed. after comparative tests, the cyclones TSN-11 and TSN-15 were more effective, the numbers "11" and" 15 " correspond to the values of the angle of supply of gas and dust pipes in the upper part of the devices. Cyclones are convenient for possible grouping with other types of cyclones.

In industrial practice, it is customary to divide cyclones into highly efficient and high-performance ones. Cyclones TSN-11 and TSN-15 are highly effective. The efficiency of dust capture in cyclones depends on the size and density of the captured particles, the gas velocity at the entrance to the cyclone, and the gas density. The maximum speed of gas supply depends on the diameter of the cyclone and the dispersed composition of the dust. It is established that the optimal speed of the gas flow at the entrance to the cyclone is 2.0-3.5 m/s. Large and denser particles are captured in cyclones much more efficiently than small ones, since they are affected by large centrifugal forces.

It is characteristic that with an increase in the speed of the gas flow entering the cyclone, its efficiency increases.

Figure 1.1 shows the dependence of the efficiency of cyclones on the hydraulic resistance ΔP and on the air flow QB.

ArcelorMittal Temirtau JSC has installed not only conical, cylindrical and combined cyclones for gas removal – centrifugal and inertial, but also wet dust collectors: centrifugal scrubbers, high-speed dust collectors, Venturi pipes, as well as bubbling and foam dust collectors [2].

Wet dust collectors are very effective for removing particles with a diameter of more than 0.3 microns from dusty gases, as well as for cleaning hot explosive gases from dust [1]. The results of the study showed that wet dust collection is characterized by high efficiency, the ability to clean gases with a high initial temperature, low costs for the technological process of gas separation and the formation of iron-containing slurries. For the treatment of sludge water, during wet dust collection, the sludge is discharged into the recycling water supply system of the Converter production for subsequent supply to the radial settling tanks.

From figure 1.1 it follows that the cyclone "matryoshka" is ineffective, which has a very low separation efficiency, and is also metal-intensive. In scrubbers, dusty gases, at a speed of up to 20 m/s, are fed tangentially through the inlet pipe to the lower part of the cylindrical body. As a result of this supply, the gases acquire a rotational movement inside the body. Under the action of centrifugal forces, particles are deposited on the inner surface of the housing, and water flows down the surface of the housing, wetting the particles and carrying them to the lower conical part, from which the slurry water is continuously removed from the device through a hydraulic seal, which provides flushing nozzles for water supply and flushing out the deposited slime.

The efficiency of precipitation in a wet dust collector, as shown by tests, is 80 %, with a water consumption of 100 grams per 1m3 of the gases to be cleaned [2].

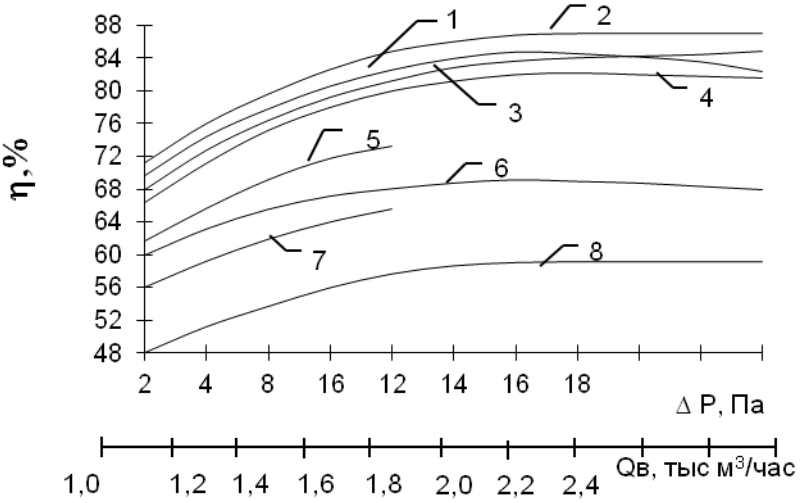

Figure 1 - Dependence of the separation efficiency and types of cyclones on the hydraulic resistance ΔP and on the air flow QB. 1 - "TSN-11"; 2 - "TSN-15"; 3-Cyclone Vcniiota; 4-Snot designs; 5-Lyota designs; 6-TSN-15U; 7-TSN-24; 8 - "Matryoshka"

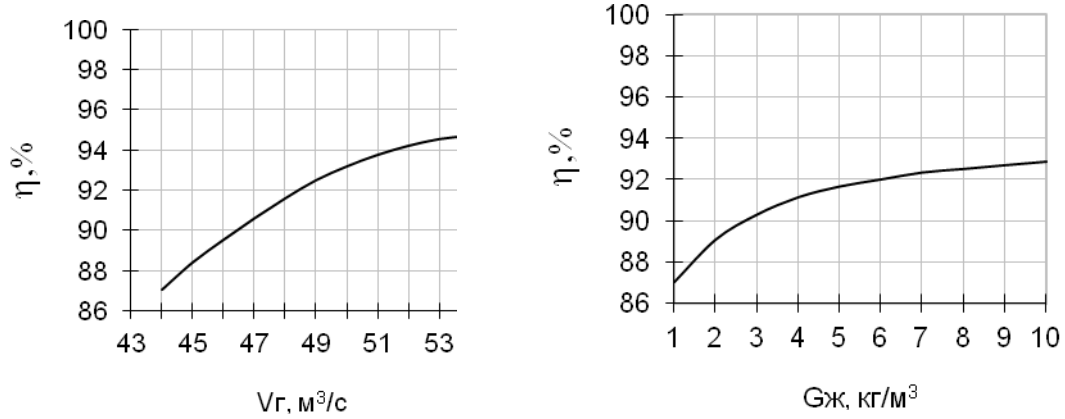

Figure 2 - Dependence of effective separation of the dust collector with Venturi pipe from gas flow QG (a) and liquid flow (b). a - dry cleaning, b - wet cleaning

As a result of a sharp decrease in the flow rate in the cylindrical part of the cyclone body and a decrease in the centrifugal forces, droplets settle on the inner walls of the cylindrical part of the cyclone body and then are fed through the slurry pipe to the recycling water supply system and enter the radial settling tanks.

Studies have shown [2], increasing the speed of the feed stream of slurry, increase the concentration of the contained suspended particles and the increase in flow rate increase the efficiency of the dust collector, figure 1.2.

Dry cleaning (figure 1.2, a) the efficiency of the collector increases with the velocity of the gas stream and the concentration of the contained dust; with increasing liquid flow rate in the Venturi tube, the efficiency of dust collection is increased (figure 1.2 b).

Data analysis shows that the yield of iron-containing slurries and dusts at power plants in the CIS is about 15 million tons / year . The total coefficient of their use is 76.5%, including 53% of iron – containing slurries. Almost completely used grate dust and large scale, the degree of use of slime is: agglomeration-79%; Converter-31.6%; open-hearth - 20%; blast furnace-42.5%; fine scale-46.9%.

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MINERALOGICAL INTERPRETATION OF A RARE-METALS GRANITE DEPOSIT USING AUTOMATED MINERAL ANALYSER

Pegmatites are source of a variety of metals that are valuable for new technologies and that in different contexts are critical. Such is the case of Lithium, whose reserves are mainly present in Chile (8.6 Mt). In case of resources this country along with Bolivia and Argentina account for 64% of world resources in continental brines [1]. Produced mainly in Australia from spodumene ores (the most abundant Li-bearing mineral), this light metal is nowadays used mainly in battery manufacturing with 65% of end-use application [1]. Indeed, the demand of lithium is expected to growth at a rate of 19% per year up to 2028, while rechargeable batteries expected to grow eight times more up to 1 Mt of Lithium Carbonate Equivalent (LCE) by the same year [2]. Other metals present in pegmatites are Niobium and Tantalum which are produced majorly by Brazil and Rwanda respectively at 90% and 31% globally. Beryllium is majorly produced by the USA and used mainly in military purposes. All these metals are classified as critical by the European Union (EU), as the majority are imported from different countries.

Many greenfield projects were under development in the recent years where Li minerals (spodumene, lepidolite, hectorite, amblygonite or petalite) are in abundance [3]. In the EU context, the Variscan orogeny has an important lithium content with >60% of the identified deposits with approximately 8.8 Mt of Li_2O identified in minerals such as spodumene, lepidolite and zinnwaldite [4]. Geological characterization through different techniques is vital to give some

insights of how the ore may behave during concentration as well as subsequent processing which are influenced by mineralogy, chemical composition, particle size, mineral association along with liberation parameters. This type of characterization addresses the challenges of sustainability, producing cleaner concentrates.

In the present research, an attempt was made to study a rare metal granite deposit from Variscan orogeny. Different characterization in terms of physical, chemical and mineralogical properties are evaluated for this rare metal deposit. Six different samples were collected in the form of drill cores and subjected to assess these properties. The chemical properties of these samples were studied through X-ray Fluorescence (XRF), Inductively Coupled Plasma Mass Spectrometry (ICP-MS), Atomic Absorption Spectroscopy (AAS) to quantify different elements and metals present. The mineralogical investigation was carried out by using X-ray Diffraction (XRD), Scanning Electron Microscopy (SEM), Electron Probe Micro Analyzer (EPMA) and Laser-Induced Breakdown Spectroscopy (LIBS). Further, liberation analysis was studied by using an automated mineral liberation analyzer (MLA), as well through sink-float analyses. Finally, an effort was made to compare these three deposits through these characterization techniques.

From the characterization studies, it was found that the ore deposits contain Li as a major mineral along with Sn, Nb, Ta, and Be as secondary minerals at a lower grade. Geochemical correlations that were found for the orebody are in agreement with the literature reported for these types of granites, which are characterized by the depletion of Fe, Mn and Mg in favor of more sialic elements like Na, K and Al. Further, it is found that the paragenesis of the orebody led to determining that muscovite can be associated with lepidolite series (main Li-bearing mineral in the deposit). Li concentration is varied at a broader range in between 3000 to 4200 ppm. The mineralogical analysis revealed that 90% of the orebody is abundance by albite, muscovite, quartz and K-feldspar. Liberation analysis in these deposits indicated that muscovite could be found liberated in between 45%-65% while grounded at particle size below 1 mm. Average size of ore minerals can be found in Figure 1 below.

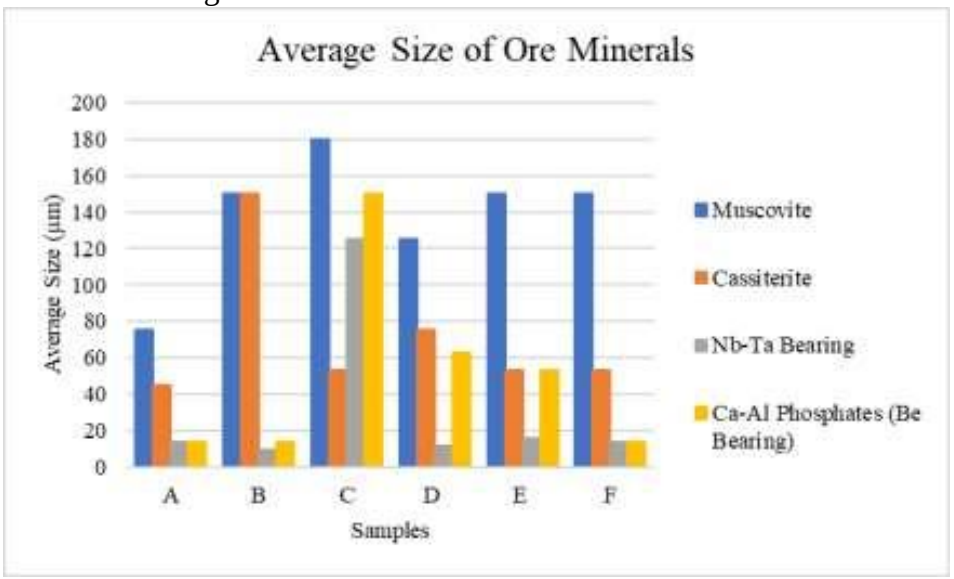

Figure 1 - Average size different ore minerals present at a Rare Metals Granite of Variscan Orogeny

Also noticed that muscovite grains could be liberated at particle size between 300-500 µm. When liberation of muscovite range in between 50%-90% can be recovered at mass recovery 50-80%. Other than Li, Nb-Ta minerals are associated mainly with quartz, whereas calcium phosphates (which are accounted for Be) are primarily associated with Albite. Based on these findings, ore bodies can be classified for the beneficiation, and an optimum flowsheet comprising of flotation and gravity separation can be designed for the effective recovery of these critical metals.

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FEATURES OF SURFACE INTERACTIONS OF A CARBOXYLINE REAGENT AND ALKYL ESTERS OF PHOSPHORIC ACID WITH APATITE

Flotation is the only way to enrich apatite from apatite-nepheline ore nowadays. Due to constant increasing volumes of production apatite concentrate, number of apatite in the origin ore is decline. This trend creates a demand for new effective reagent modes. Using a mixture of certain collectors allows getting a synergistic effect during flotation [1, 2].

In this work, the effect of collectors of various compositions on the foam flotation of Apatite ore at high pH values was studied. A synergistic effect (Figure 1) was found when using a mixture of saponified crude tall oils (SCTO) in combination with Phospholan PE65 (Phospholan PE65 is an anionic surfactant of an alkyl phosphate ester). This phenomenon can be explained by optimizing the intermolecular interaction in the sorption layer.

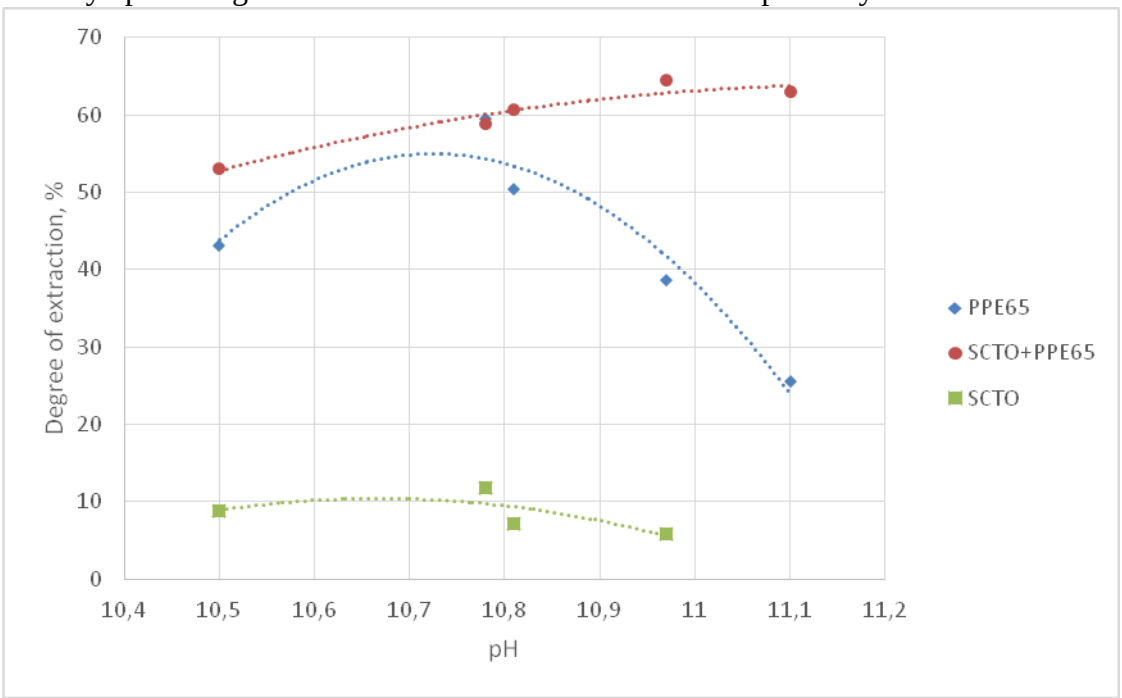

Figure 1 - Dependence of the degree of P2O5 extraction on pH when using collectors of different compositions.
PPE65 – Phospholan PE65; SCTO+PPE65 – [38% Distilled tall oil (sap.), 31% Deciduous tall oil (sap.), 31% Coniferous crude tall oil (sap.)] + PhopholanePE65 – In a 3:2 ratio; SCTO - 38% Distilled tall oil (sap.), 31% Deciduous tall oil (sap.), 31% Coniferous crude tall oil (sap.)

The spontaneous process of formation of organic supramolecular structures is based on interactions involving coordination links with Ca2+, donor-acceptor and electrostatic interactions between phosphoryl and carboxyl solidophilic groups.

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ECO-FRIENDLY RECOVERY OF GOLD IONS FROM THIOSULFATE SOLUTIONS USING ZERO VALENT ALUMINUM (ZVAl) AND ACTIVATED CARBON (AC): EFFECTS OF COMPETING IONS ON GOLD RECOVERY AND CHARACTERIZATION OF GOLD LOADED ZVAl/AC FOR DEVELOPMENT OF A GOLD STRIPPING METHOD

The need for innovation in eco-friendly green technologies to be used for safer mineral processing methods has led to significant attention being given in finding alternatives for toxic and corrosive chemicals such as cyanides and halides conventionally used in gold leaching [1]. Ammonium thiosulfate leaching has been identified as a possible alternative method, however recovery of the Au ions from the thiosulfate solutions remains one of the impediments in the implementation of this technique [2]. The use of zero-valent aluminum (ZVAl) and activated carbon (AC) to recover gold ions from thiosulfate solutions is a new and unique phenomenon that is promising to eliminate the current challenges since it has been reported that high gold recovery can be attained by their use [3], [4].

The method was evaluated using the gold leaching solution and results show that when ZVAl and AC are used independently, Au cannot be recovered. However, when used together, ZVAl and AC can recover Au effectively (i.e., >99%) from thiosulfate solutions. An investigation was also done on the effects of cat ions namely; Cu^{2+}, Ni^{2+}, Fe^{2+}, Zn^{2+} and Co^{2+} that possibly co-exist with Au in different ores and may compete with Au ions during recovery stages. Results revealed that the competing ions had varying effects on Au recovery, however when Cu ions are present in solution, other competing ions had minimal effect on Au recovery as it remained high when competing ion concentration was increased.

After successful Au recovery from thiosulfate solutions, the next stage of the process flow would be to separate the Au from the ZVAl, and in order to establish a basis for the development of an accurate procedure, a detailed analysis of the ZVAl/AC residues was carried out using a Mineral Liberation Analyzer (MLA). Results showed that composition of the recovered Au minerals exists in three categories; i) pure gold (6%), ii) Au-Cu alloy (49%) and iii) Au-Cu alloy highly associated with ZVAl (44%). There is also a significant difference in size between ZVAl and Au minerals as the D_{50} for ZVAl was found to be 27 μm while the D_{50} range

of Au mineral categories was 2.4 μm to 3.4 μm. The density of Au dominant minerals was found to be high at 13-18 g/cm^3 while that for the Al dominant minerals was 0-5 g/cm^3.

In conclusion, ZVAl and AC can be successfully used to recover Au ions from thiosulfate solutions, and in the presence of Cu ions in thiosulfate solutions Au ions can still be selectively recovered successfully despite the presence of competing metal cations. Characterized ZVAl/AC residues show that Au minerals exist as fine-heavy particles while ZVAl particles exist as large-light particles. Subsequent gold stripping (or separation) procedures can therefore be developed based on size, density, and liberation differences of the minerals in the ZVAl/AC residues.

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STUDY OF JOINT-FORMATION OF MINERALS OF "ERDENETIIN OVOO" DEPOSIT

KEY WORDS: ore, mineral, chalcopyrite, pyrite, quartz and joint-concentration.

In 33rd article of Mongolian underground law indicated that "Hereafter, about studying compositions of minerals, raw materials and their technologies and improving processing technologies". Copper concentrate is major exportation product of Mongolia and upgrading production of concentration of copper ore has been issued as fundamental matter.

For "ERDENETIIN OVOO" deposit, there are areas of oxidation, dissolution, compound ore, concentration of 2nd sulfide and 1st sulfide of ore through the vertical area. Deposit is in form of stockwork and body of ore does not develop threshold with rock that which contains and cracks in the ore before and after the metallizing process differentiate from one another and generate setback and negative influence in technology of metallizing process and technology process.

In this research work, experiments and research in regarding to the types of joint-formation of ore minerals resulted in to foresee difficulties that occur during joint-metallizing process when mining ore, to choose efficient and optimal version and presented a method to increase efficiency.

The aim of research work: regarding to the type of joint-formation, to optimally and efficiently operate joint-metallizing process of copper molybdenum.

1. To conduct research by type of joint-formation of minerals.
2. To study the impact of the joint-formation of ore of "ERDENETIIN OVOO" deposit on the joint-concentration process.

Research method: the calculation and research performed on EXCEL software, MICROMINE mining software, integrated planning and monitoring MAS (mining analysis system) of 'ERDENET MINING CORPORATION' LLC.

Study of joint-formation of mineral of Erdenet deposit and its results.

Scientists from Russia and Mongolia have determined that the ‘ERDENETIIN OVOO’ deposit contains the following types of ore mineral compounds [1]:

1. Magnetite (FeOFe2O3)
2. Pyrite (FeS2) quartz (SiO2)
3. Molybdenite (MoS2) pyrite (FeS2)
4. Chalcopyrite (CuFeS2), pyrite (FeS2), quartz (SiO2)
5. Chalcosine (Cu2S), bornite (Cu5FeS4)
6. Polymetallic (galena (PbS), sphalerite (ZnS), tennantite (Cu12SbS13)
7. Bornite (Cu5FeS4), chalcocite (Cu2S), covellin (secondary sulfide concentration zone).

Of these, chalcopyrite-pyrite-quartz and pyrite-quartz are present in the northwestern part of the deposit. In the southeastern part of the deposit, hundreds of meters from the central fault, chalcocite-bornite, molybdenum-quartz, pyrite-quartz and polymetallic ores are formed. Figure 1.

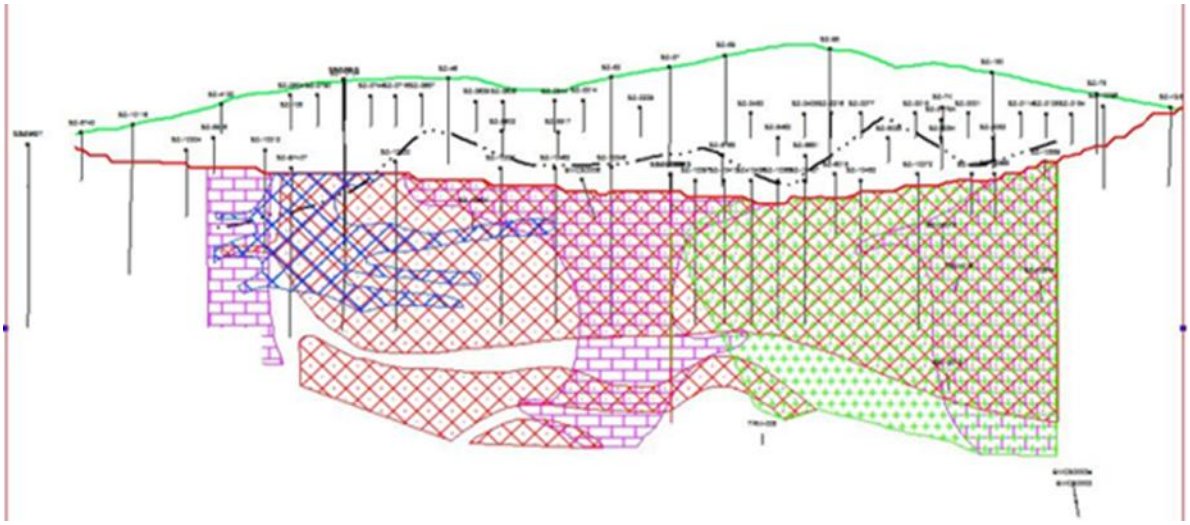

Figure 1 - Mineral distribution of ‘ERDENETIIN OVOO’ ore, as of September 2019

Note: - joint-formation of chalcocite bornite, - joint-formation of pyrite quartz, - joint-formation of molybdenite-quartz, - polymetallic, - exploration wells, its number, - land surface, - mine bench, - the boundary of the secondary concentration zone

Pyrite quartz compounds occur in the periphery and central part of the deposit. Molybdenite quartz joint-formations are quite common in all layers of secondary and primary ores, but their quantitative manifestations are different. The main minerals in the molybdenite joint-formations are molybdenite, quartz, pyrite, and chalcopyrite, and the accompanying impurities are Re and Se.

Minerals such as chalcopyrite-pyrite-quartz have hydrothermal origin. The chalcopyrite-pyrite-quartz bond is considered the most efficient. It is very common in the deposit, but is replaced by lower (hypogenic) chalcocite bornite in the southeast. Chalcopyrite and pyrite are inlaid, nested, irregularly shaped, forming pyrite-chalcopyrite veins. The thickness of the chalcocite bornite ore zone varies up to 400 m in the southeastern part of the deposit. The location of this ore in the vertical part of the deposit is ambiguous: it is located below the secondary concentrate sulfide ore, and in some cases intersects several times in the deep part of the deposit with the primary chalcopyrite-pyrite-quartz ore. The mineral composition of chalcocite-bornite joint-formation is very diverse and is dominated by bornite, including chalcocite, chalcopyrite, pyrite, sphalerite, tennantite, galena, molybdenite and rutile. Polymetallic joint-formations (galena-sphalerite-tennantite) are located in the zone of secondary enrichment and primary ore, and have been studied in the periphery and center of the deposit. By

defining the boundaries of ore mineral cohesion, it is possible to anticipate the difficulties of co-concentrating during ore mining and to select the most technologically efficient option. Technologically efficient options for each ore combination have been identified through experimental studies. The researcher [2] conducted experiments on chalcopyrite-pyrite-quartz and pyrite-quartz ore to determine the effect of copper and non-ore mineral concentrates on copper extraction and copper content. Figure-2

Figure 2 - Correlation between mineral content in ore and copper content in joint-concentrate

The copper content of chalcopyrite is 34.57%, which is due to the predominance of primary sulfide ore, which reduces the quality of copper and copper recovery in the concentrate, but depends on the jointly-formating of non-metallic minerals. Chalcopyrite coexists with aluminosilicate [3]. As the free silicon oxide joint-concentration in the ore decreases, the aluminum oxide content increases, which negatively affects the copper recovery and copper content in the concentrate. Since it is not possible to mine and concentrate from only one type of ore mineral complex, Figure 3 averages the ore extracted from different mine benches in terms of mineral content.

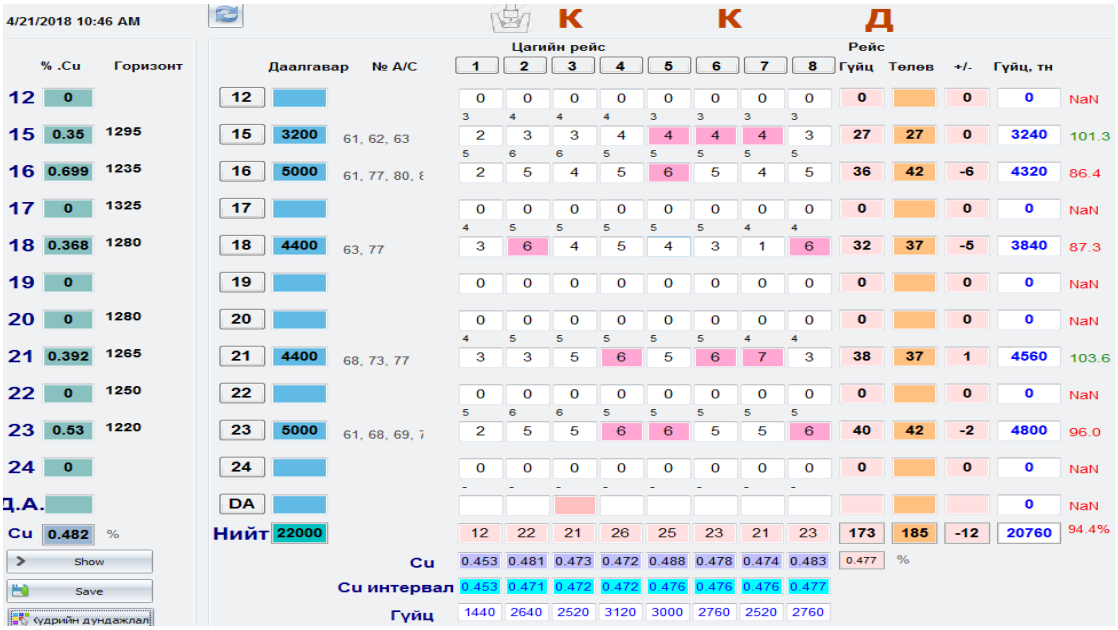

Figure 3 - Monitorin card for ore mining planning and performance

Explanation: 12-24 - excavator number, DA - internal warehouse; Cu - 0.35 - 0.699,%; - copper content of the ore to be mined; 1220-1325 - number of open pit ore mining levels / horizon /;

3200-5000- mining ore planning, tons; 61-80 - number of ore transportation vehicle (BELAZ);
Cu - 0.453 - 0.483 - copper content,%

It is possible to control the mineral content of the ore being shipped from the open pit bench to the concentrator.

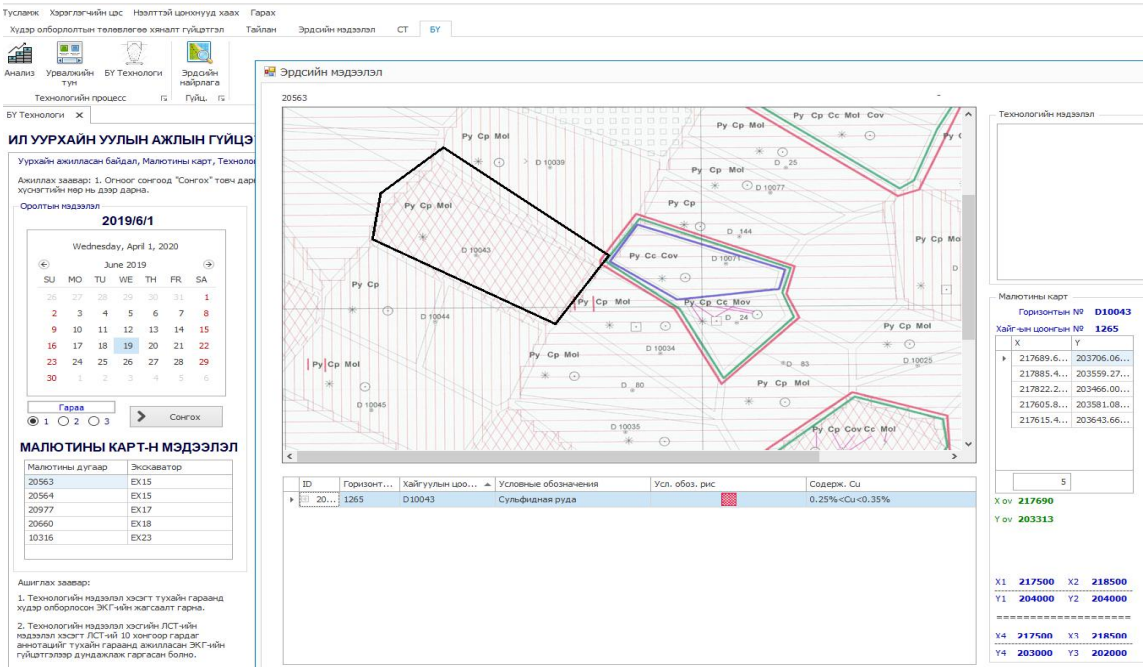

Figure 4 - Information on ore in open pit bench

Explanation: It shows the main minerals in the working block of the excavator when click on the number of the excavator operating on the mine bench.

Ore content planning is changed when equipment is stopped at one of the open pit benches, the enrichment process may fail when moving an excavator to another bench with the same content of copper. It is related to the fact that the ore properties of the bench have a different mineral structure depending on the valietral generation. Mineral information of 'Erdenetiin ovoo' deposit is monitored electronically using a MAS (mining analytical system) control system in order to define it and to properly manage the technological process. Figure 4.

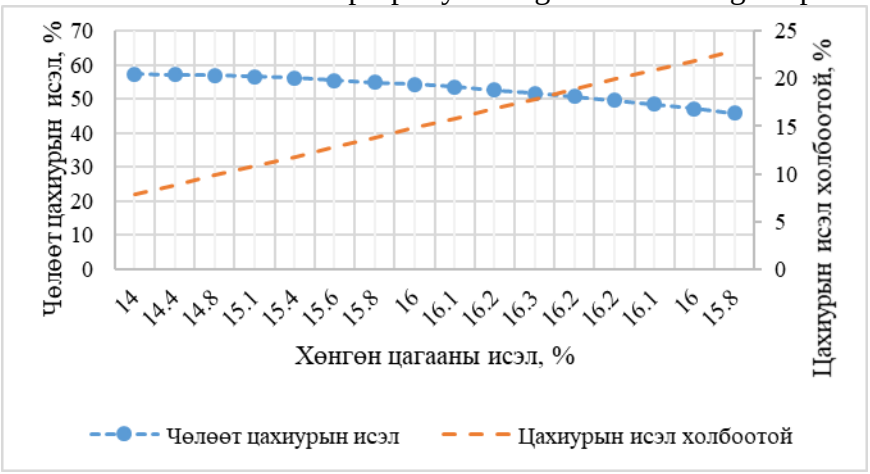

Figure 5 - Correlation between increase in alumina and silica (related), decrease in silica

Much of the non-metallic minerals are formed from silicates it is the 85% of the earth stone coverage. The test result shows that the reduction of silika bring the increase in alumina (correlation cofficient -0.9), The increase in alumina is directly related to the increase in associated silica (correlation cofficient 0.81) figure 5. The absolute economic efficiency of each

useful mixture is determined by the following formula in order to define the rational indicator to separate completely the i type minerals of valietral generation of [6-7].

$$Эei = \frac{Ai * Цi * Рэi}{Ki},$$

Where: Ai – i one year production amount of the product in i, by the unit of the weight.

$Цi$ - – i wholesale price of the product in i

$Рэi$ - i a year opeational expenditure to separate profitable mixture in i

Ki - i The investment required to extract the profitable mixture in i

Depending on the mineral valietral generation in the ore, the rational dose of the reagent is given by the following formula.

$$У = \frac{\sum_{i=1}^{7} Qi * Уi}{\sum_{i=1}^{7} Qi}$$

Qi – the amount of ore loading with the valietral generation i type in the given shift, ton

$Уi$ - the rational dose in ore concentration reagent with i type valietral generation g/ton.

$\sum_{i=1}^{7} Qi$ – the amount of total ore loading, ton

Rational yield of 74 μm whole class of ore grinding can be determined by the above method.

$$Б_{-74} = \frac{\sum_{i=1}^{7} Qi * Бi_{-74}}{\sum_{i=1}^{7} Qi}$$

Qi – the amount of ore loading with the valietral generation i type in the given shift, ton

$Бi_{-74}$ - rational yield of 74 μm whole class of ore grinding with valietral generation in i type, %

$\sum_{i=1}^{7} Qi$ – total ore loading amount, ton

The ore minerals are the same in terms of profitable components, but it can be different depending on the nature of the technology, this study shows how this can affect the technological process accordingly.

Conclusion:

1. ‘Erdenetiin Ovoo’ deposit’s geological section was mapped showing the operational frame by September 2019, based on the documents studied by Russian and Mongolian scientists.

2. Had test research by the type of valietral generation on ore pyrite-quartz and chalcopyrite-pyrite-quartz ore types, the copper content in chalcopyrite in ($CuFeS_2$) is 34.57%, therefore the copper quality and copper recovry is reduced when sulfide ore dominated, but depends on the co-existing content of non-metallic minerals.

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IMPROVEMENT OF THE PROCESSING TECHNOLOGY OF THE LEAD COMPONENT OF BATTERY SCRAP

At the Institute of Non-Ferrous Metals and Materials Science of Siberian Federal University work is underway on complex mechanical and electrical cutting of lead acid accumulator scrap to produce liquid stand-alone products (electrolyte solutions, polymer materials out of disassembling cases and lead composition represented by lead alloys, as well as dispersed chemical compounds PbO, PbO_2, $PbSO_4$, PbS and Pb^0). The relevance of the task seems extremely significant for the reasons for the increasing consumption of lead, primarily for the production of before-mentioned products and a short depreciation of products.

Following are objects of study:

- Improving the technology for disassembling amortized accumulators
- improvement of the metallization technology of the oxysulfate fraction of accumulators during joint processing with lead alloys with unconditional refining of compact metal.

At both stages environmental safety and reduction of energy consumption should be ensured. Existing methods for the implementation of stages do not ensure compliance with these requirements.

It is proposed that after draining the electrolytes from the rechargeable washing units with reagent solutions with incidental leaching of filter sludge and separating them from the solutions, an electromechanical separation of the polymer component is provided.

Compact lead alloys and sludge go to the joint metallurgical processing including the melting of the compact component and the recovery of lead from chemical compounds. The reduction of metal from oxygen slurry compounds by elemental sulfur in molten caustic soda, into which the processed material is fed, is proposed.

The chemistry of recovery is described by the equations:

$$3PbO + S + 2NaOH = 3Pb + Na_2SO_4 + H_2O$$

$$1.5PbO_2 + S + 2NaOH = 1.5Pb + Na_2SO_4 + H_2O$$

The lead sulfate included in the composition interacts with alkali and turns into hydroxide, followed by reduction of lead:

$$3Pb(OH)_2 + S + 2NaOH = 3Pb + Na_2SO_4 + 4H_2O$$

The thermodynamic probability of occurrence of these reactions, starting from a temperature of 320°C, is proved.

Oxisulfate sludge composition, %: $PbSO_4$ - 70; PbO - 6.7; PbO_2 - 4.5 and PbS - 0.9 are processed in a plant consisting of a steel reactor equipped with a paddle mixer with a speed controller, placed in a shaft electric furnace with a temperature controller (550-700°C).

The conditions of deep metal reduction (> 99%) are experimentally determined. It was shown that metallization begins with a temperature of more than 500°C. However, the metal is represented by fine particles in an alkaline melt that not merging into a "lens". The effective formation of a compact melt takes place at temperatures above 550°C. The process is accompanied by mixing a solid-fluid system (50 rpm). At the same time, the consumption of elemental sulfur for processing a unit mass of oxysulfate sludge is from 5-8%.

After draining the reduced lead, a new portion of sludge is mixed with sulfur in the melt. After processing 5-7 downloads of sludge to remove sodium sulfate the method of salting out from aqueous caustic solutions is used, followed by salt conversion to obtain a liquid product.

A feature of the metallurgical redistribution is the transience of the reduction reactions (up to 15-20 minutes), environmental safety (lead and its compounds are under a layer of the technological environment - caustic soda), and a relatively low temperature of 650° C. The proposed technological system easily implements lead refining to the condition required in the production of accumulators.

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MINING OXYGEN ON THE MOON: TRANSFORMING DRY MINERAL PROCESSING FOR SPACE AND EARTH

In-Situ Resource Utilisation (ISRU) is essential to enable the further exploration of space by humankind. Off-Earth feedstock will provide propellant, oxygen, water, and building materials, allowing further travel and habitation. The production of oxygen from lunar soil, or regolith, has received particular attention in recent years as it can be used both for life support and propellant for further missions. A wide range of chemical extraction processes to produce oxygen from lunar regolith have been developed. The overall flowsheet is, however, similar to that of terrestrial metal production from a mined ore. The process flowsheets both include excavation, haulage and beneficiation of the regolith or ore to provide the feedstock for the chemical extraction of oxygen or metal.

For example, hydrogen reduction of the lunar regolith produces oxygen as a result of the reduction of ilmenite; a high ilmenite content is therefore preferable, however lunar regolith contains less than a few percent and must be upgraded first. Additionally, sizing to remove coarse and fine fractions is also required to control the feedstock into the reactor. Terrestrial mineral processing technologies will not work directly on the Moon, due to the low gravity, lack of atmosphere and, critically, the lack of water. Dry processing is the only viable route for regolith beneficiation.

Electrostatic beneficiation is of particular interest, as it does not require a process fluid and is enhanced by the absence of water. Furthermore, ilmenite is amenable to concentration using electrostatic methods, and is used widely in the beach sands sector terrestrially. here, the potential for electrostatic beneficiation on the Moon is discussed, showing results from a freefall tribocharging electrostatic separator purpose-built in our laboratory, in which it is shown that there is an optimal electrostatic field strength for particle recovery. Furthermore, we discuss the scale of lunar mining operations to produce 1000 kg/y O_2, and the potential for crossover of technologies and concepts into terrestrial mining operations.

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THE SEPARATION OF ND AND PR BY NONSTATIONARY EXTRACTION BY 2-ETHYLHEXYL PHOSPHONIC ACID MONO-2-ETHYLHEXYL ESTER

The similar chemical properties of f-elements do not allow the developing the effective schemes of separation, based on extraction by different solvents. The low efficiency of the separation of rare earths metals by extraction on one stage requires the combination of a large number of mixer-settlers in a cascade. The creation of a separation manufacture requires the large investment, therefore, at present, the problem of increasing of the rare earth elements separation factor is extremely urgent. In [1], the specification of technologies of producing of purity rare earths metals from the natural and technogenic raw materials, which applied in China, is presented. Achievements of global rare metal industry are presented in the monograph [2].

A nonequilibrium nonstationary extraction separation process, which combines the new principia of organization in the frames of traditional equipment, can compete with the traditional equilibrium completely exchange process. In the recent decade appeared the works dedicated to the methods of the separation of elements, which used nonstationary processes, based on the differences in the kinetics of the chemical reactions. At present, the mechanism of the kinetic of the interphase transfer in the extraction processes is being study [3]. In [4], high efficiency of a nonstationary process for the separation of rare earths metals, compared with it under the equilibrium conditions is shown. In [5], an increase of separation factor of the pair Nd/Pr under nonstationary conditions by TBP liquid membrane from nitric media using the periodic oscillations of temperature in the extractor was described.

We offer to use the principle of a nonstationary extraction in separation process of the pair of Nd/Pr from chloride medium by the extractant based on P507. 2-ethylhexyl phosphonic acid mono-2-ethylhexyl ether (PC88A, HEHEHP, EHPNA, P507) - the most selective commercial extractant for separation of REE. In the last 15 years, it shifted out the classical TBP and D2EHPA from technology of producing of individual rare earths metals of light group [6]. The results which have been received by an experimental setup allowing the monitoring the influence of cyclic change of physical-chemical parameters on an extraction in the online mode are discussed. Comparison of two ways of implementation of an extraction in the nonstationary mode is carried out. The results of some experiments on the set-up are shown in the Figure, as times profiles of the main parameters of the system.

From the left graph in the Figure it is visible that with oscillation change in temperature in the reactor a periodic increase in the separation factor $\beta_{Nd/Pr}$ to 2.6 ± 0.1 was achieved. This effect is possible if the extraction system heats up or cool faster than the state of thermodynamic equilibrium is established.

From the right graph in the Figure it is visible that with oscillation change in the acidity of the aqueous phase, the effect of increasing the separation factor is not achieved, with the addition of acid or alkali, a decrease in $\beta_{Nd/Pr} < 1.0$ and subsequent return of the system to equilibrium state to $\beta_{Nd/Pr} = 1.6 \pm 0.1$ occurred.

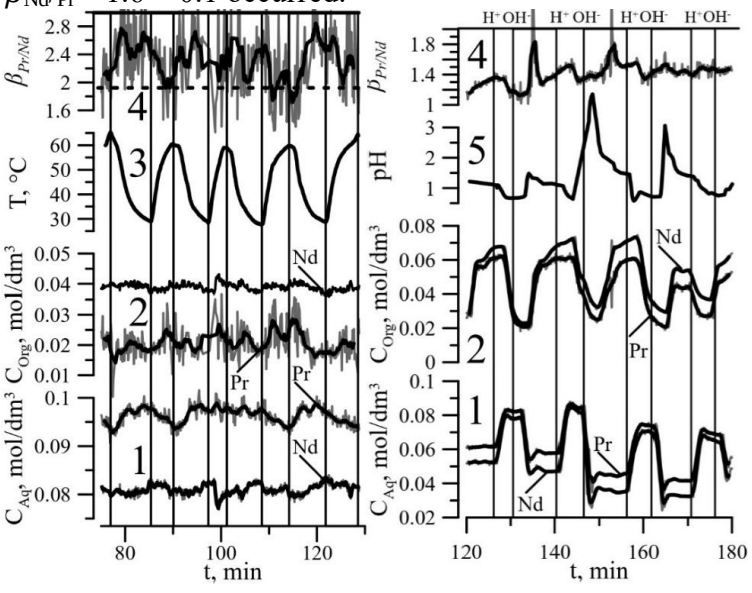

Figure 1 - The times profiles of the main parameters of the system during a cyclic change in temperature in the reactor (left graph) and a cyclic change in pH (right graph): 1 – the concentration of Nd and Pr in the aqueous phase, 2 – the concentration of Nd and Pr in the organic phase, 3 – the temperature in reactor, 4 – the separation factor of Nd/Pr pair, 5 – the pH in the raffinate

Based on the observed phenomena, the effective mode for extraction separation of rare earths metals has been created.

The values of the extraction constant (K_{Ex}) in the range of 15 – 60 °C were calculated from experimental data for joint extraction of Nd and Pr with the extractant based on P507 from chloride media. The values of the changes in enthalpy (ΔH) and entropy (ΔS) were calculated for each metal from the temperature dependence of the extraction constant.

The Ministry of Education and Science of the Russian Federation supported the research (state task 0785.00.X6019).

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THERMAL ACTIVATION OF THE SINTERED KAOLIN-LIMESTONE MIXTURE FOR ALUMINA EXTRACTION

The aluminum industry is one of the fastest growing global sectors in the world, especially among developing countries. Increased worldwide demand for aluminum oxide, currently at more than 160 million tons per year, is expected to lead to a gradual global decline of high-grade bauxite. In addition to that the high-grade bauxite is concentrated in limited number of countries and the high cost of transporting the raw materials [1].

Many aluminum-producing countries have thus become increasingly interested in developing alternative technologies to produce alumina from non bauxitic sources with the intention that these technologies will lead to a significant reduction in the consumption of bauxite ore and transportation costs. In recent decades, kaolin and kaolinite-based solid wastes such as coal fly ash and oil shale have attracted considerable attention for alumina extraction due to the high content of alumina in these ores and they are distributed on a large scale in the world [2].

Thermal treatments at a controlled temperature range and mechanical treatments were generally employed to activate kaolin before the acidic or alkaline extraction procedure of

alumina due to the low chemical reactivity of kaolinite. Thermal treatment processes such as calcination is an effective method to activate the kaolin ore through dehydroxylation of kaolinite [3].

The calcined kaolin can be transformed into metakaolinite, amorphous SiO_2 and Al_2O_3 after calcination at appropriate temperature. After calcination, kaolin has excellent product properties such as high chemical activity, high whiteness and high dissolution degree of aluminum, which can be widely applied in the production of paper, functional materials, building materials, alumina and chemical products. However, the temperatures outside the reasonable ranges could lead to the beginning of crystallization, the presence of new stable phase (mullite and cristobalite etc.) and the decreased activity in calcined products. Therefore, in order to get high-quality calcined kaolin, the calcination temperature should be controlled accurately [4].

According to the literature review, little studies were carried out in studying the thermal activation of the kaolin-limestone mixture using the carbonaceous additives and its effect on the percent recovery of alumina and on the efficiency of the self-disintegration process of the sintered mixture.

The effect of thermal activation on improving the alumina extraction efficiency from kaolin ore processed using the lime-sinter process has been investigated. Charcoal and the residue of anodes after using in aluminum electrolysis plants were added to kaolin-limestone mixture in the range 1-4% of the charge mass then sintered in the temperature range 1250-1360°C. The sinters obtained at different sintering temperatures and the sludges produced from subsequent leaching of the produced sinters using sodium carbonate solution were characterized by means of X-ray diffraction analysis (XRD), X-ray fluorescence spectrometer (XRF) and particle size distribution analysis (PSD). The sinters obtained from the sintering process were leached under the following conditions; 120g/L Na_2CO_3 solution concentration, 70°C leaching temperature, 1/5 solid to liquid ratio, 15minutes leaching time.

The results indicated that is the coal addition has positive effects on increasing the percent recovery of alumina from kaolin that can be attributed to the increased temperature produced from the compassion of the added coal which accelerate the decomposition of calcium carbonate and the dehydroxylation of kaolinite mineral. The maximum extraction of alumina reached 82.69% with the addition of 1.5% charcoal and 80.59% with the addition of 2.5% anodic coal at 1360°C.

It is clear that there is about 7.12% difference in the percent recovery of alumina at the best sintering conditions and under the used leaching conditions. The higher addition of coal leads to decreasing the percent recovery of alumina which can be attributed to the high temperature produced from the compassion of the added coal that helps in the formation of mullite ($Al_2O_3.SiO_2$) phase from which alumina is difficulty extracted.

The coal addition has positive effect on the carrying out of the self-disintegration process at low temperature compared to that carried out at high temperature without the addition of coal and hence increase the percent recovery of alumina at the low sintering temperature.

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MICROWAVE ACTIVATION OF KAOLIN ORES FOR THEIR PROCESSING BY ACIDIC METHODS

Microwave processing of materials has recently found application in metallurgy, but over the past 10 years it has gone beyond the scope of laboratory research and is gaining momentum on an industrial scale. Microwave ovens are mainly used for drying coal in various fields, including steel production and regeneration of granular activated carbon in gold metallurgy. Microwave units are installed in Canada, the USA and China. Also in the literature it is reported that there are studies in the treatment of sintering of magnetite concentrates, drying of agglomerates, utilization of metal dust and processing of ceramics [1]. This indicates the possibility of applying microwave to the processing of kaolinite ores in order to obtain alumina.

Perspective direction in the process of kaolinite ores is thermal modification. This process allows to reduce the negative impact of layered silicates on the main technological operations by changing their physical and chemical properties and to increase the reactivity of kaolinite. This fact makes the extraction of alumina from kaolinite ores by acid leaching possible.

The main technological operations of acid processing of clay ores include thermal modification of pre-ground kaolin, leaching under atmospheric conditions, filtration the pulp with separation of silicate sludge, acid regeneration, iron removal, extraction of Al^{3+} and calcination of $Al(OH)_3$ to obtain alumina [2]. According to studies, the use of hydrochloric acid is preferable for leaching, since its use promotes easy filtration of suspensions after leaching, easy purification of the obtained solutions from iron and removal of impurities such as titanium dioxide from ores. Also, silica residue is well extracted from solutions of the resulting $AlCl_3$ [3].

The purpose of thermal modification of layered silicates is to change the microstructure of substances by sequentially removing adsorbed, interlayer (bound) and crystallization water. When kaolin is heated above 550° C the structure of kaolinite is irreversibly destroyed with the formation of amorphous metakaolinite in its structure up to 830° C, the order characteristic of the original mineral is preserved. Currently methods are known in which the preliminary heating of the material is carried out by electric furnace at a temperature of 600-800° C [3]. Microwave heating, unlike traditional heat generation systems, is carried out by converting electromagnetic energy into thermal energy inside the material, spreading throughout the volume. This mechanism allows to remove moisture from clay materials evenly, affecting the deeper layers at relatively low temperatures, reducing the duration of the process and energy costs [4]. A feature of kaolinite as an object for microwave heating is the presence of water in its composition. The water content has a significant effect on the dielectric properties of silicate minerals, which allows kaolinite to be exposed to electromagnetic radiation.

The effect of the thermal activation of kaolinite for its processing with hydrochloric acid has been investigated. The study used a sample of kaolin of the Troshkovsky deposit, which was subjected to grinding in a hammer mill to a particle size of -0,2 mm, then was divided into 5 equal parts and sent for further heat treatment. The ground samples were subjected to heat treatment in various modes. Convective heating was carried out in a muffle electric furnace at a temperature of 550° C with an exposure for 30 minutes. Microwave heating was carried out in household microwave oven with an exposure for 3, 5, 7, 10, 15, 20 and 30 minutes, respectively. Thermally modified kaolin samples were characterized by means of differential thermal analysis (DTA), X-ray diffraction analysis (XRD), X-ray fluorescence spectrometer (XRF) and particle

size distribution analysis (PSD). The change in the specific surface area of the material was characterized by adsorption of methylene blue.

Differential thermal analysis (DTA) of thermally modified material confirmed the removal of water during microwave processing occurs uniformly throughout the volume, unlike convective heating. Microwave processing reduced kaolin activation time. After 10 minutes of microwave treatment, a dehydrated material was obtained which is most suitable for hydrochloric asid leaching. A researching of the adsorption capacity for methylene blue showed the removal of crystallization water led to a significant deformation of the crystal lattice of kaolin, which caused an increase in the porosity of the material and its activity. A further increase in the processing time decreased its adsorption capacity. Also, the results of the experiment showed that during microwave processing, the Al_2O_3 content in the particle size -0,2 mm increased from 27,75 to 30,50 %, and during roasting in a muffle furnace, to 31.10%. Despite the high Al_2O_3 content and dehydration of the sample processed by the convective method, it is significantly inferior in properties to the material after microwave processing. The adsorption capacity of a convective sample is 85.67 mg/g, while for a microwave sample it is 134.1 mg/g.

Microwave activation has positively affect the properties of clay materials and allows counting on the possibility of implementing the process of hydrochloric acid leaching in atmospheric conditions with the achievement of high technological parameters.

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PURIFICATION OF QUARTZ RAW MATERIALS TO OBTAIN OPTICAL FIBER

Currently, in terms of industrial consumption, quartz barings (quartzites, sands, sandstones, siltstones) occupy one of the leading places among various types of mineral raw materials. Obtaining sufficiently pure quartz concentrates depends not only on the feedstock, but also on its enrichment technology. In this regard, the improvement of existing and the development of new effective technologies for the enrichment of quartz raw materials are today's problems. In Uzbekistan, fundamental changes are taking place in all industries, including silicate, in particular, in the production of optical fiber. Currently, intensive work is underway to develop a broadband high-speed Internet connection, and this, in turn, requires communication, connecting wire lines based on optical fiber. For the production of optical fiber, quartz raw materials are imported from foreign countries as the main raw material component, which naturally affects the cost of production. The quality requirements for this product are very high, therefore, to obtain optical fiber, only pure raw materials are used, as the main component of quartzite should be enriched, the content of iron oxide in which should be minimal. In our Republic there are more than one hundred deposits of quartz raw materials, but it should be

noted that these quartzites contain impurities of clay and feldspar concentrates. In the natural state, any of deposit doesn't satisfies the quartzite requirements. In the absence of high-quality raw materials in Uzbekistan, for the production of optical fiber, due to the underdevelopment of industrial enrichment of quartz raw materials, the search for rational methods for enriching existing natural raw materials is of particular relevance. In this regard, the problem of developing competitive technologies for the enrichment of local raw materials in order to obtain high-quality products is relevant for the Republic of Uzbekistan today. When particularly careful removal of iron-containing impurities is required, chemical enrichment methods are used. Their essence is the conversion of iron-containing impurities (films of iron oxides, hematite grains) into soluble compounds. To this end, quartzite is treated with various reagents: sodium hydroxalate, sulfuric acid, hydrogen chloride, etc. [1] Pure quartzite is relatively rare in nature and in most cases requires enrichment. A feature of enriched quartzite is the presence in it of large grains of quartz with a fraction of up to M 3.5. Before starting the enrichment process, quartzite undergoes an additional washing and drying procedure [2]. The authors of [3] note that traditional roller separators provide a stronger magnetic field, since they have a practically zero gap between the magnetic roller and the inner surface of the tape, in contrast to drum separators, which still need a gap for normal operation. The authors of [4] noted that vein quartz from various deposits often does not meet production requirements and needs deep enrichment. The composition and content of impurities, even within the same deposit, as practice shows, can vary widely. The main mineral impurities are ore minerals, mica, feldspars, as well as secondary mineral formations on the surface of quartz. The greatest difficulties are associated with the extraction of minerals with increased fineness (0.25 - 0.5 mm), as well as their intergrowths with quartz.

Undesirable impurities are concentrated in the clay fraction, in the heavy and in the form of a film on the surface of quartz grains. Accordingly, quartzite and vein quartz were subjected to crushing, grinding, sieving, washing, classification, scouring and magnetic separation. After each stage of exposure, the chemical composition was determined (Table 1).

Table 1 – Chemical composition.

Type of raw material	Content of oxides, (wt.%)									
	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	Na_2O	K_2O	Cr_2O_3	SO_2
Quartzite of the Jerdanak deposit										
Natural	92,25	3,28	-	1,33	1,35	0,16	0,51	0,14	-	0,98
Purified	99,69	0,08	-	0,02	0,03	0,04	0,09	0,05	-	-
Vein quartz of Samarkand deposit										
Natural	98,09	0,70	-	0,08	0,16	0,08	0,64	0,14	-	0,01
Purified	99,48	0,17	-	0,04	0,06	0,02	0,17	0,06	-	-

Previous studies by X-ray diffraction analysis of the main diffractogram reflections identified the following iron-containing minerals in Djerdanak quartzite: phenaxite – $KNaFeSi_4O_{10}$ (d = 3,24 Å); enstatite – $Mg1{,}12Fe0{,}88Si_2O_6$ (d = 3,18 Å); pyrite – FeS_2 (d = 2,57 Å); Hercinitis – $FeAl_2O_4$ (d = 2,45 Å) (Figure 1).

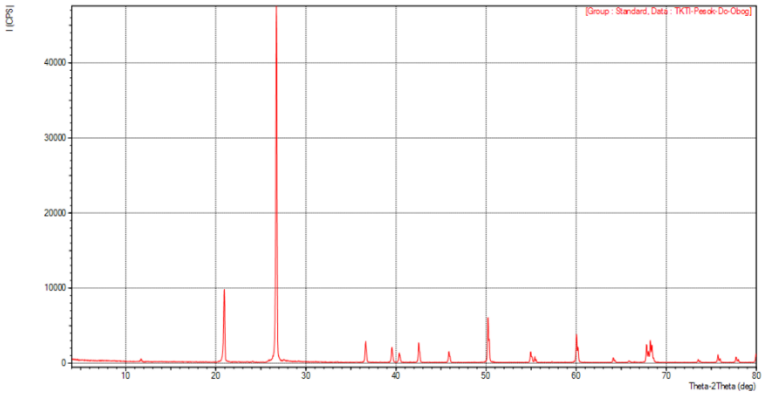

Figure 1 - Diffraction pattern of quartz sand of the Jerdanak deposit

The chemical and mineralogical compositions of quartzite of the Jerdanak deposit and vein quartz of the Samarkand deposit were studied. An X-ray examination revealed the practical absence of feldspars in the studied sands. The results of the enrichment of quartz raw materials by washing, classification, rubbing and magnetic separation are determined. The decisive role of the washing process in removing undesirable components has been established. It was established that the used processes of enrichment of quartz raw materials made it possible to obtain the SiO2 content: in quartzite of the Jerdanak deposit 99.69%; vein quartz of Samarkand deposit 99.48%;

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RESEARCH AND DEVELOPMENT OF DEEP PROCESSING TECHNOLOGY IN THE APPLICATION FIELD OF NEW ELECTROLYTIC COPPER FOIL RAW MATERIALS

KEY WORDS: electrolytic copper foil; coarsening; passivation; additive.

As the "connection hub" of electronic components, electrolytic copper foil is an important conductor raw material such as lithium ion battery, copper clad plate and printed circuit board, which is widely used in the fields of energy and power, electronic circuit and communication engineering. In recent years, with the development of electronic technology to miniaturization, lightening, thinness, multi-layer and multi-function, the thickness of copper foil has been reduced from the conventional 35 μm to the ultra-thin copper foil of 5 μm, and even the carrier copper foil of 1.5-4.5 μm. Meanwhile, the application and market demand of high performance electrolytic copper foil will become more and more large. This paper focuses on the study of micro-coarsening technology of reversed copper foil used for high-frequency copper clad plate in 5G communication at present, the development of additive system prepared by ultra-thin electrolytic copper foil used for lithium ion battery, and the carrier copper foil whose thickness is limited less than 5 μm that can be obtained by electrodeposited on the smooth surface of copper foil of 35 μm thickness.

At the same time, the experimental study on the replacement technology of the toxic arsenide coarsening and hexavalent chromium passivation in the surface treatment process was carried out. The developed sodium tungstate additive system are 5 mg/L hydroxyethyl cellulose (HEC), 50 mg/L bis(3-sulfopropyl) disulfide (SPS) and 60 mg/L sodium tungstate. The roughness of 35 μm thick copper foil only increased from the original value of Rz=6.5 μm to Rz=7.5 μm in the experiment, while the conventional surface roughing treatment roughness was Rz≥9.5 μm, it was decreased of 21%. Besides, the stripping strength increased from 1.8 N/mm

obtained by conventional coarsening treatment to 2.14 N/mm, it was increased of 19%. The deep plating ability can be electrodeposited on the valley bottom of copper foil surface contour, which can effectively avoid the phenomenon of deposition particle aggregation caused by the tip discharge effect. So as the raw material of copper clad plate, the substitution of arsenide coarsening can be achieved with controlling of surface roughness and increasing of specific surface area to enhance stripping strength of copper foil.

In addition, the development of phytic acid and molybdate combination system has replaced the hexavalent chromium passivation technology. The optimum process parameters contain 8 g/L sodium molybdate, 4 g/L sodium phosphate, 3 g/L zinc oxide, 2 mL/L phytic acid, current density of 0.2 A/dm^2 and passivation time of 10 seconds. The surface of copper foil did not change color after being baked at a high temperature of 280 °C for 2 hours, and had no abnormal appearance after being corroded for 8 hours in 5 wt.% NaCl solution. It shows excellent performance of resisting oxidation and corrosion. Ultimately, a series of experiment research on the processing technology of electrolytic copper foil raw materials are completed to provide scientific experimental data and theoretical basis for the actual production.

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DEVELOPMENT OF TECHNOLOGY FOR THE RARE-EARTH METALS EXTRACTION DURING THE PROCESSING OF APATITE RAW MATERIALS

Providing national economy of Russia with rare earth metals is vital for national security is an important condition for industry improvement. Taking into account the resource potential of the Khibiny group of apatite deposits, increasing the depth of processing of these ores for the purpose of extracting rare-earth metals is a strategic task. Apatite concentrate is characterized by a low REM content, so that the lanthanides contained in the apatite composition were not extracted for economic reasons. Nowadays, during the processing of apatite concentrate, the distribution of REM in solutions of phosphoric acid (15-20%) and solid industrial waste - phosphogypsum (85-80%) occur [1]. A selective extraction of an REM at this stage of development is not carried out. Manufacturers are forced to extract the amount of REM from the raw materials, followed by the separation of the total concentrate. In view of the similarity of the metals of the lanthanide group, the separation is initially performed only on subgroups. Thus, the development of a highly efficient and economically viable technology for the production of individual REM from apatite concentrate processing products is a necessary research task.

The most cost-effective source of rare-earth metals during the apatite processing is wet-phosphoric acid (WPA, industrial solutions of phosphoric acid), since it does not require any additional preparation for the extraction of lanthanides and yttrium. Unlike WPA, the extraction of rare-earth metals from phosphogypsum requires a series of preparatory operations, such as filtration and leaching, often with concentrated acid solutions at high temperatures and a significant process time. Furthermore, the profitability of phosphogypsum processing is ensured by the use of decontaminated phosphogypsum in other industries, even if the rare earth products are successfully realized [2]. The low content of rare earth metals, as well as the presence of a significant amount of impurities in both WPA and phosphogypsum, makes it impossible to use pyrometallurgical methods and seriously limits the possibility of using hydrometallurgical methods for the rare earth metals recovery.

Compared to other hydrometallurgical methods, extraction makes it possible to obtain high purity REM concentrates even from weak solutions, and a wide range of extraction parameters, the correct selection of extractants and stripping agents ensures the separation of

REM not only into groups, but also into individual components with a minimum amount of impurities. Also, a significant advantage of extraction processes is the simplicity of implementation and the possibility of fast adaptation to an industrial scale. A wide range of REM extractants (D2EHPA, Cyanex 272, Versatic, naphthenic acid, TBP, Aliquat 336, PC88A, etc.) provides an opportunity to develop the optimal extraction system for the recovery and separation of certain REM pairs from various media, from strongly acidic with pH << 1 to alkaline [3].

The technology of extraction separation and recovery of rare earth metals (yttrium, ytterbium and dysprosium) from industrial phosphoric acid solutions (wet-process phosphoric acid, WPA) was developed in this work. Moreover, the clarification technology of rare earth metals extracts from iron impurities was developed, which leads to an increase in the purity of the obtaining rare earth compounds. The developed methods ensure the preservation of the commercial quality of EPA, minimally affecting its chemical composition, which allows it to be used for the further production of phosphate fertilizers without modernization of existing technological processes. The considered technology provides an opportunity to increase the depth of apatite ores processing and reduce the deficit of rare-earth raw materials in the domestic industry.

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EXTRACTION OF LEAD AND RELATED VALUABLE METALS FROM LEAD CONTAINING SULFIDE CONCENTRATE THROUGH SULFATIZING BOILING

The article describes the thermodynamic analysis of sulfating roasting of lead-containing sulfide concentrate to extract lead and related valuable metals from it by hydrometallurgical method. Sulfating roasting, being low temperature, has a clear advantage over redox roasting of lead concentrates, which is widely used in almost all lead producing plants. It is expressed in that loss of the main component, lead, is minimal due to low vapor pressure since roasting is carried out at relatively low temperatures. In addition, formed metal sulfates such as $ZnSO_4$ and $CuSO_4$, are dissolved in water and through hydro-electrometallurgical redistribution they can be easily extracted without special technological difficulties from aqueous solutions.

The method of “sulfatizing roasting stage, leaching and cementation for the extraction of all valuable metals extraction” was chosen. Mineral composition and their interactions with each other and with oxygen in the process of concentrates sulfides roasting and resulting sulfates were studied through Roentgenogram and microscopic analyzes to assess the effectiveness and conversion of all sulfides into corresponding bisulfates.

Roasting was carried out in a SNOL-1.6 2.5 1/11-M1 model muffle furnace and thorough temperature control of reactor at $560 \pm 10^{\circ}C$. The process was done with an exposure of 5 hours

and mixture of charge with 45-50 minutes interval. Thickness of roasted/boiled concentrate layer was 2.5-3.0 cm.

After 5 hours the process is completed. That is evidenced by the fact that roasted product is presented in the form of $CuSO_4$, $PbSO_4$, $ZnSO_4$ and $Fe(SO_4)_3$. In addition, thermodynamic calculations showed that reactions of mineral sulfation at temperatures 673-1073 K. have a relatively large negative value of energy

On the diffractogram of roasted sample distinctive lines of $PbSO_4$ with interplanar distances are clearly visible $d_{(011)}$=4,26 $\overset{0}{A}$; $d_{(210)}$=3,33 $\overset{0}{A}$; $d_{(211)}$=3,00 $\overset{0}{A}$; $d_{(122)}$=2,047 $\overset{0}{A}$; $d_{(323)}$=1,49 $\overset{0}{A}$. The diffraction maxima of this phase are distinguished by a rather high intensity compared to other sulfates, despite its relatively low content.

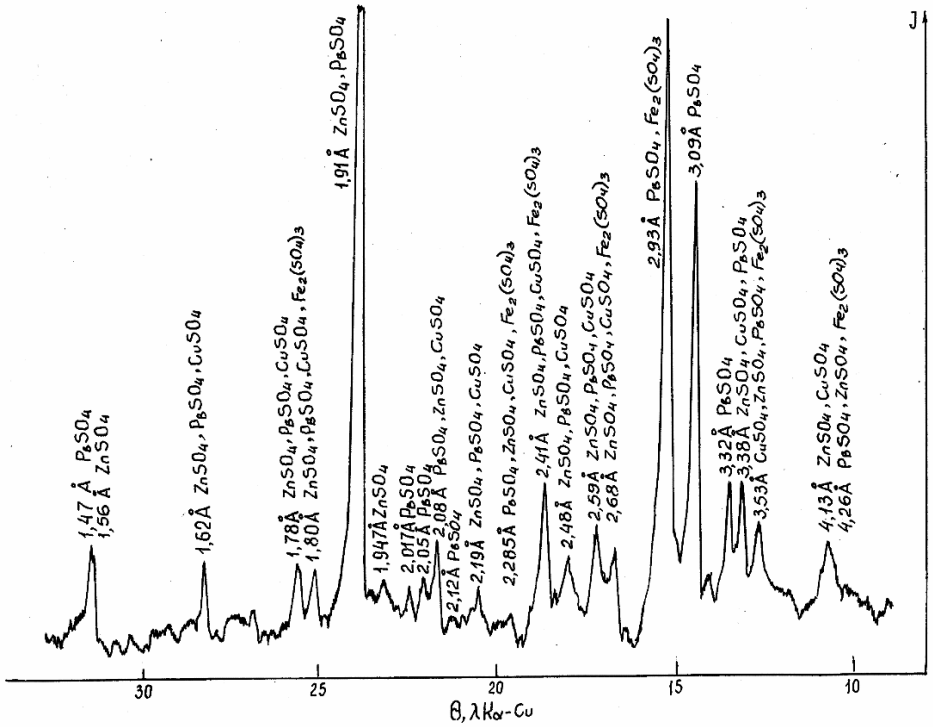

Figure 1 - Roentgenogram of roasted lead containing concentrate

Throughout the research thermodynamic analysis was carried out of. That was done for sulfatization reactions of lead sulfides and related metals, including copper, zinc and iron during the sulfate roasting of lead-containing sulfide concentrate for the purpose of hydrometallurgical extraction. Results were confirmed with roentgenogram analysis of roasted sample of concentrate.

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THE DISSOLUTION OF THE RARE EARTH ELEMENTS UNDER THE INFLUENCE OF A CARBONATE ION

The Rare Earth Elements (REE) are an important raw material resource in the economy in the 21st century. The potential of using REE is huge and it depends on the level of technology [1]. The high cost of REE-containing products and their unique technical and operational properties determine the growing interest in the REE market. It is possible to extract the rare earth metals from two main sources: traditional and man-made. Currently, the branch of obtaining REE from technogenic raw materials is actively developing: red mud, phosphogypsum, cake, slag and coal waste. The aim of this research is to determine physical and chemical laws of dissolution of REE precipitates by carbonization. It is possible to apply the results of the study in the extraction of the REE from phosphogypsum and red mud by carbonate leaching.

Phosphogypsum is a safe secondary source of lanthanides because of low general radioactive background. The content of the rare earth elements in phosphogypsum is in the range of 0.4 – 0.6 % [2], [3]. Red mud contains a significant amount of lanthanum, cerium, praseodymium, neodymium and other REE with a total content of 506 - 2500 g / t including 90 - 110 g / t Sc_2O_3 [4], [5]. X-ray phase analysis indicates the presence of the REE in oxides and carbonate forms. Given the thermodynamic characteristics of water-soluble REE carbonate complexes, the dissolution mechanism is considered according to the reactions (1) и (2):

$$LnPO_{4(s)} + 2CO_{3(l)}^{2-} = (Ln(CO_3)_2)_{(l)}^{-} + PO_{4(l)}^{3-}; \quad (1)$$

$$Ln_2CO_{3(s)} + CO_{3(l)}^{2-} = 2(Ln(CO_3)_2)_{(l)}^{-}; \quad (2)$$

The solubility isotherms of lanthanide carbonates and phosphates were experimentally obtained (Figures 1 and 2).

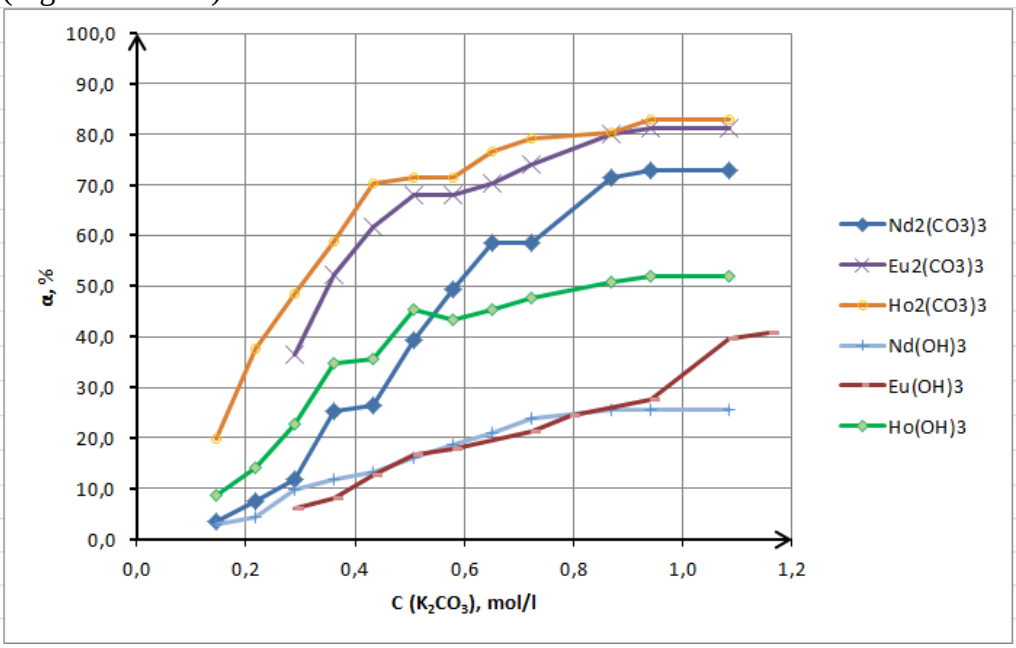

Figure 1 - Isotherms of dissolution of the REE's carbonates and hydroxides in carbonate medium

It was determined that the dissolution of REE's carbonates and hydroxides are similar in the concentration range of carbonate ions of 0.15-1.2 mol / l, further reaching the maximum degree of extraction into the solution. According to the isotherms the heavy rare earth metals dissolve better than the others. REE's phosphates dissolve at high carbonate ion concentrations and need high temperatures. The experimental results are presented in Figure 2.

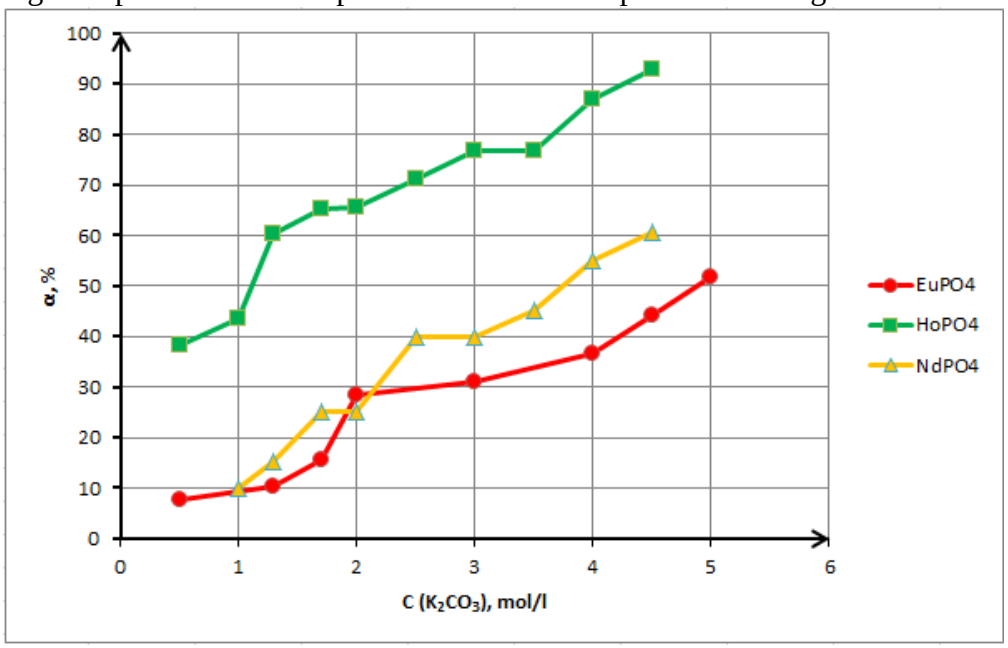

Figure 2 - Isotherms of dissolution of the REE's phosphates in carbonate medium

The dissolution of carbonates, phosphates and hydroxides of neodymium, europium, holmium was considered in this research. The isotherms of dissolution are curves with a large angle of inclination in the concentration range of 0.2 - 0.8 mol / l carbonate ion. It has been experimentally established that holmium has the best solubility, europium is less soluble and neodymium hydroxide and carbonate have the least solubility. Neodymium and europium phosphates show similar solubility, dissolving worse than holmium phosphate. Light and heavy rare earth elements were taken for experiments, therefore, it can be possible to make an assumption about the similar behavior of other REE's carbonates, phosphates, and hydroxides. The solubility results of these precipitates confirm the potential of carbonate leaching of sludge and the possibility of extraction the REE's ions from them.

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A CONTRIBUTION TO UNDERSTANDING THE INFLUENCE OF GANGUE PARTICLE FRACTION (FINE OR ULTRAFINE) ON THE FLOTATION OF FINE/ULTRAFINE PARTICLES

Due to extinction of high-grade ore deposits, low-grade ore deposits have to be mined and, because of their complex structure, have to pass through a specific mineral processing system. Froth flotation is the most effective technology to beneficiate mineral fines from complex ores although there is a high energy consumption during comminution to achieve optimum liberation size. As a result, the pulp may consist of ultrafine particles (<10 μm) which have negative impact on flotation recovery. The ultrafine particles cause problems such as high reagent consumption, slime coating and an increased rate of surface reactions[1]. The understanding of gangue particle behavior in flotation systems and their optimization will help to increase flotation selectivity.

The issue of ultrafine particleis known as "the slimes problem" in the field of processing, which was first reviewed by Taggart (1951) and Gaudin (1957) [2]. Reagent adsorption and surface wetting phenomena were the focus of the researchers on this issue. Later, photographic evidence of Spedden and Hanna (1948) and Whelan and Brown (1956) clarified the significance of hydrodynamic conditions on bubble-particle attachment. The first analytical relationship between flotation rate and hydrodynamic conditions was published by Sutherland in 1948. It shows that the probability of particle collection (P) is equal to the product of the probability of collision (P_c), the probability of adhesion (P_a) and the probability that subsequent detachment would not occur (P_d). Later Reay and Ratcliff (1973) delineated that the probability of collision is equivalent to the square of the diameter of particle (D_p) divided by the diameter of bubble (D_b) [1]. Although this numerical technique serves to explain the general relationship between size of bubble and particle to flotation rate, there are cases that cannot be explained with this technique because the particle size of the gangue mineral and related hydrodynamics are ignored.

The effect of the gangue particle size is described in Leistner et. al. in 2017. The flotation tests of this research were carried out with 10% magnetite (valuable) and 90% quartz (gangue). These two mineral types were subjected to flotation tests with fine (10-50 μm) and ultrafine (<10 μm) size combinations. As expected from Reay and Ratcliff's numerical technique, the flotation experiments performed with the ultrafine magnetite - ultrafine quartz particles gave low flotation recovery results and the fine magnetite - fine quartz particle tests gave good results. On the other hand, flotation tests with the ultrafine magnetite - fine quartz gave very good results and the fine magnetite - ultrafine quartz particles gave poor results [3]. These results cannot be explained by Reay and Ratcliff's numerical technique for probability of collision and further investigation is required.

In this work, experimental conditions of research of Leistner et. al. are reversed to understand the effect of gangue particle size on flotation recovery. For each flotation experiment 90% magnetite and 10% quartz are used and again all combined as fine and ultrafine particle size fractions. The result of this research will contribute to the understanding of fine/ultrafine particles in the flotation system and to the improvement of the bubble-particle collision theory.

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THE STUDY OF REE EXTRACTION BY LOW-GRADE PHOSPHATE MINERAL COMPLEX DECOMPOSITION

The chemical industry in the Republic of Uzbekistan is capable annually to process 6 million tons of phosphate raw-material which contains 100000 tons REE. Extraction of REE out of phosphate raw-material would give possibility to make profits of million dollars. Therefore, the financial support of the current project would be very important and give the chance to develop the proposed cost-effective technology. Existing technologies of the processing of low-grade phosphorites do not provide complex use of its components. Considering multi tons of processing of phosphorites, losses of REE make accordingly some thousand and hundreds of tons a year.

Increase in the productivity of the ground is possible only due to the application of mineral fertilizers. Among them phosphoric fertilizers which are produced from phosphate raw-material, are very special. From year to year greater the quantity of phosphorites is processed into the fertilizers. Content of REE in phosphorites reaches up to 0.07%. Depending on ways of processing of phosphate raw material the part of these elements passes in ready fertilizers, and a part in production wastes. Considering the scales of processing of phosphates, the loss of REE in a year within the production wastes of fertilizers will make some tens of thousands of tons since none of the existing technologies of complex fertilizers does consider the effective and complex use of components of the phosphoric raw-material.

Regular application of phosphoric fertilizers containing REE in agriculture leads to accumulation of these elements in plants and in the ground. REE, brought into the ground together with fertilizers, are toxic agents rather than useful factors. The problems related to the stocks of raw material and preservation of the environment cause the expediency of the production of phosphoric fertilizers by methods which allow the extraction of these elements from phosphates. It demands also questions of complex use of mineral raw material. One of important points in questions of the extraction of REE in technology of mineral fertilizers is studying of distribution of these elements in initial phosphate raw material, industrial products of its processing and ready fertilizers as well. It allows define that product or that stage on which it is useful and necessary to purify them from REE.

Therefore, there is an extremely sharp problem of processing of phosphorites on new types of Phosphorus Fertilizers with satisfactory technical and economic parameters and wide assortments.

Laboratory experiments was held in order to study the interaction of components of the acid processing of phosphorites, solubilities, fusibility and character of solid phases in the triple system and systems with more than fore components, including nitrite, nitrate of calcium, phosphates of sodium, calcium and ammonium, and also fluorides and silicon-fluoride sodium, ammonium, and salts of REE.

According to the technology, the decomposition of phosphorites by nitric acid is carried out in a reactor. Extraction of REE is performed during allocation of ions of calcium and fluorine by partial ammonization of the first hydrogen ion of the phosphoric acid.

REE is extracted by organic solvents from the allocated deposits followed by the further re-extraction and washing of them by the acidified water and sedimentation of REE from the water phase using gaseous ammonia.

The purified solution (from fluorine, REE) is processed into pure phosphates of ammonium, sodium, calcium and phosphorus fertilizers.

The basic technological scheme of manufacturing of the complex processing of low-grade phosphorites consists of following stages:

- In the first section of a reactor the circulating solution and phosphate raw material, and in the second section - nitric acid and/or gases of ammonia move;
- After branch of an insoluble deposit and fluoric salts are allocated nitrite-nitrate sodium crystals, and uterine the solution is distributed on two parts: the first part comes back to the first section of a reactor, and the second part – on preliminary ammonization;
- From preliminary ammoniated solution the deposit of concentrated REE is separated;
- Further uterine the solution is processed on pure phosphates of ammonium, calcium and phosphorus fertilizers.
- REE are extracted from deposits by organic extragent followed by re-extraction by washing with acidified water.
- Sedimentation of REE from the water phase of gaseous ammonia.

Moreover, the process itself is simple and most importantly ecologically clean and favorable. The above described method of processing of phosphates enables applications of any kinds of highly carbonized non-enriched poor phosphorites.

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REUSE OF TAILINGS IN THE DISSOLUTION OF MN FROM MARINE NODULES

The nodules are spherical bodies that are scattered in the sedimentary zone of the seabed and their growth is closely related to the biogeochemical processes and water sediments. These nodules are mainly composed of Mn, Fe, SiO_2, Ca, Ni, Cu, Co and Al. Manganese nodules are an attractive source of base metals and critical and rare elements and they used as a base elements matrix can be highly demand for the industry. In previous studies, it has been shown that high concentrations of reducing agent (Fe) in the system are beneficial for the rapid extraction of manganese. However, it is necessary to optimize the operational parameters in order to maximize Mn recovery The present work investigates the effect of using of tailings, obtained after Slag flotation in a foundry plant on the Mn dissolution from marine nodules, where a statistical analysis was carried out using factorial experimental design for time, MnO_2/Fe_2O_3 ratio and H_2SO_4 concentration.

71% of the total surface of the earth is covered by oceans, which in most of the sea bottom, mineral deposits of economic interest such as cobalt-rich crusts, polymetallic hydrometallurgical sulphides and manganese nodules can be found, reaching reserves ranging between 1 and 3 billion tons, associated with large metal reserves such as Cu, Ni, Co, Fe and Mn, where the last one being the most abundant, with an average content of around 24% [1]. The use of iron as a reducing agent stands out for its abundance and positive results [2-5]. This last author investigated the effect of working with elemental Fe as a reducing agent at low H_2SO_4 rates. They concluded that the most incident variables in the Mn extractions from the nodule were the

Fe concentration and the nodule article size. In miners' countries, it is necessary to find new uses for tailings with the application of more environmentally friendly hydrometallurgical techniques. This results in an attractive proposal given the quantities of waste generated in the country by flotation, providing an added value for this [6].

Marine nodules were used in this investigation where their chemical composition is presented in Table 1. The tailings sample used in this study was obtained after the slag was floated during the production of copper concentrate. Several phases containing iron were present in the tails, while the Fe content was estimated at 41.9%. As the Faith was mainly in the form of magnetite.

Table 1 - Chemical analysis (in the form of oxides) of manganese nodules

Component	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	K_2O	CaO	TiO_2	MnO_2	Fe_2O_3
Weight (%)	3.54	3.69	2.97	7.20	1.17	0.33	22.48	1.07	29.85	26.02

The effect of the independent variables on the Mn extraction rate was studied using the response surface method, which helped in understanding and optimizing the response by refining the determinations of relevant factors using the model. An experiment was designed involving three factors that could influence the response variable, and with three

levels for each factor for a total of 27 experimental tests, where the purpose was to study the effects of H2SO4 concentration, particle size, and time on the dependent variable.

The results presented in Figure 1 show the benefit of operating at high concentrations of reducing agent (Fe). The highest Mn extraction of 77% was obtained after 40 min with an MnO2/Fe2O3 ratio of 1:2 where the leaching time required to reach a 70% extraction rate has been shortened significantly, while 67% extraction was reached in 5 min. The tests conducted in this investigation were in pH ranges between −2 to 0.1, and potentials from −0.4 to 1.4 V, because the presence of Fe2O3 maintains the regeneration of ferrous ions, resulting in high levels of ferrous ion concentration and activity, favouring the dissolution of Mn and avoiding the formation of precipitates through oxidation– reduction.

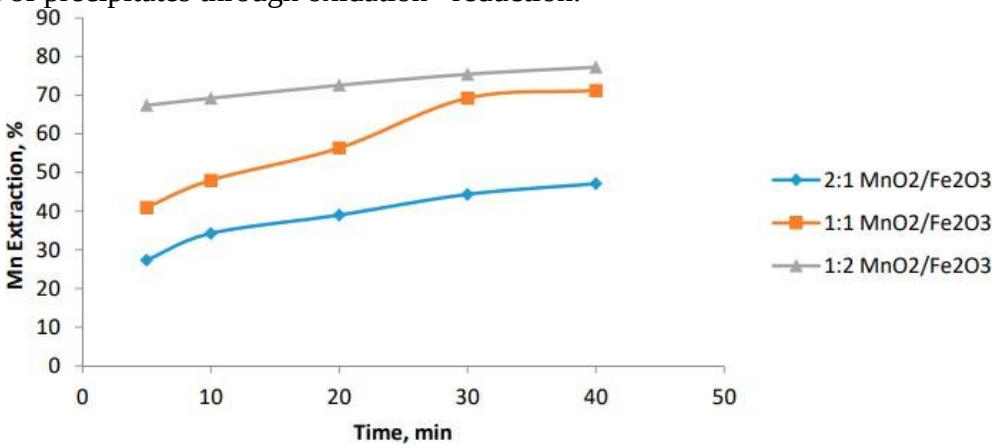

Figure 1 - MnO_2/Fe_2O_3 ratio effect on the manganese extraction (25°C, -75 + 53 µm, 1 mol/L H_2SO_4)

The highest Mn extraction rate of 77% was obtained at an MnO2/Fe2O3 ratio 0.5, 1 mol/L H2SO4, particle size of −47 + 38 µm, and leaching time of 40 min. In future work, the leaching of marine nodules should be studied using different Fe reducing agents but under the same operational conditions. It is also necessary to determine the optimal MnO2/Fe2O3 ratio that improves Mn dissolution.

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STUDY OF YTTRIUM / IRON (III) SOLVENT AND SOLID-PHASE EXTRACTION KINETICS AND SEPARATION

Rare earth metals (REMs) are widely used in various high-tech industries due to their unique optical, electrical and magnetic properties. In recent years, REMs became strategically important raw materials and their consumption reflects the level of technology development in the country. Russia has huge resources of REMs but in the meanwhile almost no production. In this research, it was suggested to use wet-processed phosphoric acid (WPA) as a raw material for recovering rare earth. WPA is an intermediate product in the process of phosphate fertilizers production [1]. In this case, there is no need to build new mining and processing enterprise, because REMs would be recovered by introducing a stage of rare earth by-product extraction.

Liquid extraction of REMs, using di-2-ethylhexyl phosphoric acid (D2EHPA) as a liquid extractant, has been studied for a long time in our department, proving to be effective when used for recovery and separation of REMs from a complex water-salt solutions with low pH value [2-3]. A factor complicating the implementation of solvent extraction is the use of flammable, volatile and toxic organic solvents, which might form an interfacial emulsion with the water phase. Therefore, a decision was to test solid extractant TVEX-D2EHPA in this research. Solid-phase extraction combines the properties of both extraction and sorption processes. The use of solid-phase extraction has a number of advantages compared to solvent extraction, such as compatibility with a continuous stream of acid saline solutions, which can provide scalability of the process [4].

WPA contains large amounts of ferric ion, which significantly affect the process of REM extraction due to competitive effect. The aim of this research was to study kinetic characteristics of solid and solvent extraction of Iron (III) and REMs on the example of Yttrium.

Based on the revealed differences in the elements extraction kinetics, it turned out to be possible to carry out their effective separation at the solvent extraction stage. A high yttrium and iron separation coefficient of 23.2 is ensured by the short phase contact time (up to 2 min).

Solid extractants have an undoubted technological advantage. Compared with solvent extraction, the use of solid extractants can reduce the dependence of the yttrium extraction degree on the temperature factor. However, the equilibrium in the system is established within 1–2 h. The convection presence in the heterogeneous system does not significantly affect the extraction rate. The extraction rate coefficients were calculated using different diffusion models and showed adequate converge. The calculated value of solid-phase extraction activation energy amounts to 18.5±2.0 kJ/mol, characterizing the regularity of gel kinetics.

The iron (III) extraction degree into the solid phase is significantly less compared to solvent extraction and does not exceeds 9%. The differences between solvent and solid-phase extraction of iron by a D2EHPA solution is explained by the extractant configuration in the styrene/divinylbenzene matrix. Extraction resins have undoubted operational advantages. Such resins are characterized by high mechanical strength, high chemical stability in aqueous solutions of acids and alkalis, and can be used in coarse systems and bulk filters. The absence of significant amounts of flammable solvents, which accompanying solvent extraction, complies with the principles of green chemistry.

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USING MACHINE VISION FOR FLOTATION INTENSIFICATION

Structure of flotation foam is a fundamental factor that determines the quality of the flotation product. Definition of parameters of the foam will deliver the data for optimization of the flotation process.

Nowadays there are some solutions that consider monitoring of flotation process. One of the brightest examples is OUTOTEC® FROTHSENSE that provides with data on velocity, stability, color of froth and other parameters of the process [4].

Research in machine vision to define the parameters of flotation process considers a wide range of algorithms and methods of image processing. For example, [1] has developed an algorithm for flare detection of froth parameters on a low-contrast videoflow of potassium salts.

Another area of research is represented by application of convolutional neural networks to classify the froth into defined groups depending on the size of bubbles [2]. A similar principle of classification is implemented in [3], in which the authors suggest several algorithms for monitoring of platinum metals flotation.

The work in scope considers using computer vision library OpenCV to determine the radius and number of bubbles during flotation. For that, threshold binarization for image processing and Hough transformation for detection of circumferences were used. An example of a processed image fragment acquired during flotation is shown in Figure 1.

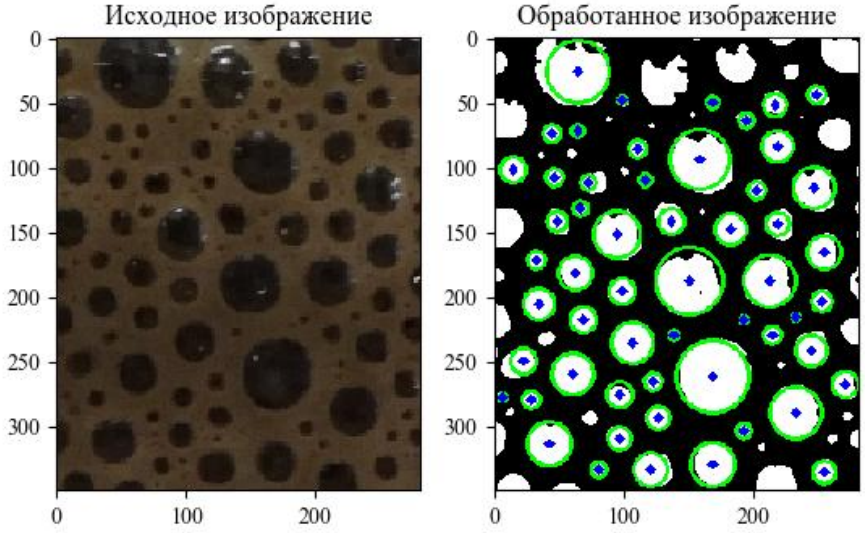

Figure1 - Flotation foam bubbles detection on an image

The resulting dataset contains radii of the detected circumferences. In general, application of the considered method seems reasonable, however, for a better detection, further improvements should be made to the fitting algorithm for bubble detection in dependence on the type of ore and lighting.

The work is carried out with financial support of Ministry of Education and Science of Russian Federation according to grant program “Research and development in priority areas of development of Russian’s scientific and technical complex for 2014 – 2020”, the project № 05.616.21.0127 (RFMEFI61620X0127).

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KINETIC AND THERMODYNAMIC ASPECTS OF FLOTATION ENRICHMENT OF POLYMETALLIC RAW MATERIALS

Over time, the quality of processed ores and the content of metals in them continuously decreases. Increasing requirements for the complex use of raw materials on the background of depletion of known balance deposits of non ferrous and noble metals requires the use of new approaches in the enrichment of this raw material [5]. To improve the technological indicators and increase the economic efficiency of processing polymetallic ores it is necessary to use the kinetic and thermodynamic dependencies of flotation ore dressing to rationate technological parameters at the design stage of technological schemes. Kinetic studies and the distribution of

minerals by floatability are necessary both for assessing ore enrichment at the initial stage and at the stage of more detailed study. The study of flotation kinetics can be used to determine the time required for flotation. The selection of the Eh and pH range is necessary for selective flotation of minerals, while keeping the stability of their oxidation process. Under these conditions, it is possible to select optimal concentrations of oxidants in order to improve the required technological indicators. The zone of stable existence of sulfate ions will be the optimal flotation zone of the raw material [4]. The purpose of this study is the development a methodological approach to analyze kinetic and thermodynamic parameters for improving the efficiency of flotation processing of polymetallic raw materials.

Carbon-containing, sulfide copper-zinc and gold-containing ores were selected as the objects of research.

Dictionem shales are grayish-black, black, and brown thinly layered carbonaceous rocks. They are low-grade oil shales due to their high ash content. The choice of shale as an object of research is due to the importance of this object as a source of strategic metals, such as precious, rare, non-ferrous metals and trace elements [2, 3, 6].

Copper-pyrite ores are an important industrial type of copper-sulfide ores. The main valuable components are copper, zinc, and sulfur. The development of these deposits is profitable due to the possibility of complex processing of raw materials, that is, the associated extraction of components with copper (zinc, gold, silver, sulfur, iron), the cost of which is significantly higher than the cost of copper [1].

For sulfide gold-containing ores, a characteristic feature is resistance. As a rule, gold-containing sulfides (mainly pyrite and arsenopyrite) have a crystal structure that is poorly permeable to cyanide solutions. Most of the grains of native gold in them have thin and ultra-thin dimensions. More than 80 % of the particles are less than 20 microns in size. The presence of sulfide and oxidized minerals of non-ferrous metals requires a special chemical treatment that is associated with the oxidation of sulfides associated with gold [4, 7].

To determine the kinetic dependences of flotation of selected ores, flotation enrichment of the selected raw materials was carried out on a flotation machine JK Flotation Test Batch Machine with subsequent x-ray fluorescence analysis of concentrates on a spectrometer EDX-7000 Shimadzu. The HSC Chemistry 9.0 program was used to evaluate the chemical reaction on the mineral surface through the formation of various products of this reaction. It is an environment for creating models for various types of basic operations from chemical processes to economic optimization. To achieve the goals of research, the capabilities of the program to create Pourbaix diagrams were used. Analysis of the hydrophobizing ability of the primary collector for flotation of sulfide of potassium butyl xanthate was carried out in two stages: the wetting angle at the mineral-water-air boundary was determined without treating the mineral surface with a reagent and with its pretreatment by a collector, then the floatability parameter was calculated for both cases.

According to the data obtained in the study of kinetic dependencies of various raw materials, the best convergence results are shown by the Beloglazov equation, the Kelsall model, and the Modified Kelsall model. Technological indicators of sulfide flotation in the presence of oxidants are higher, what can be explained by the intense oxidation of the transition ions formed on the surface of minerals, which helps to align the flotation properties of the surface. When adding potassium bichromate as a dispersant, the content of chalcopyrite and sphalerite in the collective concentrate is maximum, which is a positive factor in flotation enrichment. It is possible to integrate the proposed research methods into technological schemes in order to optimize technological indicators and increase profits.

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STUDY OF A TWO-STAGE BACTERIAL AND PRESSURE OXIDATION PRETREATMENT FOR REFRACTORY GOLED CONCENTRATES PROCESSING

Steadily decreasing grade of mineral raw materials creates a need to develop and optimize technologies for processing lower-quality ores and concentrates to ensure production of metals according to demands. Refractory gold ores, which form significant part among gold deposits, cannot be processed without pretreatment since fine-grained gold is entrapped in sulfide minerals, typically pyrite (FeS_2) and arsenopyrite (FeAsS) [1]. In order to enhance gold recovery, pre-treatment is needed prior to cyanidation to destroy crystal lattice of minerals and make dispersed gold accessible for the leaching solution [2]. One of the promising methods for treating such materials is pressure oxidation (POX), which enables to reach high rates of gold recovery within 1-1.5 hours. However, its efficiency may be lowered while treating certain types of materials. For instance, high content of sulfur in pressure oxidation feed (>6%) results in excessive heat generation, that may lead to the need to decrease pulp temperature with quench water, thus increasing a liquid-to-solid ratio and dimensions of the autoclaves [3], ultimately influencing capital and operational expenditures (CapEx and OpEx). Therefore, studies should be aimed at selection of the most suitable approach for treating refractory gold materials with high content of sulfur.

One of the promising methods is a two-stage technology, which comprises bacterial and pressure oxidation. At the first stage, sulfide minerals are subjected to oxidation by bacteria to decrease sulfur content and make it appropriate for further treatment in autoclaves. Then, the bio-oxidation residue is treated in pressure oxidation vessels to complete sulfide minerals oxidation process and prepare the residue for subsequent leaching.

The subject of the current work was a flotation concentrate with 21.5% S and 55.5 g/t Au. Bacterial oxidation was conducted in three stirred tank reactors connected in series at 40℃ with aeration. The air supplied to the first reactor was enriched with CO_2. Pressure oxidation of the

concentrate and the residue of bacterial oxidation was conducted in titanium autoclave Parr of the volume 1.9 l with an agitator and oxygen supply at 220℃.

The results have shown, that although two-stage process requires more time than a single-stage POX and allows gold recovery at almost the same level, addition ofn bacterial treatment stage prior to POX significantly reduces S content in the pressure oxidation feed and decreases a liquid-to-solid ratio by more than 2 times, thus avoiding a need to dilute the pulp with quench water. Therefore, gold recovery rate can be improved with lower CapEx and OpEx.

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ADSORPTION TECHNOLOGIES AS A WAY TO REDUCE THE INDUSTRIAL LOAD ON THE ENVIRONMENT IN COPPER METALLURGY

Copper concentrates and scraps are the raw materials for obtaining the final products of metallurgical copper plants. It is obviously, that already at the stage of concentrate production, environmental pollution occurs due to the discharge of thickeners and accumulation of tails, metal ions are contained in wastewater in the range from 2 to 20 mg /dm^3, which significantly exceeds the maximum permissible concentration for normal water [1]

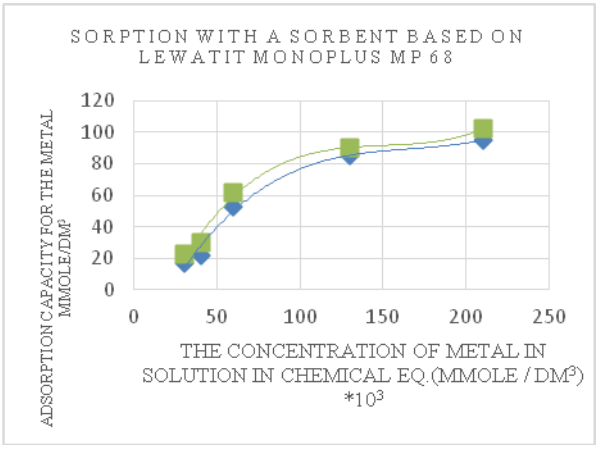
In the nearest future the problem of spending of the main discovered mineral will only increase with increasing the total mass of dumps of mining and metallurgical plants, there it`s important to develop technologies that allow to make separation of ions of valuable components with toxic nature [2, 3].

Copper ores are polymetallic. The main impurities of this ores are: zinc, lead, nickel, cobalt, gold, silver, platinum group metals, sulfur, tellurium, selenium, cadmium, germanium, rhenium, indium, thallium, molybdenum and iron.

In this research were studied the possibility of sorption extraction of valuable components from wastewater systems.

1. The possibility of application of nonselective sorbents for the purification of wastewaters and dusts from plants was investigated with the possibility of separation of metals after desorption.

2. The sorption and desorption curves for rhenium and molybdenum ions were obtained by using model solutions. Examples of the obtained experimental values are shown below in Figure 1.



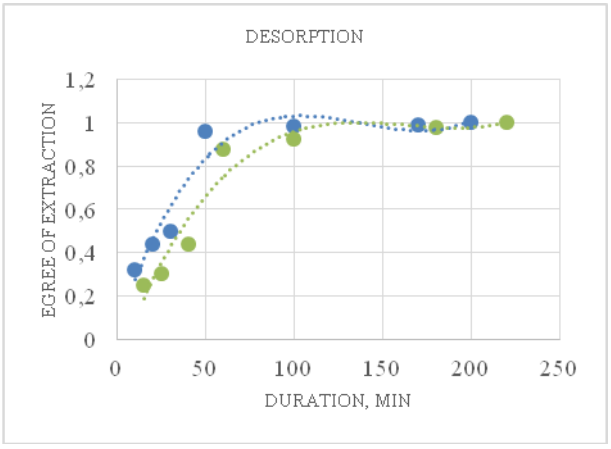


Figure 1 - Sorption and desorption curves. Key: blue - sorption and desorption of rhenium, grey - sorption and desorption of molybdenum. Both metals are in the form of an anion

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DENSIFICATION OF GRADED POWDER COMPOSITES FOR COMPONENTS WITH HIGH WEAR RESISTANCE REQUIREMENTS

Materials with high wear properties are necessary for the mining of raw materials. Technical ceramics with the high hardness, compared to metals, offer a good possibility here. However, ceramics have the disadvantage of a low ductility, compared to metals. Therefore, a combination of the high hardness of ceramics and the high strain of metals would be an ideal material for the extraction of raw materials. Composite materials and here in particular the particle-reinforced MMCs represent a very good possibility. These MMCs combine the positive properties of the wear resistance of ceramics and the high strain of metals in a new material. One possibility for the production of such MMCs is the powder metallurgy.

However, there are some problems, which must be taken into account, in the selection of materials for such MMCs. For example, the materials must have similar thermal expansion in order to avoid damage due processing. Within the framework of Collaborative Research Center 799 (CRC 799) at the TU Bergakademie Freiberg, an austenitic steel with Transformation Induced Plasticity effect (TRIP-effect) was used as matrix material and Magnesiumoxid partially stabilized ZrO2 (Mg-PSZ) as reinforcing particle material. The advantage of this material

combination is that Mg-PSZ and the TRIP steel have a similar coefficient of thermal expansion and good interphase bonding. Furthermore, the TRIP-effect provides an increased energy absorption capacity of the composite material, while the Mg- PSZ increases the wear resistance and crack toughness of the MMC. The increase in wear resistance can be attributed to the hardness of the ceramic, while the crack resistance can be attributed to the increase in volume during the phase transformation from the tetragonal to the monoclinic phase. Because if Mg-PSZ particles are exposed to a stress field, that precedes crack propagation, a phase change occurs. The Mg-PSZ undergoes an increase in volume and generates a compressive stress field in the matrix, which counteracts to the stress field of the crack. Thus blocks the crack propagation and increases the lifetime of the component. For these reasons, an MMC made of these two materials is an ideal composite material for wear applications. It is also important that the reinforcing particles are not simply present in the matrix as disturbances, but are firmly integrated. This is the only way to increase the wear resistance of the component. This requires the formation of an interdiffusion phase between the matrix and the reinforcing particle. This ensures that a Mg-PSZ particle does not simply break out of the matrix under load. Thus the positive properties of the composite material can be ensured under load.

However, it is not cost effective to manufacture the whole component from one MMC if only a small area is exposed to stress and wear. Therefore, several methods have been established to apply wear resistant layers to a base material such as flame-sprayed coating for example. However, there is the problem that stress peaks occur at the abrupt material transitions, which often lead to a separation of the composites. A graded material can help here. This is because a gradient runs along the cross-section of the material which shows a significant change in the physical structure of the material. The material properties change almost continuously along the gradient. Since there is no abrupt material transition, there can be no stress peaks that lead to a separation of the wear-resistant layer. In addition, the gradient allows an optimal adaptation of the course of the properties to the external stress field and functional properties can be adjusted in components which are not possible with a direct material transition. Powder metallurgy again offers the possibility of producing such graded composite materials.

Powder metallurgy enables the production of graded particle-reinforced MMCs. But although powder metallurgy has achieved some success in this respect, it requires that the semi-finished products are very similar to the final component. During sintering under pressure, these semi- finished products are densificated to a close-component. However, it is much cheaper to produce simple semi-finished products and then to form and compact them by powder forging to complex components with the desired graded structure. However, in powder metallurgy, densification plays a decisive role. On the one hand, compacting the components leads to an increase in material properties. On the other hand, pores carry a high risk of fractures and cracks. Therefore it is important for the functionality of a component to eliminate or reduce the residual porosity to an absolute minimum in order to be able to use the full range of properties. In order to compact a graded preform of a particle-reinforced MMC to the full density of a compact material, a detailed knowledge of the stress progress and the compaction behaviour as well as of the material flow is necessary. In addition, to a multitude of other characteristic values such as shrinkage and Poisson's ratio those parameters are the most important. Knowledge of the stress distribution is important for achieving full density. This is because a defined relationship between hydrostatic and deviating stress components must prevail. Knowledge of the compaction behaviour is necessary to ensure consistent compaction in all layers of the graded structure. In addition, the flow of material must be precisely controlled in order to avoid cluster formation and to ensure that clusters that have already formed are broken up. Furthermore, despite the flow of material, the desired and adjusted graded structure of the component must be maintained. Otherwise it is not possible to obtain a fully dense component or to maintain the desired graded particle structure during powder forging.

Within the framework of the CRC 799 at the TU Bergakademie Freiberg, TRIP-Matrix Composites were compacted in this way with axial grading up to full density, while the graded

structure was retained. With this method it is now possible to produce components on the powder metallurgy route which have a high wear resistance and can use the full range of properties of composite materials.

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'ERDENET MINING CORPORATION' LLC RELATIONSHIP STUDIES ON QUANTITY AND QUALITY INDICATORS OF TECHNOLOGICAL LIME

KEY WORDS: lime, turbidity pH, activation, percent consumption.

The aim of this research work is to rationalise lime consumption by establishing mathematical modeling in order to determine the effect of technological lime and Ambient pH on flotation of copper molybdenum ore.

Several flotation reagent are used on concentration of copper-molybdenum ore in a concentrator, amomg them only lime is supplied from the domestic market. it is used to create an alkaline environment to separate pyrite from copper minerals and molybdenite. Calcium cations have a depressant effect on pyrite expect from hydroxyl ion . Pyrite suppression. Lime neutralizes the action of ions, which adversely affect the technological process therefore make it as the environment adjustable and provide it to ore mills and copper-molybdenum flotation in the form of lime milk. In order to maintain the technological regime of 'Erdenet Mining Corporation' LLC regularly, need to study the factors affecting concentrate quality and metal recovery. Sampled lime from the reagent section conveyor, as well as from the wagon in accordance with the standard, further defined the relationship between them, based on the materials described as of 2017-2019 or 36 months which described their quality indicators, study was performed to rationalise lime consumption.

Studied lime quality indicators relationship of 'Erdenet Mining Corporation' LLC, by mathematical statistical methods, determined the correlation, performed a regression analysis based on one factor.

The aim of research work: intended to to study the technological lime's quantity and quality of "Erdenet Mining Corporation' LLC and further to have research on the quality indicators' impact on lime consumption and copper, molybdenum recovery, to rationalise consumption.

Study work objects:

1. To have research on lime quality
2. To determine how lime quality affects its consumption and copper recovery
3. To conduct study in order to rationalise lime percent consumption

Research method: The calculation performed on EXCEL software.

Lime quality indication is determined according to 3 indicators. Showed the lime quality standards onTable 1.

Table 1 - Technological lime's quantity – quality standard of 'Erdenet Mining Corporation' LLC

No	Indicator name	Lime grade of Calcium deposits		
		I	II	III
1	Amount of active CaO+MgO, not less than%	90	80	65
2	Amount of active MgO, not more than %	2	2	2
3	The amount of the incompletely burned part, not more than %	12		

Activation - CaO + MgO content, according to the percentage of dry substance. The insoluble residue is the water-insoluble part, that is a loss. If the insoluble particles exceed the allowable amount, the use of lime will increase, the dough becomes clogged in lime milk

pressing tubes, further it is difficult to adjust the turbidity pH automatically, increases the loss of metal in the waste. To monitor and regultate the reagent concentration in turbidity is the unique way to maintain the optimal reagent regime utomatically and create a reliable and efficient system with maximum flotation and minimum reagent consumption.

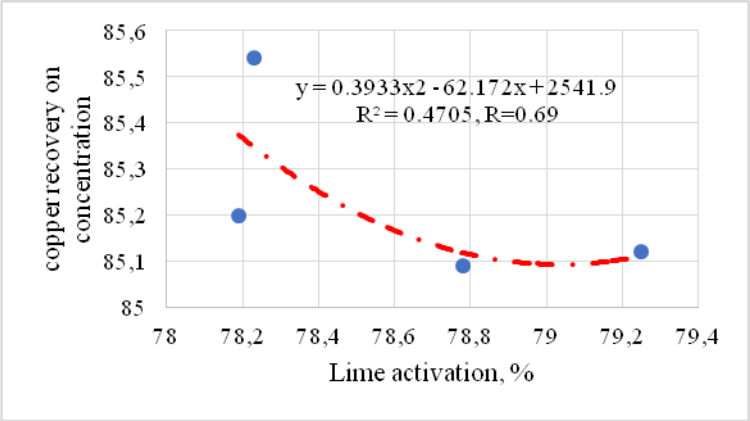


Figure 1 - Correlation between copper recovery on varietal concentration and lime activation

Content of copper recovery on varietal concentration is more thatn 85% when lime activation is more than 78%. The correlation coefficient is 0.69, which means strongly correlated.

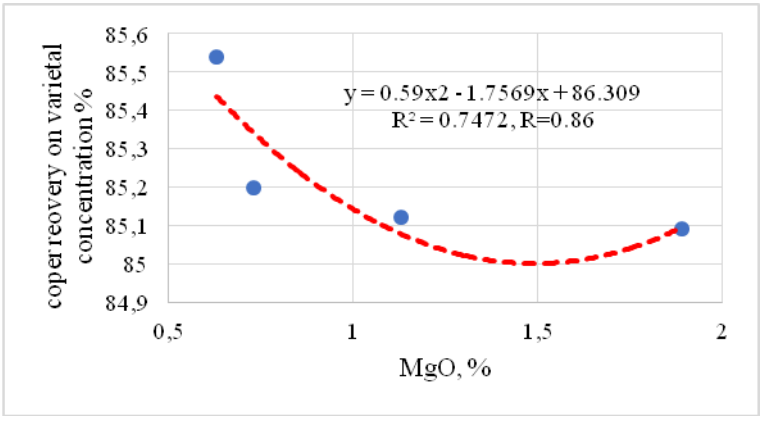
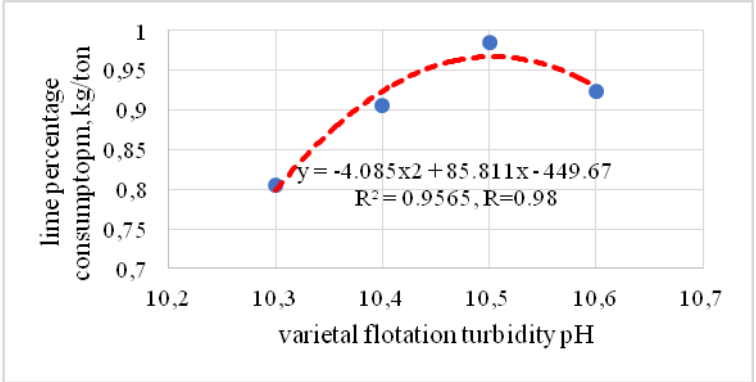


Figure 2 - Correlation between copper recovery on varietal concentration and magnesium oxide content

Content of copper recovery on varietal concentration is more thatn 85% when magnesium oxide in the lime is more than 0.65-1.9%. The correlation coefficient is 0.86, which means strongly correlated.



Figrure 3 - Correlation on lime percentage consumption and varietal flotation turbidity pH

When to increase varietal flotation turbidity pH, lime percentage consumption was increased, therefore it has significantly strong correlation. 10.3 - 10.4 is the most rational amount

of turbidity pH, and the most less amount of lime consumption. This depends on the nature of the ore, as shown in the following figure.

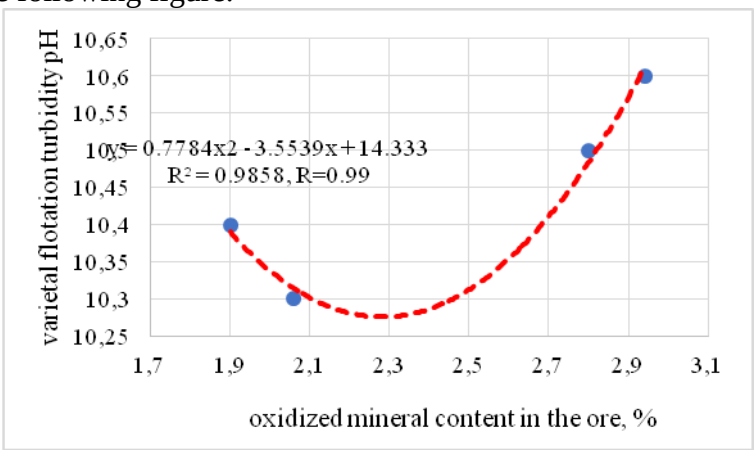


Figure 4 - Correlation on oxidized mineral content in the ore and varietal flotation turbidity pH

The study shows that when increase oxidized mineral content in the ore, varietal flotation turbidity pH was increased, therefore it has significantly strong correlation. When oxidized mineral content 1.9 – 2.7% , pH indicator is 10.3 – 10.4. This is reflected in the research works of Russian and Mongolian researchers. The most rational amount of varietal flotation turbidity pH is 10-10.2 in primary copper dominated ore.

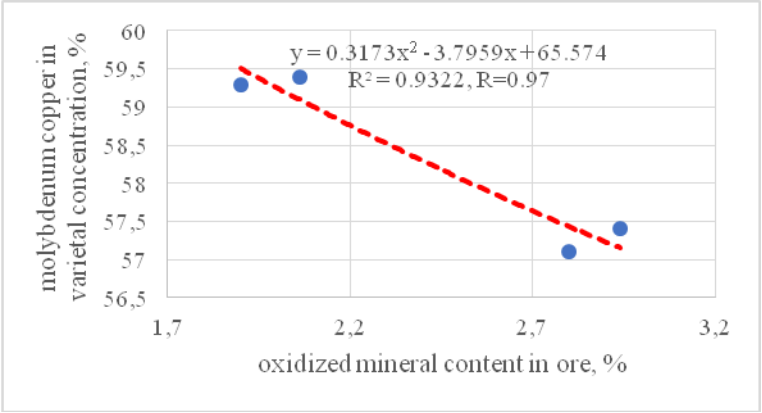


Figure 5 - Correlation on molybdenum recovery in varietal concentration and oxidized mineral content in ore

Increasement of oxidized mineral content in ore has negative impact on molybdenum recovery in varietal concentration.

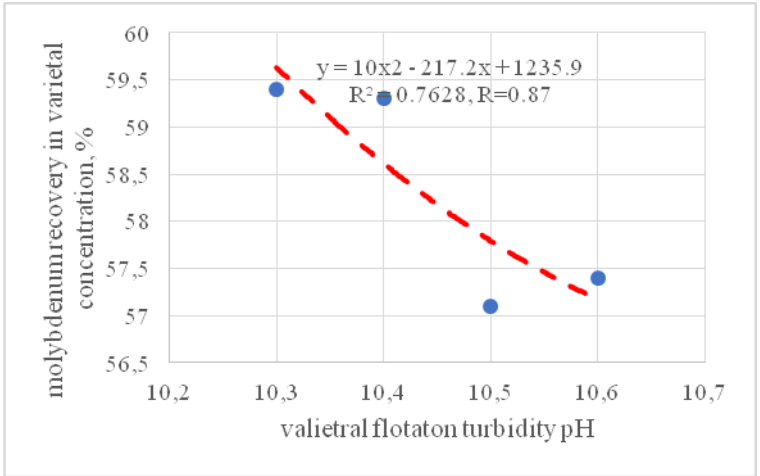


Figure 6 - Correlation on varietal flotation turbidity pH and molybdenum recovery in varietal concentration

When increase varietal flotation turbidity pH, molybdenum recovery in varietal concentration is decreaed.

Lime percentage consumption has economic profit when calcium lime deposit I-II grade lime is incorporated into the flotation process. Researcher (4) rationaled the following proper ratio at laboratory level, such as At low pH, alkyl acid allyl esters and molybdenite collectors have high copper and molybdenum yields and low iron yields in a mixture of aromatic hydrocarbons (non-polar collectors - petroleum products), based on the flotability of primary copper sulfide chalcopyrite.

Conclusion:

1. Quality indicators of lime, activation, magnesium oxide and insoluble residues strongly affected to the copper recovery in varietal concentration.

2. When concentrate 1 ton sulfide ore, lime's the most rational amount and percentage consumption amount that has economic profit is 0.8 – 0.9 kg/ton.

3. Increasement of varietal flotation turbidity pH reduces the molybdenum recovery in varietal concentration.

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THE EFFECT OF SURFACE PROPERTY ON COPPER RELEASE FROM BORNITE-NEW PERSPECTIVE OF COPPER POLLUTION MONITOR

The development of mining industry brings numerous copper sulfides to be exposed to air, resulting in human beings suffered the risk of diseases such as neoplastic disease, Alzheimer's diseases and childhood cirrhosis due to the copper pollution [1]. Bornite, a widespread copper sulfide, whose dissolution takes an essential part in copper release and the formation of acid mine drainage (AMD). Given that the dissolution of bornite is a redox reaction and mainly occurs in high potential region, the high-potential conditions of AMD environment further promotes its dissolution, thereby exacerbating copper pollution [2]. On the other hand, the sulfur-rich film forms on bornite surface and hinders further dissolution in high potential region [3, 4]. These findings came up with a question: how the high potential affects the p surface property of bornite in acid environment? To fill up this knowledge gap, we conducted the electrochemical experiments and surface analytical techniques to monitor the surface property of bornite at constant high potential.

We conducted the electrochemical experiments in a conventional three-electrode cell. Graphite rods were used as counter electrodes, and an Ag/AgCl (3.0 M KCl) electrodes was used

as reference electrodes. The distilled water with pH 1.5 (by 20% (w/w) dilute sulfuric acid) was used as electrolyte. 20 minutes sparging by nitrogen gas to remove dissolved oxygen before and during experiments. Chronoamperometry (CA), was performed at the potential of 0.50, 0.60, 0.70 and 0.80 V for 6 hours respectively; afterwards, we conducted Electrochemical Impedance Spectroscopy and Tafel experiments. After electrochemical experiments, the bornite electrodes were rinsed with deionized water, then transferred to a vacuum box and dried at 45 °C; afterwards, the dried samples were investigated by a Raman and X-ray photoelectron spectroscopy (XPS).

We found that Cu exists in the form of Cu (I) during bornite dissolution, and S^{2-} converted to S_2^{2-}, S_n^{2-}/S^0 and SO_4^{2-}--decreased electrochemical conductivity of bornite--hindered the further dissolution. The corrosion current density was inversely proportional to potential that bornite surface subjected. The amount of S_n^{2-}/S^0 increased and the corrosion current density decreased with the increase of potential until 0.70 V. An obvious reverse emerged at potential of 0.80 V- the corrosion current density increased with the decrease of S_n^{2-}/S^0-bornite further dissolution. The sulfur film played the key role in bornite dissolution, and affected the copper release from bornite. These findings open the new door on copper pollution control.

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MINING DUMP PROCESSING PLANT

The use of crushed or ground materials helps to accelerate the processes of firing, dissolution, chemical exposure, etc., due to the fact that the surface of the processed material is significantly increased. The intensity of most technological processes directly depends on the surface size of the processed solid materials. If you increase their surface by reducing the size of the pieces, you can significantly increase the speed of the process itself, as well as increase the yield and improve the quality of the final products [1]. The process in which pieces of solid materials are reduced in size is commonly called crushing or grinding. Crushing is most often understood as the reduction in the size of large pieces. The process by which small pieces are crushed is commonly called grinding.

Grinding, as a rule, is subjected to natural raw materials (various rocks), fuel (coal), semi-finished products and ready-made products. Grinding is called large, if the transverse size of the processed pieces is from 200 to 1000 millimeters, medium and intermediate, if their size varies from 50 to 250 millimeters, small - from 20 to 50 millimeters and thin (grinding) - from 3 to 25 millimeters. Grinding can be dry or wet (carried out with the addition of a certain amount of water to the source material) [2].

When crushing or grinding pieces of solid materials, a lot of mechanical energy is expended, so you should choose the grinding method as correctly as possible. The grinding process is

characterized by many factors. One of the most significant of them is energy consumption. The stronger the material being ground, the greater the energy cost.

In this article, we will consider wet grinding, namely disintegration with the addition of a certain amount of water to the starting material. Disintegration is a process of mechanical grinding of solids that can be represented by crushing or grinding. The high energy of the jet, in this installation, is generated due to the centrifugal force of the jet flowing from the rapidly rotating (up to 50,000 rpm) rotor. Grinding to a fine fraction is carried out in one stage of processing, which traditional mechanical crushers (jaw, roller and centrifugal) are incapable of, which will require several stages of processing.

The possibility of implementing and creating a new method of processing dumps with the addition of water to the source material is confirmed by engineering calculations. The obtained experimental data are almost completely similar to design calculations. The calculation was made for the density of the material behind the nozzle of the rotor disk: ρ = 4 t / m3 or 4000 kg / m3 - which corresponds to the density of granite. The disintegrator is designed for grinding rocks with a maximum particle size of up to 300 mm. In this case, the drum diameter will be at a level of from 2000 to 2200 mm, and the length will be no more than 1.5 m. The capacity of the disintegrator due to the new method can be increased by 1.5-3 in comparison with traditional mechanical crushers and their analogues. This will be very noticeable in the energy consumed for the production of 1 ton of rock, as well as increased wear resistance, and as a result the resource of this installation. The increase in energy consumption due to the additional rotation drive of the hollow shaft of the rotor can be partially compensated by a decrease in the load on the rotation of a less unbalanced drum in the working position, due to an increase in the rotation speed and a more uniform distribution of material on the inner surface of the drum [3].

The economic effect of the proposed grinding technology develops due to the achievement of a high degree of crushing in one apparatus and in the rejection of the stages of medium and fine crushing in the technological chain. The installation allows you to get up to 3 grams of gold and rare-earth metals from 1 ton of the waste dump. According to the results of the installation calculation, it can be concluded that the more productive the installation, the lower the cost of processing 1 ton of rock. Currently, this technology and the installation itself will be indispensable in the processing of mining dumps.

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HEAT TREATMENT OF RAILWAY WHEELS

Heat treatment of railway wheels is the most important technological operation that provides railway wheels with the necessary mechanical properties. For almost all railway wheels, heat treatment is a process of thermal hardening of the rim. After quenching at a temperature of 850 °C rapid cooling to a temperature of about 300 °With only the rim exposed. This is usually done with water. After the rim is quenched, the disk and hub are still at a temperature close to the lower critical temperature. Further cooling of the wheel is performed in air, which provides the rim with high strength and compressive residual stresses. The final

operation is to release the entire wheel at a temperature of 500 °C. This release is made to reduce the overall level of residual stress, but without significantly changing the microstructure and mechanical properties of the wheel material.

Purpose of heat treatment of a railway wheel.

The main goal of heat treatment of a railway wheel is a high homogeneity of the microstructure in the rim, both in the radial and tangential directions. This is necessary to ensure uniform wear of the riding surface and prevent the formation of non-roundness of the wheel. In addition, wheel operation defects such as fatigue damage to the riding surface are minimized.

One of the main requirements for wheels for railway transport is the high wear resistance and strength of the rim, which should be maintained even after repeated wheel turning. To fulfill this requirement, it is necessary to obtain a uniform and uniform material structure across the thickness of the rim. The process of microstructure formation in the wheel rim mainly depends on quenching conditions, in particular, on the cooling speed of railway wheels.

Equipment used for heat treatment:

1. the quenching Furnace is used to maintain a constant temperature, which is given in the map, high-speed pulse burners are used, which are installed horizontally opposite each other at the level of the movable hearth. Due to the large number of burners and their location, the optimal distribution of heating power along the entire length of the furnace occurs.

2. Heat recovery Unit is used for flue gas utilization, the furnace is equipped with a Central heat recovery unit integrated into the chimney system, which is designed to heat the combustion air to an optimal temperature.

3. Quenching machine, used cassettes with nozzles to temper the surface of the ride. The temperature and time of quenching is carried out according to the requirements of the technical map. The indicated parameters of the heat treatment process provide uniform cooling of the railway wheel rim, the formation of a railway wheel rim at a depth of 30 mm from the rolling surface of the structure, providing high wear resistance and strength of the rim while maintaining the required level of plastic properties and impact viscosity, as well as high resistance of the railway wheel to cyclic loads due to the formation of fields compressive residual stress s that inhibit the growth of cracks during operation.

4. Tempering furnace, uses pulse burners for optimal temperature maintenance.

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POST-COMBUSTION ARTIFICIAL NEURAL NETWORK MODELING OF NICKEL-PRODUCING MULTIPLE HEARTH FURNACE

In a nickel-producing multiple hearth furnace, there is a problem associated to the automatic operation of the temperature control loops in two of the hearths, since the same flow of air is splitted into two branches. A neural model of the post-combustion sub-process is built and served to increase the process efficiency of the industrial furnace. A brief review of the literature evidences the conceptualization of the system of extreme control that aims at maintaining the temperature at the maximum value planted by Angulo [1], was not successful because it required the measurement of the composition of the gases, which is not possible to do adequately due to the critical characteristics of the atmosphere inside the furnace. A linear mathematical modeling for the state-owned Commander Rene Ramos Latour factory - a nickel-producing plant, by Ramírez [2] was performed. Models that characterize post-combustion were achieved by experimental identification, with mean square error (MSE) ranging between 0.72 and 6.1. The multivariable strategy was tested, which seemed to be effective, but it was not

implemented definitely because the Nicaro plant closed in 2012 as it was not economically sustainable. Such a dynamic mathematical modeling was obtained by Montero [3], with goodness of fit within 63 and 84 %, for Commander Ernesto Che Guevara - a nickel and cobalt producing plant located at Punta Gorda in Holguin province of Cuba. A classical multi-variable control strategy was simulated, where as an input variables the ore flow fed to the furnace, the air flow to H4 and H6 were selected, and as output variables H4 and H6 temperature and concentration of the waste carbon monoxide were selected. Although the former mathematical models (i.e. the model in the furnaces of Nicaro [2] and the model in the furnaces of Moa [3] allowed to deepen the dynamic behavior of the post-combustion sub-process to reach conclusions for the operating points, due to the linear character of the models; it did not enable the design of advanced control strategy required for the process complexity.

Obtaining a mathematical model that describes the process from the phenomenological point of view would be extremely complicated, since the physicochemical processes involved would lead to partial differential equation systems, non-linear and variable in time. For this reason, the experimental identification was implemented. As an auxiliary tool to select the variables to be used in the control, a statistical analysis was carried out based on a set of operating data, which were continuously and properly measured. The statistical analysis and descriptive time series methods were performed aimed at determining the variables which influence most in the behavior of TH4 and TH6. Operating data from the reduction furnace were taken for this analysis with a sampling period of 120 s, from May to July 2015 and then again from four months of 2018 and it was processed using Statgraphics Plus 5.1. Step-function experiments were carried out in order to determine the prevailing time constants of the post-combustion sub-process and taking into consideration the existence of sudden disturbances.

The experiments were carried out in the reduction furnace operating under adequate technical conditions and it is provided with better sensibility in response to the temperatures of the H4 and H6 in the presence of variations on the opening of the regulating valves. The reduction furnace is provided with 8 combustion chambers (6S, 8N, 8S, 10N, 10S, 12N, 12S and 15S), 67 arms in the central shaft and all the domes are under proper technical conditions.

The justification of the ANN is given because the complex structure of multiple variables does not allow evaluating a single stochastic process of temperatures throughout the furnace, but rather that there are only time series in the different chambers and hearths, therefore, it is not a trend analysis in the length of the process time in the entire furnace is very effective. Thus, the ANN is able to learn from the hidden patterns in those variables and adjust the stationary behaviors. The software MATLAB® and the identification toolbox with neural networks developed by Nørgaard [4] were used for the analysis of ANN in this study. Specifically, a totally connected network architecture with three regressors as inputs, hyperbolic tangent in the hidden layer and a linear neuron as output was taken. The structure of the ANN was (NNARX) 221 and although multiple tests were performed; the best results were obtained with this structure. The results show prediction errors for TH4 of 0.6 and 0.3 for TH6, with hyperbolic tangent five neurons in hidden layer. These results are better than errors (0.72 for TH4 and 2.25 for TH6) with linear models applied to a similar process [2].

Despite the significant effort made in research about reactions occurring during material processing operations, the knowledge of such reactors is still essentially incomplete particularly in the context of the reduction of laterites, to which the present study is linked. It is proven through statistical analysis that among the most influencing variables on the temperature of the hearths four and six (H4 and H6) are the opening of the valves regulating the air flow to the previously mentioned hearths. The multivariable character and nonlinear behavior of the thermal profile of H4 and H6 were tested regarding the air flow supplied to these hearths, in a stationary state. The testing and error process allowed selecting the ANN which better characterizes the post-combustion sub-process of the multi-hearth furnace. In practice, it is shown that a small number of neurons in the hidden layer is enough in order to obtain a good neural model of the process. In the same proportion as the number of neurons is increased, in the said layer, the

models do not differ much although light improvements are evidenced in the auto-correlation function of prediction error and similar confidence levels. In addition, this implies a greater volume of calculation by the network. The results of the comparison showed that the model obtained through the use of ANN, reflects with more accuracy the dynamic characteristics of the post-combustion sub-process than the linear models according to the mean square error, thus testing the potentialities that offers this tool of artificial intelligence.

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THE CENTRAL KYSYLKUM PHOSPHORITES' ORIGIN CHARACTER AND CONDITIONS OF DETERMINATION OF RARE EARTH ELEMENTS AND URANIUM IN THEM

The granular phosphorites' origin of the Central KyzylKum occurred mainly in the Paleozoic era, 300 million years ago and has organogenic character. The nature of the host rocks, the particularities of phosphorite lithology, their frequent connection with glauconite facies, the findings of marine phosphatized fauna, etc., show that the accumulation of phosphorites occurred in marine basins of normal salinity, in the shelf zone. Multiple formation of the seas and their drying explains the presence of several layers (more than 5).

Researchers have tried differently to explain the genesis of phosphate accumulations. The most widespread hypothesis of A.V. Kazakov, according to which phosphorites precipitate by force of chemogenic in the offshore zone when lifting deep sea waters, saturated with carbon dioxide and phosphates, which enrich sea water in the depth range 400–1000 m due to the decomposition of dying microplankton off. When entering the shelf under conditions of reducing pressure and increasing water temperature, phosphates and calcium carbonates reach the saturation limit and precipitate, forming phosphatized silts.L.V. Kazakov explained the relation of nodular phosphorites with platform sediments by the fact that the platform seas had a wide shallow shelf, on which precipitated phosphates were "smeared" over a large area. [1]

When analyzing phosphorite deposits, the presence of alternating three layers was established.The first layer occurs at a depth of 22-25 m, after 7-12 m followed by a second layer, and, 3 layer follows after 12-15 m of depth. Industrial importance in today is shown up to be first 2 layers, from which washed burned phosphorite concentrate is obtained at the Kyzylkum phosphorite plant. The presence of the fourth and fifth layers was detected. The first two layers have a thickness of 60-80 cm, the second about 53-58 cm. In the first layer, the amount of useful component - P_2O_5 makes up 12-16%. The second layer is considerably richer and the average P_2O_5 content makes up 19-21%.

In the early 2000s, in the countries of the Middle East and North Africa's , phosphorite deposits in clays with bone residues of fossil fish, uranium and rare earth elements have been detected. [2] Phosphate fish bones are found in many deposits that are various ages and in the

phosphorites of Central Kyzylkum. In fact, the remains of ichthyofauna (bones, teeth, fish scales) turn out to be enriched with uranium. Similar deposits are occurred shallow, which allows them to be developed in an open method: easy to get concentrate, fit for hydrometallurgical processing by simple gravitational enrichment of clays. [3]

In chemical plants, when receiving phosphate fertilizers, the acid method has been using, where, together with a useful component - P2O5, radioactive elements can get into fertilizer.

Therefore, the aim of the present research was to establish the presence of radioactive elements in phosphorites with the goal to extract them.

Using the neutron activation analysis (NAA) method of phosphorite samples, selected from the Tashkurinsky deposits, various stages of processing at the Kyzylkum phosphorite combine showed the presence of uranium in them, thorium and 11 rare earth elements. Currently, studies have begun on the extraction of these elements from phosphorites in order to obtain environmentally friendly phosphorus fertilizers.

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DEVELOPMENT OF METHODS OF ENRICHMENT OF ANGRENIAN LOCAL COAL AND PROSPECTS FOR EXTRACTION OF METALS FROM ASH

When creating effective technologies in the sectors of the fuel and energy industry, special attention is paid to research and development of technologies that provide for the most complete and rational use of each country's own raw materials.

Uzbekistan has proven reserves of coal in the amount of 1900 million tons, including: brown - 1853 million tons, stone - 47 million tons. Predicted resources amount to over 5.7 billion tons of coal. Large reserves of coal are concentrated in the southern regions - incl. Active mining is carried out at Angren brown coal deposit, Shargun and Baysun coal deposits.

Improving the quality of coal raw materials at the present stage is possible only with the use of enrichment methods that allow to obtain high-quality coking and thermal coal, which are in demand both in the domestic and foreign markets [1].

At foreign coal processing plants, gravity, flotation, magnetic and dry enrichment methods are used [2]. In Russia, when coal is enriched by flotation, intermediate products of oil refining and petrochemical waste are used as reagents [3].

A characteristic feature of the Angren brown coal deposit is that coal reserves are compactly concentrated with deposits of aluminosilicates, which affect the quality of coal. Because of this, coal with a high ash content of 40 to 55 is mined in the «Angrensky» deposit.

To reduce the ash content of brown Angren coals, studies were conducted on the basis of the Technopark of the Navoi State Mining Institute (NGGI) and the laboratory of the NGGI to determine the possibility of enrichment of Angren coals. The material composition of coals was studied, where up to 20 elements from the group of rare (Li, V, Mo) and precious (Ag) were found in ash. Studies are underway to extract some of these elements.

For enrichment, gravity enrichment methods using depositing machines and a screw separator were used. The results showed that for the enrichment of coal from the Angrensky deposit, the use of the gravity concentration method on depositing machines is effective. The results obtained indicate a high deposition efficiency for coal enrichment. So, when depositing at one time, it is possible to bring into the tailings a product with a dump ash content of 62-68% and a yield of ash product of up to 32%, i.e. when using this enrichment method for coal of particle size class -2 +1 mm, the ash content of the initial ore can be reduced from 49% to 32%, thereby increasing the calorific value.

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ASSESSMENT OF COPPER RECOVERY FROM OXIDATIVE LEACHING OF KHAN MINE TAILINGS

Khan Mine located in Arandis, Erongo Region, Namibia, is a copper mine that closed in 1918. Mine tailings are important secondary source of copper [1], [2]. The present study aimed at finding the process conditions to optimally extract copper by oxidative leaching from the complex historical mine tailings containing a variety of copper oxide minerals and sulphides which combine to give about 0.99% Cu.

Quantitative experiments conducted on a completely randomized basis included Particle Size Distribution (PSD) analysis of milled tailings which were then characterized by X-Ray Fluorescence (XRF). The leaching experiments followed a 4×2 factorial design with the two factors being sulphuric acid concentration and time. Leaching experiments were done in $H_2SO_{4(aq)}$ with 0.25M $Fe_2SO_{4(aq)}$ as an oxidizer while varying the acid concentration from 2M, 1.5M, 1M and 0.5M at 2, 4, 8 and 12 hours at a constant solids to liquids ratio of 1:5. After leaching the residue was taken for XRF analysis. The experimental work was partially informed by the work of Stevanović et al. [3] and literature by Mukherjee and Gupta [4].

The particle size distribution analysis yielded P_{80} of 75 microns. Leaching results showed that an increase in acid concentration did not have an effect on the recovery of Cu, but the recovery was high at 2 and 12 hours compared to other hours and the average recovery of copper into the pregnant leach solution was 63% Cu. XRF analysis results of the residue showed that the residues contained a lot of sulphur of about 4.4%.

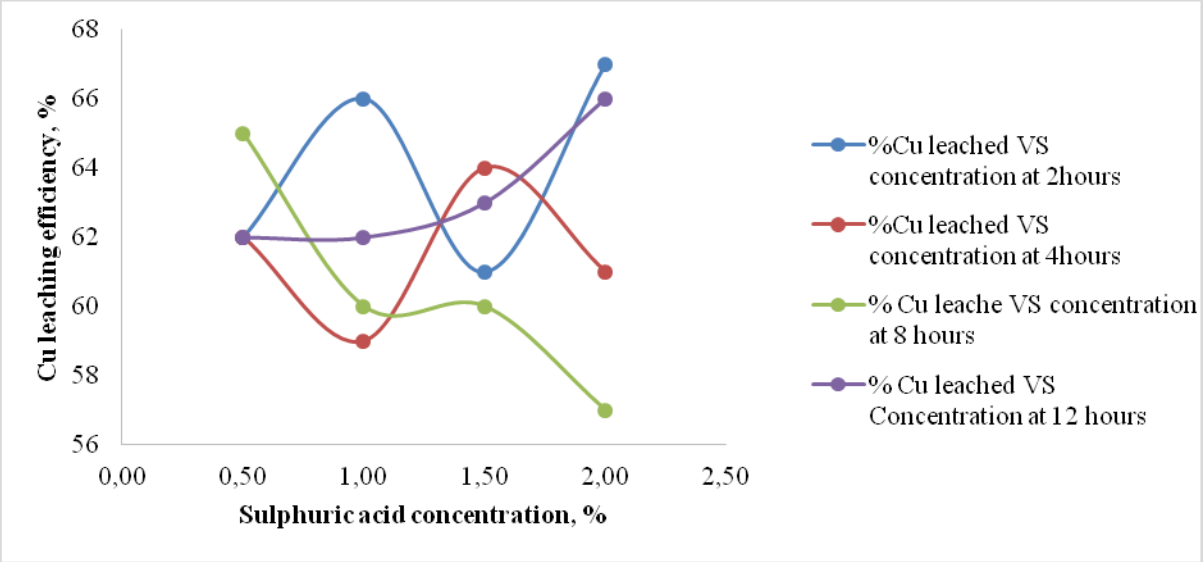

Figure 5 - Recovery of copper vs concentration curves at different hours

The experimentation was done to examine copper dissolution in acid in the presence of an oxidizer, and the outcome has shown it is practicable. It has revealed an average copper recovery into the pregnant leach solution of 63%. Future work can involve variation of the oxidizer concentration, agitation rate, and solids: liquids ratio to improve the copper leaching efficiencies.

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EVALUATION OF TANTALITE LIBERATION BASED ON JIG PROCESS STREAMS

The primary source of tantalum is columbite-tantalite ores which are oxides of tantalite [1]. It is economical to use gravity concentration in the processing of tantalum ores due to its high specific gravity [2]. The jigging process is adequately discussed by [3] and [4]. Tantalite (Ta_2O_5) recoveries at a mineral processing plant for high-grade tantalite pegmatite ore have been historically low. Particle size analyses of the jig tailings established a mean P80 of 6.2 mm

at which the Ta_2O_5 is not fully liberated. This study established the particle size for optimum liberation of tantalite which is recovered by jigging.

Quantitative experiments were conducted on a completely randomized basis. Experiments included Particle Size Distribution (PSD) analysis of jig tailings, feed and concentrate with each stream classified into four size classes per trial, for a total of five (5) trials. Classified material was pulverized then characterized by X-ray Fluorescence (XRF). ANOVA was applied in analyzing the statistical significance of the findings.

The particle size distribution trends of jig feed, tailings and concentrate show that the particle sizes of the concentrate were much smaller compared to those of the feed and tailings (Figure 1). Recoveries in the 1-2 mm particle size range were consistently high (~70%) for all experimental trials.

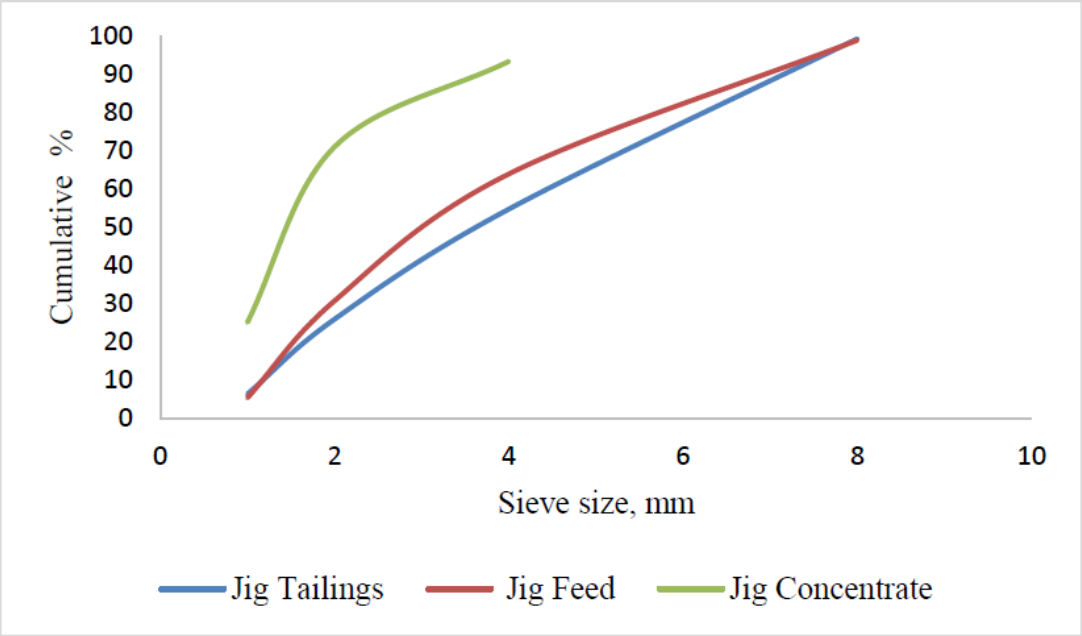

Figure 1 - Particle size distribution curves

Average tantalite recovery from the jig is 47%, with average grade in the feed, concentrate, and tailings at 607, 1641 and 451 ppm respectively. 1-2 mm is the optimum particle size for tantalite concentration by jigging. The *p*-value of 0.006 indicates a significant difference at the 5 % level in tantalite recoveries for different particle size classes of jig feed. A ball mill can be installed to grind the existing tailings with shaking tables used for the tantalite concentration.

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THERMODYNAMIC EXPLANATION OF THE CARBONIZATION PROCESS OF RARE-EARTH METAL PHOSPHATES

The use of rare earths is increasing every year. Moreover, the development of high-tech industries requires even more of them. This shows that in the future these elements will play an even more important role in the development of the global economy.

One of the richest sources of rare earth metals is phosphate raw materials, for example, apatites of the Kola Peninsula. In the process of their processing, huge amounts of solid dumps are formed, where REE is concentrated.

Therefore, in our study, a key reaction for processing solid waste dumps is a reaction of the form: $LnPO_4 + 2\ CO_3^{2-}{}_{(aq)} = Ln(CO_3)_2^{-}{}_{(aq)} + PO_4^{3-}$.

The change in Gibbs energy of the target reaction must be calculated for the thermodynamic assessment of the carbonization process [1]. During the calculations, it was determined that this value for each of the elements considered is significantly lower than zero [2,3], and its average values are from -327 to -142 kJ / mol.

Thus, it was determined that the reaction is thermodynamically possible and to determine the specific parameters of the processing of solid dumps of phosphogypsum, it is necessary to conduct additional kinetic studies.

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RHEOLOGICAL EXPLORATION OF MULTI-COMPONENT PARTICLE SLURRY SUSPENSION – AN APPLICATION IN HYDROCYCLONE SEPARATOR

KEYWORDS: Mineral suspension rheology, multi-component, hydrocyclone, CFD, Viscosity mathematical model.

Metal extraction industries occupy a major share on the supply of commodities from underground through mineral processing. In a mineral processing unit, the importance of the suspension rheology is evident, with a changing percentage of solids, design parameters of the equipment, and environmental conditions. Due to the multiple properties of the natural ores the

hindered-settling velocities for the settling or non-settling particles changes. As we focus on the multi-component particles, the mixture effect is even more crucial to understand during any mineral processing. The rheological characteristics may also represent the particle-particle and particle- fluid interaction and aggregation[1], which eventually influences the transportations and separation mechanism. Hence, it is very important to predict the component effect on the mixture viscosity accurately.

To understand the effect of the rheological impact on the mineral processing equipment, the experimental analysis or computational approach such computation fluid dynamics can be adopted. The pre-processing of the minerals before the extraction process usually consists of the wet circuit equipment such as grinding[2], hydrocyclone classifier, etc. [3] explored the viscosity effect in hydrocyclone in and out streams by installing an on-line viscometer set up. Recently, authors [4] worked on the experimental exploration of bi-modal and poly-dispersed minerals (silica, magnetite and chromite ore) as pure and mixture feed to a double-gap rheometer (Anton-Paar MCR301) to evaluate the flow curves. The data was utilized to develop a multicomponent viscosity model including the fines fraction corrections.

$$\eta_r = \frac{\eta_H}{\eta_w} = (\eta_{lw})\left(\frac{\eta_H}{\eta_{lw}}\right) = \left(\frac{\eta_l}{\eta_w}\right)\left(\frac{\eta_H}{\eta_{lw}}\right) = \eta_{Lr}\eta_{Hr} \quad (1)$$

Where,η_{rmix}, η_{lr}or η_{lw} and η_{Hr} or η_{H-lw} represents the relative viscosity for mixture, lighter component slurry viscosity, and heavier component viscosity in a lighter component slurry. Further, it can be expanded as

$$\frac{\eta_L}{\eta_w} = k_1 * \left(1 - \frac{\alpha_{tL/(L+w)}}{0.62}\right)^{-1.55} \quad (2)$$

$$\frac{\eta_H}{\eta_{lw}} = k_2 * \left(1 - \frac{\alpha_{tH/(H+L+w)}}{0.62}\right)^{-1.55} \quad (3)$$

In equation (3), $k_2 = k' * k_2'$. The k_1, k_2' are constants represents the $F_{-38\mu}{}^{0.39}$ (fines below 38 microns and k' is defined as a function of intrinsic viscosity. As introduced previously, the CFD approach has been adopted utilizing the new mixture viscosity model as a user-defined function to define the material property in ANSYS FLUENT software for a 3-inch hydrocyclone separator [5]. Further, the multi-component interaction given by newly modeled rheological and settling behavior of different density and poly-size particles during the classification is explored. The predicted classification parameters and viscosity distributions at various radial and axial position (as a function of volume fraction) are validated by comparing it to the experimental data. The initial full – water simulation is started using the RSM model to resolve the turbulence. Further, VOF is utilized to create the air-core at a low-pressure zone. The modified ASM is used to introduce the magnetite and silica particle as a feed mixture for 0:100 (pure silica), 50:50, and 100:0 (Pure magnetite). The description is not presented for the brevity of the manuscript.

Rheology and its effect – In a hydrocyclone separator.

Figure 1(a) shows the experimental 20 wt. % viscosity data for the various proportion of the magnetite and silica. At the low shear rate, the viscosity is observed to be highest, as observed in the experiments. With the increase in the percentage of magnetite, the magnitude of viscosity is observed to be increasing. This indicates that as compared to the lighter particle, the magnetite viscosity is higher by magnitude (0.15 – 0.02 Pa. s) as all the particles are accumulated near the spigot zone. Figure 4 (b-i) illustrates the mixture (50:50) viscosity when predictions have been done without the MCV – UDF, and the viscosities obtained by the same is observed as under-predicting. It is observed from the contours of the mean viscosity predicted by the numerical calculation (see Figure 1 (b-ii) & 1(c)); the maximum viscosity has close estimation to the experimental data.

The predicted viscosity for the 20% solids mixture in 3-inch hydrocyclone is obtained up to 0.031 Pa. s, whereas for the 50 % solids, it increased ten times up to 0.28 Pa. s. The 20 % solids condition is validated with the rheological experimentation at various shear rates. The similar studies of different other wet mineral processes can be explored to reduce the inefficiencies or understand the design faults to achieve higher productivity.

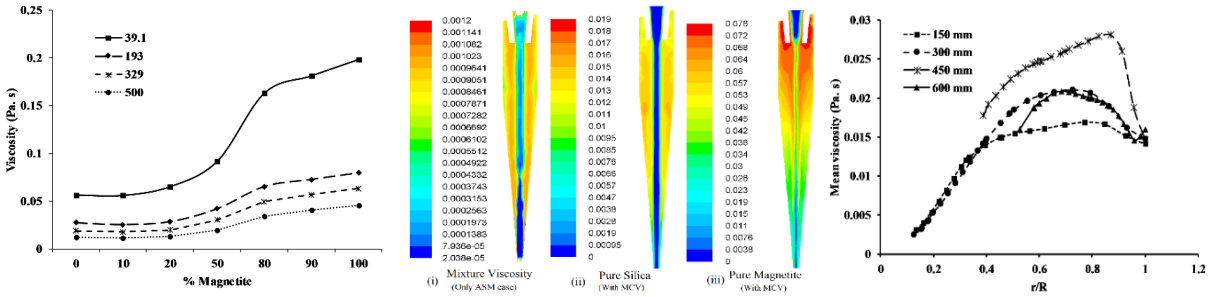

Figure 1: (a) Experimental viscosity data with the change in % magnetite at various shear rates. (b) Viscosity contour of (i) Mixture in only ASM case (ii) pure silica and (iii) magnetite in a 20% solids classification system. (Pa. s) (c) Mean viscosity presented radially.

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ANALYSIS OF THE POSSIBILITY OF PRODUCING LARGE-CRYSTAL FLUORINE ALUMINUM

Fluoride compounds occupy one of the most important places in modern chemical technology and technology. Fluorine is an essential companion of phosphorus-containing raw materials. The reserves of fluorine in phosphate raw materials are more than 100 times higher than their reserves in the contents of fluorspar.

The technological scheme for the production of aluminum fluoride consists of the following stages: neutralization of hexafluorosilicic acid with aluminum hydroxide, separation of the suspension with the removal of silica gel, crystallization of aluminum fluoride, filtration and drying of the finished product.

At this stage, companies producing aluminum fluoride have stringent requirements for crystal sizes, which should be at least 45 microns. However, at most plants in the CIS countries, the technology for the production of aluminum fluoride does not allow to obtain crystals larger than 45 microns in excess of 85 wt. % Therefore, the aim of this scientific work was to study the possibility of obtaining coarse-grained aluminum fluoride with crystals of a given size by adjusting the technological parameters of the individual stages of production.

A small number of works has been devoted to the production of aluminum, which are aimed at studying the kinetics of crystallization, establishing the influence of the contents of the initial mixture of acids on the contents of the final product [1], as well as solving technological and economic issues [2, 3].

The main attention was paid to the technological parameters of the stages of neutralization of hexafluorosilicic acid and crystallization of aluminum fluoride, since these stages have a significant effect on the size of crystals and their habitas.

The main parameters were chosen: the molar ratio $Al(OH)_3$: H_2SiF_6, the initial temperature, the speed of rotation of the stirrer, and the duration of the stages of neutralization and crystallization.

In research the influence of the molar ratio, the results showed that the largest crystals are formed at a molar ratio of $Al(OH)_3$: H_2SiF_6 equal to 2.0 Under these conditions, a polydisperse contents with a particle size of 5 to 200 μm is formed, while under other molar ratios, the maximum particle size reached 150 microns. Moreover, more than 75% of the particles have a size of more than 45 μm due to the fact that the unreacted part of hexafluorosilicic acid negatively affects the crystal growth rate, its habitas and other indicators of product quality. Therefore, to perform subsequent syntheses, a stoichiometric molar ratio of 2 was taken.

In research of the influence of changes in the initial temperature in the range of 70-90 °C. It was found that with an increase in the neutralization temperature, a narrowing of the particle size range was established, while the proportion of particles greater than 45 μm increased from 75 to 85%. This result is due to the fact that at a lower temperature, aluminum fluoride sent for filtration begins to crystallize already at the filtration stage.

In research the effects of the duration of neutralization in the range of 20-30 min and the speed of rotation of the mixer 50-100 rpm did not show a noticeable effect on the size of the crystals of aluminum fluoride.

Based on a research of the influence of technological parameters on the size of crystals formed at the stage of neutralization of hexafluorosilicic acid with aluminum hydroxide, the optimal values of the studied parameters are established:

- molar ratio of $Al(OH)_3$: H_2SiF_6 at the stage of neutralization, equal to 2;
- the initial temperature of the stage of neutralization is not less than 80 ° C;

At the crystallization stage, the influence of such parameters as temperature, duration and speed of mixing was investigated.

The results of the research of the effect of crystallization temperature on particle size showed that, at a temperature of 95 °C, a significant increase in crystal size occurs. So, at a crystallization temperature of 80 °C, a polydisperse contents is formed with a particle size of 5 to 200 μm, and at 95 ° C - from 5 to 500 μm, while the average particle size has increased from 60 to 85 μm. This is confirmed by published data, which show that crystallization of salts at higher temperatures, all other things being equal, contributes to an increase in the average crystal size in the product. So, the average crystal size rises with increasing crystallization temperature, as evidenced by the results. Therefore, the crystallization process must be carried out at higher temperatures.

Changing the duration of crystallization from 4 to 6 h did not affect the size of the formed particles, which indicates the end of the main crystallization phase.

In research the effect of the mixer rotation speed on the fractional contents of aluminum fluoride, the parameter ranged from 40 to 75 rpm.

The results showed that with an increase in the speed of rotation of the mixer at the stage of crystallization of aluminum fluoride, a decrease in the average and maximum particle sizes is observed, which is explained by an increase in the number of revolutions, and the rate of formation of nuclei also increases due to the inertial emission of unstable “embryos” from the heated ones due to their formation of areas of the maternal environment into neighboring richer and colder areas, where growth of embryos to stable sizes is greatly facilitated. But an increase in the mixing speed has a positive effect on the kinetics of the process.

Based on the study of the influence of parameters on the size of the crystals formed at the stage of crystallization of aluminum fluoride, the optimal values of the parameters are established:

- crystallization temperature - 95 ° C;
- the rotation speed of the mixer at the crystallization stage - 40 rpm./min
- the duration of the crystallization process is 4 hours

Based on the results of the research, it can be concluded that the most important parameters affecting the size of the crystals formed and their habitas are the nature of the crystallizing salt, the intensity of mixing, the degree of supersaturation of the solution, the crystallization temperature and the presence of impurities. One of the main parameters that have a significant effect on the growth rate of individual crystal faces and its habitas is the temperature and intensity of mixing. This is due to the influence of temperature both on the rate of nucleation and on the rate of their growth, moreover, this effect is manifested in the process of crystal growth, since with increasing temperature crystal growth is accelerated to a greater extent than the process of nucleation.

The nature of the growth and size of the crystals formed is determined not only by the crystallization stage, but also by the stage of neutralization of hexafluorosilicic acid with aluminum hydroxide. It was experimentally established that the main parameters affecting the size of the aluminum fluoride crystals are the molar ratio Al (OH) 3: H2SiF6 at the stage of neutralization, the initial temperature of the stage of neutralization, the crystallization temperature and the speed of rotation of the stirrer at the stage of crystallization. The optimal values of these parameters are established, which ensure the production of crystalline aluminum fluoride, corresponding to the normative documentation, with a fractional contents varying in the range from 40 to 140 microns, and a content of particles larger than 45 microns in excess of 95 wt. %

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NUMERICAL MODELLING METHODS FOR EVALUATING THE FORMABILITY OF NEW COMPOSITE MATERIALS

KEYWORDS: TRIP Steel; Zirconia Composite; Numerical Simulation; Crystal Plasticity; Local Deformation Behavior.

In the continuously advancing technological world, there is an increasing demand for materials with desired material properties. High strength and formability materials are in demand in the automotive and aerospace industry. Metal matrix-based composited provide an excellent solution for high energy absorbing structural applications. The mechanical attributes of composite materials depend on the features of every single phase, its geometry and the assembly

in the material. TRIP steel magnesium partially- stabilized-zirconia composites are of great interest for various applications due to their high energy absorbing capacity which owes to transformation in present phases during deformation. The metastable austenitic phase in these materials transforms into martensite under applied strain, and the Mg-PSZ particles transform into a monoclinic phase from the tetragonal phase under stress [1, 2]. This transformation in the material into more compact and hence harder phases during deformation strengthens the material by increased hardening while allowing the material to deform under applied external load [3, 4].

To use MMCs as structural materials in commercial applications, the response of the material for different loading conditions must be investigated. For simulation purposes, reliable material models must be developed. For engineers, continuum mechanical models reproducing the thermomechanical behavior of an MMC are of high interest [5]. Apart from the typical stress-strain relationship, also some tendencies of microstructural evolutions are included in these types of models. For macroscopic structural simulations using the Finite Element Method (FEM), such phenomenological models in the framework of continuum mechanics are very efficient and the numerical treatment is well-known.

In this research, the TRIP/TWIP material model already developed in the framework of DAMASK is tuned for X8CrMnNi16-6-6 TRIP steel and 10% Mg-PSZ composite. A new method is explained to more accurately tune this material model by comparing stress/strain, transformation, twinning, and dislocation glide obtained from simulations with respective experimental acoustic emission measurements. The optimized model with slight modification is assigned to the steel matrix in 10% Mg-PSZ composite material. In the simulation model, zirconia particles are assigned isotropic elastic properties with a perfect ceramic/matrix interface. Local deformation, transformation, and twinning behavior of the steel matrix due to quasi-static tensile load were analyzed. The comparison of simulation results with acoustic emission data shows good correlation and helps correlate acoustic events with physical attributes. The tuned material models are used to run full phase simulations using 2D EBSD data from steel and 10% Mg-PSZ zirconia composites. Form these simulations, dislocation glide, martensitic transformation, stress evolution, and dislocation pinning in different stages of deformation are determined and qualitatively discussed for steel matrix and ceramic inclusions.

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MATHEMATICAL HEAT BALANCE CALCULATIONS FOR REVERBERATORY FURNACE DURING THE MELTING OF NICKEL ALLOYS

Currently, the nickel industry uses reverberatory furnaces for either smelting or nickel refining. Reverberatory furnaces for nickel can reach temperatures ranging from 1400°C to 1450°C. To achieve these temperatures, reverberatory furnaces use fuel in large quantities, generally natural gas, because it makes little use of the energy that is potentially available by oxidizing the sulphide charge. In situations where the furnace temperature reaches high ranges and where a significant amount of energy is required, optimizing a reverberatory furnace is necessary [1]. Consequently, heat balance calculations are required to study the effect of variable parameters on the process. To calculate the energy balance, the following are taken into account: the chemical reactions inside the furnace during the nickel smelting process, the inlet and outlet temperatures of the gases, smelting temperature and heat losses of the walls sides and roof of the furnace [2] (Figure1.). It is of scientific and technical interest to develop measures to adjust the natural gas supply systems, according to the composition and temperature conditions of the melting.

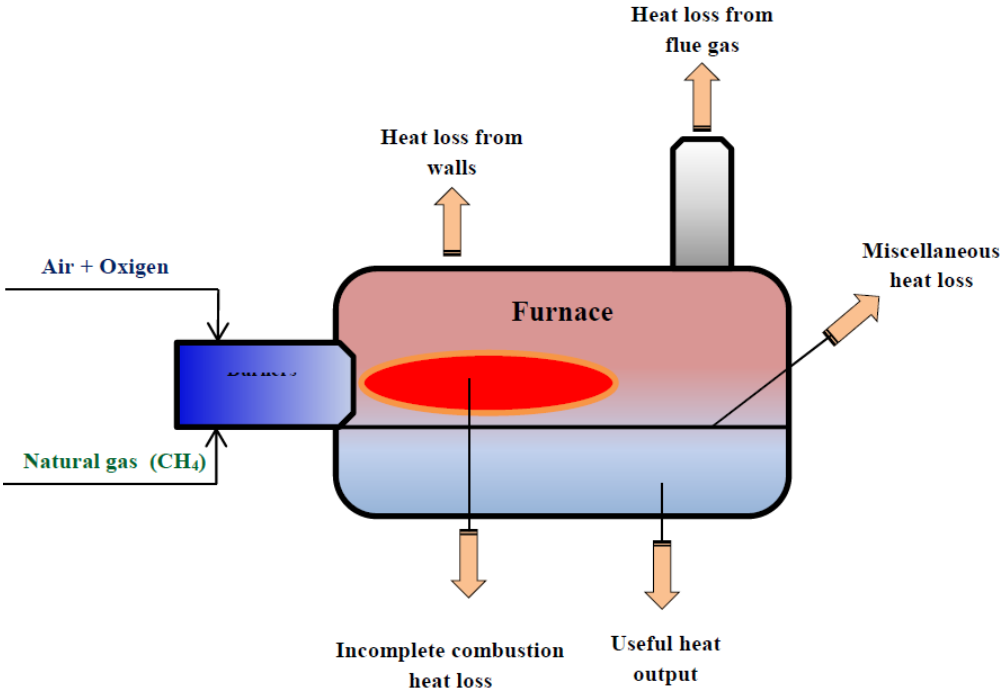

Figure 1 - Schematic representation of energy balance in an nickel reverberatory furnace

The mathematical method for solution is based on the first law of thermodynamics [3]. Considering a uniform flow and state, the boundaries of the control surface are taken outside the reverberatory furnace. Heat losses are serious drawbacks to take into account, they are generally losses due to heat conduction and convection to the circulating air. The inlet and outlet flows of the reverberatory furnace are intermittent, that is, the mass in the control volume and the height of the molten materials vary with time. This variation is shown in the study over a period of 5 hours. Walls and roof upper part has heat losses, especially sensible heat, latent heat and internal energy are calculated [4].

The analysis of the first law of thermodynamics to obtain the heat balance for a nickel reverberatory furnace is presented in this article. The parameters and compounds that affect the nickel smelting process have been studied. The results of the calculations and the experimentally measured data are 95% consistent. It is considered that with the use of this method the efficiency of a reverberatory furnace can be analyzed to obtain technical and economic characteristics.

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SYNTHESIS AND CHARACTERIZATION OF PT_2INCU_2SN AND RELATED PHASES

The starting point for my Bachelor thesis was the finding of few mineral grains of an unknown mineral with the composition $Pt_{0.667}\,Cu_{0.333}Sn$ in Khabarovsk, Russia [1]. Prior to my thesis, the aforementioned phase was successfully synthesized in the lab during a Bachelor project [2]. Due to its purely metallic composition, it was considered as a potential starting point to develop new High Entropy Alloys. Contrary to alloys like e.g. steel, these alloys are composed of at least five metals in equimolar proportions. As a result, the entropy of configuration is increased. This is seen as a major effect to promote the formation of a single solid solution HEA-Phase from a melt. It is this so called "high entropy effect" that was eponymous for this new class of materials. Scientific interest in HEAs has grown due to them exhibiting desirable physical properties like a high hardness, low density, corrosion resistance and superconductivity even under adverse conditions like extreme temperatures. In this sense, HEAs represent a new field in material science. Investigations are mainly conducted to find new HEA solid solution-phases and to what extend the physical properties can be influenced by substituting elements [3, 4].

Further experiments deemed the Pt_2InCu_2Sn-System a promising candidate. Samples were prepared by mixing the powdered elements in a mortar. Thereupon 0.2 g of powder were pressed into pellets by using a hydraulic press. Synthesis was carried out by arcmelting as well as heating cylindrical pellets in sealed ampules with an oven. In the oven, samples were heated from 673 - 1173 K at 1 K/min. One sample was taken out every 100 K to undergo rapid cooling with tap water. For structure determination, X-ray diffraction experiments were carried out. The chemical analysis was performed by EDX. Furthermore, DTA up to 673 K was performed to further obtain a more information on processes during heating.

The results of the X-ray diffraction experiments showed that with increasing temperature, the amount of secondary phases in the samples decreased. Rietveld refinement was carried out on the measurement of the sample which was heated up by arcmelting. A hexagonal crystal structure with space group P 6_3/mmc, a = 4.247(4) Å, c = 5.476(8) Å was found. Every peak except one with low intensity was explained by the fitting. This result was in accordance with the EDX analysis, the atomic concentration of elements in the sample was close to the expected value and therefore implies the formation of a single phase instead of several intermetallic

phases. The same applies for the sample which was heated to 1173 K in the oven. Also, superposition of the two XRD-measurement shows nearly identical results.

During heating, the DTA graph shows one sharp exothermic peak and two broad endothermic peaks. By heating up a Sample with the stoichiometry InSn and the help of a phase diagram, the exothermic peak can be explained as the melting peak of an InSn alloy. Due to the multitude of systems that contain the elements Pt, Cu, In and Sn, it is hard to find a concise explanation for the two endothermic peaks. Their shape at least indicates a reaction or phase transition which took place over an extended temperature range.

In summary, the experiments delivered results, which strongly indicate that the synthesis of the Pt_2InCu_2Sn-phase was successful. By using Rietveld refinement it was possible to find a crystal structure to sufficiently explain the measurement. The result is also backed by the chemical analysis obtained by EDX. The DTA was able to provide an insight into the processes during heating in the lower temperature range. Future investigations should initially focus on the physical properties of the new alloy. Secondly, further elements should be introduced into the system and the changes of the physical properties could be explored. Furthermore, it is necessary to establish phase diagrams, by which all resulting solid solution phases can be contextualized.

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ELECTROCHEMICAL BEHAVIOUR OF GOLD IONS ON CARBON ELECTRODES PRODUCED FROM RICE HUSK

Activated carbons (AC) have a set of unique properties: electrical conductivity, high specific surface area, resistance to many chemical reagents, due to which their practical applications are constantly expanding. High interest in gold is associated with various fields of application of this metal and its value as an asset in the financial market. Gold is the subject of numerous studies of electrochemical processes occurring at the surface of various materials. The purpose of this work is to study the anodic oxidation and cathodic reduction of gold ions using carbon-based materials, which were obtained by carbonization and activation of rice husk (RH). In the present work, gold electrodeposition process on the carbon electrode was studied by means of voltammetry, while the morphology of the electrodeposits was analyzed by scanning electron microscopy (SEM).

The cleaned and dried RH was collected from local farms of Almaty region, Kazakhstan, and subjected for carbonization at 500^oC in the argon atmosphere. Carbonized RH was mixed with potassium hydroxide by use the weight proportion of 1:5 (carbonized rice husk to KOH) and activated at 850^oC under argon atmosphere. The resulting mixture was subjected to washing by distilled water until the neutral pH. Specific surface area of resulting carbon materials was

investigated by use of “Sorbtometer-M”. Microstructural and elemental analysis was carried out using the Quantum 3D 200i Dual System SEM, JEO JSM-6490LA scanning electron microscope and Raman spectroscopy (“NTEGRA Spectra Raman”). The electrochemical investigations were conducted by using Autolab Potentiostat/Galvanostat Model AUT83945. A working solution with the concentration of 100 $mg \cdot L^{-1}$ were prepared by diluting the standard samples of Au^{3+} ions (“IRGIREDMET”) with distilled water. The basic background electrolyte was a solution of 0.1 $mol \cdot L^{-1}$ hydrochloric acid.

In order to identify the surface morphological features of synthesized samples, the SEM has been used. As it can be seen from Figure 1 a,b, the samples have a complex structure. Surface macrostructure represent typical macropores with diameter of 4-22 μm (Figure 1a,b). The typical Raman spectrum of graphene exhibit three peaks: peak D at 1351 cm^{-1}, peak G at 1580 cm^{-1}, and peak 2D at 2700 cm^{-1}. The ratio between the intensities of peak G (I_G) and peak 2D (I_{2D}), I_G / I_{2D} gives an estimate of the number of layers. Analysis of Raman spectra (Figure 1c) of carbon material obtained from RH showed the content of graphene films with three or more layers (I_G / I_{2D}= 0.63; 0.50; 0.43; 0.30). The obtained adsorbents composed of amorphous silica and carbon. Specific surface of annealed RH was determined by BET method; it was 2818 $m^2 g^{-1}$, pore specific volume was 1.59 $cm^3 g^{-1}$ and average pore size was within 1.0 ÷ 2.0 nm. The carbonized and activated rice husk (CARH) have a rather low redox potential and the stationary potential is 0.05 V (Ag/AgCl). The measured stationary (real) potential of gold in a hydrochloric acid medium is equal to 0.47 V (Ag/AgCl). The potential difference between gold (oxidizing agent) and sorbent (reducing agent) is 0.42 V relative to the reference electrode. Cyclic voltammetry curves of gold ions in 0.1 M HCl measured on carbon-capped electrodes are illustrated in Figure 1d (curve 1). This curved represents an oxidative peak (0.8 V) in the reverse scan and a reductive peak (0.55 V) in the forward scan. The background electrolyte based on 0.1 M HCl measured on a carbon electrode was also examined in this potential region (Figure 1d, curve 2). However, no clear redox processes were observed. Since activated carbon has a large surface area, large charge-discharge currents of the double electric layer (non-Faraday currents) were revealed.

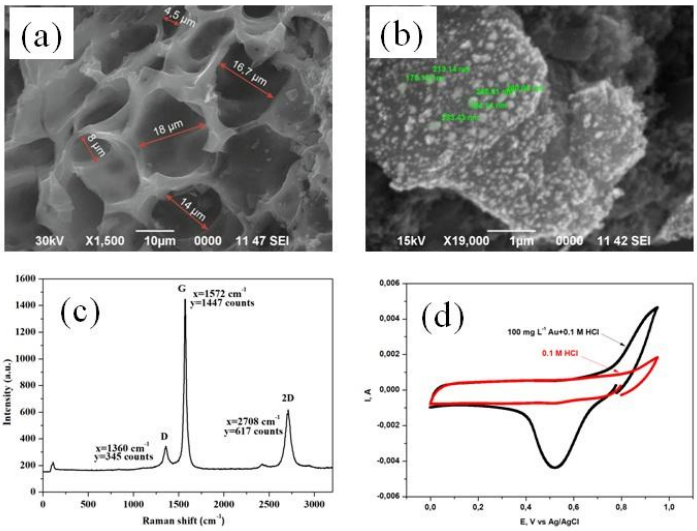

Figure 1. (a) SEM images of the surface of the carbon electrode before and (b) after adsorption of gold, (c) Raman spectra of activated carbon, (d) Cyclic voltammograms on carbon electrode in (curve 1) 0.1 M HCL + 100 $mg \cdot L^{-1}$ $HAuCl_4$ and (curve 2) 0.1 M HCl at 5 $mV \cdot s^{-1}$.

In turn, charge-discharge currents are due to the large surface area of electrode, which is reflected on the voltammograms. Thereby in order to calculate the kinetic data on the gold electroreduction reaction on this material, compensation should be made for a non-Faraday current. For this purpose, the currents of a double electric layer were taken from the value of the cathodic current peak. Finally, the resulting peak current values were used to calculate the diffusion coefficient which will be discussed during the Conference.

The resulting material obtained on the basis of RH was studied by modern and informative methods of physico-chemical analysis including scanning electron microscopy, Raman spectroscopy and BET analysis. It was demonstrated that the resulting material has a developed macroporous structure and possesses a high specific surface area. The electrodeposition of gold was studied in solutions containing $HAuCl_4$ forming $AuCl_4^-$ ions. When current density was equal to zero, the system exhibited a constant open circuit potential of about +420 mV vs. Ag/AgCl.

ACKNOWLEDGMENTS

The work was carried out in the framework of project No. AP05134691 by the support of the Ministry of Education and Science of the Republic of Kazakhstan.

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RESEARCH OF THE TECHNOLOGICAL VARIABILITY OF PYRITIC POLYMETALLIC ORES OF THE ARTEMYEVSKY DEPOSIT

Polymetallic ores are the most favorable object for the development of the principles of technological typification of processed raw materials, since even in the conditions of an undeveloped system of automation of flotation operations, the plant necessarily provides shift reports for at least three controlled elements: Cu, Pb, Zn. These three elements are simultaneously reflected in each of the resulting concentrates. Taking into account the possibility of calculating the ratios between the metal contents in the ore, it is possible to form a fairly representative multidimensional information space, which can be analyzed using neural network modeling methods. The application of the ratio of metal content in the ore was successfully used in the development of the classification of technological flotation schemes of, for example, pyritic copper and copper-zinc ores [1]. The geological and mineralogical features of the pyritic polymetallic deposit are reviewed in the literature [2-4]. For specialists in the field of classical flotation, the main link in the development of the classification of processed raw materials is a set of preliminary studies, which includes mineralogical, fractional, granulometric analyses of the ore, as well as some studies of the physical properties of the minerals included in the ore. This approach to creating a system of technological classification is not acceptable, since it does not provide an online mode because of the constant variability of the type of ore mixture processed at the plant.

For the analysis, an array of results of shift work of the plant obtained during the processing was formed. The statistical array consisted of 342 observations. The classification of the array of initial observations of input parameters was carried out using the 12:12-24:1 Kohonen neural network model KSOM, 12×2 format. The initial data was divided into learning – 172, control – 85 and test – 85 samples.

To achieve higher reliability in the identification of topological Kohonen maps for diagnostic purposes a methodology is proposed. It includes the interpretation of calculated average values of studied parameters of all neurons, using the method of factor analysis, design of selected neurons on the plane of the main components F_i – F_j and applying on them the physical values of the vectors of the measured parameters and contour lines of output functions. The developed approach of technological classification of processed raw materials allows us to trace the changing trend on the topological map of Kohonen. According to the presented trend, it is hardly possible to count on adequate actions of operational personnel to manage flotation operations. This observation confirms the reason for the observed large variability of technological indicators.

Laboratory tests for the identified types of ores were conducted in order to select the flotation mode, which achieved the maximum technological indicators of enrichment. In the performed experiments the average increase in the content and recovery of the main metals into the concentrates was: 1.08% and 3.87% for copper, 2.45% and 4.15% for zinc, respectively.

As a result of the research, the complexity of the processed pyritic polymetallic ore of the deposit is shown. The use of Kohonen neural networks in solving the problem of technological typification of pyritic polymetallic ores is justified, since the flotation process is essentially a multifactorial and nonlinear object. It is shown that Kohonen maps are a visual arrangement of multiparametric information, can be used to detect differences in the system behavior modes, abnormal modes can be detected and unexpected data observations can be discovered, the subsequent interpretation of which leads to new knowledge about the system under study. The interpretation of the Kohonen map carried out using the factor analysis methodology allowed us to identify four main clusters of subtypes of the processed ore mixtures of the deposit. The developed technology can be implemented at the plant online with the help of express data analysis control, which allows you to promptly change the reagent modes in order to achieve higher metal recovery and better quality of the resulting concentrates.

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ANALYSIS OF A NEW AIR CLASSIFICATION METHOD FOR THE QUARRYING INDUSTRY

Concrete and asphalt are among the most important building materials. The production of concrete and asphalt requires the production of aggregates. The global production of aggregates is estimated at 66.2 billion tonnes in 2022. Natural aggregates make up about half of these aggregates. The mining of these is done in open-cast mining (in quarries). There rocks are first loosened by blasting, then loaded by excavators onto heavy goods vehicles (HGVs), which transport them to a crusher, which crushes them. This is followed by further processing steps, which may include crushing processes and classification into different grain spectra.

During these extraction, conveying and preparation processes, part of the natural stone product is inevitably crushed to less than 63 µm. This grain spectrum is known as a rock filler. The proportion of these fine grains can be between 15% and 50%, depending on the aggregate product. Rock filler has a negative effect on the technical properties of products such as asphalt. In asphalt production, a high proportion of fillers results in asphalt that is over-hard, fragile and

prone to cracking. The permissible filler content in asphalt is between 5% and 10%. For aggregates used in concrete production, filler contents of less than 16% are required, depending on the aggregate. For coarse aggregates, the filler content must even be below 0.5%.

A reduction of the aggregate filler content is therefore indispensable. The demands on the quality of building materials, especially on the proportion of rock filler, have become increasingly stringent in recent decades. As a result, some companies are not able to sufficiently reduce the proportion of rock filler in the aggregate with their existing processing plants. As a result, the grains are stored on stockpiles and cannot be supplied to the economy.

The processes that are used today for the removal of fillers from aggregates are divided into screening processes, hydroclassifiers and air classifiers. Screening processes and hydroclassifiers are used in particular for higher throughputs and are characterised by a comparatively low energy requirement and a comparatively low space requirement. However, screening plants are susceptible to wear and tear and require high maintenance and investment costs. The disadvantages of hydro classifiers are their water consumption and the need for subsequent drying of the material to be classified as well as the costly separation of fines. Likewise, the installation of hydro classifiers is often associated with costly approval procedures. Both hydro classifiers and screening processes are not suitable for retrofitting existing processing plants. Aero-classifiers or air classifiers are mainly used for the classification of fines with a separation efficiency of a few micrometers, but are also used for the removal of fillers from aggregates. These processes, especially deflector wheel classifiers and grit classifiers, usually require a very large amount of space. Although there are some low-built processes, such as cascade classifiers, which are in principle suitable for retrofitting, the use of such systems is often associated with an increased energy requirement. At present, there is no energy-efficient classification process available that is so low-built that it can be installed directly in the conveying flow and thus retrofitted to existing processing plants, thus enabling the recovery of stockpile material.

The aim of this dissertation is to discuss the functionality, the dimensioning and the technical-economic suitability of a newly developed classification process. This method has been patented under patent number DE 10 2018 115 480 A1. The process features a mechanical dispersion unit as a technological innovation. This is intended to enable a low construction, energy-efficient classification and a degree of selectivity necessary for common applications. The low design should enable the system to be integrated directly into the conveying flow. This can take place, for example, at belt transfer stations. This means that no further process step, such as upstream storage in silos, would be necessary for emptying. The cost of approval procedures can also be reduced by a low construction. Furthermore, the installability of the new development at belt transfer stations allows an uncomplicated retrofitting of existing processing plants. Thus an increase of the resource efficiency of the stone and earth industry can be guaranteed.

Therefore, this paper takes up the problem of rock fillers for the stone and earth industry and presents the relevance of a low-built classifier for this branch of industry. Subsequently, the state of the art, i.e. the technical solutions for filler removal that are used today, is presented. The disadvantages of these technical solutions are worked out in differentiation to the state of the art. The working hypothesis can be based on these disadvantages. It states that by using a mechanical dispersion unit, low overall heights and a lower energy requirement compared to conventional classifying processes can be guaranteed. In order to verify this working hypothesis and to fulfil the objective, a newly developed process is presented on the basis of a laboratory system. This system consists of four main components which are considered separately. The mode of operation of these components is described on the basis of physical relationships, which are validated by laboratory tests on the test system. On the basis of these correlations, a dimensioning of these components in dependence on each other as well as in dependence on the throughput and the permissible material load is made possible. The determination of the permissible material load is carried out by means of laboratory tests. It allows a dimensioning of

the new classifier in dependence of different throughput rates, on the basis of which a simulation of the overall height and the energy consumption at higher throughputs can follow. Based on this, a quantitative, technical-economic evaluation of the newly developed classification process is carried out.

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EFFECT OF HALIDE ADDITION ON ELECTROLESS SILVER PLATING

We adapted the addition of halide ions which is an important tool in the synthesis of well-defined Ag nanoparticles, to electroless Ag plating. These auxiliary reagents distinctly interact with the seeded synthesis of metal nanoparticles by mechanisms such as oxidative etching, adsorption and complexation Just recently, a more unified and coherent description of shape control phenomena is emerging, which is based upon such general processes, and an inclusion of electroless plating in this perspective is of high interest. As we will show below, the presence of halides severely affects electroless Ag plating. Besides from a drastic reduction of the reaction rate, the nano- and microstructure of the Ag deposits is strongly altered. We will discuss the observed changes within the mechanistic framework of colloidal nanoparticle synthesis, and argue that the underlying rationales can be extended to our system. As an application example, superhydrophobic coatings with multiscale roughness are produced.

Deionised water was employed in all procedures. Laboratory glassware was cleaned with concentrated nitric acid. Following materials were used as received: 1-hexadecanethiol; $AgNO_3$; ethanol; ethylenediamine; $HAuCl_4$ 30% in water; KBr; Makrofol; methanol; NaCl; NH_3 33% in water; potassium sodium, tartrate tetrahydrate; $SnCl_2$ dihydrate; tetraoctylammoniumbromide; trifluoroacetic acid.

Galvanic replacement. For galvanic Au exchange, the Ag-coated polycarbonate foils were immersed in an ethanolic solution containing 4 mM $HAuCl_4$ and 10 mM tetraoctylammoniumbromide for 15 min. Subsequently, the films were exhaustively washed with diluted ammonia solution to remove Ag halides, followed by washing with water and drying. The metal films were then coated with a self-assembled thiol monolayer by immersion in a 10 mM ethanolic solution of 1-hexadecanethiol, which was followed by thorough washing with ethanol and drying. Contact angles were measured on dry specimen.

Effect of halide addition on electroless Ag plating and results. However, in electroless plating, precipitation reactions are undesirable, because finely dispersed particles act as potential nuclei for metal reduction in the solution and thus impair the life span and surface-selectivity of the deposition baths. In the case of Ag halide particles, the tendency of Ag nucleation is further increased by the light sensitivity of the materials (compare with Ag photography). Beside these stability issues, precipitates can sediment on the work piece and be incorporated in the evolving metal film. In order to achieve precipitate-free plating solutions and to allow for the use of relatively high halide concentrations, our bath formulations were based upon a previously established protocol which uses an excess of the complexing agent ethylenediamine. This bidentate ligand effectively binds to Ag(i) and thus reduces the concentration of free metal ions (see *e.g.* the logarithmic stability constants of 7.64 for the complex $[Ag(en)_2]^+$ and 13.15 for the complex $[Ag_2(en)_2]^{2+}$). At the same time, the Ag(i) ions are not stabilised to a degree that would prevent their reduction by the mild and non-toxic reducing agent tartrate, which is frequently employed in electroless Ag plating. In summary, all baths used in this study are based on a

standard composition of 17 mM $AgNO_3$, 100 mM ethylenediamine, 120 mM tartrate and 9.5 mM trifluoroacetic acid, which was introduced to adjust the pH to a value of 10.9. The acidification was performed to increase the stability of the solutions against decomposition, which is an issue at high pH. Varying amounts of halides were added to this standard composition, focusing on Cl^- and Br^- as the most important halide additives in the shape-controlled synthesis of Ag NPs. Polycarbonate foils served as substrates for the Ag deposition, which was conducted at room temperature for 24 h. Prior to electroless plating, the foils were covered with Ag nanoparticles to provide seeds for the plating reaction. This was achieved using a common activation procedure, in which surface-bound Sn(ii) ions react with Ag(i) to form small Ag nanoparticles of mostly <10 nm size. After Ag deposition, the polymer membrane was dissolved to free the structures deposited within the pores. As it can be seen from SEM images of the resulting products, the bimodal Ag film structure is maintained in the case of the new substrate (Figure 1a). However, the pores confine the growth of the Ag microparticles within the membrane. This leads to the evolution of coarse-grained Ag microwires, which are covered by a porous nanoparticle film located on the former pore wall (Figure 1b). Such structures are interesting for several application fields. For instance, in surface-enhanced Raman spectroscopy, wire-nanoparticle assemblies provide particle-particle junctions which can act as field-enhancing hot spots. Electrocatalytic applications can benefit from the continuous conduction pathways of the wires and the additional surface area generated by the nanoparticles.

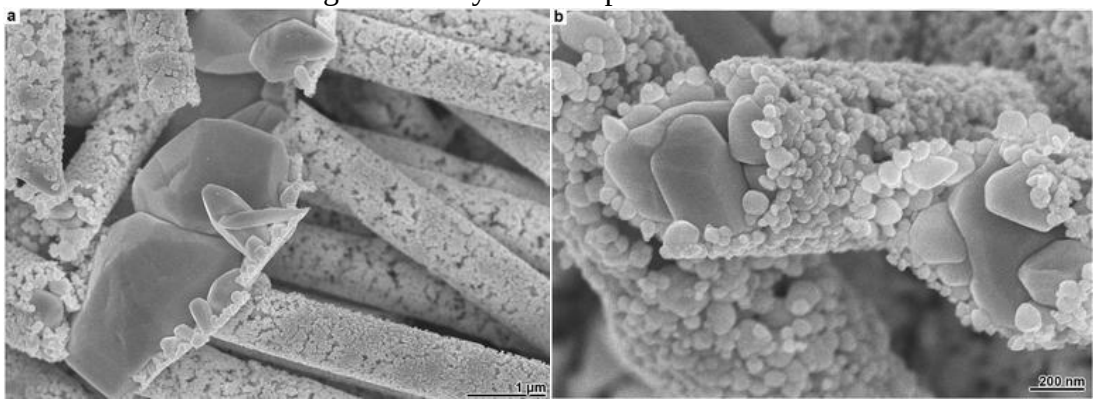

Figure 1 Electron micrographs of Ag structures obtained by Cl^- assisted electroless plating using ion-track etched polycarbonate as the substrate. (a) Ag surface film and particle-decorated microwires. (b) Magnified particle-decorated microwires

The morphological control provided by the outlined approach is relevant for highly structure-sensitive applications such as heterogeneous catalysis, sensing, nonlinear optics or surface-enhanced Raman spectroscopy. As an example for structural tailoring, we subjected an island-like Ag film obtained with moderate Cl^- addition to a galvanic replacement reaction. The resulting coating possesses a pronounced roughness on both the nano- and microscale and, as a result, can be used to render surfaces extremely hydrophobic.

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PREPARATION AND HIGH-TEMPERATURE PROPERTIES OF WASTE MOSI2-BASED COATINGS ON REFRACTORY METALS

With the rapid development of technology, the demand of mineral resources has been increasing, which leads to the formation of large numbers of spent resources, and the accumulation of solid wastes causes the pollution of ecological environment and serious loss of resources. Du Xiangwan, the member of Chinese Academy of Engineering, pointed out that we can make full use of solid waste through classification and recycling to build "No Waste Society". Therefore, comprehensively use the waste resources to realize "No Waste" has become the key to take the sustainable development of mineral resources. $MoSi_2$-based materials, which is made up of $MoSi_2$ with small amounts of bentonite, is used as an important kind of heating elements at high temperature with good thermostability and anti-oxidation properties due to that a layer of dense SiO_2 oxide scale can be formed on the surface to prevent the diffusion of oxygen. Therefore, $MoSi_2$-based materials are widely used in high-temperature industrial furnaces and exhaust systems of internal combustion engines. However, the consumption of $MoSi_2$-based materials increases every year, and a large number of long-term used $MoSi_2$ heating elements are abandoned in the factories and companies around the world, causing the waste of resources and environmental pollution. Therefore, how to realize the recycling use of spent $MoSi_2$-based materials has become the core issue of the research. Mo, which is in $MoSi_2$ heating elements, is a kind of rare metal and it plays an important strategic role in metallurgy, petrochemical industry and mining industry. According to the latest data of USGS (United States Geological Survey) in 2018, the global Mo resources can be only exploited for 58.6 years. Thus, based on the concept of full utilization on the Mo-containing wastes, important scientific significance and economic value will be obtained.

As a kind of strategic refractory metal, Mo has lots of advantages such as low density (10.2 g/cm^3), low coefficient of thermal expansion (5.8×10^{-6}/K), stabilized physical and chemical properties, and thus it is widely used in aerospace to prevent the failure of key components of spacecrafts during service at elevated temperature. However, molybdenum and its alloys have poor oxidation resistance, which also restricts its applications at high temperature. Research show that Mo and its alloys can be coated to improve the anti-oxidation properties. It is also found that the spent $MoSi_2$-based materials can be rushed into spent powders, the main component of which is $MoSi_2$. As a kind of high-temperature materials, $MoSi_2$ is considered as one of the most excellent coating materials due to its high melting temperature (2030 °C), low coefficient of thermal expansion (8.1×10^{-6}/K) and good thermal stability, and a layer of SiO_2 oxide scale can be formed on the surface at high temperature environment to inhibit the oxidative destroy. In addition, molten SiO_2 has good fluidity at high temperature environment, which can fill the microcracks and voids in the coating, playing a role of self-healing to make it bear some shock deformation. Therefore, $MoSi_2$ is considered as an ideal coating material, and spent $MoSi_2$ can be used as raw materials for preparing anti-oxidation coating on Mo substrate, making the good oxidation resistance obtained by the coating.

As a new kind of coating preparation method which has been developed in recent years, spark plasma sintering (SPS) technique has been widely researched. Compared with the traditional methods of coating preparation such as slurry, chemical vapor deposition and pack cementation, some advantages such as rapid sintering, short sintering time, energy conservation and densification sintering are all obtained by SPS, making SPS widely used in the sintering of alloys and ceramics. According to the report by NASA (National Aeronautics and Space

Administration), MoSi2 is used as binder and radiation agent in toughened uni-piece fibrous insulation (TUFI) and high-efficiency tantalum based ceramic composite structure (HETC) to withstand the high temperature that generated on the surface of the aircraft, showing that MoSi2 has been the frontier and focus of studies in aerospace around the world in recent years. With the rapid development of industrialization, the position of molybdenum, which acts as the representative mineral resources, will not be changed for a long time in the future, and the promotion and application of spent MoSi2 can play a strategic role in resource utilization. Therefore, it is urgent to study the MoSi2 coating using spent MoSi2-based materials to solve a series of problems at the high-temperature environment, and improve the high-temperature anti-oxidation coating on Mo substrate.

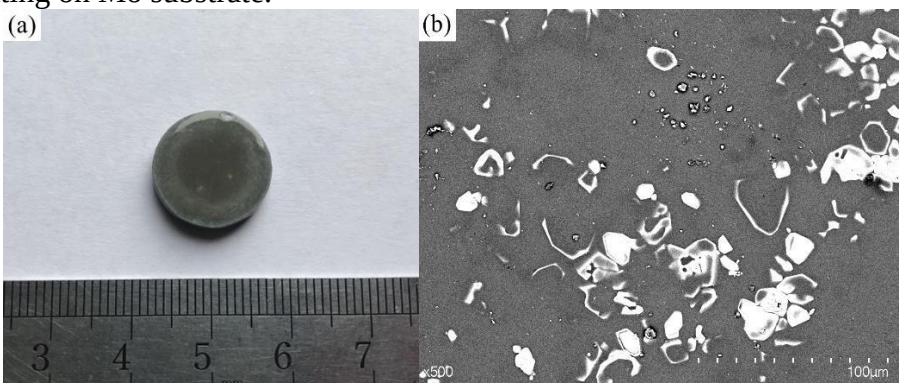

Figure 1 - Oxidation behavior of MoSi2-based coating at 1500°C
(a) Morphology of MoSi2 coating after oxidation for 40 h
(b) Surface morphology of MoSi2-30ZrO2coating after oxidation for 20 h

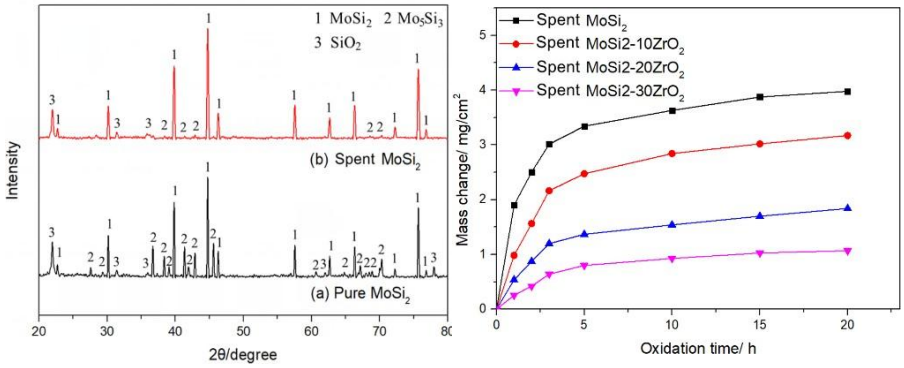

Figure 2 - Oxidation behavior of MoSi2-based coating at 1500°C
(c) XRD patterns of spent and pure MoSi2 after oxidation for 40 h
(d) Oxidation kinetics curve of MoSi2 and MoSi2-30ZrO2 coatings after oxidation for 0-20 h.

Nowadays, with the rapid development of aerospace, the service environment of the coating becomes more severe, which puts forward the higher requirements for the high-temperature properties of the coatings. However, the reliability of the coating at high-temperature environment can be seriously deteriorated by the failure which occurs during service, such as wear, debonding and spalling. The wear properties of the coating are closely related to the microstructure and mechanical properties (hardness, fracture toughness, etc.). Wear is prone to cause pits on the surface of the coating, which increases the surface roughness, leading to the formation of fatigue cracks. Although MoSi2 has high hardness and strength, its brittleness will greatly reduce the wear resistance of MoSi2-based coatings. In addition, the creep resistance of MoSi2 is poor at elevated temperature, and the spalling of the coating that caused by wear will accelerate its creep behavior at high-temperature environment, which will reduce the strength or cause the fracture, decreasing the reliability of the coating seriously. Some second-phase particles (such as ZrO2, HfO2, SiC, etc.) are reported to be able to effectively improve the fracture toughness, wear resistance and creep resistance of MoSi2 coating at elevated

temperature, and strengthen the bonding strength between the coating and substrate. However, the high-temperature mechanical properties (wear resistance, creep resistance and bonding strength) and related mechanism of $MoSi_2$ coating prepared by SPS using spent $MoSi_2$-based materials are still required to be clarified. Therefore, the explosion of the high-temperature mechanical properties of spent $MoSi_2$ and its composite coatings prepared by SPS is urgent to be carried out, and the strengthening mechanism on the reliability of the coatings by adding second-phase particles has to be revealed, which has extensive application value for improving the high-temperature properties of $MoSi_2$-based coating and developing the concept of "No Waste Society" with the full utilization of waste mineral resources.

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HYDROMETALLURGICAL TREATMENT OF COPPER CONCENTRATES AND MIDDLING PRODUCTS WITH HIGH ARSENIC CONTENT OF THE UCHALINCSKY MINING AND PROCESSING PLANT

According to the ISCG, world demand for copper was steadily increasing, more than tripled over the past 50 years, impacting the mining industry considerably. At the same time, the ore grades of deposits were declining, which have influenced on the technological process and ore benefication parameters. The average grade of metals in ore deposits has decreased by a factor of 1.5, and the number of difficult-to-process varieties in the total volume of raw materials has risen from 15 to 40%. [1] The presence of arsenic and antimony in raw materials has become one of the biggest challenge for copper industry. Tennantite, enargite, luzonite and orpiment, minerals of complex sulphosalts, are the main copper-arsenic compounds that can be found in copper sulphuric deposits. The presence of the valuable component (copper) and toxic elements (arsenic and antimony) makes ore processing and producing of technological products – copper concentrate and tailings, more challenging. The increase of the impurities' concentration in the copper concentrate initiates a problem with its further pyrometallurgical treatment (smelting). Turning sulfosalts into tailings leads to a significant copper loss. In Russia, the Uchalinsky mining and processing plant is an example of the factory that faced with such obstacles.

The arsenic bearing minerals in mined copper sulphide deposits, for decades, has been processed by roasting and smelting processes. In the past, the arsenic presence was not considered as detriment because arsenic trioxide was recovered as a marketable product, which, of course, is not acceptable anymore. Today the presence of arsenic is regulated by environmental legislation of every country, and it is required for copper smelters that their concentrates should contain less than 0.5 % arsenic. Therefore, most studies focus on hydrometallurgical methods, using acid or alkaline reagents. In most hydrometallurgical processes, the arsenic is extracted into solution by high temperature water leaching, acid leaching, alkali leaching and pressure leaching, then the arsenic is separated and precipitated from the pregnant leaching solution by lime or iron compounds.

Amongst up-to-date technologies, an alkaline sulphide hydrometallurgical process has demonstrated successful results in selective dissolution of arsenic and antimony from copper concentrates containing enargite and tennantite. [2,3] The alkaline sulphide leaching is one of the most promising alternative processes for the separation deleterious impurities from sulphide copper raw materials with complex structure that allows to remove arsenic and antimony selectively, leaving valuable metals unreacted in the solid phase. The objective of this study was investigation of possibilities to use sulphide leaching process for pretreatment of the copper

concentrate and the middling product from JSC «Uchalinsky GOK» in order to increase the quality and the grade of the flotation products.

The experimental data from the tests with copper concentrate showed that temperature and solid/liquid ration have a strong effect on the extraction rate. The best leaching results were obtained using solution with concentration of 4M NaOH and 1,5 M Na_2S (t=95ºC) within 3 hours (with almost 100 % arsenic removing). The middling product also fits this pattern. However, when modifying the solid/liquid ration to lower values (1-3), it can be observed that kinetics go down, the maximum extraction was only 40.66%. This effect can be associated with the formation of a protective product layer over the surface of the particles - the copper sulfides produced by the reaction that hinders the diffusion of the reagents to the unreacted core. As the solution volume increases (using less density pulp) arsenic removal improves dramatically and reaches more than 98-99 %.

The implementation of hydrometallurgical pretreatment technology in the existing circuit process of the factory could significantly increase the quality of the copper concentrate, making products that meet the requirements of GOST R 52998-2008 for the high grades. Moreover, it will be beneficial for the economy of the plant, as there will be no need in paying fines. Recirculation of the middling product will increase the total extraction of the valuable component, which minimise waste of metals with the tailings. As a result, the competitiveness in the market will grow and the economy of the factory will strengthen and stabilise.

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LITHOLOGICAL HETEROGENEITY ANALYSIS TO EVALUATE ROCK BURST AND GAS OUTBURST POTENTIAL IN DEEP LONGWALL COAL MINING

Coal is a vital mineral accounting for ~38% of the world's electricity generation and ~71% of the world's steel production. The fast depletion of shallow coal deposits forces the extraction of deep-seated coal deposits. Retreating longwall coal mining is the most-suited method for deep coal mining. Deep coal mining is usually associated with high stress state and high gas pressure conditions leading to dynamic hazards like rock bursts and gas outbursts. Several researchers have identified parameters influencing the occurrence of rock bursts and gas outbursts in deep coal mines considering coal seam to be homogeneous, however, the coal seam is inherently heterogeneous [1]. Heterogeneity may occur during different depositional cycles in the sedimentary environment over the long period of the coal formation. The variation in coal lithotypes due to heterogeneity may adversely affect the mechanical and reservoir behaviour of the coal seam that may lead to rock bursts and gas outbursts.

Coal Mine Velenje produces lignite from a heterogeneous lens-shaped deposit which is 165 m thick in the centre and pinches out towards the boundaries. Retreating longwall top coal caving mining is practised with varying mining depth (200-500 m). The lignite coal seam has a varying abundance of xylite, detrite, and mineral matters contributing to the complex mechanical and reservoir behaviour [2]. Different coal lithotypes exhibit contrasting mechanical and reservoir properties depending on their abundance in the coal seam. The transition from a strong and low permeability hard coal (xylite) to a weak, and porous soft coal (detrite) may lead to increased gas emissions.

Previous research by the authors [3, 4] evaluated the effect of heterogeneity on rock burst and gas outburst occurrences by incorporating a heterogeneous area and assigning different properties to the area as compared to the rest of the coal seam using a field example from Coal Mine Velenje. Cao et al. [4] found that lithological heterogeneity can influence the microseismicity associated with rock burst and gas outburst occurrence.

Previous research experience of lithological heterogeneity encountered at Coal Mine Velenje was used to simulate new heterogeneous models. The effect of mechanical properties variation on rock burst and gas outburst potential was assessed in terms of vertical stress, gas pressure, strain energy, and gas flow behaviour. A fork-shaped solid with different distributions of xylite and detrite was incorporated in the analysis as the heterogeneous zone. An object-based geostatistical non-conditional simulation method was adopted to randomly distribute different coal lithotypes in the heterogeneous zone using Gaussian distribution. Several subroutines were written

in FLAC3D to incorporate lithological heterogeneity and to facilitate exact assignment of geomechanical and reservoir properties to each lithotype in the heterogeneous zone. A two-way

sequential coupled numerical model between ECLIPSE 300 [5], an industry-standard compositional reservoir simulator, and FLAC3D [6], a widely used geomechanical modelling software, was developed for seamless exchange of data between software using a Matlab routine. Porosity and permeability were used as the coupling parameters between the two software.

The effect of change in the mechanical properties of the coal lithotypes on rock burst and gas outburst potential was analysed for 90% heterogeneity. It was found that the mechanical properties variation influences vertical stress with higher vertical stress acting on harder lithotypes. Gas (pore) pressure did not show any conclusive trend with slight variation along the longwall panel for the change in mechanical properties of coal. Softer coal tends to accumulate more strain energy as compared to harder coal making it vulnerable to rock bursts and gas outbursts. The rate of gas flow decreased until the heterogeneous zone was encountered and then increased rapidly with the failure of coal in the heterogeneous zone. The gas flow rate exhibited a variation of ~3 m^3/min for the change in mechanical properties. The rate of change in vertical stress, strain energy accumulation, and gas flow rate in zones of heterogeneity suggests that soft coal is more vulnerable to rock bursts and gas outbursts in the presence of lithological heterogeneities. This paper will present the findings of the research carried out in detail.

ACKNOWLEDGEMENTS

The first author is thankful to the Itasca Consulting Group for FLAC3D version 6.0 license under the IEP program. Contributions made by the engineering staff of Coal Mine Velenje, and that of Dr Sergej Jamnikar in particular, are gratefully acknowledged.

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METHODOLOGY FOR EVALUATING MEASURES TO REDUCE THE TECHNOLOGICAL RISK CAUSED BY THE ACTION OF THE ELECTROMAGNETIC FACTOR AT THE ENTERPRISES OF THE FUEL AND ENERGY COMPLEX OF RUSSIA

Electromagnetic fields are one of the sources that affect human health. High biological activity was noticed by scientists in the early twentieth century [6]. Research results obtained using radar tools. There are more sources of EMF in everyday life [7-9]. This leads to electromagnetic pollution of the environment. The data published by the World Health Organization, which confirm the impact of this type of pollution on the human environment. World-class specialists are studying the problem of electromagnetic safety, because it is relevant.

Currents and charges create an electromagnetic field in space, which is characterized by vectors of electric and magnetic strength.

Instruments measured the levels of non-ionizing radiation at the workplace of electricians. The measurements were made in the power supply shop of the complex for liquefying natural gas. The electrician's workplace is located next to the automated workstation, next to the auxiliary needs panel and the DC board. A hygienic assessment of levels of exposure to EMF was made by electrical and magnetic components.

Next step – modeling. A method is needed to visualize the distribution of EMF from equipment for convenient presentation of measurements and studies. Models of the transformer and the open switchgear were constructed in the EFC-400 program and the distribution of the magnetic field was simulated. Judging by the indicators of the program we can conclude that the electrical equipment does not affect the magnetic field above the maximum allowed level [10]. But in conjunction with other sources of radiation and the time that personnel spend in this area, these fields overlap and their level of exposure increases significantly.

Protective materials can be used after calculating their effectiveness. An electromagnetic shield is a design to weaken the effects of electromagnetic fields. The main characteristic of the protective screens is the shielding efficiency [5]. Shielding efficiency is expressed in decibels. It is important to consider geometric dimensions and the material of which the shield is made. Shielding can be implemented by some designs [1-3] - premises, cameras, structures. The most effective are mesh shields, which have the greatest economic efficiency. It is important to take into account some difficulties during changes in design and production technology. Therefore, it is recommended to install shields not around a particular installation, but on parts of equipment that emit the largest EMFs. It is also necessary to carefully select the joining places of these structures, in order to avoid the spread of the electromagnetic field through seams. It was decided to use a screen with the following parameters: size 2×4 m, steel wire 0.21 mm thick, mesh size 0.3×0.3 mm. The step from the radiation source is 0.2 m.

The research includes assessing the working conditions of personnel, modeling the distribution of non-ionizing radiation, methods and means of protection that contribute to the effective organization of measures for the protection of workers. The study analyzed the actual parameters of electromagnetic safety at the facility of transport and storage of natural gas; a mechanism is proposed for modeling the electromagnetic effect of the transformer on an adjacent working area; the option of minimizing the negative impact of the transformer by shielding is proposed; the effectiveness parameters of the developed shield were estimated, which amounted to 37.1 dB. Currently, production requires high energy costs, which affect the technical and economic performance of factories. Maintaining all the elements of system is especially important [4].

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GEOMECHANICAL ISSUES IN THE DEVELOPMENT OF THE PIT RESERVES OF THE DIAMONDIFEROUS DEPOSITS OF THE UDACHNY MINE

At the moment, the Udachninsky Mining and Processing Plant (UGOK) is developing two primary diamond deposits: the Udachnaya and Zarnitsa kimberlite pipes, the Piropovy Ruchey placer deposits and the Udachnaya pipe deluvial placer deposit.

Crucial to the development of the UGOK is the kimberlite pipe “Udachnaya”. The deposit is located in the Daldyno-Alakite diamondiferous region, the Republic of Sakha (Yakutia). The kimberlite pipe can be traced as a single ore body from the surface to a depth of 250 meters. Below it is divided into two independent ore bodies - East and West (VRT and ZRT), separated by a block of enclosing sedimentary rocks.

Underground mining is complicated by the geological conditions of the pipe and the surrounding rock mass. The mineral deposit is located in extreme climatic conditions of the Far North with an extremely poorly developed infrastructure. The pipe is located in the permafrost region, the sharply continental climate is characterized by large daily temperature differences, which negatively affects the stability of the rock massifs.

The entire rock mass is formed without watertight horizons, which leads to the free promotion of aggressive and highly mineralized brines, with a total mineralization of up to 400 grams per liter, the rock mass of the pipe is extremely broken, a network of deep cracks (up to 50 meters) and various faults distributed randomly is widespread. Ore and rock masses have low stability, a negative dependence of the stability of kimberlite on the time of its contact with the mine air has been established. The most disturbed is the mass of waste rocks in the space between the VRT and the ZRT, and many disturbances and manifestations of fracturing are noted in it.

The sudden uncontrolled collapse of this array on a safety cushion can cause a powerful dynamic blow to the underlying mine workings, creating a shock-air wave that is dangerous for the mine. The conducted studies analyzed the probability of the occurrence of this event, proposed solution options taking into account the situation at the Udachny mine.

To ensure the safety of mining operations while developing sub-quarry reserves in the conditions of the Udachnaya kimberlite pipe, the research and observations of the mining and geological situation during the mining of the Udachnaya kimberlite pipe from the moment the underground mine was commissioned are considered. The main parameters of the applied development system are described, geomechanical factors complicating mining operations are studied, recommendations are given on the further direction of scientific research.

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INFLUENCE OF INTEREST RATE AND OPERATING TIME ON THE OPTIMAL LOCATION OF LONG-LIFE MINING FACILITIES

Haulage of the mined out material generates a big expense, therefore, the best conceivable haulage system has big economic significance. It is quite usual, that the mined out material is hauled to one point during the whole operation, which could take several decades. In 1773 Christoph Traugott Delius described an important rule of mine design, saying [1]: "It is necessary, that a vertical shaft cross the vein at its middle depth." If we take a step further, and take the time value of money into account, the optimal location of the destination point or the vertical shaft will move, depending on some parameters [2]. If the collectingpoint is not in the optimal location, the profitability of the mine is significantly reduced.

If we know the geometry of the mine and the mined out material, the speed of the production, the mining method and the transportation route, we can calculate the summarized freight ton kilometer for every possible location of the collecting point, in the function of the interest rates [3]. In this way, the external factors influencing the transportation cost, for example the change of the fuel price, can be ignored and the result will be time resistant. Thereafter, the optimal location of the collecting point can be defined.

The movement of the optimal location of this point can best be demonstrated trough a simplified model. The calculations, mentioned earlier, were performed with the geometric and production data of a typical Hungarian opencast lignite mine, with a lifetime of 30 years. The possible locations of the collecting point were on a 6 000 m line, located on the edge of the mine. Figure 1. shows the effect of different interest rates on the optimal location of the collecting point.

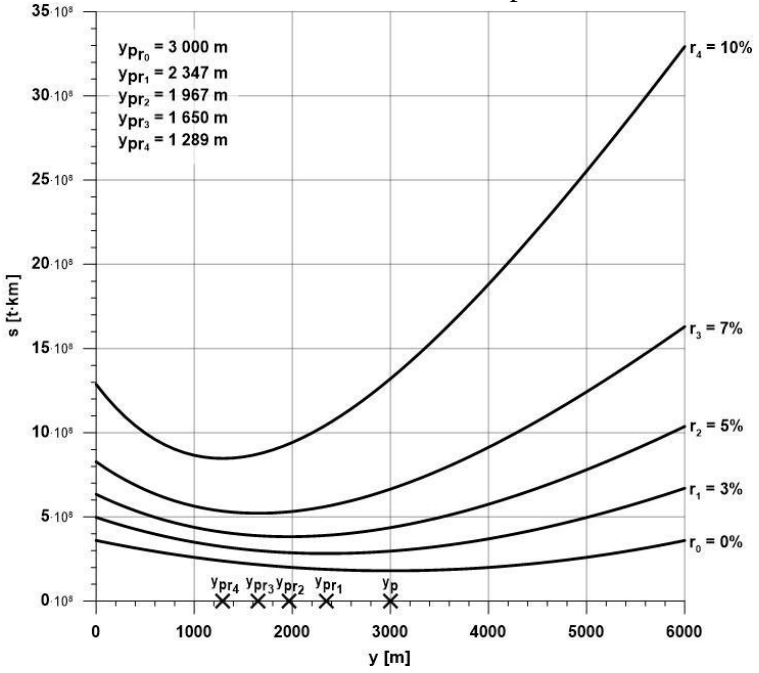

Figure 1 - Burden collecting work (s) in the function of the location of the collecting point (y), at different interest rates (r_n), with the optimal locations(y_{pn})

It could be seen, that the cost of transportation can increase greatly, if the collecting point is not chosen properly. The costs can increase by up to 50%, depending on the interest rate and the

lifetime of the mine. This method can be applied to other mines as well, provided that all the necessary parameters are known.

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STUDY OF THE POSSIBILITY OF FORECASTING METHANE CONCENTRATION IN A VENTILATION ROADWAY UP TO 10 M FROM THE LONGWALL FACE – CASE STUDY

In accordance with the Polish mining regulations, there must be at least four methane concentration sensors in a ventilation roadway: up to 2 m away from the ventilation roadway decommissioning line, up to 10 m from the longwall face and 10-15 m from the intersection with another excavation corridor.

An additional air stream is often supplied to the section of ventilation roadway between the longwall outlet and roadway decommissioning line by means of air duct, the ventilator of which is placed in the fresh air current. Thus, ventilation roadway is filled with a stream of air that is the sum of streams: flowing through the longwall and supplied by air duct. Methane concentration at the locations of mentioned methane sensors varies considerably, which results from the heterogeneity of air and methane mixture.

Previous forecasts of longwall methane content or methane concentration in ventilation air refer to the amount of methane at the longwall outlet from ventilation roadway or at the outlet from the longwall ventilation area. Under normal longwall mining conditions, when there are no circumstances locally increasing methane hazard (e.g. faults, places where coal is heated, etc.), the highest methane explosion hazard occurs during mining in the vicinity of ventilation roadway. For this reason, measurements of methane concentration in the ventilation roadway, in a place slightly distant from the longwall face, i.e. up to 10 m in front of the longwall face, are of greatest importance for safety.

The paper presents an ex post forecast of methane concentration at the outlet from ventilation roadway on the basis of equations previously developed and verified by H. Badura and its errors were calculated. Then, using the same equations, a forecast was conducted at the sensor location up to 10 m in front of the longwall face and its errors were analysed. Since the measurement of methane concentrations in the locations under consideration differed, the results of forecasts also differed. Therefore, in order to assess the accuracy of forecasts, their absolute and relative errors were compared. The error analysis showed that the forecast of methane concentration at the end of a ventilation roadway was slightly more accurate than near the longwall.

On the basis of error analysis, it is concluded that until separate forecasting equations are developed, the forecasting equations developed for the longwall outlet from ventilation roadway should be used to forecast methane concentration in the immediate vicinity of the longwall outlet.

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BASED ON THE DEFECT THEORY, THE PRACTICE OF COAL SEAM IMPACT IN ROADWAY DISLOCATION LAYOUT MINING IS CARRIED OUT

According to the problems of the mine pressure bumping accident frequently occurred in coal mining face in extra-thick coal seam , the defect method was applied to prevent and control the mine pressure bumping in extra-thick coal seam [1] , the artificial defect mass [2] was applied to migrate the stress field of the coal mining face in extra-thick coal seam , the energy continuously and slowly releasing could form a pressure releasing and protection zone during the stress filed migration process and thus the danger of the mine pressure bumping could be reduced.

Based on the theory of engineering defects method , taking mining protective layer, dislocation arrangement of roadway , blasting boreholes , large diameter boreholes and other artificial defect technical method applied could effectively make the stress migration forward to the deep of the coal mining face and could have an energy released effect . An active stress monitoring and measuring technology was applied to the effect inspection.

The observation results showed that based on the artificial defect mass pressure pre — release, the pressure was decreased and migratied efficiently , on the 93171 coal mining face during the stoping process didn’t appear the phenomenon of stress accumulation.

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FORECASTING DISPLACEMENT OF ORE CIRCUITS WHILE CREATING THE EXPOSED ROCK MASSIVE SHOTPILE IN THE OPEN-PIT

The parameters of the shotpile of the rock mass blasting operations have a significant impact on following technological operations: mining costs and mine safety. The decrease in productivity and increase in the cost of mining operations due to irrational parameters of the shotpile are significant. A review of scientific papers shows that controlling the parameters of the shotpile of an exploded rock mass, scientists differ significantly in their research. At the moment, taking into account a lot of studies [1,2], there is no common mathematical model for forecasting the formation of the shotpile of the blasted rock mass by borehole charges.

In this article the method which allows to estimate the movement of blasted rock mass, depending on the degree of simplification of the methodology there are two models: estimation model is production model, and refined model describing the movement in time and space of each piece of the blown-up rock mass weight. The mathematical model is blasting of rock mass a of the discarded part into quadrilaterals, each of which moves independently during the flyrock travel phase. In this work, the estimation model takes into account the movement of the displaced rock mass as a single part, which is repelled by a single row of wells.

The estimated calculation model does not allow to accurately determine the movement of the rock mass, since multirow short-time explosion of borehole charges is a very difficult task and requires sufficient computing power. Therefore, a number of assumptions are made when constructing the evaluation model. The above method allow to estimate the amount of displacement of each row of wells depending on the explosive ratio, the parameters of the hole patternand and blasting without a compensatory slot. The resulting displacement of the contours of the ore body is determined by certain values of the displacements of each row. The advantage of this scheme is that it makes it possible to estimate the displacement of the ore mass depending on the applied drilling and blasting operations, having minimal machine time.

For the refined model of coefficients for the assumed dependencies are selected and a number of positions are introduced relative to the initial velocity vector of the departure of the exploded rock mass [3]. The average modulus of the velocity vector for the rocks of the first row of wells, based on the law of conservation of energy, is proportional to the square root of the explosive ratio. The value of the initial speed varies according to the height of the level increases from zero at the level of the soles of the ledge to the maximum value at the center of the explosive charge is then reduced, up to a certain amount to the roof ledge. This relationship is approximated by a polyline. The angle of inclination of the initial velocity vector to the horizon is a probabilistic value, and its mode increases, and the variance decreases with the growth of the number of the row of holes.

The theoretical calculation of contour displacement is performed for existing parameters of drilling and blasting operations. An algorithm for calculating the displacement of contours of ore bodies in the shotpile of blasted rocks has been developed. The values of the ore body contour displacement model obtained from the evaluation model show the correctness of the assumptions made and the efficiency of the estimation model.

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REMOVAL OF RESPIRABLE DUST IN HEADING FACES OF UNDERGROUND COAL MINES BY USING FILTRATION TECHNOLOGY

Coal dust, one of the main hazards in underground coal mines, can pose serious health risks to coal miners. In recent years, with the enhancement of mechanization level of coal mines, the dust concentration in mining face or heading face has risen sharply [1]. Some investigations have reported that the dust concentration in most mechanized heading faces can reach 200-500 mg/m^3. Most of the dust is respirable with a particle size of less than 7 μm. Coal miners exposed to the work environment full of respirable dust are vulnerable to coal workers' pneumoconiosis (CWP). Although occupational health and safety has been paid much attention by relevant government departments and coal mining enterprises, there are still quite a number of CWP cases reported in some countries including China, Australia, and the United States [2]. Therefore, it is necessary to improve dust control technology to reduce the harm of respirable dust to workers' health.

The dust control technologies commonly used in underground coal mines include water spray, wet dust collector, ventilation and foam spray. These technologies have their own advantages and disadvantages. Water spray and wet dust collector have a low operating cost, but the dust removal effect is not satisfactory. Because they can only remove dust particles with larger size and hold a low separation efficiency for respirable dust. Moreover, a large amount of water will be consumed by using them. On the other hand, it is difficult for ventilation methods to eliminate rock dust in the roadways. In contrast, foam spray can effectively suppress respirable dust, but the foam that covers the dust source may obstruct the worker’s view, and the high cost of the foam material severely limits its application [3]. Accordingly, traditional dust control technologies can not completely solve the problem of respirable dust in coal mines. In order to address this issue, the research group developed a set of dust removal system based on the filtration technology to reduce the dust emission and diffusion from the source. This study demonstrates the operation principle of the dust removal system and its application effect in the heading face of underground coal mines.

The dust removal system mainly consists of the filtering unit and pulse-jet cleaning unit. Before the formal system design and practical application, some necessary laboratory research has been carried out to optimize the dust removal performance. The laboratory research mainly includes three parts.

Firstly, a small-scale filtration experiment platform was built to investigate the effects of pleat coefficient, face velocity, filter material type and loading quality on the pressure drop of filter media. The experimental results show that the pleat structure of the filter media affected the filtration resistance by changing the effective filtration area. At the same face velocity, the effective filtering area of filter media decreased with the increase of pleat coefficient, and this relationship can be calculated by an empirical formula. In addition, the adhesion force between the filter media and dust cake increased with the increase of pleat coefficient, while the pulse-jet cleaning efficiency decreased with the increasing pleat coefficient.

Secondly, the method of setting a cone in the filter cartridge to improve the pulse-jet cleaning performance was presented. The mechanism of the cone placed in the filter cartridge to enhance the cleaning intensity and uniformity were investigated through experiments. It was found

that the cone can convert the dynamic pressure energy of the jet flow into static pressure that was considered as the main parameter affecting the cleaning effect. This method can change the flow field distribution in the filter cartridge during the pulse-jet cleaning and improve the cleaning effect.

Thirdly, the relationship between the instantaneous pressure at the nozzle outlet and the static pressure on the inner wall of the filter cartridge was studied. Based on this study, the mathematical formula for calculating the optimal injection distance (i.e., the distance between the nozzle and the top of the filter cartridge) was established, and the design of the blow pipe was improved. It was found that when the diameter of the nozzles on the blow pipe decreased gradually along the direction of the compressed air flow, the uniformity of the pulse-jet cleaning rose about 4-8 times, which greatly enhanced the cleaning performance.

Finally, according to the results of the laboratory research, a new dust removal system based on the filtration technology was designed and manufactured. It has been applied in Gequan coal mine and some field experiments were carried out to test its purification effect on the dusty air in the heading face. The test results show that the dust removal system was easy to operate and well-coordinated with the production process. After the system was turned on, the total and respirable dust concentrations at the position of the road header were reduced to 8.98 and 6.28 mg/m^3 respectively, with the average dust removal efficiencies of 97.28% and 96.42% respectively. At the position of transfer machine, the average dust removal efficiencies for total and respirable dust were 96.59% and 96.35%, respectively. In addition, the system has also been used in the construction of railway tunnel and achieved a good air purification effect, which indicates that this new technology has great potential for the dust control in underground workspaces.

This study presents a new dust removal system for underground coal mine. The laboratory research and field investigation show that this system can effectively collect the respirable dust in the workspace, indicating that it has considerable advantages over the traditional dust control technologies in terms of dust removal efficiency. In addition, since the system applies the high-precision filter cartridge as the air purification unit, it does not consume any water, which means that it has a wider applicability. Furthermore, compared with the water or foam spray, this technology is more friendly to the environment.

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A KINETIC STUDY TO EVALUATE THE EFFECT OF TEMPERATURE ON MIXED HYDRATE DISSOCIATION IN COAL

With the increasing consumption of coal resources, mining operations are also developing in depth, which leads to the increase of possibility and severity of underground accidents such as coal and gas outburst. However, forming hydrate in coal can reduce the gas pressure and delay the concentrative outbursts of gas flow. At present, considering the effect of

heat transfer in coal, the research that whether the dissociation process of hydrate in coal can effectively prevent coal and gas outburst is very important. Before, Mekala et al investigated the influence of two dissociation temperatures on the dissociation characteristics and gas production rates of natural gas hydrate in porous media[1]. Chong et al carried out methane hydrate dissociation experiments by thermal stimulation from 278.7K to 285.2K, and analyzed the laws of gas production, water production and energy efficiency of hydrate dissociation [2]. Above-mentioned researches mainly showed that temperature was an important factor for hydrate dissociation in porous media. In this work, we perform the formation and dissociation kinetics experiment of hydrate in presence of coal and tetrahydrofuran (THF) under the temperature based on different geological conditions in China by means of the experiment device with the impedance measurement function, which helps provide the fundamental data with mixed hydrate dissociation influenced by heat transfer in coal.

In this experiment, the methane gas with purity of 99.99% was used as the reaction gas, and the THF solution with mass fraction of 20% was used as the pore solution. The particle diameter of coal samples was between 5-10 mesh. The apparatus includes a gas pressurization system, a high-pressure reactor with three electrodes, a data acquisition system and a temperature controlling system. For experimental steps, firstly, 523g coal samples were added to the reactor, and then THF solution 278ml was poured into the reactor, which caused 100% water saturation. Next, CH_4 was injected into the reactor for hydrate formation experiments. After the formation step was finished, dissociation process was conducted by increasing temperature to 293.15K, during which the impedance values of three channel were monitored. Additionally, the hydrate formation and dissociation experiments were conducted with other four temperatures (298.15K, 303.15K, 308.15K and 313.15K). All formation experiments were performed at 3 MPa and 276.15 K.

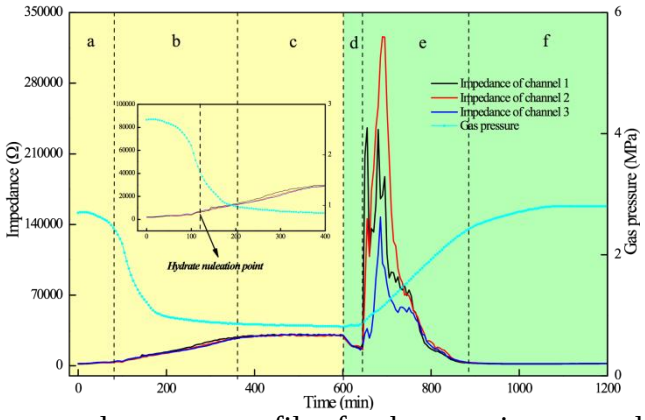

Figure 1 - Impedance and pressure profiles for the experiment conducted at 303.15K

Taking the experiment with dissociation temperature of 303.15K as an example, the formation process of hydrate was divided into ‘a’, ‘b’ and ‘c’, and the dissociation process was divided into ‘d’, ‘e’ and ‘f’ according to the trend of pressure and impedance curves (Figure 1). In the stage ‘a’, gas pressure decreased slowly due to the gradual dissolution of gas and impedance hardly changed due to hydrate didn’t form in this stage. In the stage ‘b’, the system impedance increased rapidly, which showed hydrate began to nucleate, and the gas pressure decreased rapidly at the start of this stage. Based on the fact that the sudden gas consumption and hydrate formation occurred at the same time, it can be inferred that CH_4 hydrate and THF hydrate were formed together at the nucleation point. In the stage ‘c’, the pressure gradually decreased, while the impedance gradually rose, and at the end of the stage ‘c’, the hydrate formation process was completed. In the stage ‘d’, the impedance value decreased, but the pressure did not rise obviously, which showed that THF hydrate was dissociated firstly. In the stage ‘e’, due to the endothermic effect, the hydrate was formed firstly and then dissociated, which caused impedance in three channels increased firstly and decreased. In the stage ‘f’, the

system impedance and pressure gradually reached the equilibrium state, indicating that the hydrate dissociation ended at the end of this stage.

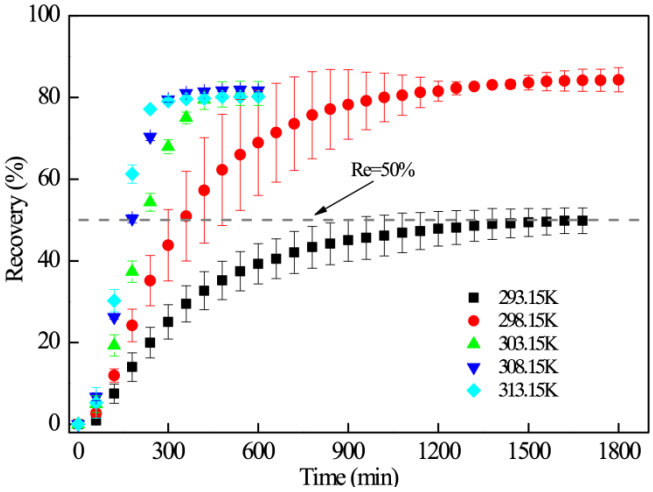

Figure 2 - Gas recovery curves for hydrate dissociation in coal samples at different temperatures

Figure 2 shows methane gas recovery curves in coal conducted under the different dissociation temperature conditions. As shown in Figure2, gas recovery rates all increased with time, and finally reached their respective maximum values. When the dissociation temperature was 293.15 K, the average gas recovery rate was 49.8%. This indicated that the formation of hydrate in coal would effectively reduce the original gas pressure at 293.15 K. In addition, lower dissociation temperatures would cause instability of gas production process.

In coal-THF system, impedance changes can effectively reflect hydrate formation and dissociation characteristics in coal. According to the pressure and impedance changes, the induction time of hydrate formation can be obtained and we can infer that hydrate reformation in dissociation process. From the recovery point of view, the higher the dissociation temperature, the larger the dissociation rate of hydrate. At 293.15K, hydrate was not completely dissociated in coal.

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TESTING NON-ELECTRIC DETONATORS AND ELECTRONIC DETONATORS WITH REGARD TO THE ACCURACY OF DELAY TIME

For the European Horizon 2020 research project „Sustainable Low Impact Mining “(SLIM- project) blast optimisation tests took place at the Erzberg mine, Austria. Erzberg is the biggest open-pit siderite mine in Central Europe. [1]

To improve the efficiency of the quarries and to minimize the ecological impact on the environment, various tests were carried out, such as tests with different detonators (electronic and non-electric) and different delay times. The choice of the right delay time has an influence on the blast result regarding vibrations, fragmentation, and the downstream processes. [2] To better estimate the influence of delay time deviations of the detonators on the desired blasting sequence, both types of detonators were tested in advance for accuracy.

The setup of the test series is based on the standard blasting design used for production blasts at the Erzberg mine. This considers manufacturer, type, number of detonators, length of wires/tubes, connections and initiation.

To measure the initiation times precisely, the detonators were equipped with detectors consisting of a pair of twisted, isolated copper wires. The detonation burns the isolation, melts the copper and closes the electric circuit, which triggers the connected oscilloscope. To ensure this mechanism works properly, a small amount of plastic explosive was used as a booster. A total of four test runs were implemented with the non-electric system, each with ten detonators and different surface delay. Six tests were carried out with the electronic system, each with seven detonators. The delay times, which were measured with the oscilloscope were transferred to tables and the difference between target times and actual times is determined.

The difference between the programmed time and the actual ignition was measured for the electronic detonators. For the non-electric detonators, the difference between the target time, which is made up the delay of the detonators and the surface delay, and actual time was measured. Resulting the time interval between the individual detonators was determined. Based on this series of tests, it was determined that it is important to add the delay time of the tube from the non-electric system. For the correction, the velocity of detonation of the non-electric tube was assumed to be 2000 m/s.

As expected, electronic detonators are very accurate and precise, non-electric detonators on the other hand have clear deviations from the target time and the actual ignition timing. The mean discrepancy of the delay time was 0,055ms at electronic detonators and 7,5ms at non-electric detonators. In the non-electric system, the reason of delay scatter is due to the inaccuracy of the detonator, detonator shock tube, surface connector and the surface tube. Considering the length of the shock tube for each detonator and the velocity of detonation within the tube, adjusted detonation times can be calculated.

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DEVELOPMENT OF THE METHOD FOR REDUCING HARMFUL EMISSIONS FROM THE OPERATION OF DIESEL ENGINES TO COAL MINES

Currently, the mining industry in Russia is taking a big step forward, in particular, the number of coal mines is increasing. As a result, the number of auxiliary equipment necessary for the implementation of these processes is increasing [1]. Diesel carriers used for transporting people and goods (since this method is safer), repair work, and also for the construction of new mines are very popular.

One of the most acute problems in coal mines is the contamination of the air with harmful substances. At the moment, there are several regulatory documents that normalize the content of carbon oxides, nitrogen oxides, hydrocarbons and other harmful compounds in the air of the working area of coal mines.

The most common way to reduce harmful compounds in the air of the mine working zone is to dilute the mine air with clean supplied air to the required concentrations, but it is not possible to effectively apply this method in every mine zone.

Therefore, it is necessary to develop a method to reduce the concentration of toxic substances in the air of the working area without the use of additional ventilation.

One of the ways to improve the composition of the exhaust gases is to change the composition of the diesel fuel used by introducing environmentally friendly components and bioadditives that allow the most complete combustion of fuel and the conversion of carbon monoxide into carbon dioxide [2].

Environmentally friendly additives were obtained from renewable raw materials, namely, from various oily crops grown in Russia. To obtain these bioadditives, we used the process of converting fatty organic acids into groups of esters having a low molecular weight.

When bioadditives are introduced into diesel fuel, emissions of harmful substances are mainly reduced after the use of environmentally friendly fuel in the engine. The hydrocarbon content in the exhaust gas is reduced to 55%., Volatile organic compounds - up to 59%, carbon oxides - up to 45%, the amount of dispersed particles is reduced to 63% [3].

Thus, the use of bioadditives as part of hydrotreated diesel fuel during the operation of self-propelled diesel equipment in coal mines makes it possible to bring the concentration of harmful substances in the exhaust gases to the required standards.

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EVALUATION OF A NEW TYPE OF BOREHOLE SURVEYING PROBE

Since deviations from the planned course of blast holes in the mining industry can lead to increased blasting noise, vibrations and rockfall, the exact measurement of boreholes contributes significantly to minimizing such emissions. Possible sources of error while drilling can be caused mainly by geological discontinuities (heterogeneous nature of formation and dip angle), but also by mechanical (type of rods, drill bits and tooling, applied weight on bit, hole inclination angle and quality of the equipment) and human (the experience of the driller) origins [1]. There are several different surveying concepts and designs for different types of boreholes, some of them outdated and no longer in use. Basically, all methods used nowadays are based on a cylindrical housing, in which various sensors, for measuring the inclination and direction, are protected when entering along the surface of the borehole. The recorded values are usually simultaneously sent to the surface via a connected cable or rods and displayed on an electronic device [2]. Due to the high precision required, correspondingly expensive sensors are necessary. Since the development of electronic devices, especially smartphones, drove so called micro-electro-mechanical systems, which evolved from the process technology in semiconductor device fabrication, to ever higher precision, a company decided to use this more cost-effective sensors in a borehole surveying probe [3].

The novel probe was tested for applicability, reliability and above all for its measuring precision at Austrian quarries and mining sites. For comparative results data was recorded with the current borehole probe of the University of Leoben too. Different borehole path results were compared between the two probes, and for repeatability and precision between the results of each probe, as individual boreholes were surveyed several times successively. The measurements took also place at geologically different compositions along the boreholes, so that, for instance, interferences with the magnetic field and therefore errors in orientation due to iron-rich minerals could be investigated.

For comparison of the measured data to actual values, an experiment was designed where a borehole can be simulated. To avoid interferences, the setup was completely made from wood and held together only with wood glue. The probes could be placed in adjustable angles and orientations and were additionally compared to so to say real values, azimuth and inclination, measured with a geological compass.

All data recorded by the probes were evaluated using their company-specific software and then processed with Matlab for further calculations with the aim of improving the comparability and clarity of the measured values. To calculate the deviation in between the repeatedly measured boreholes, their nearly vertical paths were horizontally cut at the deepest possible point, leading to the greatest calculated deviation of each measurement.

The results showed greater measuring deviation of the novel probe, compared to the one the University of Leoben has in use. The distance between the two average points of the two probes did not show a significant difference, but the spread or the deviation in between the repeated surveys of the same borehole clearly showed a less precise measurement from the novel probe. Similarly, the testing on the wooden construction showed fewer stable values. Considering that the probe and furthermore the calculating system of the company was still a beta version, a higher precision in newer models can be expected. Also mentioned should be the different price range, as the prices differ about twentyfold.

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INSIGHTS INTO THE MINERS-PROGRAM: A NEW EUROPEAN APPROACH FOR STUDENT MINE RESCUE EDUCATION

Mining has always been an industry, where even small accidents can lead to a disaster. Therefore, the operation of well-organized and trained mine rescue teams has become a necessity in every mining operation for more than the last hundred years. However, in the recent years, the industry has undergone structural and organizational changes. Due to different circumstances, such as the implementation of modern mining operations with a relatively small workforce, the capacities in manpower do not meet the numeric demands for having their own mine rescue teams. Because of that, it became obvious, that a new way to fill the need for competent

personnel became imperative. The MINERS-Program is the first joint European program for the education of future engineers who are trained in crisis management.

The Mine Emergency Response and Rescue School (MINERS) is an international cooperation between Montanuniversität Leoben, TU Bergakademie Freiberg, University of Zagreb and the Trinity College Dublin as well as the industry partner Boliden AB supported by the EIT RawMaterials. It´s goal is the implementation of a university course, which provides knowledge of mine rescue tasks and the handling of emergency situations. To distribute the workload and to use the assets of the different parties to their fullest potential, the project is split into three different workshops with the duration of one week. Each of the workshops tries to teach different key competences. These range from first aid and the coordination of a rescue operation to actual underground trainings with closed circuit breathing apparatus.

The first iteration of the project was realised from March to October of 2019. The first workshop happened in Zagreb and worked as an introduction and teaching individual skills. The following workshops in Freiberg and Leoben taught skills in squad behaviour respectively general emergency management. Both workshops finished with an underground exercise wearing closed circuit breathing apparatus.

This paper gives an insight into the structure of the workshops, which were designed to provide basic training to students without relevant experience in this field. Furthermore, the impacts of Student Mine Rescue Teams to the individual development are discussed from a student's point of view.

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FORECASTING THE THERMAL REGIME OF MINE WORKINGS IN OIL MINES

At the moment, 23% of the total volume of oil produced in Russia is heavy high - viscosity oil. There are more than 700 deposits of bituminous rocks in Russia. Their volumes are estimated at 40-80 billion tons according to various estimates [1]. For the extraction of this oil is a high-tech mining methods, the most effective current is thermal-mining method of oil production, where it is possible to achieve an oil recovery of 70%. According to the conditions of occurrence, several dozen fields in the Chechen Republic, Krasnodar territory, the Republic of Tatarstan, Kazakhstan, Uzbekistan, and Azerbaijan are potentially promising for thermal-mining production of high-viscosity oil and bitumen. There are also promising deposits in Canada, Venezuela, Kuwait and the United States [2]. The main problem with this method of mining is a strong deterioration of the microclimate parameters in the mine workings. Heated steam, oil-containing liquid, pipelines, steam breakouts in mine workings-all this contributes to an increase in the air temperature in the workings of more than 40 OC and an increase in air humidity up to 95 %. For safe operation in the mining block, it is necessary to ensure the normative values of microclimate parameters [3]. From the beginning of the production of the thermal-mining method of oil development at the Yaregskoye field, studies were conducted on the influence of the injected steam on the microclimate of mining operations. Konoplev Yu. P., Tskadaya N. D. and other scientists were engaged in the problem, were developing technical solutions aimed at improving the parameters of the microclimate.

The author of article has produced the formulation of research problems, theoretical studies of thermophysical processes at the oil mine, the designation of important factors in the formation of a heat mode mining block, depending on the stage of development of the block. A mathematical model was constructed and the results of calculations were verified using the proposed method with field studies.

A comprehensive study of thermophysical processes in the mining block was performed. The dependence of the oil flow rate and the significance of heat sources on the time of operation of the mining block is revealed. Based on the research staff of Mining Institute of the Ural Branch of the Russian Academy of Sciences the analysis of the sources of heat mining block, identified the importance of certain sources of heat and gives their classification by cooling or heating effect on mine air. A scheme of heat distribution in the massif and mine workings is constructed, and a mathematical model is developed based on it. The resulting mathematical model allows you to perform reliable calculations of air temperature.

The organization of separate airing of the mining block is proposed, which will allow to provide acceptable values of air temperature in the mine workings of the slope block. For airing, it is proposed to use ventilation wells drilled from the ground surface, through which fresh air will be supplied

The practical significance of the work is the possibility of applying a mathematical model of thermophysical processes to predict the temperature regime of mining blocks. Main scientific and practical results obtained in the course of the work:

1) It is revealed That when predicting the thermal regime of a mining block, it is necessary to take into account its development stage;

2) A mathematical model of thermophysical processes occurring in the mining block is Constructed and verified;

3) A technical solution for airing the mining block using a ventilation well is Proposed and its advantages are revealed.

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METHOD OF PLACEMENT OF FILLING MASSES IN A GOAF USING LONG-WALL MINING SYSTEM

The analysis of the world experience in the development of potash deposits was conducted. It showed that the main problems in the development of potash mines are a high level of extraction losses and an increased risk of flooding of stopes due to the discontinuity of water-bearing strata. An implementation of the long-wall mining system with stowing of a goaf allows comprehensively solving these problems.

The issues of stowing of a goaf during the development of salt formations are understudied. Combination of the long-wall system and “managing the roof by stowing the goaf” processes has not been implemented a lot. The world experience of stowing goaves during the development of strata using the long-wall system is analyzed in the article. A placing of filling masses in goaves that increases the safety of undermining of aquifers is proposed. The suggested method and proposed solutions are supported by laboratory tests of filling materials and mathematical modeling of the zones of deformation in overlying rocks.

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EXPERIMENTAL INVESTIGATION ON METHANE EMISSION CHARACTERISTICS OF COAL AFFECTED BY IMPACT LOADING

The exploitation of coal not only provides energy power for industrial development, but also brings negative effect on human society, including environmental pollution, ecological damage and mining disaster. In China, there are abundant coal resources, more than 95% of which need to be exploited by underground mining [1]. The complex geological conditions of coal seam have caused unknown difficulties in mining engineering. Currently, the depth of coal mining in China gradually increased at a rate of 8~12m per year [2]. Deep coal seam subjected to enormous in-situ stress reserves natural methane whose content and pressure are higher than the shallow coal seam [3]. Coupling dynamic disasters of stress and methane are increasingly serious and complex, such as rock burst of coal seam containing methane and coal and gas outburst [4]. In working face of coal mine, the phenomenon of abnormal methane emission is a common occurrence, creating an unsafe working condition for miners. And, mining-induced roof movement generate stress waves or dynamic loading, which have an effect on the methane emission of coal. Therefore, it is indispensable to study methane emission characteristics of coal affected by impact loading. The previous studies have shown that the influence of different factors on methane emission characteristics. However, limited investigation has been conducted on effect of impact loading on methane emission from coal. In this paper, by using a self-made experiment system for methane emission of coal affected by impact loading, methane emission characteristics were analyzed and discussed. Furthermore, the control measures of abnormal methane emission in coal mine and treatment method of coal seam for coalbed methane extraction were put forward.

The experimental system for methane emission of coal affected by impact loading is composed of gas supply module (helium and methane), impact loading module, vacuum module, gas collection module and data acquisition module. The detailed experimental procedure is as follows: (1) Preliminary treatment of coal sample and system air tightness detection: the cylindrical coal samples were put into constant temperature drying oven at 60 ℃ for 24 h to

remove the pre-existing moisture. The marked dry coal sample was put into the experimental tank, and valves were switched. The 2 MPa helium was filled into the reference tank and experimental tank to observe whether the pressure gauge value changes after 24 h. (2) Coal sample adsorption: the tanks and pipeline were vacuumed using a vacuum pump for 24 h, and then methane was filled into the reference tank to reach the desired pressure of 2 MPa. Subsequently, the methane from the reference tank was refilled into the experimental tank to allow the coal sample to reach adsorption equilibrium. After the pressure gauge value remained unchanged for over 24 h, the valve was opened to perform the methane desorption experiment. (3) Methane emission and impact loading: large quantities of free methane was first released from the tank and collected by a rubber bladder. When the pressure gauge value dropped to atmospheric pressure, the pipeline outlet was immediately connected to the gas measuring cylinder. When the methane emission lasted for 10 s, the impact hammer was free falling from the preset height to impact the coal sample. Finally, the amount of methane desorption was read according to the liquid level scale of the measuring cylinder.

In coal mine, abnormal methane emission from coal seam often occurs when it subjected to impact loading. The methane emission characteristics are directly dependent on the pore structure of coal, which is a typical dual porosity system containing porous matrix surrounded by fractures. The coal matrix is the primary storage space for methane, and the remaining methaneis basically free in the network fractures. Adsorbed methane and free methane can be converted each other by adsorption and desorption. The occurrence of methane can affect the coal structure, which may reduce the mechanical strength of coal. This can be explained from two aspects: for one thing, coal swelling or shrinking induced by methane adsorption or desorption can cause the micro deformation of coal structure; on the other hand, the free methane between the structural surfaces of fractures is like the lubricating oil which may reduce shear friction resistance.

Methane-containing coal is subject to elastic and plastic deformation under impact loading, causing the formation, extension and connection of new fractures in coal. Accordingly, the desorption, diffusion and seepage of methane eventually lead to abnormal methane emission. In turn, the methane emission may produce the deformation of coal. Meanwhile, the larger the impact loading energy is, the more serious the damage of coal is and the more fractures are formed. Increased porosity provides a channel for methane transport, and the methane occurring in coal is finally released to the working space through desorption-diffusion-seepage process.

The pore structure of experimental coal samples was analyzed by MIP, drawing the conclusion that micropores occupy the main part of the pore structure of coal mass, on the surface of which most methane is adsorbed. Then, the impact loading stimulates damage of coal mass, causing pore failure and fracture extension. Subsequently, desorption, diffusion and seepage of adsorbed methane occur. The greater the impact loading energy is, the easier methane emission is. On this basis, the control measures of abnormal methane emission in coal mine and treatment method of coal seam for CBM extraction were put forward. In this paper, experimental investigation was carried out with the effect of impact loading intensity on methane emission characteristics as the focus, which is one of the effect factors alone. Afterwards, coal rank, methane adsorption pressure, impact time point and other effect factors will be considered for further discussion.

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EXPERIMENTAL STUDY OF THE INFLUENCE OF VES FRACTURING FLUIDS ON THE PORE STRUCTURE OF COAL

For a long time, coal has been one of the most important energy sources for the development and advancement of human civilisation. However, because of the environmental pollution caused by the utilisation of coal and the shortage of supply of the conventional energy form, coal bed methane (CBM), a type of unconventional natural gas, has received an increasing amount of attention. The main component of CBM is methane, and it produces only water and carbon dioxide during combustion, which is cleaner and more environmentally friendly than coal. Furthermore, CBM resources are widely distributed around the world. Therefore, in recent years, many countries have promoted the exploitation of CBM. Hydraulic fracturing technology is widely used in the CBM industry to improve gas flowability. During the fracturing operation, the fracturing fluid is injected into the wellbore; then, the coal is broken by the high-pressure fluid, and a large number of artificial fractures are generated in the coal seam around the wellbore, significantly enhancing the gas flowability of the coal.

The interaction between coal and fracturing fluid and its influence on the pore structures of the coal are the key factors affecting the production of coal bed methane (CBM). To address this issue, the viscoelastic (VES) fracturing fluid were selected and used to treat Illinois coal. A series of low-temperature nitrogen ad-/desorption experiments and NMR measurements were conducted to comparatively analyse the evolution of the coal pore structure after treatment.

The results and the conclusions of this study can be summarized as follows:

1. The fracturing fluid treatment seriously impaired the sorption capacity of the coal. The reason for this may be that the intrusion of the fracturing fluid residues blocked the pores, thereby reducing the number of effective sorption sites on the coal surface.

2. The VES fracturing fluid inflictst serious damage to the nitrogen sorption capacity. In addition, after treatment by the VES fracturing fluid, the area of the hysteresis loop formed by the ad-/desorption curve is significantly reduced, which means that the pore volume inside the coal sample is reduced, or the pore shape is changed. During the treatment, the residue of the VES fracturing fluid entered into these ink-bottled pores through the bottleneck and adhered onto the pore wall.

3. During water washing, the residue cannot be removed because of the adhesion of the residue to the pore wall. Thus, after the intrusion of the residue, on the one hand, the volume and internal surface area of the pore decrease, such that the nitrogen sorption capacity of the coal samples was damaged. On the other hand, the internal shape of the pore became similar to the cylindrical pore, reducing the area of the hysteresis loop during the ad-/desorption process. The VES fracturing fluid treatment caused the greatest decrease in the pore volume of the coal. In the range from 2 to 10 nm, the pore volume of the coals treated by the VES fracturing fluid was significantly lower than the coals treated by the slickwater or guar gel.

4. After the treatment, the residue entered into the pore system and adhered on the pore wall surface. The residue adhered on the rough region can form a more stable structure because of the uneven surface, such that the residue cannot be effectively removed during the water-washing process. At this time, because the rough regions were covered by the residues, the

nitrogen molecules cannot be absorbed on these regions. Meanwhile, there is relatively less residue adhered on the smooth regions, such that the molecules can still be absorbed on these regions.

5. The VES fracturing fluid changes the coal pore structure, mainly through the physical intrusion of the residue into the coal pore and the occupation of the interior space of the pore system. It can be inferred that the intrusion of the residue poses an adverse impact to the CBM flowability, thereby reducing the production of the gas. Thus, it is necessary to improve the chemical composition of the water-based fracturing fluid or further develop the flow-back technique, such that the residue remaining in the reservoir can be minimised.

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RESEARCH OF THE ADHESION PROPERTIES OF ORGANIC DUST SUPPRESSING COMPOUNDS

One of the most significant problems of industrial safety and labor protection at the enterprises of the mineral resource complex is the increased dustiness of the working area air [1]. The main source of dust emission at enterprises engaged in open-pit mining is technological roads [2]. To reduce the aerotechnogenic load on the air of the working area and the environment, hydrodusting of dusty surfaces is most often used. However, this method often has an exceptionally low efficiency, which is why surfactants that increase the wetting and binding properties of dust suppressing agents are widely used [3]. The choice of the most effective and rational dust suppressing solution is complicated by many factors that determine the possibility or feasibility of using a particular solution, as well as the fact that at the moment there is no specific method for evaluating the effectiveness of dust suppressing compounds, which would allow to determine the possibility of using various means of dust suppression.

Basically, the use of dust suppressants consists in creating a fixed layer on the dusting surface or impregnation and strengthening a much thicker layer of dusting material, which leads to a decrease in the intensity of dust emission [4]. Evaluating the effectiveness of various means of dust suppression requires a comprehensive approach due to the need to consider a large number of factors and parameters. The authors of the article propose a method for evaluating the effectiveness of dust suppressing solutions, which consists in determining the adhesive properties of the compound, as an indicator of the binding and bonding ability of dust suppressing agents. It is known that the values of cohesion and adhesion determine the value of the loads necessary for the destruction of certain conglomerates and complexes formed as a result of the binding forces. Thus, the determination of the adhesion of a solution, which reflects the value of dusty particles binding force, allows to determine the strength of the bonded layer and hence the efficiency of dust suppressing agents.

To evaluate the effectiveness of using dust suppressing solutions, a model of a quarry road was made in 1:40 scale in two versions: horizontal and inclined. Determination of the adhesion ability of the studied solutions has been performed using a modified dynamometer DOSM-3, which is a measuring device itself, connected to a homogeneous smooth plate. The scale of the device reflects the tension and compression of the elastic element in units of length (mm). Therefore, to convert the units of its deformation, the device was calibrated for loading and unloading, and the value of compression or stretching of the elastic element and the value of the load in units of mass (kg) were established. When studying the adhesive properties of the solution, a dusting material (SiO_2, coal dust) was distributed to the road model, the dust suppressing compound under study was applied with a certain flow rate, and the measuring device was installed

with a plate on the newly applied solution and remained on the surface of the model until the composition completely dried. Then the dynamometer was detached in a direction perpendicular to the road surface and the separation force value was recorded. Taking into account external factors that affect the measurement result (e.g. the mass of the plate itself, fasteners, etc.), the actual load necessary to detach the plate from the surface of the model was calculated using the linear interpolation method and the data of the calibration table. In turn, the value that characterises the load required to break the adhesive bond determines, among other things, the strength of the bond between the dust particles and, accordingly, the strength of the entire coating formed as a result of dust suppression.

The proposed method was used to determine the effectiveness of several dust suppressing compounds that differ in active astringents and wetting agents. At the same time, organic solutions were taken as the main object of research, which are a cheap, but not much less effective analogue of expensive surfactants of artificial origin. In addition, the properties of the dust suppressing composition developed by the authors on the basis of an astringent aqueous solution of starch and flax in a certain ratio were also studied. In order to keep purity and correctness of the experiment results, the surface of the road model was cleaned and covered with dusting material and dust-suppressing solution again after each experiment. During the research, the properties of the most common dust suppressing aqueous solutions of beet molasses, ginger oil, lignosulfonate, as well as a solution of flax and starch (with concentrations of 1, 2, 3 and 5%) were studied. As a result, it was determined that the highest value of binding (adhesion) ability has an aqueous solution of beet molasses (414.9 Pa), and the lowest – a solution of ginger oil (225.8 Pa).

The method proposed by the authors of the article for determining the adhesive properties of various solutions allows to evaluate the effectiveness of dust suppressing agents by determining the forces that characterise the strength and resistance to physical effects of the coating formed as a result of the use of binding dust suppressing compounds. This, in turn, makes it possible to choose the most effective and appropriate means of reducing the aerotechnogenic load in certain conditions. The authors of the article suggest further refinement of the model for estimating the adhesion ability of solutions from the point of view of similarity theory, as well as the development of an advanced mathematical apparatus for a more accurate assessment of the adhesive properties of compounds, taking into account a larger number of influencing parameters.

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IMPROVEMENT OF PRODUCTIVITY IN QUARRYING BLOCK STONE USING NEW CONSTRUCTION OF BLASTHOLE CHARGE

The development of block stone deposits should be conducted from the standpoint of resource conservation and rational use of this valuable mineral raw material while preserving its natural strength properties. The development of such deposits with high strength properties is currently mainly carried out using drilling and blasting operations. Existing technologies for explosive breaking of stone blocks currently provide block output in the maximum range of 20-25% of the volume of mined rock mass under favorable geological conditions. According to estimates, over the past 15 years, 296 thousand m^3 of blocks and 4034 thousand m^3 of rock mass were mined at the Drugoretsky field of the Republic of Karelia, the block output was about 7.4% [1]. In the Raivimaki field of the Republic of Karelia, the actual output of blocks under difficult geological conditions is about 10%. [2] One of the productive methods for solving the problem of low output of blocks is optimization of the charge construction due to the use of special explosives that reduce the rock-fracture zone of the extracted large blocks , as well as improving the method for calculating drilling and blasting parameters.

The advantage of the drilling and blasting method is its relatively high productivity, while the rock-fracture zone of natural stone extends to 10-15 cm [3]. Studies of the disturbance of the block stone from the explosion were carried out by such scientists as Y.G. Karasev, N. T. Bakka , G.P. Paramonov, V.N. Kovalevsky , J.G. Dambaev and others.

The author of the article analyzed existing studies on this topic and determined the most modern and accurate method for calculating the blasting parameters for cutting block stone, which takes into account the geometrical parameters of the block, the physical and mechanical properties of the rock, as well as the explosive characteristics of the explosive used. Calculation of the drilling and blasting parameters was made for the proposed new construction of the blasthole charge, consisting of the element of a universal gas-generating cartridge and a detonating cord. Also the calculation of the radius of rock-fracture of the block from the explosion was performed.

To identify rock joints and their distribution in the block, a study was conducted on the Vozrozhdenie deposit, where two experimental explosions were carried out with the old charge construction using black powder as explosive and the proposed construction. Identification of joints on the surface of the block was carried out using the paint method developed at the St.Petersburg Mining University [4]. As a result, we obtained dependence diagrams of the changes in specific rock-fracture as a function of the distance to the blasthole for both charge constructions and the actual radius of rock-fracture.

The practical significance of the work lies in the use of the proposed method for calculating the parameters of explosive blasting, due to which it is possible to calculate the powder factor that is minimally sufficient to cut the block, as well as in the use of a new construction of blasthole charge for cutting stone. The main scientific and practical results obtained in the work:

1) The advantages of the proposed charge construction over existing ones are revealed.

2) For the proposed charge construction, the powder factor decreased, the blasthole spacing increased, resulting in a decrease in the cost of drilling and blasting.

3) When using the proposed charge construction and calculation method at the Vozrozhdeniye quarry, the output of blocks by reducing the radius of rock-fracture increases by 5%, which allows more profit from 1 m^3 of mined rock mass.

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ASSESSMENT OF RISKS IMPEDING SUSTAINABLE MINING USING FUZZY SYNTHETIC EVALUATION

The mining industry faces intractable barriers to sustainable development due to its involvement with indigenous communities as well as links with the economic and political systems of the country. The challenges arise from a number of risks that must be assessed and managed. It has been emphasized that the risks associated with mining-related sustainability should be extensively examined, which in turn will help establish strategies to promote sustainable mining. The likelihood and severity of each risk vary due to its unique characteristics. The impact of any risk on project goals puts enormous pressure on implementing sustainable mining strategies. It is anticipated that the root causes of industrial underdevelopment may be associated with many risks. However, there is very little and scarce information on sustainable practices and related literature on risks.

This study advances the current literature on sustainable mining related risk assessment. It was presumed that decision-makers have two key questions: what the most likely risks are and how they affect the sustainability of the mining industry. In order to answer these questions, a total of 41 risks grouped into eight categories were finalized. The risk categories include 1) Economic and financial risks, 2) Environmental risks, 3) Natural and external risks, 4) Political and legal risks, 5) Organizational and managerial risks, 6) Operational and technical risks, 7) Health and safety risks, 8) Socio-cultural risks.

This research was completed by a systematic approach. First, mining professionals were consulted for data collection. Ratings on the probability of occurrence (P) and the impact (I) of the risks were obtained from 165 experts. Finally, the fuzzy synthetic evaluation model was developed to assess the identified risk. The risk assessment model has been divided into three levels, i.e., evaluation of each risk, evaluation of each risk category, and the evaluation of overall risk level.

The risk assessment was performed using fuzzy synthetic evaluation. This method expresses mathematical logic to quantify the impact and severity of fuzzy variables. Using this

approach, empirical knowledge of practitioners can be represented to achieve reliable decisions [1]. It can overcome problems of the vagueness of multiple factors in the risk assessment process by converting qualitative evaluation into quantitative evaluation through linguistic expressions [2]. Many scholars used this method in various fields because it facilitates quantification of the factors that are imprecise or hard to assess [3]. Summarized from previous studies [4], the procedure of fuzzy synthetic evaluation is described below.

In the first stage, each risk was assessed according to values assigned by professionals on probability and impact. The next step is to determine the membership degree of each factor, that is, to establish a quantitative relationship between the risk i and evaluation levels (5-point linguistic scale). The membership functions for P and I values were obtained to calculate their values. Finally, score for individual risk and risk categories was calculated.

According to results, ranking of risk categories by score is operational and technical > organizational and managerial > economic and financial > health and safety > environmental > political and legal > natural and external > socio-cultural. It was observed that the overall risk level was high, indicating that understanding the factors and implementation of methods of sustainable mining is of great significance. In view of the current situation of sustainable mining, some suggestions are put forward to provide scientific support for the future framework of sustainable mining. There is an urgent need for an integrated, comprehensive, practical, and implementable plan to make the concept of sustainable mining play a leading role. In the future, technology development will be accelerated, and the upgrading cycle of technical equipment will be continuously shortened. Therefore, increased attention should be paid to the innovation of engineering technology to enhance digitalization and informatization in mines. For this, intelligent mines need to be built or existing mines to be transformed by improving the degree of mechanization and automation of the existing mining systems. Mining enterprises should also foster a safety culture and improve the level of safety standardization by taking care of primary health and welfare services, the living environment, and other social issues of employees. Skill training for the workers and an appropriate workplace will result in improved work efficiency and mine productivity, which in turn will contribute to sustainability.

One advantage of this study is that according to our knowledge based on literature search, this is the first study of its type.

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RESISTANCE OF THE STEMMING TO THE EJECTING ACTION OF THE DETONATION PRODUCTS

As you know, the bottom hole as a result of compaction under the influence of an explosion is tightly wedged in the hole. The main compaction of the face material occurs at the initial moment of explosion development due to the impact of shock waves and piston pressure on the face of the face of the detonation products. As a result of this compaction on the contact of the face with the walls of the hole there are forces of lateral expansion, the value of which can be determined by the formula: [1]

$$\sigma_б=\theta P, \text{ kg /m}^2 \quad (1)$$

where $\sigma_б$ -is the value of the lateral expansion forces;

θ-the coefficient of lateral strut of the face material;

P-is the average pressure of the gaseous detonation products in the charging chamber, kg/m^2.

Since the forces of the lateral strut are greater than the resistance of the face material to shear, during the explosion, the face does not slide along the walls of the hole, but is cut along a cylindrical surface that very closely coincides with the side surface of the hole.

The roughness of the borehole walls also contributes significantly to the cutting of the face during an explosion. The process of ejecting the plug from the hole can be represented as follows. Since the beginning of the detonation of the explosive charge, the gaseous products of detonation, acting on the end of the face, tend to move it. Until there is a shift, the resistance to the ejecting action of the detonation products is due to the inertia of the rest of the own mass of the face, the forces of internal friction and adhesion of the particles of the face material. But immediately after compaction of the latter, the face is shifted and in the future its movement is prevented only by weight and internal friction forces. The diagram of the forces acting on the face during the explosion of the spur charge is shown in Figure 1.

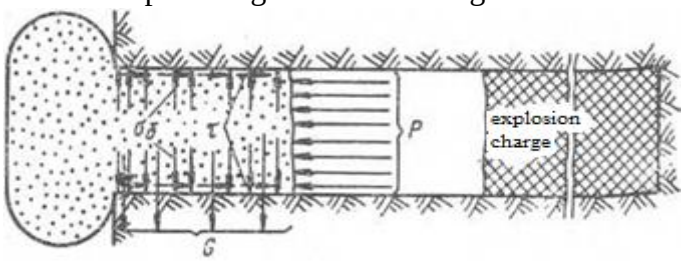

Figure 1 - The scheme of the forces acting on the stemming from plastic or granular materials during the explosion: $\sigma_б$ — lateral pressure forces; τ — displacement resistance of the stemming material; G — weight of the stemming; P — average pressure of gaseous detonation products

In contrast to other types of stemming [2] plastic (clay, sand-clay or loam stemming) and granular stemming (sand, granulated blast furnace slag or drilling fines) are porous. Therefore, during the expansion process, the gaseous products of detonation can seep through the pores and scatter the part of the face that has time to go beyond the hole. In addition, the forces of the lateral strut, which are directed to the walls of the hole, are also contributing to the bulging of the plug that is flying out of the hole, and are not balanced by anything after the plug is ejected from it. Experimental studies of the MakNII [3,4] also show that the part of the culvert thrown out of the hole is dispersed.

The resistance that the hammer provides to the products of detonation can most accurately be characterized by the work spent on overcoming it. Therefore, in order to assess the role of the mass of the bottom hole, internal friction forces and adhesion from the quantitative side when considering the quality of the bottom hole material, it is necessary to determine the work spent on overcoming the resistance provided by each of these factors.

If we assume that the mass of the face does not change during the explosion, then the work of the detonation products spent on overcoming the inertia of the rest of the face mass can be determined from the expression:

$$A_m = \frac{m}{2}(v_к^2 - v_н^2) \quad (2)$$

where A_m -is the work of the detonation products to accelerate the mass of the stemming to the final speed, kgm;

т -weight of the stemming, kg;

$v_н^2$-initial speed of the stemming, m / sec;

$v_к^2$ - the final speed of the stemming, m / sec.

The mass of the stemming is equal to:

$$m = \frac{G}{g} = \frac{\pi d^2}{4g}\gamma_з l_з, \quad (3)$$

where G is the weight of the stemming, kg;

g - acceleration of gravity, m /sec^2;

d-bore diameter, m;

$\gamma_з$-the volume weight of the stemming material, kg/m^3.

$l_з$ -the length of the stemming, m.

Substituting expression (3) in expression (2) and considering that $v_н^2$=0, we get:

$$A_m = \frac{\pi d^2}{8g}\gamma_з l_з v_к^2 \quad (4)$$

The work on overcoming the forces of internal adhesion between clay particles of a sand-clay mixture is determined by the area of the shear diagram, which is constructed on the basis of experimental data. To determine the amount of work spent on overcoming the internal friction resistance of the face material during the movement of the face in the hole, it is necessary first of all to allocate the part of the total shear resistance that depends on the friction.

The work of the detonation products spent on overcoming the friction forces on the shear surface will be:

$$A_{тр} = l_з R_{тр}. \quad (5)$$

where $R_{тр}$ is the total resistance of the friction forces along the entire length of the face, kg.

The value of the $R_{тр}$ during the departure of the face from the hole does not remain constant, but changes from the maximum to zero, since as the face exits the hole, the total resistance of the friction forces decreases.

According to the authors [1], the impact of the explosion on the stemming is shock, and the material of the face is re-compacted and its physical and mechanical properties change, the results of experiments differ from the actual values of the friction forces and adhesion of the face material. However, this difference can be eliminated by introducing appropriate correction factors.

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THE POSSIBILITY OF USING OPEN-PIT CONVEYOR TRANSPORT IN THE CONDITIONS OF THE TSANKH FIELD

In many fields, trying to take conveyor transport, but because of the high cost of the conveyor complex and future possible breakdowns, even because of other doubts, complex conveyor transport is not fully applied. An unspecified problem is that the workability of rubber belt conveyors is deteriorating given cold climatic conditions, and the rubber conveyor belt itself takes up a large majority of the cost of the conveyor. Therefore, it is necessary to clarify the uncertainty regarding this topical issue.

Currently, open-pit conveyor transport is used in some deposits of Mongolia, but not integrated conveyor transport. The problem is that in many fields, the ambient temperature drops sharply in the winter season, so most engineering designers cannot solve the use of integrated conveyor transport in completeness due to the temperate climate and financing.

There is a manufacturer who offers stationary rubber conveyor belt of the UKLS type of general purpose with rubberized belt designed for transportation of granular rocks, small-sized rocks with an apparent density of not more than 3.5 tons/m^3, as well as piece goods in areas with a temperate climate at temperatures from -45 to +40°C, also for operation in a temperate climate, placement category 1 according to the state standard.

A rubber belts are made of general purpose and special: fire-resistant (non-flammable during slipping); non-electrified (with antistatic additives that prevent the ignition of the methane-air environment by surface electrostatic charges); frost resistant (up to –55°C) or heat resistant (up to +100° C). General purpose rubber belt operate at temperatures from -25°C to + 60°C.

And also it should be noted that, besides the rubber belt of the conveyor, the following signs should be considered and according to these signs an analysis is carried out on the basis of a detailed report on the field and also on the basis of other data.

- By type of conveyor (straight line)
- By tilt angle (horizontal, tipping)
- By type of conveyor frame (hard frame)
- By destination (mobile)
- By type of freight flows (for ordinary freight flows)
- By according to the location of the carrier branch of the belt (with the upper carrier branch)
- By the cross-sectional shape of the load-carrying branches of the belt (with a flat rubber belt)
- By type of rubber belt (with a smooth rubberized belt)
- By the number of drives (multi-drive)

In brackets analyzed the result of alternatives.

When designing and calculating rubber belt conveyors, consideration should be given to the conditions of their operation (production conditions and the environment). These include the type of room or place in which the conveyor is installed (or its main part), the characteristics of the macro-climatic region in which it is located, and the temperature and humidity of the surrounding air. And also in the transported freight in combination with moisture, the load-carrying belt, drums and roller conveyor belts are heavily contaminated, which often causes slippage of the belt on the drums, running down to the side and, as a result, accelerated wear. Contamination of the belt reduces the drive capacity of the drive drum. This makes it difficult to clean the load-carrying body. In this case, the calculation can be limited to some increase in the thickness of the outer lining.

To design a belt conveyor, it is suggested to consider the following:

- indicate the purpose of the conveyor in the technological process of production, at the moment does not correspond with the operating equipment
- to plan the circuit of the conveyor route with indication of all its main dimensions

- optimize the physical and mechanical characteristics of the transported freight flow
- calculate the planned mass (t/h) or volumetric (m3/h) capacity of the conveyor. If several different freight flows are to be transported on the conveyor, the capacity is set for each freight flow and the sequence of freight flow supply to the conveyor is indicated.
- determine the mode of operation of the conveyor
- identify ways to load and unload the conveyor
- pay attention to the voltage of the electrical network and the type of the current conveyor
- determine the required availability of the conveyor

When used improperly, it leads to deterioration of the rubber belt and to other parts. Therefore, the following must be considered for the rubber belt:

- Textures

(A) To increase inclination

(B) To control product

- Cleanability
- Cut resistance
- Enhanced impact resistance
- Wear Resistance
- Fire retardance
- Oil & Chemical use
- Heat & Cold

Cover type, quality and thickness are matched to the service life of the belt involved. A specific cover formulation used in an individual belt construction is determined by the material to be carried and the environment in which the belt will operate. Modern day belt constructions, with their high adhesion levels and synthetic carcasses, are considerably less susceptible to moisture and chemical attack and do not require edge protection. The manufacturer make possible the slit-edge belt distribution programs currently used in the belting industry. Moisture, sunlight, ozone, chemicals, heat, cold and petroleum products all have an influence on belt performance and life.

Before these belts will train properly, they must be warmed to a temperature above freezing. When calculating the temperature mode of operation of the drive (its temperature stabilizes over time, approximately equal to 5-6 hours), it is necessary to know the constants of the freight flow, which are approximately equal in duration to the time constant of thermal transients in the drive.

Frost, snow and ice can also affect belt performance:

- On an incline surface a layer of frost can cause load slippage
- Ice can build up on conveyor hardware and cause more damage than material buildup
- Ice can form on the troughed side of the belt and plug chutes

Due to the overlying difficulties it is necessary to consider the conveyor hood option.

The standard hood model is offered in 3 styles.

- Full hood: 180^0 cover available fixed or with one or two opening sides. This model covers the belt and idlers providing maximum safety for personel and extending the wear life of the covered components. It also prevents material loss due to high winds.
- 3/4 Hood : Same as the full hood, but with one side permanently opened at 45^0 angle.
- Partial hood: Same as the full hood, but with both sides permanently opened at 45^0 angle.

And further consider the following requirements.

- odd shapes for convex and concave areas
- extended down to cover the return belt
- flexible canvas for hinged sections
- holes for idler lubrification
- holes in bands for pull cord eye bolts or sprinkler pipes

- side mounting base plate

In addition to the hood of the conveyor is considered a gallery. The gallery is a bridge-type engineering structure.

For the steel supports of the galleries, two types are proposed: flat and space. The branches of flat supports are made, as a rule, from double-T-iron.

Loads of galleries are divided into three groups: technological, construction, from atmospheric influences.

Technological loads:

- weight of the soil on the tape (long)
- weight of industrial wiring (long)
- weight of conveyor structures (long)
- resistance to movement of the tape (long)
- repair (short)
- loading from start of the conveyor (short-term)

Building:

- weight of bearing steel structures, fences, thermal insulation (permanent)

Atmospheric:

- weight of dust on the coating (long)
- snow weight (short term)
- wind pressure (short term)

In the process of transportation on the conveyor, the freight flow experiences tremors, vibrations, as a result of which the mobility of the particles increases and the angle of conveyor decreases to the angle of slope. The angle of slope affects the cross-sectional area of the load placed on the belt, and therefore the performance of the conveyor.

It should be noted that with continuous uniform loading of stationary conveyors, the inclination angle can be increased by 1-2 °. With an ordinary load, the angle of inclination may be greater than with a sorted one. If there are large pieces in the load, the permissible angle decreases, with decreasing speed, the tilt angle increases.

The study of freight flows and their appropriate adequate analytical introduction allow us to reasonably choose the main design parameters of the transporting machine, solve the problems associated with storage, correctly evaluate various technical and economic decisions, etc.

Large freight flows and the irregularity of their arrival on the conveyor should be considered when developing the method of traction calculation and calculation of the receiving capacity of the conveyor. Due to the need to change the length of the conveyor as the bottom moves, it is required to design special telescopic conveyors for horizontal and inclined mining workings. In addition, relatively quick assembly and disassembly of the conveyor bed should be ensured.

To select a rubber conveyor belt according to receiving capacity, it is necessary to know the instantaneous volume flow rate of the transported material. It is usually obtained by dividing the value of some averaged “apparent density”, depending on the grain size distribution of the freight and other factors.

To select rubber belt conveyors, the following are required:

- Allowable angles of inclination of the conveyor to the horizon
- The minimum width of the belt depending on the size of the pieces of the transported freight flow;
- Allowable safety margin of rubber belts;
- Number of gaskets depending on the width of the rubber belt;
- Maximum allowable sags of the rubber belt at the minimum tension point of the load branch, etc.
- Rubber conveyor belts are manufactured in widths from 400 to 3000 mm.

- The speed (m/s) of rubber belt movement should be chosen from the normal range of preferred numbers, and the diameters of the rollers should be chosen from 89 to 127 mm.
- Power (kW) of drive motors should be chosen from 75 to 160.
- When designing rubber belt conveyors for a given field, a volume capacity of the V (m^3/h) (with tolerances of ± 10%) of the following normal range is recommended: from 400 to 5000;

The service life of rollers without repair for at least three years, fixed and rolling conveyors for eight years and mobile for quarries and coal mines is four years. The conveyor readiness factor must be at least 0.96 for stationary and rolling conveyors and at least 0.90 mobile for quarries and coal mines. For long-distance transport, conveyor lines with a length of more than 100 km and a length of one conveyor of 8–10 km have been created.

All the above proposed must be considered when calculating and selecting the design and power parameters of conveyors.

The field has a mountainous climate with sharply continental features. In the coldest month of the year, the temperature can fall below -40°C, in the field area, it practically does not fall below -45°C. Based on this, it can be concluded that this does not exceed the temperature limit of the frost-resistant conveyors.

It should be noted that the cold in the region of the field is transferred much easier because of the dry air. Also in the region is not a big level of humidity, even in summer. This means that there is little contamination of the rubber belt, and durability increases.

In belt conveyors, the rubber belt is the most expensive and most wear part. Especially sharply reduced its durability during transportation of abrasive materials. And the field has a small amount of stripping work. At the expense of mining, coal of all grades, except anthracite, differs in relatively small abrasivity compared to the abrasivity of most minerals, as a result of which the task of protecting the belt from abrasive wear is not for coal. The introduction of rubber belt conveyors in the field contributes to the improvement of the technical level and efficiency of mining production and creates favorable conditions.

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A DATA-CENTRIC LOOK AT DOWNSTREAM IMPACTS OF ELECTRONIC AND NON-ELECTRIC DETONATORS AND VIBRATION-OPTIMIZED DELAYS AT AN AUSTRIAN HARD ROCK MINE

It is widely recognized that fragmentation by blasting has a significant influence on the subsequent downstream processes of loading and crushing. To validate potential improvements

in blast outcomes resulting from changes in the design, image analysis is typically employed. Coarse fragmentation is linked to reduced diggability and higher crusher energy consumption, decreasing overall efficiency [1,2]. However, this approach is not always practiced or possible. Where only raw data is available, the impact of optimization efforts is more difficult to quantify.

In the context of one such effort, an Austrian hard rock mine trialed electronic detonators and blast-specific inter-hole delay sequences optimized for vibration. Electronic detonators have been associated with improved fragmentation [3,4]. Other blast design parameters and procedures remained unchanged. During the project, data on loading and crushing equipment was collected using retrofitted sensors and artificial intelligence processes. Conclusions are drawn about the downstream impacts of electronic and non-electric detonators, including the optimized delay times, by applying statistical methods following a careful data cleaning process.

Results show that the choice of detonator has a statistically significant impact on downstream processes, with the observable difference being more pronounced for crusher energy consumption than for dig times. However, the magnitude of the effect is low. A comparison between regular and optimized delays for electronic detonators yields similar results. Based on these findings, it appears that within the setting of the mine the choice of detonator type and the use of vibration-optimized delays does not affect fragmentation in a noticeable way.

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ARCTIC «PSO»

According to the results of the program of the V International Conference "Arctic: Shelf Projects and Regional Sustainable Development" - "Arctic 2020", the Arctic region requires intensive social and economic development, development of innovative programs and technologies for the development, preservation and restoration of territories, which exist in permafrost and global climate change. For their implementation, specialists of a new profile are needed. The subsoil of the Arctic has about 83 billion barrels of oil, about 1550 trillion cubic meters of natural gas and 780 billion tons of coal. The Arctic zone of the Russian Federation produces 99% of diamonds, antimony, apatite, phlogopite, vermiculite, rare and rare-earth metals, 98% of platinoids, 90% of nickel and cobalt, 60% of copper. The local industry is present only in monocities and on the Arctic shelf. It is dispersed in separately selected territories. This is due to territorial and economic factors and environmental protection issues. Requirements are

emerging that create new problems that need to be solved when developing Arctic territories to create projects of a new qualitative level.

There is "life" in the Arctic tundra, despite the sedentary and small number of local people. It has a number of features: the availability of sanitary aviation, the high cost of food, fuel, electricity, the portable nature of housing (plague, yarangi), mobile lifestyles, coexistence of communities at great distances from each other. On the basis of the study it was found that the Arctic is an "inhabited" planet. Humans are adapting to its changing conditions all the time. These conditions make it possible to use a nomadic, mobile habitat system without breaking the fragility of the Arctic biosystem. Based on the results of the study, the methods of Arctic habitat have been developed, which are recommended for new projects:

1. The development of the territories should be carried out in a gentle regime of nature management, with the introduction of strong regulations, monitoring and absence of mass negative impact on the environment.

2. At creation of «PSO» (industrial and residential formations) it is necessary to apply non-waste technologies for the organization of production. It is important to protect the existing biosystem, to apply prudent logistics operations to achieve the least amount of transportation.

3. When creating the Arctic «PSO», there is a need for people to work on a shift basis. It has been established that the age of the main category of personnel is 18-35 years. This category has some special requirements. The need for regular training and professional development in the conditions of the shift work mode in the Arctic environment [1].

4. Creation of Arctic projects requires the search for new technologies that ensure energy saving and the production of own electricity from alternative sources. Application of "green" standards, combined energy sources in order to reduce the use of fossil fuels and minimize environmental damage.

5. For creation of self-sufficient production and residential education it is necessary to form the following functional zones: production zones; residential zones consisting of separate residential groups; zones of production and cultural and domestic service; natural and artificial natural environment. The purpose of such organization is the creation of the environment favorable for life activity and working capacity to increase the efficiency of the labor process in the conditions of long closed autonomous existence [2].

6. In order to provide self-sufficient functions of «PSO» there is a necessity to provide it with agricultural products. Their partial production can be provided by growing on Arctic agricultural farms. These are seafood, algae, fruits and vegetables. It is necessary to create an autonomous system of existence to reduce dependence on their supply and transportation to hard-to-reach, remote Arctic territories [3].

7. The training of specialists to solve such problems requires the creation of new and scientific units to develop new technologies and systems in the Arctic environment. It is necessary to meet the demand for specialists and to train them for specific conditions in Arctic agricultural production [4].

8. It is important to stabilize, preserve, and restore animal habitats. It is necessary to create multifunctional ice production complexes in the conditions of global thermal climate change.

Application of the methodology for the design of the Arctic «PSO» will provide an opportunity to solve problems related to the development of the Arctic and create a comfortable environment to ensure effective life and work capacity in the extreme north.

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JUSTIFICATION OF THE ORDER AND SEQUENCE OF JOINT DEVELOPMENT OF CONVERGED LAYERS BASED ON COMPUTER MODELING

Coal mines are complex dynamic systems for which many deterministic and random factors must be taken into account when making decisions about mining development options. One of the ways to reduce the negative consequences of mountain pressure in the conditions of development of close formations is the advanced development of the overlying layer [3]. However, in the conditions of many possible variants of the order and sequence of mining operations, the justification of the most appropriate is a multi-factorial task and it is advisable to use computer modeling to solve it.

Justification of the order and sequence of joint development of converged strata.

To simulate a coal mine, we used the "mine 3D" software package developed with the participation of DonNTU employees.

Using the example mine of the “Komsomolets Donbassa”, a spatial model of coal seams and a network of mine workings is constructed (Figure 1).

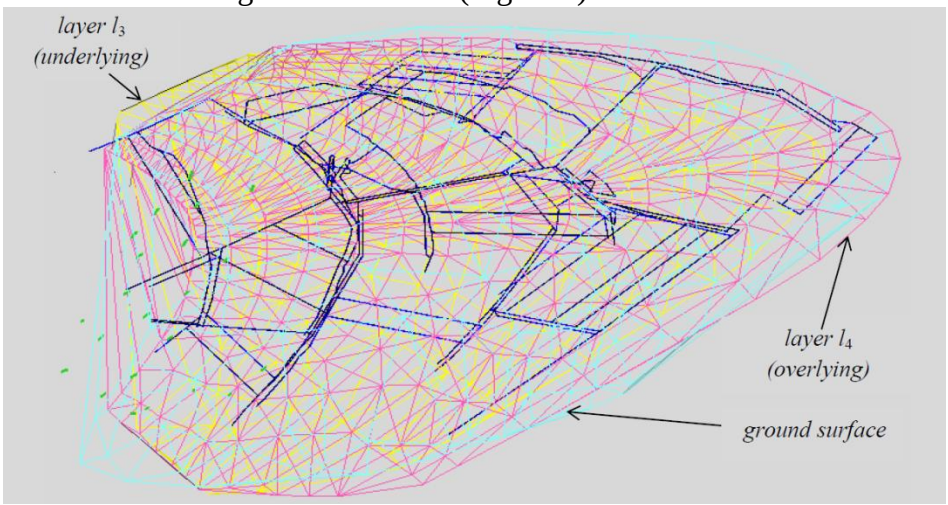

Figure 1-Model mine of the Komsomolets Donbassa

Since the l_3 stratum at this mine is dangerous due to sudden coal and gas emissions, regional degassing is applied simultaneously with the l_3 stratum overworking of the l_4 seams [2]. When forming variants of the calendar plan, it is necessary to ensure that the upstream reservoir is not less than one extraction pillar ahead of the underlying stratum. Using a computer model,

the spatial and temporal parameters of the reserve mining options were determined, in particular, the difference in the time of mining for five longwall in block 4 on the reservoirs was determined l_4 and l_3 (Table. 1, Figure 2). As a result, a variant is formed that provides as the required advance of mining operations, and the maximum possible concentration of mining operations.

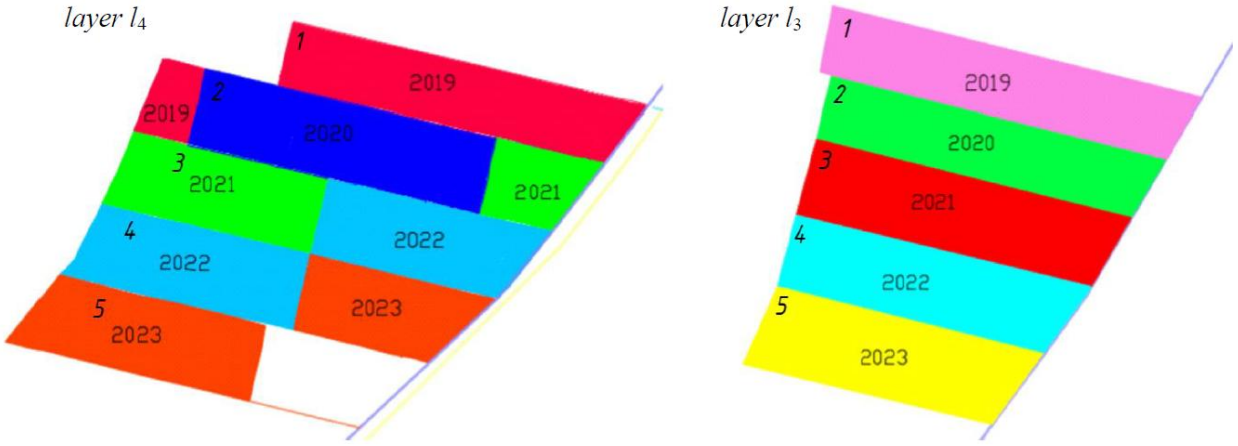

Figure 2 - Schedule of mining formations

Table 1 – The difference in the time of working out of layers

The name of Lava	Start of development				The end of the development				Difference in the beginning between layers		The difference in the end between layers		Duration		Total	
	l4		l3		l4		l3						l4	l3	l4	l3
	month	year	month	year	month	year	month	year	month	year	month	year	year	year		
1 Western lava	4	1992	2	2004	5	1995	1	2005		12		10	3	1	3year 2 mon.	
3 Western lava	7	1995	2	2006	10	1996	11	2006		11		10	1	0	1year 4 mon.	10 month
2 Western lava	2	1997	3	2005	6	1999	12	2005		8		6	2	0		10 month
4 Western lava	1	2000	1	2007	12	2001	8	2007		7		6	1	0	2 year	8 month
5 Western lava	5	2002	4	2009	11	2003	3	2010		7		7	1	1	1year 7 mon.	
6 Western lava	8	2006	planned in 2013		3	2008							2		1year 8mon.	

The use of spatial computer modeling in justifying the order and sequence of working out of close formations allowed us to take into account many influencing factors and form an effective option for working out reserves.

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RESEARCH OF LABOUR INTENSITY OF THE OPERATOR OF TECHNOLOGICAL PROCESSES

Nowadays the assessment of labour intensity is purely theoretical and does not cover the entire list of factors that affect employees. Automation of processes occurs in many areas of industry and allows to replace jobs with increased exposure to harmful and dangerous factors with mechanized processes and eliminate adverse effects on people. At the same time, the constant operation of technological processes should be controlled by operators who work in a

shift mode for 12 hours under the influence of factors of the production environment and the labour process [1].

According to the protocol for measuring the intensity of the labor process, the operator's workplace has the second (2) class of working conditions. The timing of the operator's work process and the assessment of labour intensity, according to R 2.2.2006-05 Guide on Hygienic Assessment of Factors [2] showed that fifteen indicators out of twenty-three are assessed as the third (3) class of working conditions. The final class of working conditions for the stress factor is 3.2.

During the operator's work process, the sources of erroneous actions and external factors that provoke their appearance in the system of cause-and-effect factors labour stress – erroneous actions – emergency were analyzed. For the analysis, the Bow Tie method was chosen, which allows describing the ways of development of a dangerous event from the causes to the consequences. This method allows you to take into account the influence of factors of the production environment and labor process on the work of the operator of technological processes, actions and basic operations. The influence of escalation factors is also taken into account.

The operator's professional risk was assessed by classifying the main risk factors and possible consequences and assigning weight coefficients to them. Basing on the received score data, a moderate level of risk was determined. The analysis of the operator's erroneous actions has established the main types of erroneous actions and the most likely consequences of their implementation, on the basis of which the risk matrix is compiled [3]. Risk assessment matrix shows that the equipment failure has the most serious and hazardous consequences, resulting in continuous downtime and significant economic losses. At the same time, the most common reasons for the event occurrence are operator's errors related to skipping an action or not following the action order. To assess the risk of an accident, a combined method was used, combining the score and matrix methods [4]. To determine the comparative value of the accident risk, a number of indicators have been introduced that quantitatively assess the occurrence of damage.

The research represents an analysis the factors that affect the operator of technological processes. It is established that a special assessment of working conditions cannot fully assess the intensity of the operator's labour process. In the intensity of work – wrong actions – emergency system an occupational risk of the operator assigned to moderate (5), the risk of erroneous actions during operation of the operator is assessed as unacceptable (16), the risk of accident is defined as moderate (18). It is necessary to develop measures to reduce the risk of erroneous actions.

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IMPROVING THE TECHNOLOGY OF DEEP-WATER MINING OF SOLID MINERALS USING CAPSULE WITH ATMOSPHERIC AIR

The development of new technologies for mining mineral deposits has always been an urgent problem. Especially if the deposits are located in unknown and inaccessible environments, for example, mining at the ocean depths.. [1, 3]

The paper considers the possibility of improving the technology of deep-sea mining of solid minerals, ferromanganese nodules (FMN), cobalt-rich manganese crusts (CMC), deep-sea polymetallic sulphides (PMS), using a submerged capsule filled with atmospheric air. [2]

The analysis of existing development systems is presented, and the main world concept of development is highlighted. The structure of complex mechanization of underwater mining with the analysis of each structural unit is presented and analysed. The key limiting factors of production, and the main disadvantages of deep-water mining systems, are identified. The calculation of the cycle parameters with the output to an economically feasible annual productivity, as well as the necessary depth of immersion of the capsule, was made.

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STUDY OF THE OUTBURST HAZARD OF FORMATION D6 IN THE TENTEK REGION (CENTRAL KAZAKHSTAN)

Hazardous natural phenomena in coal mines include emissions of rocks, coal and gas, which is difficult to predict in a mining enterprise.

As the experience of investigating such cases shows, emissions are preceded by the appearance of a dust cloud, the extrusion of coal from the face, the ejection of a pit and other phenomena that accompany tunneling. Coal and gas emissions result in fatalities, significant material damage and a long stop in the faces where these phenomena occurred. In connection with these, it is relevant to establish regularities and forecast emissions, depending on the geological conditions of occurrence of formations, host rocks and their physical and mechanical properties.

The assignment of strata to outburst and especially outburst ones due to sudden emissions of coal and gas, as well as mining operations on such strata, is carried out in accordance with the Instruction developed and approved by the organization in agreement with the authorized body in the field of industrial safety [1].

The industrial coal content of the Karaganda basin is associated with the Ashlyarik, Karaganda, Dolin and Tentek suites. The most coal-bearing and valuable are the layers of the Karaganda and Dolin formations, as well as the lower layers of the Tentek. The methane content of the coal-bearing stratum in the Karaganda coal basin is very high, which determines the high gas abundance of the mines. All of them are classified as over-categorical or hazardous by sudden emissions of coal and gas [2].

The depth of the gas weathering zone in the basin varies from 40 to 300 m. Its minimum value is characteristic of the Ashlyarik Formation and the lower Karaganda Formation. Most often, it varies between 100 - 200 m and only in the mines of the Tentek region it increases to 250 - 300 m. Natural methane content intensively increases from a depth of 200 m and below the gas weathering zone, reaching 15 - 20 m3 / t or more. The methane mobility of the pool mines at a depth of 250 - 350 m is two times higher than in the mines of the Vorkuta deposit [3].

Forms of methane emission into the mine atmosphere: ordinary emission, and sudden emissions of coal and gas are possible from a depth of 250-300 m. With increasing depth of mining operations, the number of emissions and their intensity increase. Seams K18, K12, Kl0, K7, D6 are considered hazardous by sudden emissions of coal and gas.

Until now, sudden emissions have not been observed in the working faces of the basin as a result of the preliminary degassing of the coal mass with the help of formation degassing wells, which allow capturing 4-6 m3 of methane from 1 ton of coal reserves. At a depth of 400-450 m from the surface, with a decrease in the natural gas content of coal by an average of 5 m3 / t, the gas pressure in the coal seams decreases to 0.5 - 0.9 MPa. The minimum gas pressure at which emissions occur in the basin is 1.1 MPa [3].

Jurassic coals, to which the coals of the D6 layer belong, are typically brown, highly metamorphosed, grade Bz. Moisture content of working fuel coals averages 17–25%, raw coal ash content is 16–21%, and bed ash content is 19–26%. In terms of ash composition, Jurassic coals are close to carbonaceous, the melting temperature of ash is 1300-1400 ° C. Low-sulfur coals (0.5 - 0.8%), medium- and polyphosphorous (0.01 - 0.08%), are characterized by a high content of carbon (73%) and hydrogen (5.4%). The yield of volatile substances is 43 - 53%. Coals have a high calorific value. In terms of combustible mass, it is 28.1 - 29.7 MJ / kg. The net calorific value of working fuel is 15-17.6 MJ / kg. Coal dressability, in general, is average, the yield of concentrate with a density of 1.4 g / cm3 reaches 78 - 83% with an ash content of 8 - 10%. The yield of concentrate with a density of 1.8 g / cm3 is 88 - 95% with an ash content of 12 - 16%. Coals of classes 100 - 50 mm (24%) and 50 - 25 mm (21%) prevail in the sieve composition.

Stratum D6 “Kassinsky” has an average thickness of 3.85 m (when changing from 1.7 to 5 m), an average angle of incidence of 130 (from 30 to 300), and gas content varies from 7 to 25 m3 / t. Gas-dynamic phenomena (GDJ) occur when conducting work in the faces of the mine workings. These include; sudden emissions of coal and gas; extrusions (wringes), collapse (rash) of coal with increased gas evolution; gas breakthroughs with dynamic fracture of mine workings; coal and gas emissions during blasting operations.

To clarify the geological characteristics of the sections of the outburst formation, the results of a standard set of geological and geophysical well surveys, cross-hole electrical correlation, and underground seismic exploration are used. The methods for forecasting the outburst hazard of coal seams include: regional methods; prognosis at the autopsy site; current methods carried out during the preparatory workings. Based on the results of the regional outburst hazard forecast, the critical depths are established from which the outburst hazard forecast is made, so for the D6 formation it was 230m.

On seams with a thickness of 3.0 m or more, in zones of discontinuous geological disturbances with an amplitude equal to or more than a seam thickness, an additional hazard assessment is carried out using a comprehensive hazard indicator, which includes indicators of coal strength, initial gas recovery rate, and minimum natural coal moisture.

Laboratory studies of the coal strength of the D6 layer, selected during mine workings from 360 to 520 m in depth at the D6 layer at the Shakhtinskaya mine, showed that the strength of the coal packs varies from 0.38 to 0.56 cu. Thus, the strength of coal sampled at depths from 412 to 680 m at the Lenin mine varies from 0.36 to 0.57 cu, the strength of coal selected at depths of 350 - 640 m at the Kazakhstan mine is within 0.33 - 0.49 cu

Studies of determining the minimum value of the natural moisture content of coal W showed that the average humidity of coal packs of the D6 seam according to the results of studies at the Shakhtinsaya and Kazakhstani mines, respectively, decreases with a depth of 3.5% (at a depth of 350 m) to 1.5% (520 m), and 3.5% (350 m) to 2.5% (650 m), and the change in the average humidity of coal at the mine them. Lenin is weakly correlated with depth, however, the general tendency for its decrease remains from 1.2% (670 m) to 60% (500 m).

Studies have shown that the main contributing factors to the integrated emission hazard indicator from the depth of the coal seam D6 of the Tentek region are the strength of the coal packs, the initial specific rate of gas recovery and humidity of coal.

It has been established that the hazardous value of the complex emission hazard indicator equal to 10.5 ± 1.17 arises from a depth of 480 m, provided that there is no influence of debilitating geological factors, which are also subject to detailed study, especially in terms of methane distribution in the reservoir.

The research methodology, the results obtained can be used to predict outburst hazardous areas during the design of new horizons of coal mines and during mining at existing mines.

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THE COMPARATIVE ANALYSIS OF THE RUSSIAN AND AUSTRALIAN LEGISLATIONS FOR TOXIC GASES AFTER BLASTING WORKS

In 2019, blasting activities are an inherent part of the world industry. Actually blasting works are conducted prevalently in mining sector of industry, especially open-pit mining, and in building and construction. This kind of mine development is not exceptional because of fuming which is a combination of post blast toxic gases like NO2 nitrogen dioxide, NO nitric oxide, CO carbon monoxide. Occupational safety and health issues in the open-pit mining still demand for attention and action because of high rates of an increasing amount of the occupational accidents and diseases worldwide causing by lack of universally recognized legislation about fuming. The purpose of the comparative analysis of regulations and requirements was to recognize common and distinguishing matters, to consider the need of legislation for fuming question that would be appropriate worldwide.

Nitrogen dioxide can occur acid rains and poison the atmosphere due to spreading fume clouds; it also affects prevalently on workers' health and life and it is the main concern of the occupational safety. But other than that, in accordance with Federal Law No. 116-FZ of July 21, 1997 "On Industrial Safety of Hazardous Production Facilities" open-pit mines are hazardous production facilities (II, III or IV hazard category). Therefore, facilities that have been defined as hazardous must meet requirements by legislation in this sphere.

The idea of the method was a comparison of the legislation of the Russian Federation and the foreign legislation by dividing all documents into two main sectors, in particular the sphere of the occupational safety and the sphere of the industrial safety. In order to conduct the comparative analysis the Russian and Australian legislations were chosen due to the competence of the both countries in management of fumes. It can be attributed to abundance of Australian companies that proceed blasting operations worldwide and a huge amount of open-pit mines in Russia.

In Russia, exposure limits are established by the hygienic norms GN 2.2.5.3532-18 "Maximum permissible concentrations (MPC) of harmful substances in the air of the working zone" [1]. Concerning an Australian legislation, "Workplace Exposure Standards for Airborne Contaminants" (Date of effect: 27 April, 2018) establishes hygienic norms and how to meet your duties under the Work Health and Safety (WHS) Act and the WHS Regulations. As the first stage of this comparison, two different kinds of exposures were analyzed for the open cut blasting. It should be noted that occupational exposure standards in Russia are much stricter than in Australia. Particularly, In Russia the Short Term Exposure Limit for NO_2 is 2,0 mg/m^3 and 9,4 mg/m^3 foe Australia.

As for industrial safety, "Safety Rules for Blasting" [2] in Russia establishes requirements to the natural and artificial covers generally intended to protect from the post blasting hazards in particular fuming. The formulas to calculate the dimension of the hazardous zone take into consideration the event of absence of the wind or when it has perpendicular direction the radius of the safe zone can be calculated; in the event of the straight direction. In accordance with Australia there is a Queensland Guidance Note QGN 20 v 3 [3] that contains the instruction to identify the internal and external potentially exposed sites and how to develop master fume map. Obviously, the map demonstrated in Australian documentation contains much more information and it has regard to different classes of fumes and classes of weather stability which causing fumes themselves, but this map is regarded as being indicative only. The Guidance Note also includes figures of gases to be able to identify its class by vision what makes the note application-oriented.

Therefore, it is obviously that the absence of worldwide-recognized sequence to manage characteristics of fumes that could be used to estimate the professional risks. On the one hand, Russian documentation do not take into consider weather conditions and classes of fumes and it is not applied-oriented for personnel. On the other hand, the parameters that are regarded at the Australian documents do not include field measures to assess the risk at the particular time; Australian system is based of predictions, which are hard to make in the case of frequently changing atmosphere conditions. However, the parameters are considered in both legislations can be basic for the international documentation. At the same time, the development of an international legislation establishes certain restrictions in establishing requirements:

1. The lowest occupational exposures should be accepted worldwide in order to not infringe existing national legislations;

2. In case of developing the dimension of the safe zone, all climate zones should be regarded;

3. The document should include two ways to estimate the NO_2 characteristics, in particular by vision with examples with descriptions and by monitoring gas analyzers (personal and immobile).

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TECHNOLOGY FOR FORMING PERSPECTIVE SECTORS OF A TECHNOGENIC DEPOSIT

Involvement of a yet formed technogenic deposit into its processing is of great environmental and economic importance. When calculating economic efficiency, it is necessary to take into account not only additional product output but also the reduction of the costs for creating and operating tailing dumps, waste storage, prevention or diminishing the environmental pollution damage caused by dressing mill wastes. [1]

By reducing the content of valuable component in tailings even by basic points, it is possible to get a significant effect due to the huge production quantities and cost reduction due to decreasing the cost of crushing and grinding operation, which accounts for 40-50% of the total cost during the normal ore processing. When processing tailings, these items of expenditure will disappear as tailings will be already crushed and broken down for almost any processing method.

Allocation of the boundaries for promising, cost-effective zones and ones expedient for processing in the technogenic deposit being formed is a topical problem in modern science. [2]

To solve this problem, it is necessary to complete the following tasks: to study the effect of spiral solid swirling on the polydisperse flow structure in a pipeline; to determine process parameters of the laboratory plant intended to control segregation while forming a technogenic deposit; to manufacture a laboratory plant; to carry out laboratory study of the polydisperse mixture segregation; to reveal distribution dependences for axial and tangential components of flow speed in a pipeline cross-section, the effect of solid swirling on the flow structure change as well as separation efficiency.

At present, the formation of technogenic deposits represented by waste from enrichment plants occurs naturally without taking into account the segregation process, which leads to significant costs when involving them in development.

Also, after five years of storage of the tailings of enrichment, physicochemical transformations begin to occur in them, leading to a decrease in the value of technogenic raw materials.

Control over segregation process during the technogenic deposit formation and the creation of insulating material solves a plenty of problems during the tailing dump reprocessing. Namely, it gives a clear view of the valuable component content in a particular processed site, identifies areas that are promising for use in various industries, retains the value of man-made raw materials and significantly increases the mining operation safety. [3]

During this study, a technology was developed for the formation of perspective sectors of the technogenic deposit, a device for its implementation and insulation material, computer simulations of the segregation process and laboratory studies on various polydisperse materials were performed. This have shown that application of this plant resulted in increasing separation

performance for polydisperse mixtures during their stacking in different positions (horizontal and vertical) and decreasing the temperature effect on segregation.

Solid particles conveyed along the straight section near the lower part of pipe wall are involved into spiral motion from the very beginning of the vortex motion in the helical fins. For this type of the carrying medium motion, solid inclusions tend to locate in the layered stream, in the area of both tangential and increased axial speed values.

Thus, flow swirling at remaining average conveyance speed allows to separate the flow by particle size and density with separation efficiency of 88% for fine fraction -3.1+0 mm at swirling pitch.

To preserve the value of technogenic raw materials, an innovative insulation composition has been developed, which has high adhesion and strength, frost resistance, water resistance, environmental friendliness, and it also does not burn.

The dependences were revealed for the parameters of the formed area on the used mining and transport equipment and the laid volume of technogenic raw materials; distribution of the axial and peripheral components of the flow rates in the pipeline section; The efficiency of the separation process from the diameter of the pipeline and the winding pitch is established.

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STABILIZATION OF THE QUALITY OF THE ORE MASS IN THE UNDERGROUND DEVELOPMENT OF SHEET DEPOSITS

The defining indicator of a mining enterprise is the quality of the extracted mineral raw materials. Mining products according to the set of properties of mined minerals must meet certain requirements of processing enterprises.

The instability of the quality of the ore stream creates problems in the processing of ore due to the need to change the process modes of treatment, which leads to an overuse of concentration agents, worsens the quality of the concentrated product, reduces the degree of extraction of useful components and increases the cost of processing.

The aim of the work is to substantiate the parameters of stabilization of the quality of ore flows during underground mining of the Zhezkazgan deposit based on established patterns of formation of ore flows.

The idea of the work is that the multi-stage process of stabilizing the quality of ore flows is carried out by rational formation of ore flows of the required quality of ore raw materials in the required volume at each technological process (mining, delivery, etc.).

The difference lies in the fact that the averaging process for the conditions of underground mining of the Zhezkazgan deposit is multi-stage. We propose a mathematical model for determining the necessary production volumes in technological processes (mining, delivery,

etc.) for each stage of averaging production units, based on the method of mathematical statistics, ensuring the formation of ore flows of a given quality in the required volume. At each stage of averaging, its own initial data, limitations, averaging criteria, place of averaging,

Each stage of averaging corresponds to the stage of planning the stabilization of ore quality for the planning period. Operational planning (for weeks, days, shifts) is provided for the stages of the in-mine, precinct, and panel (inter-hole) averaging. This is due to the fact that for such facilities it is difficult to accurately determine the average copper content in the ore mined for a long period of time.

At the stage of formation of the panel ore flow in the averaging mode, the task is to determine the volume of ore production from each mine face to achieve the quality of ore in the panel ore flow close to the planned one for the site (pic 1).

The value of the copper content in the ore shipped from the i-th face α_{iz} is determined by daily (shift) testing and by the results of operational geological exploration. The main optimized parameter is the copper content in the panel ore stream and the objective function of the task can be represented as a functional (objective function):

$$F = \left| \frac{\sum_{i}^{n} \alpha_{iz} Q_{iz}}{\sum_{i}^{n} Q_{iz}} - \alpha_{p} \right| \min$$

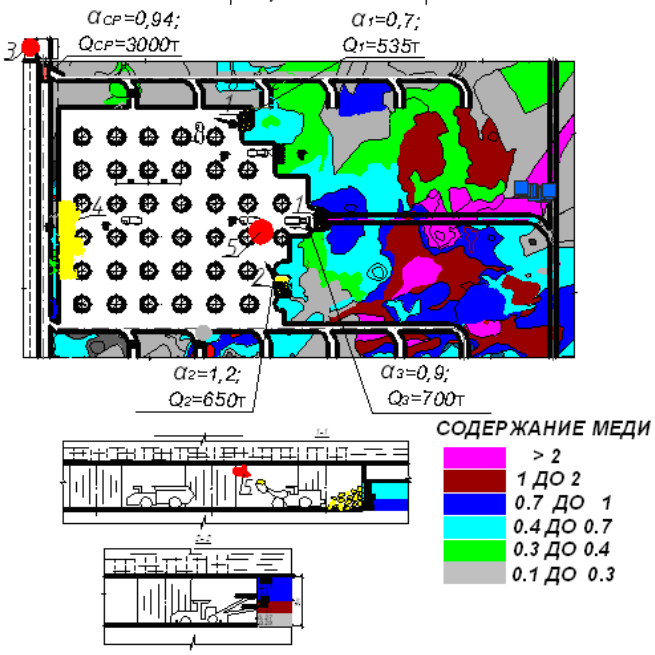

Figure 1 - The process scheme of the formation of the panel ore flow in averaging mode: 1 – shipped mine face; 2 – reserve mine face; 3 – ore passageway; 4 – AC; 5 – RMS (radiometric monitoring station)

The testing of the metal content was carried out at various levels of ore flow using the proven modern method of geophysical operational testing. The error in the results of the X-ray method of testing and chemical analysis turned out to be insignificant, which amounts to 10-15%.

The technology of stabilization and multi-stage averaging of the ore flow, the recommendations for determining the optimal volumes of shipment of ore mass in technological processes that provide the formation of ore flows of a given quality are proposed.

The classification of methods for multistage averaging of the quality of the ore mass makes it possible to systematize the control of the processes of formation of ore flows, which differs by the stage of averaging in the ore flow.

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DESIGN OF A GOLD MINE SHAFT HOISTING SYSTEM

A mine shaft is a primary vertical or near-vertical opening through mine strata used for ventilation, drainage and or for hoisting of personnel or materials; connects the surface with the underground workings [1]. Mine shaft size includes the shape, diameter and depth of the shaft. It is affected by increased production, extended depth, increase in hoisting capacities and mining methods considerations [2]. A hoisting system is collectively the openings and the equipment being considered [3, 4]. There are two types of hoisting systems: drum hoist and friction hoist. They both have their variations and are applied under different conditions. Drum hoist usually have a hoist room located some distance from the shaft where the rope will be wound on the drum. This type of hoist is suitable for inclined or vertical shafts [3, 4].

The gold mine's Wankie-N15 section uses two hoisting system. The Wankie vertical shaft hoists from level 101m below the surface to the surface and the N15 incline hoists from 252m below the surface to 101m. Tramming to N15 grizzly has increased to about 1000m at level 252m. Both the re-handling of ore and increased tramming distances have increased the cost and time on ore transportation. The tramming distances would be reduced by 50% and re-handling of ore will be eliminated. Design requirements included a hoist system with a design capacity of at least 50 tons per hour and an efficiency of 0.85. Parameters to be specified included skip size, rope size, drum size, RMS horsepower requirement, and the duty cycle.

Table 1 - Design Specifications

Parameter	**Value**
Hoisting distances	278 m
Velocity	2.43 m/s
Acceleration time = Deceleration time	3.33s
Efficiency	0.85
Net weight of the load	3.94 tonnes
Weight of Skip	2.50 tonnes
Rope size: Diameter Weight Total weight	0.0185m 1.42 kg/ m 0.394 tonnes
Drum dimensions:	
Effective weight	18.14 tonnes
Total cycle time	270 s
Root mean square power	70.78 kW

The designed single drum hoisting system surpasses the 50 tph and has relatively low power consumption. It is designed on the assumption that the hoisting system is for production with a single loading level. It will reduce tramming and hoisting costs by at least 30%. Capital cost of procurement and installation of the hoisting system is approximately US$119,250.00 based on quotations from various suppliers.

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METHODS FOR THE DEVELOPMENT OF TECHNOGENIC DREDGE POLYGONS

The share of gold mined from placers, in particular the dredge method, is steadily decreasing. This is primarily due to the depletion whole reserves [1] in the absence of frowth due to exploration. In this regard, there is a need to involve deposits in secondary development.

Significant gold reserves are concentrated in technogenic placers, which in the main regions of gold mining are from several hundred tons of metal (Zabaikalsk, Krasnoyarsk, Khabarovsk, Primorsk territories, Amur and Irkutsk regions), to a thousand tons (Magadan region) [2]. The total amount of gold in previously mined placers is estimated at 3,3-5,0 thousand tons, which is at least 18% of the total reserves of this metal in placer deposits. In the development of technogenic placers by existing enterprises, reserves are enough for work, according to various estimates, for 15-70 years [3-5].

Due to the fact that technogenic deposits have, as a rule, a rather low content of valuable components, their development requires the use of a productive and in-line development method, which is dredging.

Mining of technogenic placers has been under way for more than a century and to date quite a large overall positive experience has been accumulated in the secondary development of dredge mines. Some examples of secondary mining of alluvial deposits have shown that the economic efficiency of work on technogenic reserves is comparable to the development of integral objects with the best quality of raw materials. At the same time, the results of exploitation of technogenic deposits are quite stable.

At present, almost half of the drags are quite successfully working on technogenic placers, including dredge dumps formed 20-40 years ago.

From the experience of exploiting technogenic placers by mining enterprises, it follows that the cost of metal mining in this case is much lower (sometimes 5 times) compared with the development of whole reserves. The latter is associated with a sharp reduction in the volume of mining and hydrotechnical work, as well as an improvement in the leaching of minerals.

As the same time, in practice, during the development of technogenic placer by drags, a number of problems were identified. One of these problems was the complication of the conditions for dredging dumps with a sufficiently large capacity of productive deposits, this is

caused, first of all, by the collapse of the upper edge of the face. In addition, due to the heterogeneity of technogenic deposits vertically in production, they encountered a number of difficulties associated with uneven loading processing equipment, as well as high loads on the scoop chain, which in some cases leads to its descent.

In this work, we analyze the prospects for the development of a dredge method dor developing technogenic deposits, review the problems, and also propose methods for developing stocks of technogenic dredge polygons that can solve these problems, as well as increase the productivity and efficiency of dredging.

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BENEFITS OF MACHINE LEARNING IN THE MINING INDUSTRY: FROM EXPLORATION TO EXTRACTION

Artificial Intelligence is an ever-growing keyword that we hear nowadays. Machine Learning has been applying to almost all scientific disciplines as part of this data-driven knowledge. The development of sensors and monitoring devices provides us with a large number of real-time data; Rio Tinto creates 2.4 terabytes of data every minute, for instance. Accurate expectation is an essential key to use all types of ML. There are three main types of ML, which are unsupervised, supervised, and reinforcement learning. In unsupervised learning, we don't have any predicted or estimated outcomes. We mainly use it for clustering, which means segmenting the inputs by their features without any knowledge of incorporating factors among them. Supervised algorithms comprise an outcome variable that is to be predicted from a given set of predictors using three sets of data train, test and validation to achieve a desired level of accuracy. Reinforcement learning algorithms expose to data by which train itself and tries to gain the best attainable knowledge use for making more effective decisions in the next steps [1].

Machine Learning for Mineral Exploration.

Finding a new deposit has always been a challenging task. From 2008 to 2018, there was a 60% increase in the total Gold exploration budget compared to the past 18 years, while explored reduce from 222 discoveries to 41 at the same time. This means we need to explore more in-depth, and it's also essential to combine accessible types of geological data such as geochemical, geophysical and structural data. Machine learning has the ability to explore relationships and patterns that are not obvious; there are potent algorithms by which we can

identify anomalies among various data. Goldspot Discoveries, for instance, identified 85% of the gold formations in the Quebec Atibiti region, using only 4% of the total regional area. The algorithms fed by multiple layers of geological, geochemical, geophysical and other geospatial information [2].

Reinforcement learning for short term planning.

Maximizing Net Present Value is the final goal of the long-term production plan of a mine site. We organize short terms production plan to satisfy this goal. Short-term production plans are sophisticated as they include daily production goals; they are also responsible for determining the destination of materials. New sensors information from drills, shovels, trucks, conveyor belts, and processing mills, which may be referred to as soft data besides conventional sources like drill hole samples, monitoring devices, and tracking devices, use to update a novel continuous updating framework. The presented framework consists of two stages. It starts with updating uncertainty models with a new extension of ensemble Kalman filter and then utilizes a neural network agent that benefits from policy gradient reinforcement learning. As the operation proceeds, new data supports the framework to adapt more and more to the production goals. The framework applied to a cooper mine complex and used 5581 blocks for estimating the performance. The results show a 22% increase in cash flow mostly achieved by changing the destination of blocks from waste to sulfide leach [3].

The ability to explore data makes them more valuable and more useable than ever. Moreover, new data acquisition technologies provide a wide range of data, which takes more time to search and manipulate than analyze them. Artificial Intelligence and Machine Learning are not going to replace Geologists with Computers. Instead, they are tools by which geologists can accomplish more complicated tasks more efficiently. Unsupervised learning could help to find anomalies among data. On the other hand, supervised algorithms in comparison to conventional statistical methods allow us to estimate the unknown part of occurrences more precisely. Finally, reinforcement learning boosts operational efficiency by adapting more and more to predefined policies.

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RECOMMENDATIONS FOR METHANE PROGNOSTICS AND ADJUSTMENT OF SHORT-TERM PREVENTION MEASURES BASED UPON METHANE HAZARD LEVELS IN COAL MINE LONGWALLS

High methane concentrations are currently one of the most significant natural hazards in the hard coal mining industry [3,4]. The occurrence of undesirable concentrations may result in delays in the production process and measurable economic losses, as well as, directly affecting

the safety of mining crews working in the longwall area. In order to lower the methane risk level, mine ventilation departments must carry out extensive preventive measures, the scope of which must be appropriate to the risk level. The article describes the recommended procedure for conducting methane forecasts and selection of the methane prevention measures that adequately reflect the level of methane combustion and explosion risk.

The appropriate selection of methane exposure prevention measures can be effective at mitigating the exposure risk of the miners and associated mine employees [3]. Implementation of these measures can have the additional benefit of increasing mine output and efficiency. For example, prediction of methane concentrations can reduce the instances of unplanned equipment downtime for the sake of maintaining mine safety and integrity.

Presented in the paper procedure is the culmination of extensive research on three predictive models of short-term average methane concentration popular in polish coal mines. Identifying advantages and disadvantages of the models was made possible by verifying the models against a nearly 500-day dataset obtained from 7 longwalls with identified significant methane content. The proposed algorithm incorporates the application, within the defined framework and scope, of all three selected methane prediction models from the longwall project preparation stage until the end of its lifecycle. Furthermore, studies procedure was presented based on one of the datasets acquired from the U-ventilated longwall.

The conducted forecasts error analyses in the selected observation period allowed the following observations to be drawn:

1. Model_1 [2] is characterized by high errors, resulting in the poor quality of forecasts. Moreover, the limitations of the model do not allow us to make a methane prediction for days when exploitation does not occur.

2. Forecasts made by model_2 [1] and model_3 [1] revealed a satisfactory prediction of methane concentrations. Results prove that both tested models can be used effectively for adjustment of the scope of methane prevention measures.

3. Model_3 [1] prediction errors are lower than model_2 [1] errors. This trend is increasing particularly toward the end of the observation period. It indicates that increasing the observation period increases the level of model adaptation to the longwall-specific conditions. Moreover, the advantage of model_3 is that it can also be used to determine the maximum daily longwall face advancement at which the values of the average methane concentrations should not exceed established limit value.

The research on the accuracy level of prediction models presented in this article was conducted to develop the methodology of their application to select methane prevention methods (especially ad hoc measures) accurately. The identification of fluctuations in the occurring average daily methane concentrations in the longwall areas even one day in advance makes it easier to decide on the scope of adjustment measures. Besides, the trend analysis of the prepared forecasts set, considering the model errors, allows us to plan more time-consuming preventive actions.

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PERSONAL PROTECTIVE EQUIPMENT FOR WORKERS IN THE CONDITIONS OF THERMAL DISCOMFORT

This article discusses the problems of thermal discomfort for workers. The practical experience of the causes of hypothermia is summarized, it is noted that hypothermia at the workplace is a frequent problem for builders, military, mining, gas, oil and transport industries. Research is constantly being conducted in the field of heat-insulating properties of overalls, however, until now, most often workers work in clothes that do not correspond to heat-insulating properties for the harsh conditions of the winter period. The article sets out views on the location of zones that are most vulnerable and which parts of the body need to be heated first. The purpose of this study was to analyze the innovative properties of personal protection of workers in conditions of thermal discomfort, assess the effectiveness and comfort of this clothing. The characteristic is given to all types of protection against hypothermia. Based on the research, the main problem was identified - not the comfort of protective clothing when performing physical exertion in tight and heavy clothes, and this not only leads to a danger to the life of the worker, but also reduces its performance.

Many experiments on testing clothing for harsh climatic conditions have shown that it is possible to create clothing that will protect people from exposure to cold temperatures, but scientists have faced another problem - the need for comfortable working conditions for the employee. According to the results of the special labor assessment (SAUT) [1], there are high levels of indicators of the severity of the labor process in the workplaces of builders, military personnel, mining, gas, and oil and transport industries. The main professions of employees belong to the 3.1-3.3 class of working conditions. Lifting and moving loads because the heaviness of performing the labor function of employees manually, forced body tilts at an angle of more than 30°, and movements in space [2]. The severity of the work performed is continuously associated with the amount of energy spent by the employee on its performance and, accordingly, with the amount of heat released by the human body into the environment. Thus, all these professions are heavy, so it is necessary to pay special attention to the choice of effective PPE. It is also complicated by the rapid changeability of weather conditions in the sharply continental climate of Russia and sets developers a number of complex tasks at once. Now all these issues remain poorly understood [3] — there are no proper tactics to prevent employees from hypothermia when working in low temperatures, and the regulations for personal protective equipment do not have effective portable heat sources that every employee could use in any conditions. Our climate is incomparable to any other country in the world. Russia is at the peak of the "temperature Pole", lies in four climate zones at once, and in many cities, the snow cover never melts.[4]

Before you understand how it will be most effective to protect the worker from hypothermia, you should find out what are the most vulnerable parts of the body when working in the cold, which parts are most involved. Not all experiments in the field of efficiency of various electric heating clothing at a temperature of minus 40°C ended quite successfully. People participating in the experiment felt either hypothermia of the extremities, or overheating [1].

Research methodology:

1. Study of the human body during freezing
2. Find out the most prone to hypothermia zones
3. Analysis of personal protective equipment

4. Development and testing of innovative personal protective equipment to restore the thermal balance of a person.

Based on the research, the main problem was identified - not the comfort of protective clothing when performing physical activities in tight and heavy clothing, and this leads not only to a danger to the life of the worker, but also reduces his performance. After a detailed assessment of the currently available personal protective equipment, it became clear that employees need to improve their working clothes in conditions of low temperatures. Options for developing comfortable clothing equipped with additional heat sources that will make clothing easier, more effective for employees, and more accessible to employers are considered.

The results of the work have a social effect, which is to provide consumers with more effective heat-protective personal protective equipment. A method has been developed to justify the choice of material packages for structural elements of personal protective equipment to create comfortable conditions when exposed to low temperatures. The solution to this issue is to reduce the area of local heating. On this basis, the method of determining the area of the source under the condition of thermal comfort of the employee is described. A systematic analysis of the features of various types of heat generators for personal protective equipment was carried out. Based on this analysis, it is concluded that it is necessary to develop new methods that could be used to protect people from cooling more effectively. In the course of this study, we have developed basic schemes of head, hand and respiratory protection, built with the thermal comfort of the employee in mind. This article may represent solutions to boundary value problems in the field of PPE development with limited temperature conditions.

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MODELING SAFETY SCENARIOS FOR TAILINGS DAMS

The Tailings ponds have to be very safe structures, projected, constructed, operated and close up in a way that risks can be minimized as possible for its feasibility failures. The impossibility of eliminating completely through preventive measures or mitigating tailings pond failure risks together within other failures which contributes into amore considerable magnitude, leading to the need of modeling different facility safety scenarios to guarantee the correct operations in terms of reducing risks [1]. This scenario evaluation is carried out through qualitative evaluating methods. Results of this research consist in a proper method work out for modeling such safety scenarios at the tailings pond sites, having a definition for the warning failures by the early risks and reduction detection in those situations, guarantying to minimize populations, economical and environmental negative impacts [2].

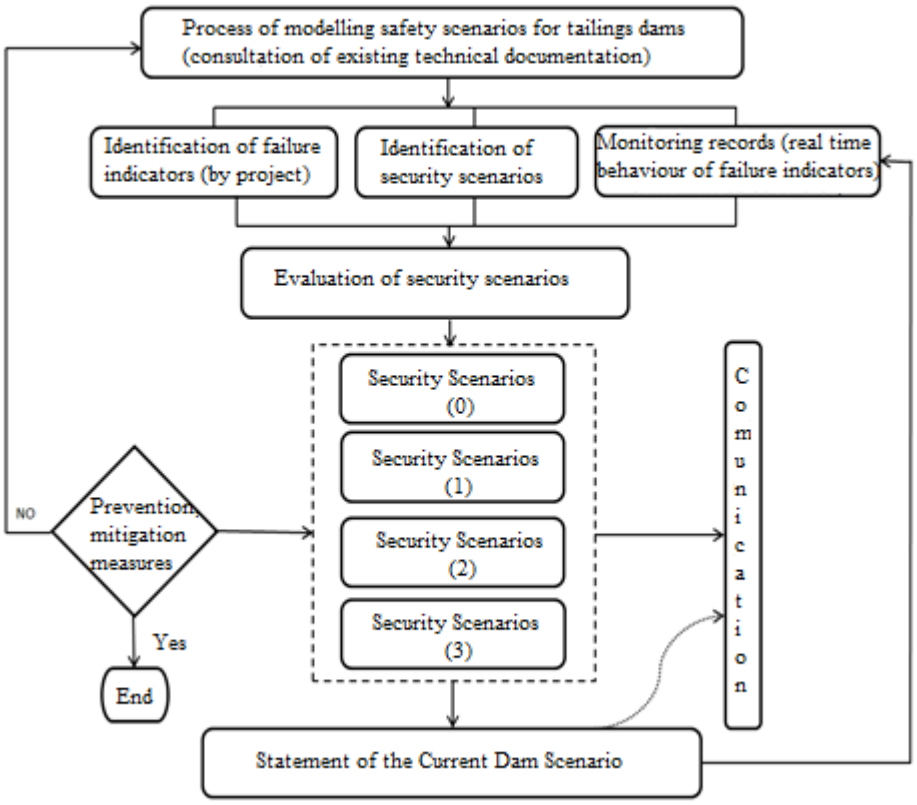

Figure 1 - Flow chart of the safety scenario modeling process for tailings dams

The methodology for modelling the safety scenarios is carried out using tailings dam failure indicators [3] (Figure1.). which are evaluated through a set of impact matrices. The evaluation methods used for the failure indicators are qualitative and quantitative, using data from historical records of the instrumental system of monitoring [4], data from safety inspections, statistical reports of incidents and accidents that have occurred in the dams, in addition to information provided by interviews and surveys of personnel with high experience in the construction and operation of tailings dams.

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ASSESSMENT OF THE STATE OF LABOR PROTECTION AT THE MINES OF SUEK-KUZBASS JSC

Energy needs of mankind are constantly growing. Coal is an affordable energy carrier that, thanks to modern technology, can meet increasing environmental requirements [1]. To date, the state of injuries at coal mining enterprises in Russia is characterized by a tendency to decrease in absolute values. Over the past 10 years, thanks to the successful work and the introduction of modern technologies in the field of labor protection, occupational injuries have decreased by more than 3 times, but nonetheless, occupational injuries in the coal sector of Russia remain unacceptably high. In connection with this, an important aspect in the safety of production is the operational management of the risks of injuries to improve the state of labor protection, which will entail social, economic and production efficiency. Using the example of SUEK-Kuzbass JSC, an analysis was made of the state of the labor protection system over the past 10 years of the company's work. At this point in time, research on the reduction of injuries in enterprises is widespread among domestic and foreign scientists. By analogy with the works of Samarov L.Yu., Kochetkova E.A, Grishina A.M, an analysis of the state of labor protection based on the calculation of injury risks is proposed. But the originality of our study lies in the fact that the assessment of the risks of injuries takes into account the dynamics of two indicators (the severity of accidents and the risks of accidents due to injuries).

To assess the state of labor protection and industrial safety, it is proposed to use an indicator of the risk of occupational injuries. The risk of occupational injuries is the frequency of injuries, calculated as the quotient of dividing the negative cases of a different type by the total number of employees [2]. The results obtained are presented in the form of correlation dependences of mild, severe and general injury risks from the year of operation of the company as a whole.

Injury risk dynamics is characterized by linear correlation regression coefficients. To rank the SUEK-Kuzbass mines by the amount of injuries, indicators were compared, in general, for a 10-year period of operation and for each year period separately.

But for a more detailed assessment of the state of labor protection at the enterprise and determination of further recommendations to reduce occupational injuries, an analysis of the causes of accidents is necessary, therefore a matrix of the causes of accidents and their severity at the mines of SUEK-Kuzbass JSC was proposed. Ranking or determining the severity of accidents for reasons is one way of determining which risk of accidents is the most serious, and therefore should be monitored first [3].

Thus, to assess the state of labor protection at the enterprise, it is advisable to use an indicator of the risk of occupational injuries, and as indicators characterizing the effectiveness of measures to reduce the risk of injuries, it is advisable to use the regression coefficients of the lines of correlation of injury risk. It is worth noting that the matrix of the causes of accidents and their severity at the SUEK-Kuzbass mines displays a qualitative description of the situation at the enterprise, and can also be used to assess the current state of labor protection at the enterprise.

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CURRENT STATE AND IMPROVEMENT OF METHODS FOR IDENTIFICATION AND ASSESSMENT OF PROFESSIONAL RISKS AT ENTERPRISES OF THE PETROCHEMICAL COMPLEX OF THE REPUBLIC OF BELARUS

On the basis of the analysis of the global level of occupational injuries, experts of the International Labor Organization come to the conclusion that there are approximately 340 million registered work accidents each year of which 2.3 million are fatal, every minute 4 people die from work-related injuries and diseases About 650 thousand deaths per year are registered in the working area from exposure to hazardous substances alone. The economic damage to society from adverse and hazardous working conditions is up to 4% of world GDP. At the same time, it is well known that one dollar of funds invested in the improvement of working conditions at production site makes a profit of about $2.6 [1-2].

According to official data of the National Statistical Committee of the Republic of Belarus, the total number of victims of industrial accidents is growing in the organizations of Belneftekhim concern over the last four years of observation. For example, total number of the industrial injures in 2016 – 23 (12 of them with severe outcome), in 2019 – 36 (14 of them with severe outcome, 2 with fatal outcome). The main causes of accidents at work in the organizations of Belneftekhim concern are the same as elsewhere in the Republic of Belarus, namely: violation of labor protection requirements by the victims; personal negligence; unsatisfactory organization of hazardous work; violation of labor protection requirements by other employees. These reasons are the result of low efficiency of functioning of the existing occupational safety management.

Comparative analysis of hazard identification and risk assessment procedures employed by the organizations of Belneftekhim concern revealed the following:

1. Hazard identification is performed by working groups (committees) that are mostly identical by the list of engaged specialists and/or experts. Occasional organizations have set the procedure of obligatory involvement of the employees directly from the workplaces into the list of the expert group (in accordance with ISO 45001-2018);

2. There are no procedures for coordination of the assessments made by several experts of one expert group for compiling a map of hazard identification and risk assessment;

3. Hazard identification is performed for all structural units, professions (positions), working places, types of works, etc. Occasional organizations have set hazard identification procedures for visitors and contractors;

4. The main operating modes in which hazard identification is performed are “Normal” and “Emergency”. The list of types of work that are part of named modes differs in each organization. Occasional organizations have established additional modes of operation;

5. Most organizations haven’t set the procedure of hazard identification directly at the workplaces. Some organizations define this procedure as “Observing the workplace and

controlling the main factors". Logical methods of hazard identification ("event tree", "what will happen if?" and others) are employed by only one organization;

6. Hazard identification is performed by organizations using various sets of analyzed factors the basis of which are hazardous and harmful production factors as described in GOST 12.0.003 standards system of labor safety "Workplace hazards. Classification". Only occasional organizations include additional factors, e.g. personal ones. A number of organizations use hazard identification techniques with minimal (partial) consideration of possible sources of information about hazards and dangerous and harmful factors.

7. Hazard identification procedures are most effective while:

taking into account the maximum possible set of operating modes of the organization, the impact of suppliers, contractors and visitors on the immediate workplaces;

involving the employees directly from the workplaces into the process of hazard identification;

using logical analysis methods ("event tree", "what will happen if?" and others).

8. The methods of risk assessment (the American method of expert assessments using the Fine-Kinney method) used by the organizations of the concern have significant differences. The specificity of the industry is not taken into account – there is fire and explosion hazard and a significant amount of harmful substances.

9. Some organizations use additional specific detailed criteria for assessing the indicators of the Fine-Kinney method and, as a result, the distribution of factors of the indicators of this method is minimized, its effectiveness, reliability and quality of further risk management are reduced.

10. Some organizations apply additional rigid criteria for assessment the Fain-Kinney method indicators, which, on the one hand, significantly increases the reliability of risk assessment and the effectiveness of risk management process, on the other hand, complicates the risk assessment procedure and making managerial decisions.

11. Some organizations, when calculating the quantitative value of risk, take into account additional adverse factors (hazards), for example, psychological factors of a particular employee.

12. The highest efficiency is demonstrated by risk assessment methods taking into account additional adverse factors (hazards) and risk management levels of "medium" - "very high".

An established integral departmental method of hazard identification and risk assessment in compliance with the specific peculiarities of the industry was presented in order to provide efficient control and management of hazards (hazardous factors). This established method has the following pre-conditions:

- taking into account the maximum number of hazards affecting the value of the quantitative risk assessment;
- providing the possibility to correlate production factors and accident rate, and taking it into account when assessing risk;
- determining the maximum permissible risk levels that ensure the best efficiency of the method;
- providing the ability to quickly and easily calculate the risk magnitude, the possibility of updating it, taking into account changes in the working environment and personal characteristics of personnel;
- providing a reliable hazard assessment by means of digitalization of input and output data.

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GEOLOGICAL MONITORING METHODS USED FOR RESTRICTING GROUNDWATER FLOWING INTO AN EXPLORATION TUNNEL

The European highway network plays a key role in regional economic development. Every EU country has an individual plan for its highway construction, each derived from the EU unified technical standards. One serious hurdle in building this highway network is the geological structure of the region. Within the Alpine-Carpathian region there are a number of different secondary phenomena which effect the stability of the rock environment and the nearby water sources.

In Slovakia there is one stretch of the main D-1 Highway system from Hubová to Ivachnová which contains a 3600m tunnel. The underground geological survey (Borovský et al., 2017) which was carried out parallel to the D-1 Highway section Hubová-Ivachnová revealed that its geological structure is formed by two Paleo-Alpine geological units of the Western Carpathians. The cross – section of the Čebrať Tunnel is situated within the Križna Nappe‘s Cretaceous carbonatic shales, and then overlaid by Triassic dolomites from the Upper Choč Nappe (Polák et al., 1998) which does not directly intersect the tunnel. However, from the intensive amount of karst weathering evident, it is obvious that the Choč Nappe is a groundwater aquifer. The tunnel is drained by groundwater and streams through open fractures and joints.

For this reason, some additional methods were used in the tunnel‘s geological exploration. Pre-boreholes were drilled in 40m lengths. The core samples and boreholes were used to confirm the engineering as well as the hydrogeological and geotechnical aspects such as: rock quality density (RQD), lithology, fractures and tectonics. The water inflow and fracturing are being measured via geophysical borehole logging. The permeability and hydraulic factors were confirmed by a water pumping test in the boreholes. Studies of the deformation parameters of the surrounding rock are being conducted using dilatometric tests. The data from the tunnel was compared with surface data. The water level in the hydrogeological boreholes, the stream water level as well as the tunnel outflow water are all being measured and permanently logged. These measurements are then used to determine which technical solutions are applied for the preservation of the surrounding water sources during tunnel excavation. Up until now, this has proved to be an effective method of protecting ground water in the surrounding rock mass.

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STUDY OF POSSIBILITY OF IMPROVEMENT OF TECHNOLOGICAL PARAMETERS OF PEAT LAYER

The rational use of the resources of a peat deposit [1] is possible when the scientific developments are used at the existing enterprises. The technology for molded peat particles extraction was developed at Tver State Technical University in 1985. Unfortunately, they were not employed in production due to subjective and objective reasons: lack of motivation of peat producers, reluctance to change proven technologies, lack of problems with the sales of milled peat (which was used in energy and agriculture). Currently, new technological equipment has appeared on the market [2] including the power plants that allow an efficient combustion of various types of solid fuels. Recently, the demand for environmentally friendly solid fuels has grown. This is especially seen in the north-western regions of the Russian Federation, due to the use of such fuel for autonomous thermal plants. The goal of the work is to estimate the influence of technological parameters of spreading of molded peat on duration of its drying and harvesting, as well as to improve physical and mechanical characteristics of finished fuel production.

The technology, which is currently widely used milled peat production, has several disadvantages [3]. The dispersion created by milling machines does not meet some technological characteristics, and does not create optimal conditions for peat drying and harvesting. After milling the spread peat has the following characteristics: uneven thickness (from 10 to 45 mm); large number of pulverized fractions; heterogeneous fraction composition; low bulk density; high probability of biochemical destruction from self heating during prolonged storage. Molded particles with an equal field loading dry out 1,5-1,8 times faster than milled crumb. Due to the shorter drying time of the larger particles it is possible to increase cycle and seasonal collection. Moreover, the density of dried spreaded particles is 400-620 kg/m^3 while the density of the milled crumb is 180-270 kg/m^3. The stability of the molded form in the rollers largely depends on the content of dry peat (not harvested from the previous cycle). The content of the dry milled crumbs in an amount up to 15% does not impair the quality indicators of the finished product. This is due to the creation of an additional amount of air-conducting pores, providing removal of the water vapor. To improve the drying conditions of peat and increase the harvesting coefficient, the fractions should be homogeneous and have an optimal size.

Peat should be evenly distributed over the entire drying area in the layer of a given thickness, which will approach the average optimal size of the molded particles. This is necessary to meet the requirements for improving the technological parameters of peat spread. The creation of even spread is ensured by mechanical dispersion and molding of a pre-milled peat mass into small pieces (analogue of fuel pellets). Additional mechanical processing in combination with molding improves the physico-mechanical properties of peat (bulk density, strength, water and steam absorption, calorific value, etc.), accelerate the drying process and increase cycle and seasonal harvesting [4]. To improve the physical and mechanical properties of peat, special technological equipment has been created. It is a milling-forming mechanism for the extraction and molding of peat. It includes a guiding jacket, a jack knife, a milling cutter, a flat knife, working rollers (grinder), a hopper, a puller, guide planes for the formed particles. Grinding performance must be consistent with tractor translational speed. Formed peat is lined with a thickness of 2-3 particle diameters. The experiments show a significant advantage of molded peat particles (pellets) compared with milled peat has been established.

Thus, the research demonstrated that in order to improve the drying conditions of peat and increase the harvesting coefficient, the following conditions must be observed. The peat particles should be homogeneous, mono-fractional and have a size close to optimal (in production conditions it is difficult to ensure the exact size). The spread of molded peat particles should be evenly distributed over the entire drying area in the layer of a given thickness, which approaches the average optimal particle size (this is necessary to meet the requirements for improving the technological parameters of peat spread). As a result, compared to the milling method of peat extraction, the developed technology will increase the density of products; arrange even spread; increase harvesting per unit area, other factors being equal; provide a homogeneous fractional composition; reduce the amount of dust during basic operations.

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SUBSTANTIATION OF DEVELOPMENT SYSTEM PARAMETERS TAKING INTO ACCOUNT BASIC DIMENSIONS OF WORKING EQUIPMENT APPLICABLE IN THE DEVELOPMENT OF USEFUL DEPOSITS BY OPEN PIT

Open pit mining is currently underway direction associated with the use of more advanced technology, having significant linear dimensions, which in turn leads to an increase in parameters development systems. The most common material handling equipment used on quarries - excavators such as mechanical shovels. Trend Analysis excavators in the development of open-cast mineral deposits, showed an increase in the number of powerful mining excavators with workers equipment back and forward shovel. Development of mining technologies using single bucket excavators in conjunction with road transport (link excavator - dump truck) many scientists were engaged: K.N. Trubetskoy, N.N. Melnikov A.I. Arsentiev, G.A. Kholodnyakov, Yu.I. Anistratov, S.P. Reshetnyak, S.I. Fomin, R.Yu. Poderni, V.F. Kolesnikov, K.Yu. Anistratov, N.V. Kosenko, D.N. Ligotsky, E.V. Loginov and others[1],[2]. In their work, researchers paid attention to issues related: with the principle of action, the scope of the working equipment, open pit mining technologies. However, the authors did not issues of the influence of the dimensions of modern working equipment on development system parameters.

An open pit to develop mineral deposits prevails both either in the global mining industry or in Russian Federation. More than 70% of all solid minerals are mined in the Russian Federation through open pits and coal mines, with almost 100% of building materials, 70% of coal, 80-93% of ores of ferrous and non-ferrous metals.Currently, opencast mining is developing in a certain direction, which is associated with more advanced equipment using. It has significant dimensions, which leads to increasing in the parameters of the mining method[3].

It is necessary to observe safety rules during the determining height of the bench. Namely, developing the type of direct mechanical shovel excavators: in soft rocks, the height of

the bench is taken either to be equal to or less than the height of the maximum digging of the excavator (to avoid the formation of so-called overhangs); in rock formations, the height of the bench might be 1.5 times, but during using it (BVR), it shouldn't exceed the collapse of the rock mass height. The height of the bench should be determined byy the project, taking into account the results of physicomechanical properties s of rocks and the mining and geological conditions of their occurrence studies, as well as the parameters of used equipment. The formation of overhangs is not allowed on the ledge[4].

Design bench sizes are the calculated values, averaged along the mining front length; and to a certain extent, they depend on benching rate and available rock mass to be mined. In reality, the bench width along the mining front varies around the average values due to the inconsistency of production processes. During the studying, an analysis was made of existing methods for determining the width of the working platform and two main methods for soft and rocky rocks were identified, a calculation was made according to existing methods.

The study revealed:

- the dimensions of the excavation and loading and transport equipment complex (excavator-dump truck link) mostly it effects on the bench high and the width of the working platform.

- the main indicator which effects the parameters of the mining method during a complex of extraction-and-loading and transport equipment using (excavator-dump truck link) is the dimensions of extraction-and-loading equipment.

- the influence dependence of the complex of extraction-and-loading and transport equipment dimension (link excavator-dump truck) on the development reveal system parameters.

Having analyzed the dependency graphs which , we can conclude that this dependence is non-linear. The values bench width is averaged over the length of the front of mining, but cannot be less than the calculated minimum value. For the effective work of the open pit, it is necessary to create conditions for the smooth operation of the link excavator-dump truck. The linear parameters of the excavator limit the main parameters of the mining method, under these conditions; vehicles have a large area for maneuvering. If it`s necessary, the bench width might be increased, however, the overall dependence wouldn`t change and would have a consistent nonlinear character.

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UNCERTAINTY INTEGRATION INTO SHORT-TERM MINE PLANNING

The spatial uncertainty of grades per ore type can be accessed through the characterisation of local probability density functions (pdfs) on point or block support. These local pdfs can be derived from stochastic simulation methods [1][2] and then be used on the

assessment of mining resources uncertainty. The need to access this uncertainty influence in mine scheduled production is paramount in highly complex geological contexts where production blocks' grade can often be close to cut-off grade and the risk of producing uneconomical blocks is present. The most straightforward approach to report this uncertainty into a mine schedule consists of calculating the mining sequence for each of the simulated realisations of blocks, followed by accessing the uncertainty of each period in each sequence, and finally opting for the optimal sequence, according to an objective function. However, this approach needs to retain the N simulated models and calculate the mining sequence for each one, which can be a cumbersome task, particularly if the dimension of the block model is high [3]. This work proposes a methodology that expedites and simplifies this process, by abandoning both the need to compute a schedule for each block model realization and the need to store and access the entire set of stochastic simulation, while allowing for block uncertainty to be used as an optimization parameter.

The proposed methodology leverages on the usage of either a Gaussian Mixture Modal or a Quantile Interpolation Mixture Model [4] applied over statistics drawn from the simulated block models. The resulting distributions aggregate each scheduling period blocks' production forecast by converting each block's static uncertainty into production dynamic uncertainty. The resulting schedule period statistics can easily be incorporated to be computed into optimization models such as mining simulation methods [5][6][7], mixed integer linear programming [8], or stochastic integer programming methods [9].

A case study of the proposed method has been conducted on a synthetic orebody akin to the Neves Corvo mine, demonstrating its range of applicability. The methodology allows for the uncertainty parameters to be used following different mining strategies such as an internal blending strategy: optimizing production grades subject to uncertainty; or a maximum selective mining approach: targeting total oretype separation during mining extraction operations.

The proposed methodology displayed the capability to allow block uncertainty to be used as a short-term scheduling parameter yielding a production with minimum deviations from the scheduled plan. Also, the application of the proposed methodology grants the possibility of easy assessment of critical periods on the planned schedule, such as the identification of possible/likely deviation from planed production grades, this in turn allows for mitigation plans to be developed beforehand. Furthermore, the proposed methodology requires minimal disturbance to current scheduling routines, which makes it easy to implement in most mining operations. It also allows for integration of uncertain and noisy data into modelling and optimization [10].

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INTEGRATED MANAGEMENT SYSTEM AS A METHOD OF REDUCING FUEL COMPANY'S RISKS

Improving the competitiveness of a fuel company without the adoption of integrated management systems certification for health, safety and environment is impossible today. Integrated management systems are the part of a whole fuel company management system that used to develop and achieve the corporate policy and goals in health, safety and environment and to manage its risks and environmental aspects. The integrated management systems are based on the OHSAS 18001 and ISO 14001 standard series [1, 2].

The main way to achieve the integrated management system continual improvement based on the latest specification is to consider the context of the organization (the external and internal factors affecting the development of the organization and achieving goals), to increase the importance of leadership of the top management, to introduce the concept of "opportunities" and to manage them, as well as operations or processes [3]. According to ISO 14001 "Risk and opportunity management actions" when planning a management system an organization should consider:

- context of the organization;
- requirements of interested parties;
- the scope of the control system.

Risks and opportunities are potential negative consequences (threats) and possible positive consequences (opportunities). Consideration of risks and opportunities when implementing integrated management systems allows the organization:

- achieve your planned results;
- prevent or reduce undesirable potential negative consequences associated with environmental aspects, obligations to comply with legislative and other requirements;
- achieve continual improvement.

The organization must also identify the risks and opportunities associated with its environmental aspects, obligations to comply with legislative and other requirements in order to achieve the planned results of the management system to prevent or reduce the undesirable consequences of violation of the requirements for health, safety and environment and achieve continual improvements Figure 1).

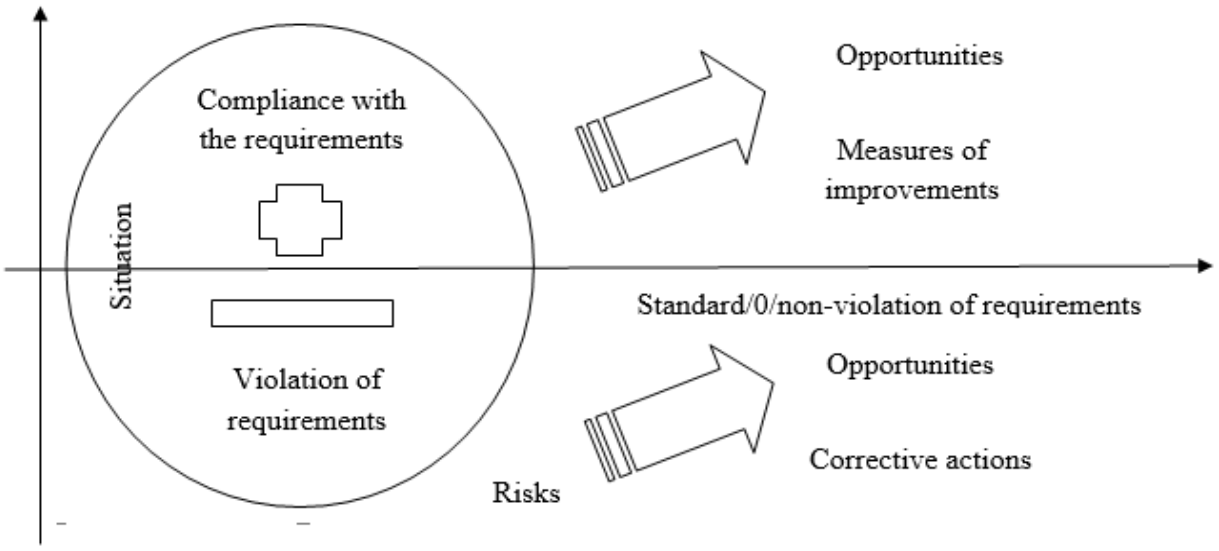

Figure 1 - An approach to understanding risks and opportunities

Thus, the creation of integrated management systems for health, safety and environment is a complex innovative process aimed at improving the efficiency of the whole fuel company management system. The result of creating an integrated management system depends on top management. The integration of management systems (health, safety and environment) that fill international standard requirements is a means for sustained company's development and reduction of company's risks.

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Underground and ground space development technologies. Rock mechanics and control of rock conditions

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MANAGEMENT OF THE STRESS STATE OF THE MASSIF ABOVE THE MINE ARCH IN THE CONDITIONS OF THE ARTEMYEVSKOYE FIELD

The development of mining operations at the Artemyevskoye field is characterized by a complication of mining and geological conditions and the geomechnical conditions of mining operations, and therefore dumping processes in zones of increased rock fracturing have become

more frequent. The formation of outfalls is determined by a number of factors, the quantitative characteristics of which vary widely, and as a result, the prediction of outfalls is very difficult.

If it is necessary to dig and fix workings in very unstable rocks and when approaching the zone of tectonic disturbances in order to prevent sudden collapses, it is necessary to provide temporary support; reduce the size of the output of the output, limiting it to the size of the installation step of the lining; not to allow workings in the absence of a replaceable stock of fastening materials in the face.

Currently, the management of the mass of rocks surrounding the workings is carried out mainly by frame support. The improvement of this direction is associated with the justification for the specific conditions of the nature of the operation of the lining, its metal consumption and the density of the installation.

An analysis of the actual state of the workings shows that most of the "domes" after being held remain practically unsecured due to the presence of large dimensions of the holding space. The latter circumstance significantly reduces the possible technical potential of the lining due to the uneven nature of its loading and untimely commissioning.

It is known that an increase in the fixed space from 100 to 420 mm leads to an increase in displacements of roof rocks by 5.2 times. At the same time, a high-quality backing of the fixed space reduces the displacement of the rocks on the production contour by 1.5–4 times.

It is known that the lining does not significantly affect the change in the stress state of the rocks in the vicinity of the mine, and increasing the density of the lining is not an effective way to reduce the displacements of the rocks on the mining circuit. At the same time, the results of analytical and mine research carried out by various scientists in recent years show that, with the formation of a rock destruction zone, the role of the roof support becomes very significant. Therefore, to enhance resistance to the shifting rock mass, various reinforcing structures or special dynamometric supports are used.

Among the various ways of influencing the stress-strain state of marginal rocks, one can distinguish a group of methods whose implementation mechanism is based on the interaction of rocks and cementation materials. Depending on the nature of the binder used, cementation, chemical and electrochemical treatment of rocks is distinguished, in particular grouting, injection, spraying.

In the history of mining practice, there are many examples of the successful use of rock plugging. The essence of the plugging method is to artificially fill the voids of cracks and pores of the rock mass with material. Grouting by injection is possible in any fractured rocks, irrespective of their petrographic composition (sandstones, shales, limestone, granites, etc.), as well as in clastic, crushed, and gravel soils that have a sufficient width of cracks and pores, allowing the passage of solutions through them.

The accumulated domestic and foreign experience in the use of injection reinforcement of rock masses in the vicinity of mine workings shows that the displacements of the mine workout contour decrease by 1.8–2.7 times, and in some cases, stop.

A significant increase in the lining resistance is achieved when the anchoring space is filled with cementation material. Here, already small deformations of the rock mass lead to an increase in the resistance of the arch support frame to 2600 kN when using concrete. The maximum result is achieved when filling the fixed space with a binder, which is based on Portland cement and reinforced with fibers and polymers. Stochastic reinforcement of cement slurry with chopped fiber increases the resistance of concrete to cracking, the overall resistance of the lining and avoids its sharp decrease when the hardening material is destroyed. This characteristic is preferable; the maximum resistance develops at the most favorable moment with very small deformations of the near-rock mass of rocks, when it is still possible to control the destruction of the rock cover. When filling the space with concrete, you can achieve the required combination of ductility and high load-bearing capacity of the lining. In this case, the final convergence is reduced by 15-25% compared with the convergence of the workings, the holding space of which is filled manually by the rock.

For the conditions of the Artemyevskoye field, it is proposed to conduct industrial tests of the technology for filling fixed voids and domes.

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DIAGNOSIS AND ANALYSIS OF PRESSURE TRANSIENT IN NATURAL FRACTURE RESERVOIR

Well testing is a Tool for reservoir evaluation and characterization. Information obtained from flow and pressure transient tests about in situ reservoir conditions are important to determining the productive capacity of a reservoir. Well test interpretation is therefore an inverse problem in that model parameters are inferred by analyzing model response to a given input. In most cases of well testing, the reservoir response that is measured is the pressure response. Hence in many cases well test analysis is synonymous with pressure transient analysis. The pressure transient is due to changes in production or injection of fluids, hence we treat the flow rate transient as input and the pressure transient as output.

For given test data in which flow rate remained constant, the following set of plots should be generated automatically without regard to the usefulness of each plot. This way the interpreter would have the full view of the test readily available.

- Semi-log (ΔP vs t or ΔP vs $\log(tp + \Delta t)/ \Delta t$, or ΔP vs Δt).
- Log-log (ΔP vs t or Δte).
- Linear (ΔP vs. $\sqrt{t}$, or vs $\sqrt{(tp+\Delta t)}- \sqrt{\Delta t}$).
- Spherical (ΔP vs. $1/\sqrt{t}$ or vs. $[1/\sqrt{\Delta t} - 1/(\sqrt{(tp+\Delta t)})$.
- Rectangular (ΔP vs. t on rectangular graph paper).

The objective from this paper is to determine the type of formation and compare between conventional method (Horner plot) and the new technique (p-derivative) and the results show that by using Horner plot cannot determine the region of radial flow easily unless after shut the well for several days and this method is not economic while when using p-derivative method the radial flow region can be determined from one point in very short time and it is more economic. Finally, in spite of the theoretical attractiveness and recent popularity of the pressure derivative method, it should not be used in the interpretation of field data without extreme caution, and the reliability of the results should be considered quite low. Since the derivative tends to amplify any pressure noise contained in the data, smoothing of the pressure versus time data prior to the taking of the derivative, is necessary. Such smoothing, however, can add distortions to the field data, and can lead to erroneous conclusions. Furthermore, in the case of high permeability reservoirs the rate of pressure change during a given test can be very small, such that the derivative becomes meaningless.

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MINE PLANNING-BASIC

As with any work, the mine planning in the mining industry is aimed at increasing the efficiency of work, reducing costs and organizing the interconnected work of all industries.

Professional programs are currently being used for mine planning, taking into account as many factors as possible in practice, which directly affect the optimal organization of the operation. That's why, for example, in the Micromine program, there is an optimization of the open pit, a separate block, which takes into account the best and worst options for operational work. Experience shows that when the same parameters are applied, the difference between the best and the worst in terms of finances can reach tens of millions of dollars. Mine planning also increases the safety of work, which is of paramount importance.

One of the key factors in planning a mine work is that it must be a few steps ahead of the work at that time, always ready to respond to any unforeseen situation, and, if necessary, make changes in

It should be noted that in planning the work, it is very important to ensure that the ore is averaged from the mine as much as possible, according to the appropriate quantity and quality. In order to carry out this process, it is necessary to have the right to organize the work of the mines, to return to the quality and quantity of the ore supplied to the factory.

Mine planning is an analysis of vast amounts of information (geological, economic, environmental, etc.) and the preparation of optimization projects based on that information.

The basis for planning is the geological information, which was developed from the information obtained as a result of exploration work. Having this information builds the final position of the open pit, the final position of the pile. Then, taking into account a number of factors, long-term, medium-term and short-term plans are built. These three concepts are conditional on the number of years of operation of the mine.

Along with the planning of the open pit mine works, the design of the filling is done according to the relevant calculations.

During the operation of the mine, Grade Control is performed, which, due to the fact that the intelligence network is several times denser, provides us with high-precision information. It should be noted that exploratory exploration should also be a few steps ahead of the current work, otherwise the information obtained from it will simply not make sense, except for checking the work already done. We use this information in short-term planning and, if necessary, review further information accordingly.

Based on the information obtained as a result of exploratory exploration, the corresponding ore level is divided into exploitation blocks, which differ from each other by different metallurgical indicators.

The cooperation between the enrichment plant, the planning department and the open pit operation department is continuous. Along with the change of the shift, there is an exchange of information on the work done and the work to be done.

The operation of the open pit can be planned in such a way that the final product is achieved in several stages. Depending on the production, the required machine structure is calculated. According to the planned plans, the distribution of this machine structure according to different periods becomes clear. As production increases, so does the amount of machinery needed.

Mine planning also includes reporting for relevant work and compiling spreadsheets. The safety of the work is a prerequisite for the planning of all works.

The planning department cooperates with all production services and supervises the planned work.

For each period (monthly, quarterly, annual, etc.), a comparison is made between actual and planned work and appropriate decisions are made for further work.

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ANALYSIS OF CONTINUOUS ROCK SLOPE DEFORMATION AT HIGASHI SHIKAGOE LIMESTONE QUARRY, JAPAN

Rock slope stability has become one of the major challenges of rock engineering projects, such as open- pit mining. This is because instability of rock slopes may results in slope failures; consequently affect mining operations and often lead to economic losses, property damages and maintenance costs, as well as injuries or fatalities [1]. In Japan, case of slope failures in an open-pit quarry has been reported [2]. To overcome this, the automated polar system, APS, Global positioning system, GPS [3], and extensometers [4] have been used for rock slopes displacement measurements. Kodama et al. [1] suggested integral joint of field measurement and 3D elastic analysis as an ideal tool for assessment of rock slope stability; inelastic deformation can be inferred from a comparison between the measured results and calculated elastic deformation once the elastic deformation of rock slope is estimated.

In this regards, we employed both field displacement measurements and numerical analysis in order to understand the mechanism and the causes of the continuous rock slope deformation observed at Higashi Shikagoe limestone quarry, Japan. Geologically, the quarry is a small-scale operation mine situated at Central Hokkaido perfecture, Japan, with rock slope of about 130 m, height as depicted in Figure1. The rock mass consists of mainly limestone, schalstein and slate rocks as main rock types. The schalstein and slate rocks have been subjected to intensive weathering, which formed clay seams of 70 m, thick at foot wall of the rock slope as illustrated in Figure1. However, the quarry has experienced four separate planar failures, which occurred in 1996, 2004, 2009 and 2017. Moreover, the mechanism of the rock slope displacement observed at the quarry has not been well understood over the past two decades. Thus, it is of high priority to assess stability of the rock slope, not only for good economic purpose, but also for safe and sure operation.

Therefore, an automated polar system (APS) was set up to monitor the rock slope deformation. Firstly, APS measured travelling times of laser beam from a beam generator to mirrors located at various points along the slope. Thereafter, changes in distance between each of the mirror points and the beam generator were calculated from the change in travelling time and velocity of laser beam. In this study, APS data from 11 mirrors (as shown in Figure 2a) measured from January 2014 to April 2019 were used to characterize deformation behavior of the rock slope. The result shows that the change in distance decrease gradually at all the elevations with total values ranges from 2 to 100 mm approximately as seen in Figure2b. Although the decreasing rate of the change in distance differs at each mirror point, indicating that rock slope displacement depends on the elevations of the quarry.

With regards to the above results, we investigated the influence of water infiltration on the rock slope displacement through comparative time series analyses of water inflow measured at a nearby artificial lake 400m away from the quarry and rainfall data. The water inflow measured represents total water inflow from surrounding area, which was assumed proportionally to the water inflow through the quarry. Figs. 3a-b confirmed that the displacements accelerated as the accumulation of water infiltration increases. Subsequently, 2D elastic analysis was undertaken to investigate the impacts of deterioration of clay found at the footwall of the cut rock slope on the deformation in terms of reduction in its Young's modulus. Finite element meshes (Figure 4a) were generated using six-node triangular elements based on the geometry of the quarry along the cross-sectional area designated as V33 (Figure 2a). Four

basic analyses were made based on mechanical properties quantified by experimental results. The simulated change in distance (Figure 4b) shows that the magnitude of the rock slope displacements strongly depends on the Young's modulus of clay. The comparison between the simulated and measured results shows good agreement at the middle and upper part of the cut rock slope. Hence, deterioration of clay found at the foot of the rock slope is one of the causes of the rock slope displacement.

From the above findings and analyses, it was concluded that the slope still shows stable behavior. However, considering the strong responses of the slope to water infiltration and deterioration effect of the existing clay, there may be periods of unstable behavior of the rock slope in the near future. Therefore, it is recommended that further studies should be undertaken on effects of excavation and backfilling using 3D FEM, and changes in temperature and loading rate on strength of the rock mass considering the geologic conditions and variation in the weather conditions within the region of the quarry; in order to further clarify the deformation mechanisms. Moreover, a study on the support system with controllable deformation for rock bolt, shotcrete and steel support will also be made in order to prevent such failure.

Figure 1 - The rock slope layout of the quarry

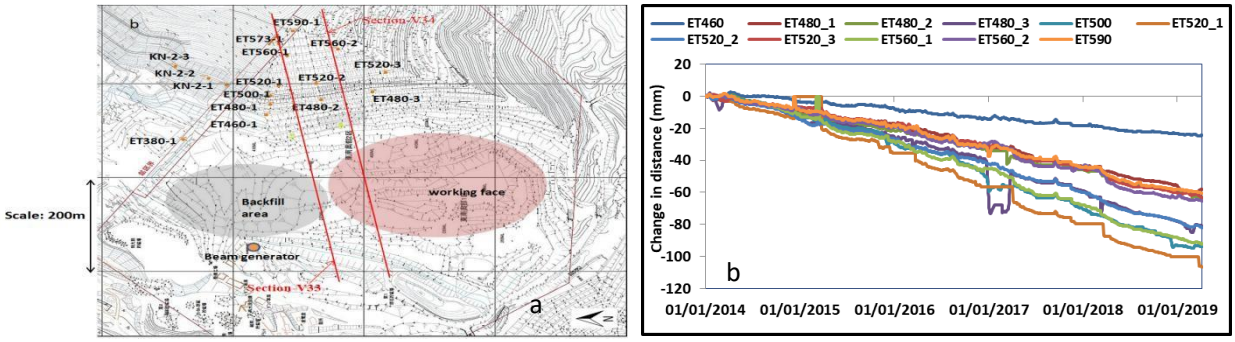

Figure 2 - APS layout (a) and Change in distance with time (b) for five years. The ET represents the mirror point locations of automated polar system (APS) set on the rock slope. Each mirror point is represented with a number that indicates its level of elevation. The red line indicates the cross sections of the mine.

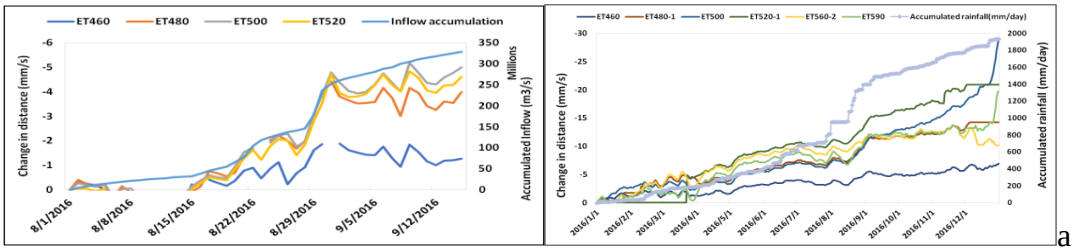

Figure 3 - Relationship between Measured change in distance and water inflow (a), and the cumulative rainfall (b)

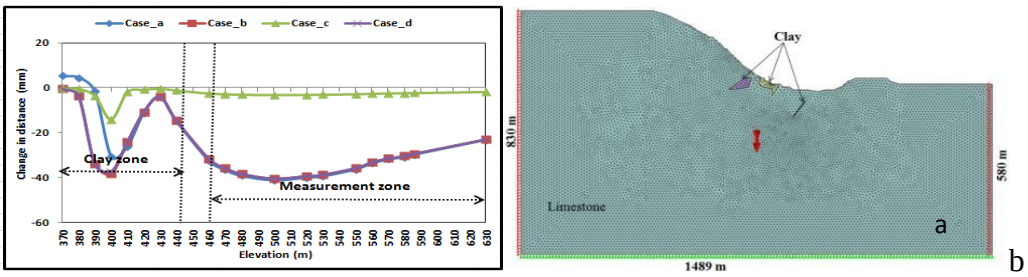

Figure 4 - The analytical model along cross-section of the quarry (a) and the calculated change in distance (b)

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MONITORING OF DEFORMATIONS DURING CONSTRUCTION OF TUNNELS UNDER RESPONSIBLE BUILDINGS AND STRUCTURES

Today, one of the important directions in the development of the metropolis is the underground transport network, which includes the construction of tunnels for various purposes. Construction work, as a rule, is carried out in cramped urban conditions, which entails the implementation of a complex of geotechnical monitoring, which without fail includes geodetic-surveying observations. In the course of geodetic and surveying observations, the planned and height displacements of deformation and sedimentary marks fixed on the earth's surface and controlled buildings and structures are determined. However, in addition to the traditional methods of measuring deformations, other methods of deformation geotechnical monitoring can be used. One of the types of geotechnical monitoring is the use of a borehole inclinometer, including in conjunction with a magnetic extensometer.

This report discusses the problems of identifying, monitoring and predicting the development of deformation processes that occur at various depths of the soil mass during underground mining operations on the construction of distillation tunnels in various ways, including using TMC (tunneling mechanized complex). The method for tracking the vertical-height movements of the soil mass using the borehole inclinometer in conjunction with a magnetic extensometer has been improved.

The implementation of the geotechnical monitoring complex is especially acute when there are critical buildings and structures in the zone of influence of the new metro tunnel

construction, which include architectural monuments, existing metro tunnels, communication tunnels for various purposes, railway lines, etc.

The use of inclinometric and extensometric measurements, in addition to the traditional methods of measuring deformations, allows you to more accurately determine the degree of influence of mining operations on the soil mass and controlled structures. The traditional methods of measuring deformations are reduced to geodetic-surveying observations on the earth's surface, which make it possible to record already completed deformations, and it may be necessary to carry out expensive repairs of a critical structure. The use of a borehole inclinometer and a magnetic extensometer when performing geotechnical monitoring of the shield penetration of the subway tunnel provides control over the vertical and horizontal movements of the soil mass in the zone of influence of mining operations. The use of a borehole inclinometer for monitoring the enclosing structures of a foundation pit constructed using the «wall in the ground» technology allows us to determine their horizontal movements over the entire depth in increments of 0.5 meters. Installation of an inclinometric well is carried out at the stage of creating enclosing structures, therefore, in the event of deformation processes, they will be fixed, since the pipe will completely repeat the deformation of the «wall in the ground».

This set of works makes it possible to fix the deformation processes at an early stage and to predict the degree of influence on the controlled responsible construction, and, if necessary, the timely adoption of emergency measures will reduce the cost of repair and restoration work.

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PHYSICAL AND MECHANICAL STUDY OF SANDSTONE

Sandstone is widely used as a building material since ancient times. Sandstone shows a verity of mineralogical, chemical, and textural characteristics. These characteristics can affect their physio-chemical properties. Especially when they are used as a construction material. This paper aims to determine the composition of sandstone through a thin section study. In this study, the Early Miocene sandstone of Murree formation was used as a building material in the Rawalakot and Poonch areas of Azad Kashmir. The sandstone samples were tested to evaluate their petrographic, mineralogical, and chemical characteristics.

The project area lies between the Khirik to Thorar, District Poonch of Azad Jammu and Kashmir. The area lies between the latitude 33˚49’30” N to 33˚52’00” N and longitude 73˚39’00” E to 73˚45’00” E on Geological survey of Pakistan topo sheet no.43 G/9. The present study deals with building stones sampling and testing. The main objective of the present study is to evaluate the best building stones for construction through standard testing.

The mechanical properties like specific gravity, uniaxial compressive strength, point load, sonic velocity, slake durability and Brazilian tests have been evaluated according to ASTM standards and compared with ASTM standard specifications to determine the suitability of these rocks to be used as building stones. The petrographic study was also performed to access the presence of deleterious materials which could affect the engineering characteristics of the rocks.

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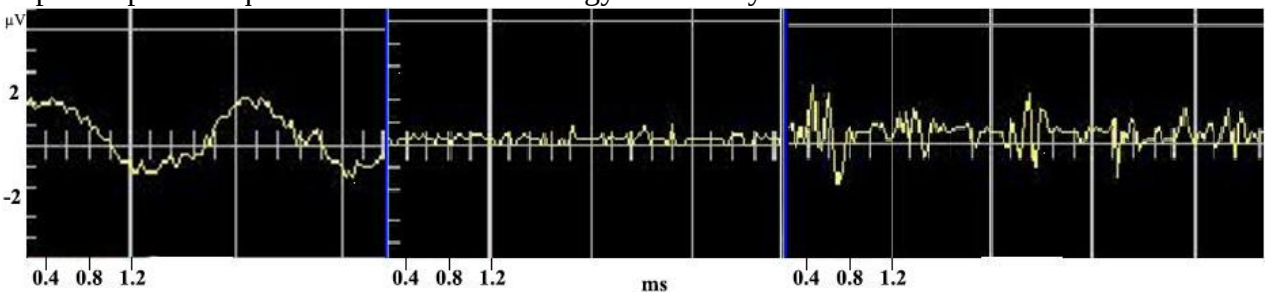
INVESTIGATION OF STRUCTURAL EVOLUTION IN THE CEMENT CONGLOMERATES USING OF ACOUSTIC EMISSION METHODOLOGY

The paper considers issues related to concrete fastenings of mine workings during the construction and reconstruction of mines.

The nature of the manifestation of rock pressure in the mine is determined by the stress state of the rock mass, as well as by the strength and rheological properties of the rocks containing the mine. An important role is played by the composition of concrete and its interaction with the structure of the rock for further stability and durability of the fastening system. Water in the concrete mix in the moment of laying in the formwork of the production support is in the state of: chemical (hydration and crystallization 4-5 %), physical and chemical (adsorption 20-25%) and mechanical connection (water capture in thin capillaries, pores 70-75%) [1]. The influence of water on the strength of the concrete structure is very high, which imposes special requirements on the technology of delivery of concrete mix.



0-45 min

cement + water colloid crystal formation

Figure 1 – Type of signals on an oscilloscope excited in a cement test at various stages of structure formation

In this paper, the rheology of cement stone is considered. Even though concrete technology has made great advancements, the exact interpretation of phenomena and interaction between different physical and chemical parameters are yet to be precisely determined. Monitoring of the early stage of the material is important as this stage defines in a great degree the final properties of the hardened concrete.Within the different monitoring techniques, acoustic emission (AE) has been recently increasingly used as it shows sensitivity capturing numerous elastic wave signals during the setting of the material and as early as from the moment of mixing [2]. The relationship between the levels of structure formation of the concrete structure and the AE signals in these periods is established.

The destructive effect of concrete lining is influenced by the aggressive environment.The Cl^- ion easily migrates through the cement dough, while the rate of diffusion depends on the Cl^-/OH^- ratio. In cement stone, the migration of Cl^- ions occurs through areas of increased permeability: microcracks, capillaries, and open pores. The binding of Cl^- ions and their diffusion capacity determines the intensity of chloride corrosion. To determine the structural changes in concrete, the AE method has proven itself. In the future, it is planned to study structural changes in concrete under the influence of an aggressive environment using a measuring complex combining AE and strain measurement methods.

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APPLICATION OF THE NEWTON METHOD IN SOLVING OF THE OPTIMIZATION GEODETIC TASKS

Various optimization methods are used in geodesy nowadays. Usually the main task in an optimization problem is to search for an optimal solution (i.e., in terms of the conditions of the problem). There are a lot of problems in geodesy, where it's necessary to solve diverse systems of nonlinear equations. Processing of different coordinate systems, geodetic network adjustment, creating of digital terrain model can serve as an example of such geodetic problems. The advent of computer technology enhances the search for new methods of solving nonlinear equations using nonlinear programming. Nonlinear programming methods involve the process of optimizing objective functions connecting known and desired (unknown) parameters. However, one cannot choose one method that would solve all the problems in modern geodesy without exception. The article presents a study of the possibility of using nonlinear programming methods in solving various geodetic problems. This topic is devoted to the work of prominent scientists: Himmelblau [1], Mitskevich [2], Kougiya [3]. In this article, the basic ideas of Newton's methods and theirs application to solve geodetic problems are considered. Additionally, the question of using computer technologies for the realization of Newton's method is presented in this paper. By applying this method, solutions are found using an objective function, its first and second derivatives. The advantage of the Newton's method is the quadratic convergence of the solution – a more perfect search algorithm in comparison with the gradient methods and the possibility to apply it when solving systems of nonlinear equations. However, this method requires prediction: it is necessary to evaluate the first and the second derivatives of the objective function in advance. This procedure can be time-consuming. In this

research, numerical methods where applied to evaluate derivatives and hence, solve this problem. Numerical methods permitted automate the solution search.

This research presents and proposes a program for determining circle parameters (i.e., radius and center coordinates).his program is created in the Visual Basic programming language. The approximation of cross-section points is used in various applications using digital image processing methods: for determining the geometric primitives shown in raster images, this was studied by Gribov & Khachumov [4]. To approximate the circumference of the results of measurements of the chimney, it is necessary to determine the coordinates of the center of the circle X_0, Y_0 and the radius R. The initial data for solving the problem are the coordinates of the chimney points obtained during the scan. To uniquely determine the parameters of the section, it is necessary to know the coordinates of at least three points, if there are more points, then the adjustment problem arises. Circle parameters are calculated within three iterations – hence, a time-saving solution. There was an increment in the accuracy of solutions, because methods based on the first derivatives linearize the objective function, but linear function have no any extremums besides its ends. Thus, it is necessary to choose a specific step-size in the orthogonal direction to linearize the objective function. This accounts for the accuracy when determining the roots of the function. The proposed methodology was tested using a geodetic problem of pipe inclination determination. Scan data were used for calculating the circle parameters for the upper and lower pipe cut. Then findings were used to determine the pipe inclination.

The article considers the theory of the Newton method of the second order, substantiates its application in solving optimization geodetic problems. The method was used to approximate the circumference of the results of measurements of the chimney. When solving this problem, the main advantages of the method were confirmed, namely, the high convergence rate of the meth-od, compared with methods using the first derivatives. The main disadvantages of the method are the highly complex computational process (compilation of the Hessian matrix and control of its sign), as well as difficult preliminary preparation of the problem for solution. Therefore, the successful implementation of the Newton method in geodetic production is possible only if the computational process is automated by writing soft-ware modules in various programming languages to solve a specific problem. In the process of writing the article, a program was created: to calculate the parameters of the circle when constructing sections of the chimney. This made it possible to automate a complex computational process and successfully apply nonlinear programming methods in geodetic production. Summing up, it is possible to acknowledge that the application of Newton’s method for solving geodetic problems, for adjusting geodetic network and for merging different coordinate systems can find wide application in geodesy.

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PILLAR FREE MINING REALIZED BY DEEP AND SHALLOW HOLE-HIGH AND LOW PRESSURE COUPLED GROUTING REINFORCEMENT TECHNOLOGY

Nowadays, the metal mines account for a considerable proportion in underground resource mining. However, with the long-term mining, the easy-to-mine and high-quality resources are gradually exhausted. The mining and utilization of the large number of poor mineral resources has become the main direction of underground resource mining in the future [1]. For these thick and inferior ore bodies, if the single-level mining mode is still used, the production capacity of the mine will be far lower than that of the rich mine, and the production cost will remain high, which will seriously restrict the economic benefits and sustainable development of the mining enterprises. On the contrary, the multi-level mining mode is a feasible and effective way for the inferior mining. However, the multi-level mining is a kind of mining mode whose practice is far ahead of the theory [2]. In the process of its application, it can encounter many problems: difficulty in maintain the stability of the stope, severe ground pressure, serious damage of surrounding rock and so on. In order to overcome these disadvantages that restrict the development and application of the multi-level mining mode, an efficient reinforcement method of surrounding rock is urgently needed.

In China, the deep and shallow hole-high and low pressure coupled grouting reinforcement technology (DSH-HLP) is wildly used to deal with these problems, whose mechanism can be explained as follows: through shallow hole-low pressure grouting, the slurry can squeeze or infiltrate into the cracks and pores of fractured rock mass near the access roadway; as a result, when the slurry cemented, the surface of the surrounding rock turns into a grouting stone with high bearing capacity, so that the fractured rock mass has the ability to withstand higher grouting pressure. Then the deep hole-high pressure grouting can further improve the permeability of slurry in the deeper range of surrounding rock and expand the bearing range of the reinforcement system [3]. Based on the technology DSH-HLP, pillar free mining can be realized by the following methods.

Before the roadways excavation, multiple rows of grouting holes are arranged at the upper part of the workface. The slurry is injected into the holes by the grouting machine, and diffusing into the surrounding rock cracks as much as possible. When multiple grouting holes are connected, a solid grouting curtain on the roof can be formed above the mining access roadway. In order to further improve the efficiency of mining and reduce the use of pillars, side boreholes are further arranged along the two sides of the roadway based on the roof grouting, in which cases the adjacent roof of 1~3 access roadways are strengthened, so as to enhance the safety and stability of the whole mining area. After the middle access roadway is mined, the filling material is directly used for backfilling. And when reaching the design strength, the left and right access roadways can be directly excavated without no pillars.

This paper introduces the design and construction of DSH-HLP based on the engineering background of mining in the middle section of -390 m in Baixiangshan iron mine in Anhui Province, China. In the iron mine, the 5th-Panel mining access roadway has a large area of pressure under the influence of multi-level mining, resulting in serious damage to the nearby mining access roadways, which is very easy to cause accidents such as falling rocks and roof caving when excavating, leading to the instability of the subsequent mining excavation. Therefore, the DSH-HLP is proposed to form the grouting reinforcement curtain around the mining access roadway, so as to prevent roof falling accidents and improve the construction efficiency and safety of mining access roadway. The DSH-HLP can also realize the pillar free mining and further improve the mining efficiency of the mine, which can provide a reference for

similar engineering. However, the DSH-HLP has higher requirements for grouting materials, and it is necessary to further study the high performance grouting slurry in the future.

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APPLICATION OF INTEGRATED PREVENTION AND CONTROL TECHNOLOGY OF IMPACT GROUND PRESSURE IN NANSHAN COAL MINE

Where the impact ground pressure disaster is more serious, the roadway section will be completely destroyed, such as coal and rock body collapse out of the blocked roadway, equipment damage can not operate normally, or even casualties, some mining areas will also appear ground collapse, resulting in serious damage to ground buildings. How to reduce the possibility of impact ground pressure, how to control impact ground pressure as the most important coal mine production, Nanshan coal mine construction of the epitaxial face for the recovery of coal pillar face, during the mining period mainly affected by mining depth, goaf side pressure, overlying 15 layers of coal pillar, face "see square", periodic pressure, etc., through the construction of pressure relief drilling to the face pre-unloading treatment, to ensure the safety of the face mining, during this period accumulated a set of safe, efficient, mature pressure relief drilling technology.

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EVALUATION OF THE GEODYNAMIC STATE OF ROCKS KUKISVUMCHORR WING OF THE KIROV MINE

The current state of mining industry in Russia and in other countries is characterized by complication of mining and geological conditions. In some cases, this leads to the occurrence of

dangerous geodynamic events (rock bump, sudden rush, cover caving, etc.) which may disrupt flow process or contribute to accident conditions. The way out is applying measures to prevent these events. The efficiency of said measures depends on the quality of field geometrization of deposits and next assessment of the geodynamic state of the rock mass. Hence, a digital field model of the Kukisvumchorr wing of the Kirov mine was generated. The assessment of the stress state of the rock mass is planned. The basis for assessing the stress state was the materials of the spatial distribution of mines and recorded data of dangerous geodynamic events at different working horizons over the past few years. The problem of the exploratory development is relevant nowadays since rock bumps still occur.

A three-dimensional digital model of the field was generated through the Micromine (mining and geological information system). Horizontal plans for development of the field, such as ore body, tectonic fractures, mines, and mined-out area, were used for creating the model. The use of the Micromine software package for building the 3D model has significantly accelerated the process of processing the received information about the field. The areas of the probable stress-strain state of the rock mass were determined and based on the 3D model of the ore body. A more simplified model of the selected field region was created for further analysis of the stress-strain state of the rock mass. The geodynamic state of the array will be assessed using the finite element method based on the Coulomb-Mohr model in the Plaxis 3D program. At this stage of the scientific research, the 3D model of the finite element network has already been created, loads have been set in the form of supports for the mines and the region of thickening of the finite element network has been determined.

Thus, the analysis of the capabilities of the Micromine software package for the geometrization of field development was carried out during the study. The program allowed to generate a digital model of the field, as well as to study the contours of field development on a 3D model. The study reveals that the geometrization of the field in the Micromine program is justified and recommended for usage in field development, scientific research as it significantly shortens the information processing time. The further research topic is the probability estimation of the occurrence of new dangerous geodynamic events and the subsequent comparison of their locations with the actual places of the recorded dangerous geodynamic events.

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THE CONCEPT OF HYDROGEN – METHANE BLENDS STORAGE IN UNDERGROUND MINE EXCAVATIONS – GAS PERMEABILITY OF CONCRETE

Power–to–gas technology gives the possibility to store the excess power from renewable energy sources by converting electrical energy into gas such as eg. hydrogen. There is however a problem with accessibility of sites where pure hydrogen can be stored. Hence, the idea of blending hydrogen with methane and use existing infrastructure for transmission and storage of

natural gas [1]. However, underground storage of hydrogen/methane blends still faces some difficulties and challenges.

Hydrogen has strong capability to diffuse through different materials, like for example steel, causing leakage problems or steel embrittlement. Hydrogen also diffuses through some minerals. Nevertheless, there are operating hydrogen storage sites in salt caverns. Other alternative storage sites such as underground mines or lined rock caverns were suggested [2], but are still being under development stage and immature for commercial operation. The paper proposes a concept of hydrogen/methane blends storage in abandoned underground mine excavations. Hydrogen storage in underground mines would increase the hydrogen production possibilities in the areas, where availability of conventional geological storage sites, like salt caverns and depleted oil/gas reservoirs is limited.

The paper is focused on permeability of concrete as a barrier for stored gases. Gas permeability from two methods: pulse – decay and steady – state, were compared. Results show, that gas permeability of investigated concrete and geopolymers depends on the composition. Pressure conditions, especially axial stress, has also a significant impact on the concrete structure, which lead to the variability of gas permeability.

Laboratory and literature research shows, that ordinary concrete have a top impermeability value of around 10^{-19} m^2, that cannot be improved with the powder and mineral additives. Ordinary concrete can be a mechanical base for sealing construction in gas depot, but need to be trimmed with liner of better sealing properties. A significant improvement of tightness of the concrete can be achieved, using a synthetic compounds. Using SBR rubber in the amount of 15% is giving the gas permeability below the sensitivity of the setup [3]. Resins are also a

promising sealing material. Although that kind of materials are impermeable for other gases like methane, hydrogen might still diffuse through it. Hence it is important to conduct the hydrogen diffusion test on any material considered for the sealing liner in hydrogen – methane blends storage.

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CREATING A DIGITAL GEOMECHANICAL MODEL OF THE SHAHUMYAN GOLD AND POLYMETALLIC MINE

While solving mine technical problems source data has mining-and-geological and mine technical characteristics of mine on base of which calculating models of geological objects are formed.

At the contemporary development level of geoinformational technologies highly relevant research are directed towards creating digital geomechanic models ore field particularly in Shahumyan gold-polymetallic mine.

Shahumyan gold-polymetallic deposit consists of 83 ore bodies which are presented by ore veins and mineralized zones [1]. Along the trend of ore bodies, these two morphological types alternate between themselves and are torn by fundamental structural faults into many

segments. The mine is represented by hydrothermal changes of andesit-dacitic, quartzitic porphyrite, tuff breccia, tuff sandstone.

Structurally Shahumyan gold-polymetallic deposit is complicated with multiple breaking faultes, from which the largest sized are (from west to east) Barabatum-Xaladj, North-East, West-Shahumyan, Central, East-Shahumyan, Tedjadin and Xaladj faults.

Ore bodies also outstand with high hardness and stability. Coefficient of rock hardness according to professor Protodyakanow is 12-14. Hardness of enclosing rocks by drillability – XIV-XVI categories. Hardness of quartiziyic andesit-dacitic porphyrites varies within the range of 2.64-2.73 t/m^3, on average 2.71 t/m^3.

In Shahumyan mine a database was created which has been regularly actualizing characterizing, mining-and-geological, mine technical conditions of the mine. Despite this fact, all the information rarely was used. For convenient usage, a cataloging of the database was needed and was decided to digitize the database and create geomechanical digital model of the mine.

The geomechanical model is digital small-blocks model of the mine, containing

- Data of the structural distinctions of the solid
- Highly rated indicators and parameters
- Parameters for calculations of underground and open pit mining`s stability.

Creation of geomechnaical digital model includes some stages, collection and processing of data, analyzing of obtained results, conversion of the graphic documentation into digital.

Collection of the data is accomplished with two methods, immediate mapping of the section and the core-sample. Gathered data is processed with the help of highly-rated indicators-numerical values characterizing rock solids stability [3].

In rock quality description (RQD) which characterizes a measure of quality of rock core in south section, ranges within from 50 to 65, which is an average indicator, in the central and north sections from 40-45 (relatively is considered to be a lower indicator) [2]. Quantity of system of joints in all sections of the mine reaches up to tree.

Conditionally we can point out that in all sections of the mine rock properties basically are similiar, rock alteration and weathering (A_2) are slightly weathered. Also identical wall roughness (J_r=1.5) joint microsurface is slippy, macrosurface is wavy or bumpy, as well identical joint walls alteration (J_a)=8, so infilling up to 5mm, soft clay (deforms with a push of a nail).

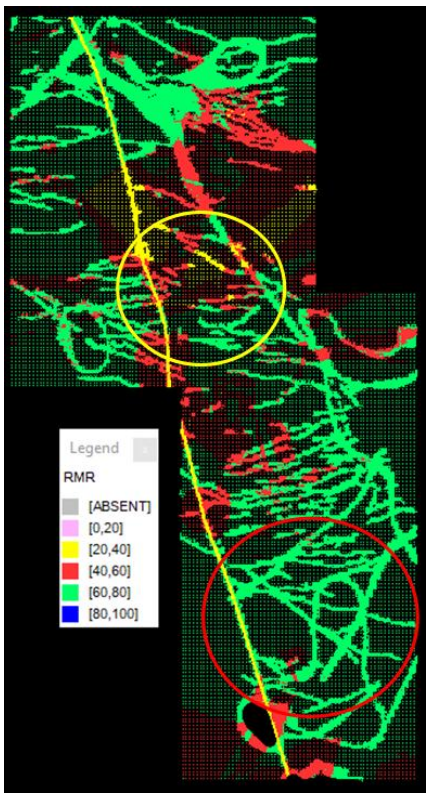

Figure 1 - Geomechanic model of Rock Mass Rating

Geomechanic model showed that the mine was presented mainly with strong and stable rocks, but in those sections where faults approach strength and stability of rocks starts falling up to medium stability (in some cases up to unstable).

Conclusion: Availability of the model in the mine allows:

- Rapidly visualize sections by physic-mechanical properties
- Simplify the calculation and lag of lining
- Simplifies the calculation of parameters of constructive elements of development system Besides above-mentioned advantages, availability of geomechanical model in Shahumyan mine as well simplified the choice of respective parameters of drill and blast work for each section.

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EFFECT OF CARBONE DIOXIDE ON THE STRENGTH OF CEMENTED PASTE BACKFILL

One of the most important geotechnical quality criteria for the hardened mine backfill is mechanical stability or other mechanical properties at a given time. Indeed, the cemented paste backfill (CPB) structure must remain stable during the extraction of adjacent stopes to ensure the safety of mine workers and to avoid ore dilution. The uniaxial compressive strength (UCS) of the

hardening or hardened backfill is often used in practice to evaluate the CPB stability at a desirable time since the test is relatively inexpensive and can be incorporated into routine control programs at the mine.

The binder consumption is the most expensive component in the preparation of cemented backfill. Hence, several studies have been conducted to reduce the binder consumption of cemented backfill. One approach is the incorporation of carbon dioxide (CO_2) during the preparation of the cemented backfill. This may lead to the increase in of the UCS of the CPB, thereby reducing the relative binder consumption. However, no study has addressed the impact of carbon dioxide (CO_2) on the UCS of CPB.

The main purpose of this work is to investigate if incorporating CO2 into the cemented backfill during its preparation would increase the UCS of cemented backfill.

The followings materials were used for laboratory mixing to prepare the CPB specimens: silica tailings, binder, and distilled water with different concentration of Carbone dioxide. As mixing water, distilled water was used. Specific amounts of CO2 were added to different volumes of distilled water to create mixing water. A water-cement ratio of 7.6 was used. The Portland cement type I (PCI) was used as the basic binder in a weight proportion of 4.5% was used as the only binding agent. The relative density of PCI is 3.1

In order to evaluate the development of cemented paste backfill containing CO_2, unconfined compression tests of CPB specimens with different concentration of CO_2 and distilled water were performed [2]. For each degree of concentration, approximately 2 to 4 samples were taken and their curing time was studied respectively after 3, 7, 28 and 90 days.

The UCS analysis was intended to compare strength development of CPB prepared with carbonated and that prepared with distilled water. In Table 3.1, the parameters of the tests are presented. As can be observed, the parameters included pH levels and curing time, and carbonated water was used. For consistent results, 2 to 4 samples were tested and the compressive strength varies between 293 to 1013 kPa, 347 to 953 kPa, and 370 to 1141 kPa for samples containing carbonated water with respective pH levels of 4.2, 4 and 3.8 at the curing times between 3 and 90 days. The compressive strength of CPB samples made with distilled water varies between 261 to 1009 kPa.

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UPLAND QUARRY SLOPE STABILITY ANALYSIS UNDER LOADING EFFECT

In contrast with flat open pit mines, upland quarry differ in complexity and dissection of the relief, steepness and length of mountain slopes, on which are forming the quarry wall. High intensity of mining and trend to recessing the depth of the upland quarry lead to the modification of the shape of the slopes in space. Common upland quarry with rebuilding the wall within the height of the mountain slopes, over time it can deepen beneath the prevailing terrain level, thereby turning it into the upland-deep type of quarry.

When there are engineering-geological elements of different composition and length above the crest of the wall in upland quarry, it is mandatory to estimate the stress-strain state of the upland quarry wall under loading condition, due to “mountain-slope effect”.

In present, as a solution of this task and to reduce the impact of the overburden stress of the natural mountain slope on upland quarry wall, it is recommended to select a technical solution, associated with the extraction of the additional volume of the rock mass, to combine the crest of the wall with the upper mark of the natural mountain slope. In this case, there will be excess of factor safety, as will only unload active pressure prism. Besides necessity of producing additional significant costs, the disadvantage of this solution is that, cutting layers of rock mass from the crest of the loaded upland wall and natural mountain slope can also lead to cutting weakened slip surface, to which the wall is leaning, which may cause melt and rain water to leak into the bodies of these disorders.

The analysis of measured studies showed that during mining operation of upland quarries, loaded with the natural slope, the wall is in composite stress-strain conditions. From the crest of the wall to the toe are forming the zones, in where the rock mass is under tensile stress which is reason of forming and occurring the cracks. Besides of that, in the area of impacting natural mountain slope is forming particular stress-strain state, characterizing by the occurrence of the stress concentration zones.

Recently, most researchers in various side of the world have proved the cracks, and as a result slip surface, forming and occurring mechanisms are quite different in jointed rock mass under loading and unloading effects. It is necessary to point that here the significant role is playing the geometry of the geotechnical constructers (height and overall slope angle) and also geological structures distributions. It is also pointed, that in the toe rock mass of the wall under loading effect are forming the tensile shear stress zones which are giving rotational movements to the elementary rock mass blocks. Moreover, the shear stress field intensity significant depends on the location of natural geological structures in upland loaded wall.

Existing slope stability analysis techniques are less effective for estimating upland quarry slopes safety. At the time being, this is due to poor developments in stress-strain state of the rock mass under loading effects, as well as significant discrepancies between the calculated and actual parameters of the potential failure prism of the wall. It should be noted that the study of the character of the stress field development and propagation contributes to an information content and objectivity of determining stability of the upland quarry wall under loading effect by natural mountain slopes. This can be achieved through the development of the geomechanical model, allowing to identify stress distribution laws and assessments of the magnitudes of that in loaded rock mass, depending on natural mountain slope shape and parameters.

This geomechanical task can be solved by physical modeling, allowing to define stress distribution character, to get qualitative and quantitative assessment of the stress field in rock mass, which is important when choosing the estimation techniques for determining the stable parameters of the upland quarry wall in loading effect.

Numerical techniques based on FEM with specific input parameters such as the height of the upland quarry wall, the dip angle of the natural mountain slope and distribution to the wall, density of the rock mass and Poisson’s ratio, then we can simulate in any point of the loaded slope horizontal σ_x , vertical σ_y and shear stresses $t_{xy.}$

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METHOD FOR CALCULATING THE INFLUENCE OF OLD LONGWALLS ON THE PROCESS OF MOVEMENTS AND DEFORMATIONS OF THE EARTH'S SURFACE USING MASSIF RELAXATION CURVES

The territory of geological and industrial coal-bearing regions of the Donetsk basin, due to the long-term history of subsurface development, are characterized by a high degree of multiple mining of the earth's surface. A change in the mining and technological situation due to the movement of the working longwall, changes in the spatial arrangement of the projected, existing and previously worked out mine workings, the presence of safety pillars, the manifestation of geological disturbances, etc. leads to a change in the stress-strain state of the rock mass. Under these conditions, an urgent task in calculating the displacements and deformations of the earth's surface from one longwall is to correctly take into account the influence of longwalls, the displacement of which was completed before mining of the longwall under consideration.

Regulatory documents [1], [2], [3] regulate keeping records of the influence of old mine workings, accepting calculated displacements and deformations during reactivation of the displacement process and the absence of mining processes in the coal mass from this mine will be equal to the values corresponding to the beginning of the attenuation stage for this longwall, subject to its consideration as new.

Clauses 4.2.4 [1], A.2.8.1[2] and 3.27 [3] of the current regulatory documents govern the fulfillment of the following conditions: the great boundary angle in the not undermining rock massive is $\delta 0 \geq 70°$; the old longwall is located in the zone of influence of the working longwalls; the old lava was not undermining before; in the calculations from the existing longwall, the repetition of the undermining was not taken into account; coal seam dip angle $\alpha \leq 25°$; lack of sagging of overburden rock over old longwalls.

Regarding the mechanism for calculating the influence of the old longwall, paragraph A.2.8.3 [2] regulates the calculations as for the existing longwall, provided that the maximum subsidence is determined using the formula that takes into account the difference in maximum subsidence during repeated and primary mining work equal to 0.15. In this case, the calculated displacements and deformations caused by the previously worked out longwall during the reactivation of the displacement process correspond to the values of the attenuation stage.

According to the works [4], [5] the geomechanical model is dynamic and depends on mining and geological factors. Changes in the stress fields of the rock mass over time occur according to rheological curves or the stress relaxation curve. These curves characterize the decrease in the stresses of the rock mass in time to the to the level of initial geostatic stresses

Depending on the type of rocks, the stress relaxation period can be can be from several days to tens of years [6], [7]. Also, in addition to the physicomechanical properties of rocks, the relaxation period depends on fracturing, the presence of clays and weak rocks in the massif.

A method is proposed for taking into account the influence of old mine workings according to the rheological stress relaxation curves of Donbass rocks taking into account the residual stress in the rock mass.

The proposed method, using the dependences of the change in the stress state of the rock mass over time, will significantly clarify the geomechanical model of the situation in the zones of influence of mining works, which helps to increase the safety of mining operations.

The practical implementation of the proposed method was tested on the data of the observation station NS-1158 along the main gas pipeline, developed by the Heroes of Cosmos mine in western Donbass.

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THE ROCK MASS STABILITY ESTIMATION THEN THE ZHDANOVSKOE DEPOSIT'S LENS–SHAPED ORE BODY IS MINED

Mining the lens-shaped or complex-shaped deposits by open stoping method presents difficulties with optimizing parameters of stopes and pillars and determining the sequencing of mining. In addition to complete excavation of the lens' deposits, it is important to provide the rock mass stability.

Lens South-West-2 (SW-2) is located at the southwest area of the Zhdanovskoe deposit. Lens SW-2 is complex-shaped with several apophyses and has pinch-and-swell form to the dip and on the strike (Figure 1). The lens measuring approximately 60 m on the strike and 55 m on the dip and having a maximal thickness of 75 m. Dimensions of the lens make it possible to use the open stoping mining method [1]. Due to the complex-shaped configuration of the lens, it was decided to mine out the lens' reserves by stages, with the pillar remained and its excavation at the last stage.

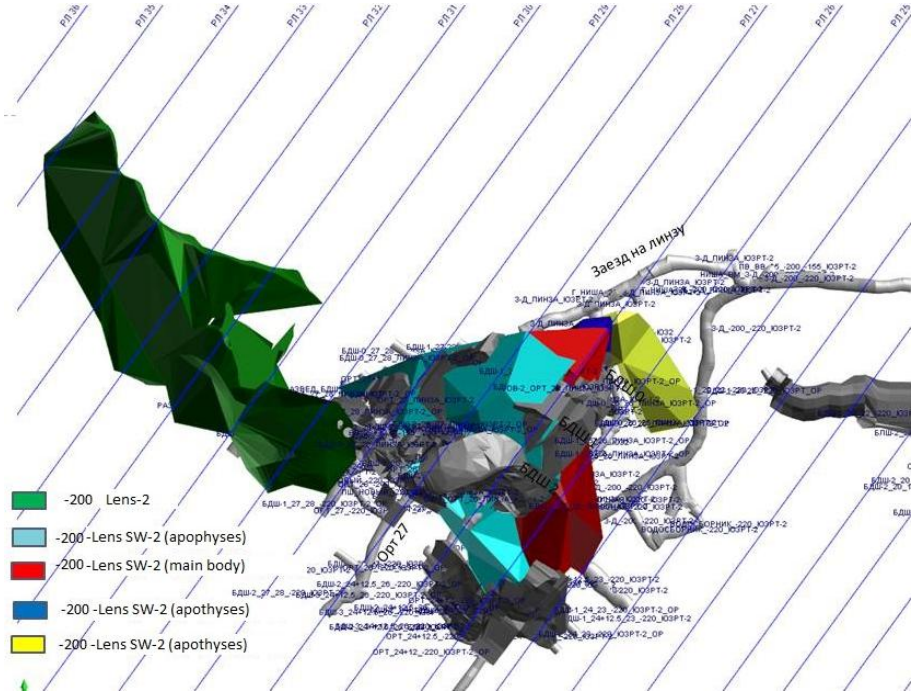

Figure 1 – Southwest lenses of the Zhdanovskoe deposit

Two main mining safety challenges arise in this area of the Zhdanovskoe deposit taking into account the above-mentioned difficulties. The first is the determination of stable dimensions of pillars and the second is ensuring the efficient span of stopes. To solve these issues, two-dimensional modeling of rock mass stress state using finite elements in elastic conditions was used. Two models of rock mass stress state were created in vertical section: on the strike and across the strike of the ore body [2]. Strength and deformation characteristics of general types of rocks were studied by scientists of Mining Institute KSC RAS and its average magnitudes were used in models. Stress magnitudes acting in the rock mass were measured by the doorstopper method in-situ in the area of South-West ore body [3]. As a result of the in-situ stress state analysis the gravitational-tectonic type of stress field was considered for modeling. The presence

of tectonic stresses was confirmed by the rock mass stress measurements and visual observations of workings.

The distributions of maximum and minimum stresses were obtained as a result of rock mass stress state modeling. From the analysis of stress field calculated by numerical modeling it was determined that the rock mass stress state around the stopes and pillars is stable in suggested technological parameters and the sequence of mining stages.

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HARDWARE-AND-SOFTWARE COMPLEX FOR GEO-ECOLOGICAL MONITORING OF EARTH SURFACE AND ROCK MASS MOVEMENTS

Dramatic changes in social, political and economic spheres of Lugansk People's Republic life, which are currently taking place can not always be managed, and lead to unpredictable changes in the environment. Problems with coal mines (their closure, restructuring, destruction as a result of hostilities, etc.), which have traditionally been the source of the region's economy, influence on the state of lithosphere. Observing the movement and deformation of the rock mass, the earth's surface and the objects under protection is one of the main tasks of mine surveying service of mining enterprise. Geo-ecological monitoring of unfavorable changes in the earth's surface and rock mass condition is an essential component of the ecological safety of the region. The Republic lacks the system to monitor the development of the process of the earth's surface and undermined rock mass shifting. Currently it is represented by separate observation stations which are quite outdated and rare in their number. Their technical condition is unacceptable, automation, system analysis and generalization of the observation data are not available. In this regard, now it is essential to launch local and regional networks of automated observation stations to perform instrumental periodic high-precision survey measurements.

A design of measuring station [1] to observe the movement of rocks has been developed at the Donbass State Technical University. There also a technique for continuous monitoring of the development of deformation processes has been suggested. It involves observation of deep benchmarks embedded in the rock mass and surveying instrumental observations on the earth's surface, as well as the use of a laser to increase accuracy [2]. However, the automation of the observation process has remained at a technically unacceptable level.

In this paper we suggest to improve available technical solutions [1, 3], creating on their background a hardware-and-software complex (HSC) to study displacement and deformation of rocks and the earth's surface, and in comprehensive research of the territory to organize a network of similar HSCs, with reference to the Center of laser-optical measurements "Orion", which is a structural unit of the Donbass State Technical University.

The HSC includes three main components: mechanical, hardware, and software. The mechanical component is represented by an observation station [1], which includes a vertical

well drilled from the earth's surface to a depth that is safe for second working. In the well, the required number of anchor-type deep benchmarks is fixed, they are connected mechanically (by wire) through a concreted driving pipe and a ball-bearing block system with a control and measuring device on the surface, which allows both mechanical determination of the benchmarks repositioning and automatic, using the appropriate hardware component. To determine the horizontal and vertical displacements of the earth's surface at the station's location, before underworking, two monumented benchmarks are laid along the dip lines and tapped seams. Then measurements, based on the registration of changes of indicators' position on a mechanical scale, with automation according to the method described above, are made using a special device [3].

Hardware component. In contrast to the method of recording changes in the indicator's position only on the mechanical scale of the measuring station [1] (or with an extra device such as camera), it is suggested to use a special elastic devise with resistance strain gauge and other auxiliary components fixed on it. A tension spring is attached to each permanent load; the rigidity of tension spring should ensure sufficient movement of the deep benchmark inside the well. There is a strain gauge indicator between the spring and the end of the wire of the deep benchmark. It will provide continuous monitoring of the movement and deformation of the undermined rock mass and the earth's surface.

As a result of the movement of the deep benchmark, the elastic element is deformed together with resistance strain gauge. The changes of resistance of the strain gauge indicate the movement of the benchmark. The function of the spring in this process is conditioned by the need for free movement of the benchmark in the well. Strain gauge indicator without a spring prevents the independent movement of benchmark, but will only transmit indications about the force acting on the benchmark until the cable breaks or one of the mechanism units fails.

Software component. Strain gauge indicators are controlled automatically using microcontrollers of the AVR family because of their availability, low cost and versatility. Analog signals of the sensors come to the amplifier, then to the analog-to-digital converter of the controller for their subsequent conversion into digital signals. Next, the arithmetic-logical device calculates according to predetermined formulas and determines the characteristics of the benchmark movement in the context of usual units of measurement.

Data from each benchmark can be written to a memory card, displayed on a PC, external display, transmitted via radio channels, after connecting the necessary modules to the microcontroller and having the required wiring. The software will give the opportunity to use the power of the controller as efficiently as possible, as well as open up possibilities for upgrading the device. HSC is powered by lithium-ion batteries powered by solar panels.

The developed hardware-software complex makes it possible to measure displacements and deformations of undermined strata and the earth's surface in automatic mode, and the installation of a special mobile communication unit for each complex will help to connect them into the system with a common control point. In the future, it is planned to develop a project for geo-ecological monitoring using the described hardware-software complex to solve geodesic and geo-ecological problems in the field of natural resources management of the region.

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INVESTIGATING THE PIPE PRESSURE OF WET SHOTCRETE FLOWING IN PIPES

The application of wet shotcrete technology in mine support is of great importance in some aspects such as decrease of aggregate rebound and dust, as well as improvement of supporting quality. However, a series of problem still exist. For example, the pipe blockage caused by the large resistance is often occurred and significantly affects the development of wet shotcrete [1,2]. Hence, it is imperative to study the rheological behavior and pumpability in order to ensure that the pipage of wet shotcrete is safe and effective. In term of pumpability, most research so far has focused on both rheology of fresh concrete and the lubrication layer formed at the interface between the concrete and the wall of the pipe that is the dominant factor to facilitate the pump [1,3-6]. From the point of view of forecasting and controlling pumpability, it is crucial to measure the rheological parameters of wet-mix shotcrete [7-15].

In order to explore the pressure change law of mining wet shotcrete in pipes, the rheology property of wet shotcrete was analyzed. The circuit pipe test system of pump wet shotcrete was built to analyze the relationship between pressure and flow rate, mix proportion, pipe shape. The change law of solid and liquid phase pressure was explored by FLUENT. Finally, the formula of on-way resistance used in mine production was proposed to predict the pipe pressure.

Results show: pipe pressure increases with the increase of flow rate and declines with the increase of water-cement ratio, the pressure may fluctuate at the circumstance of high water cement ratio which can cause cement overhydration and bleeding separation. It will is more beneficial to transport materials if the continuous grading and straight pipe were considered. According to the tests of mix proportion 1:1.5:2.25, the pressure drop is 0.032 $MPa \cdot m^{-1}$ and the bend pressure drop is 1.3 times higher than straight. We also conclude that solid phase pressure is bigger than liquid phase pressure and they both decline along the pipe based on FLUENT simulation. Finally, the formula of on-way resistance used in mine production was deduced.

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ESTABLISHING A 3D MODEL AND DIGITAL DOCUMENTATION OF BEAUFORT CASTLE BY USING GPS, 3D LASER SCANNING AND DIGITAL PHOTOGRAMMETRY

Laser scanning of archaeological sites provides a visualization approach for said sites and thus promotes the rich value of archaeological sites to the general public. While laser scanning is shaping the future of high-resolution 3D documentation of archaeological sites and features, it is still underestimated by professional archaeologists. Thus, this paper demonstrates an example of the potentials of laser scanning by monitoring and developing a 3D model of Beaufort Castle in Lebanon which is a historical and touristic attraction of great cultural and historic value. The 3D model obtained relied mainly on the use of laser scanning and UAV (Unmanned Aircraft Vehicle) techniques.

Beaufort or Qala'at al-Shaqif is in Lebanon, about one kilometer from Arnoun. It was built by the Romans on a high rock «Cher » overlooking the Litani River, Marjayoun plain and the Nabatieh area. Its geometry twists with the mountain, and its walls are built with local rocks. These make it seem "hidden" amid the rock. The historic castle is known as Beaufort, a beautiful fortress. The castle is built on a rocky section in a north-south direction rising about 710 meters above mean sea level. The castle spans on two levels: to the west is the upper castle that commits the junction of the extrusion, to the east is the lower castle which overlooks a steep slope above the Litani River.

The starting point was establishing a survey network using Sokkia GPS (base and rover) and setting up base on known station points near the castle to achieve a great accuracy network. These points were chosen to facilitate scanning the entire site. Upon ensuring the visibility of at

least four satellites within range, fixed accurate measurements were taken with precision. Then, the laser scanner is set up on a tripod over a known point, entering the coordinates of the occupation point and the height of the instrument. Setting up the target over a visible back sight and entering the coordinates of this station on the 3D laser scanner, the target is chosen. At this level, the camera will automatically open zoom in and focus on the target to precisely focus on the center of the target. The needed settings by are edited by adjusting the laser scanner height and back sight height and prior to scanning. As well, Phantom 4 Pro was used for the flying portion of this work. The mission included 245 waypoints distributed in 11 lines with a speed of 15 m/s and flying height of 40.7 m. The camera used is the FC6310 model having a focal length of 8.8 mm and pixel size 2.41×2.41 μm mounted on the Phantom 4 Pro. The mission had an 80% side and front overlapping. The total flying time was about two hours with the drone's maximum flight time being 30 minutes.

Agisoft Meta-shape is a stand-alone software product that performs photogrammetric processing of digital images and generates 3D spatial data to be used in GIS applications, archeological documentation, and visual effects production as well as in indirect measurements of objects of various scales. The data collected by the Phantom 4 Pro and by the laser scanner was projected into the same coordinate for processing. Agisoft processed around 560 digital images alongside the Ground Control Points (GCP) for an accurate final model. At the end of the process, the Root Mean Square Error (RMSE) from the forming 3d model through the report taken from Agisoft was checked. Cloud Compare is 3D point cloud processing software such as those obtained with a laser scanner or Digital image (point cloud). It can also handle triangular meshes and calibrated images by converting the Digital photos to point cloud (using Agisoft). The two models are integrated by the registration of point clouds using ICP tool and taking the reference the laser Scanner and photogrammetry. The error decreases after integrating the photogrammetry cloud with accurate reference laser scanner cloud.

This study has established an accurate 3D model of Beaufort Castle using terrestrial laser scanning and Phantom 4 pro photogrammetry to get digital documentation of the place from different directions. Laser scanning showed a high data acquisition rate in the perpendicular direction, whereas photogrammetry generated high-level planar point clouds. Such tools proved their efficiency in scanning archaeological sites since they can determine the layout conditions and topographical features based on an ortho-image. Yet, such techniques could still be of limited application if precise survey drawings are required. Constructing a 3D model of the topography along with building shapes through a hybrid convergence technology was a key issue. The accuracy of the two technologies based on GCPs before their convergence was analyzed: laser scanning has higher positional accuracy than photogrammetry, and the overall discrepancy of the two technologies was sufficient to generate convergent data. The photogrammetric point cloud data was, then, aligned and merged based on the laser scanning results. Photogrammetry could improve the 3D model by complementing the point cloud data for the upper parts of buildings which are difficult to get through laser scanning, thus increasing the accuracy of the overall topography as well as the shape of an individual building. Documenting archaeological sites and preserving all the information and details about them have always been considered important especially during natural disasters and wars. Nowadays, and with the rise of terrorist attacks in the region as in Iraq and Syria, it has become a national duty to preserve the legacy and revitalize the economy through tourism.

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ENHANCING HARD ROCK ORE EXTRACTION USING EMPIRICAL MODELLING

Drilling and blasting is among the most economical way of reducing in-situ ore deposits to smaller sizes compared to the direct use of mechanical extraction methods [1]. This is because mechanical means are costly, time-consuming and less effective in hard rock mining. Accurate prediction and measurement of blasting rock fragmentation are of great importance in hard rock ore extraction. This is because the post-blast ore size distribution dramatically influences the efficiency of all the proceeding downstream rock handling and processing [2]. Also, the secondary breakage of the rock size, when used, results in an unnecessary increase in the production cost. This research work was done at Kibini quarry, in Kenya, currently the site has been producing large number of boulders from primary blast. This calls for secondary blasting to minimize the boulders to fragments of required size. These boulders produced by poorly designed blast slow down materials handling process and give rise to the overall cost of mining.

Different empirical rock fragmentation models have been developed and adopted in predicting the fragment size distributions in hard rock drilling and blasting operations. The mostly used models are Kuz-Ram, Modified Kuz-Ram and Kuznetsov-Cunningham-Ouchterlony (KCO) which are easy to use and give reliable prediction [3]. Empirical rock fragmentation modelling, when used together with image processing, provides an easy, fast, and inexpensive method of analysing the rock size distribution, thus optimizing the production. The Kuznetsov-Cunningham- Ouchterlony (KCO) was employed in this research to determine the most suitable blast design for use in Kibini quarry.

Blast design parameters were acquired through field measurements on the site This included explosive parameters, geometrical parameters and geo mechanical rock classification data. The data was used for blast fragmentation prediction using empirical formulae. The rock mass classification was done based on Bieniawski's geo mechanical rock classification. For the prediction, a python code was developed to assist in the determination of the models' particle size distribution. For this research work, Split-Desktop, industry-standard software for image analysis in mining developed by Split Engineering was used. Split-Desktop program is an image processing software that uses grayscale to determine the blast rock fragments particle size distribution . Digital images are normally acquired using a digital camera or smartphone. Several images were captured using a smartphone with an installed Split-Camera application with scale object in place. This study modelled the existing blast design using KCO and analysed the post blast fragment sizes. The study suggested new blast design based on empirical methods. The proposed blast design was modelled and the post blast fragment size distribution analysed. Split Desktop was used for measurement of post blast particle size distribution. A comparison was drawn and optimal blast design was identified.

This research work was able to successively reduce the large boulders produced at the quarry site with less impact on the number of fines produced per blast. The finding can be used to further develop more optimal blast designs in hard rock ore excavation sites. Empirical modelling was identified as a key tool for optimizing blast fragmentation size distribution.

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USAGE OF LASER SCANNING TECHNOLOGY FOR RESOLVING OF GEOTECHNICAL PROBLEMS IN OPEN PITS

Ensuring the stability of open pit slopes is an important task for efficient and safe mining operations. Monitoring of pit walls and dump massifs is required for safe work in open pits of complex and multi-structural mining fields. The purpose of these observations is the preliminary detection of deformations and quick assessment of danger level of these deformations. That helps to take measures that outpace the danger development to ensure the safety of the following mining operations. In connection with the frequent changes of weather conditions in Kazakhstan and long distances between mining facilities and cities, ground-based laser scanning is still the most convenient method for obtaining detailed information with an accuracy of 0.5–5 mm at any time of the day with the following processing in the office. [1] This presentation shows personal experience of using laser scanning technology in the open pits of Kazakhstan for solving geotechnical and production problems.

Laser scanning has been used to monitor the ledges and pit walls for about the same time as radars (it emerged 10-12 years ago). Such a late introduction of this technology is explained, firstly, by the absence of long-range scanners with a scanning range of more than 2 km and, secondly, by the complexity of processing huge volumes of received data in real time. The latter problem has not yet been fully resolved, so lasers are usually used as a medium- and long-term estimation of ledges and pit walls condition, although nowadays several companies introduced lasers with the range of up to 6 km. Another disadvantage of laser monitoring is its strong dependence on weather conditions and the general pollution of the open pit atmosphere. Nevertheless, laser scanners are a powerful high-precision tool for collecting data, building 3D digital terrain models, which allows detailed comparison of subsequent scans with each other in order to detect changes in the position of ledges and sides of the quarry. The author personally has an experience of application of Leica HDS 8800 mining laser scanner in some open pits Kazakhstan [2].

During scientific research, the land-based laser scanning method was used to obtain data on the geometrical parameters of open pits, elements of rock jointing and discontinuous faults, rock dumps and other objects located on the earth's surface. The accuracy and detalization was characterized by the distance between the device and the object, as well as by the scanning density. It is possible to obtain to obtain elements of rock jointing and sizes of structural blocks using the results of surveying with a laser scanner when the device is located on the distance no more than 800 meters from the face of a slope. This creates a unique opportunity to obtain information without a direct contact.

After scanning on a computer using a specialized program, a point cloud with a photo overlay was created. The obtained volumetric digital point cloud of the surface was processed in order to obtain the parameters of joints and cavings (dip and strike angles, the sizes of structural blocks formed by joints) as well as the geometric parameters of the slopes, open pit walls and the remote detection of erosion, landslides and collapses. The presentation contains examples of the implementation of laser scanning at several gold ore and iron ore open pits in Kazakhstan and CIS countries. The adjacent rock massifs are composed of both hard rocks and clay soils, which

makes it possible to evaluate the multifunctionality and universality of the use of laser scanning technology.

With the help of the above-mentioned method, jointing, dangerous sites were identified, block sizes were assessed, digital models of open pits and dumps were created, geotechnical evaluation and fixation was carried, followed by recommendations for further monitoring and installation of surveillance stations [3].

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SMART CAMPUS

3D building models with roofs are important in several fields, such as urban planning and BIM (Building Information Model) [1].The prevalence of GIS in the job routines of new industries, as: government, business, and higher education institutes, has urged GIS users to request preferable third-dimensional functionalities. Three dimensional (3D) Geographic Information Systems (GIS) are the appropriate systems for storing, manipulating and visualizing spatial data in urban environments [2]. Accordingly, universities, being one of the massive facilities for new applicants, made use of GIS in several fields as in admission and facility management. This venture pursues to provide a new web-based facility with updated data for new applicants, to better comprehend the university's campus.

The primary objective of this project was to create a third-dimensional model of Block D, being one of the blocksin the Lebanese International University, Beirut,Lebanon that can be viewed inside-out.

The methodology of work for this project is divided into three stages: data collecting, field measurements and finally data processing. The collected information and data were about the employees and the schedule of courses in the block. This employees' data includes their names, emails, extension numbers, tasks, as well as working schedules, in addition to the schedules of courses occurring in each room. These collected data were organized in excel sheets. During the field measurements, a detailed building survey was done by creating free-hand sketchesfollowed by dimensional measurements using appropriate survey equipment.Finally, in the office the process was done by the integration between3software applications: "AutoCAD" for drawing, mapping, modification and cleanup of 2D floor plans, "GIS" for polygon creation and data preparation, and "City-Engine" for the generation of 3D models.

Accordingly, the final 3D model was generated by means of a unique programming language within the "City-Engine" software, known as the Computer-Generated Architecture, CGA rules. The ultimate 3D model was then exported to the Web Viewer that provides different action options such as: layers, search, settings, share, information tab and swipe view.

Eventually, the world is on track to meet the needs of the information technology development. In which, the integration between the three software applications: "AutoCAD", "GIS", and "City-Engine" has succeeded in fulfilling people's needs and meeting the urge of

GIS users to request preferable third-dimensional functionalities. By means of this web viewer, students and future applicants will be connected to different kinds of block information starting from the desired destination, registration offices, up to the schedules within the block. The application of such prototype is not restricted to universities. Actually, the ability of "City-Engine" to merge between GIS data and the 3D modeling concept can be further on utilized in smart city planning and better Green City applications. Procedural modeling uses a lot of building knowledge and can create near real city scenes [3]. The generated models can thus provide several contributions in various fields such as: electrical, waste management, and environmental.

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A STUDY OF THE HORSESHOE-SHAPED TUNNEL

Circular tunnels are the most popular in the urban metro system due to the fact that this shape is the one of the most stable shape. However, the disadvantage of circular shape is a small space utilization ratio. The horseshoe shaped tunnels have a higher space utilization ratio in comparison to circular ones. Therefore, the excavated soil of horseshoe tunnel is smaller than that of circular one. This shape investigated by many authors which using analytical [1] [2] or numerical method [3] [4] [5]. Today, tunnel boring machine could be excavated various tunnel shapes, such as circular, oval, sub-rectangular, horseshoe shape which depended on many technical purposes. The world's first horseshoe-shaped manufactured China and used at Baicheng tunel in the Menghua railway route. All the above literatures do not mention how the horseshoe tunnels were designed. Other studies have a drawback which is not determined exactly the tunnel construction clearance. Therefore, in this study presented an algorithm to determine the internal dimension of horseshoe tunnel based on the construction clearance of double-track metro from Vietnamese standards [6].

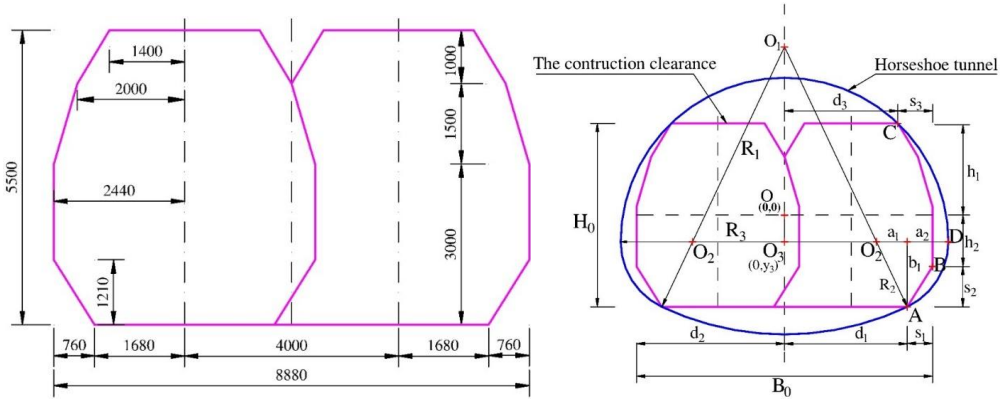

Figure 1 - The construction clearance of double-track and the geometrical configuration of horseshoe tunnel (B_0 = 8.88 m; H_0 = 5.50 m; s_1 = 0.76 m; s_2 = 1.21 m; s_2 = 1.21 m, s_3 = 1.07 m; d_2 = 4.44 m; d_1 = 3.68 m; h_1 = 2.75 m; h_2 = 1.54 m, $h1=H_0/2=h_2+s_2$)

The algorithm determined horseshoe shape follows these steps: (1) The center O3 selection and calculate radius R3; (2) Determine the location of center O2; 3) Determine the location of center O1. Assumed the position y_3 of center O_3 is known (on the vertical axis, $-h_2 < y_3 < 0$). The radius of crown, sidewalls and invert part of horseshoe tunnel is determined step by step.

$$R_3 = \sqrt{d_3^2 - (h_1 - y_3)^2} \quad (1)$$

$$R_2 = \sqrt{(x_2 - d_1)^2 - (y_2 + h_1)^2} \quad (2)$$

$$R_1 = \sqrt{d_1^2 - (-h_1 - y_1)^2} \quad (3)$$

Base on the construction tunnel clearance (TCVN) [6], the minimal internal dimensions of circular tunnel is determined, see Figure 2 (b). With the value of yO3 = -0.8m, according to the algorithm presented in the above part. The internal dimensions and shape of horseshoe tunnel is determined (see Figure 2a)

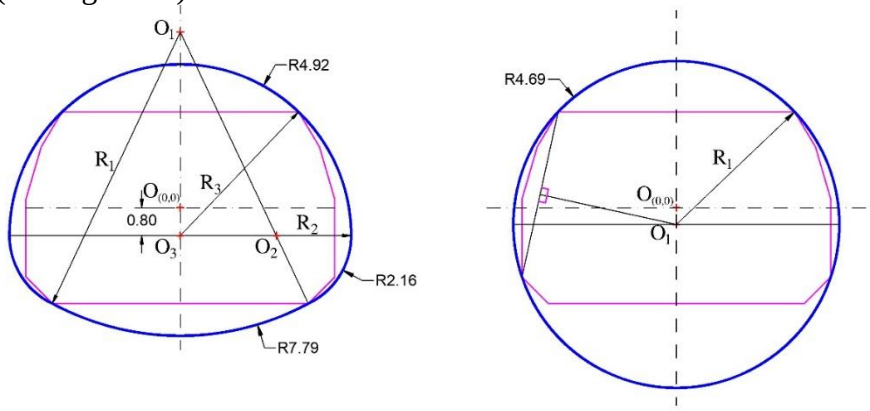

Figure 2 - Geometry of horseshoe and circular tunnel

The maximum bending moment difference between the HRM and Plaxis 2D model in horseshoe and circular tunnel equates to 7.32% and 1.77% respectively. The minimum bending moments induced in in horseshoe and circular tunnel derived from HRM model are given by 4.99% and 0.69% respectively and are higher than those from the Plaxis2D model. Overall, the derived bending moment from HRM model and Plaxis 2D model have same shape and a slight difference is observable on the magnitude. The HRM model's maximum normal forces induced in horseshoe and circular tunnels are 4.93% and 5.52% respectively. The HRM model's minimum normal forces induced in horseshoe and circular tunnels are 1.73% and 6.36% respectively and are greater than values which were measured through the Plaxis 2D model. These are less than values which were obtained through Plaxis 2D simulations.

In both of HRM model and Plaxis model, the maximum bending moments induced in horseshoe tunnel is 2 times higher than those of circular tunnel. The maximum shear induced in horseshoe tunnel is 3 times higher than those of circular tunnel. There is a little difference between maximum normal forces induced in circular tunnel and those of horseshoe tunnel. Although the internal forces produced in the circular tunnel lining is smaller than those of horseshoe tunnel lining, the internal area of horseshoe tunnel is 0.87 times smaller than that of circular tunnel, respectively 60.3 m2 and 69.1 m^2.

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ASSESSMENT OF THE IMPACT OF SPACE-PLANNING DECISIONS OF METRO INTERCHANGE STATIONS ON THE DEVELOPMENT OF GEOMECHANICAL PROCESSES IN THE SOILS

The construction of new subway stations and lines is associated with the construction of interchange stations. The correct choice of space-planning solutions depends not only on the convenience of changing the direction of passenger traffic, but also the trajectory of intersecting lines, and, consequently, the volume of construction work and the timing of commissioning of objects. In addition, design solutions determine the value of subsidence of the earth's surface in the construction zone and the stress-strain state of the structures themselves, which are the primary factors determining the possibility of construction. Domestic and foreign research scientists have been engaged in optimizing the parameters of underground structures based on geomechanical analysis. The research of Podakov V. F. [1], which became a continuation of the scientific works of Limanov Yu. A., was the basis of the normative method of forecasting earth surface movements for the geological conditions of St. Petersburg. D. M. Potts and L. Zdravkovic [2] made a study of the use of numerical analysis methods for solving problems of geomechanics of underground construction.

For the most part, transfer stations are represented as separate station complexes connected by transition corridors. The location in terms of plan and depth can be very diverse. In the work [3], attention is drawn to the important role of the relative location of the second station and the transition corridor in relation to the first station in depth. When a new station passes below an already constructed station, an additional activation muld is often formed. In this case, less influence on the earth's surface and on the formation of alternating complex stress-strain state in the structural elements of the interchange station is provided when the stations are located in parallel. If there is an angle between the longitudinal axes of the stations in the plan, the subsidence of the earth's surface can increase up to 1.7 times, other things being equal. If the stations are located at the same level in parallel and the new station is built perpendicular to the existing one, the forecast of the earth's surface subsidence from the influence of the construction of the second station is made using the calculation scheme for single tunnels. In most cases, the mutual influence of workings is manifested in increasing of tangential stresses σ_θ. Therefore, during construction, designers try to minimize the zone of increased stress by orthogonal coupling. In parallel, the values of the resulting stresses on the contours of the workings depend on the distance between the longitudinal axes. According to current practice, it rarely exceeds 1-1.5 of the equivalent station diameter, which is the reason for the high level of tangential stress values on the workings contours: with a hydrostatic stress field, they can reach 2.5 σ_3, and with $\sigma_1 = 0.25\ \sigma_3$, they can reach 3.5 σ_3. For this reason, we can assume large values of subsidence of the earth's surface.

The next qualitatively new type is the combined interchange station, which don’t have the disadvantages of separate station complexes connected by transition corridors. One of the most successful construction is the combined two-tier interchange station, the arches of which are made of reinforced concrete blocks compressed on soils and supported by side supports, that

erected in tunnels. This construction was implemented as the "Sportivnaya" station of the St. Petersburg subway. The author [4] provides detailed information about the duration of technological operations of construction, subsidence of the earth's surface by stages of work, and the stress values in temporary and permanent structural elements. Also, studies on models made of equivalent materials have shown that contact stresses reach the values of long-term strength of Proterozoic clays only at a load of 160-170% γH, which allows us to consider the station design reliable. A certain proportion of surface subsidence is due to the fact that the upper and reverse arches are represented as reinforced concrete blocks compressed into the soils.

To reduce the values of subsidence of the earth's surface, it is possible to use a low-subsidence construction technology of the station by constructing arches of reinforced concrete monolithic arches and microtunnels, following the example of the underground railway station "Porta Venezia" in Milan. To consider this variant of the interchange station, calculations were made taking into account the engineering and geological conditions of St. Petersburg, also the technological sequence of construction of the structure. Calculations were performed in software packages based on the finite element method. The results of the calculation confirmed the advantages of this method of construction in relation to the traditionally used methods of constructing interchange stations in St. Petersburg.

Thus, it seems appropriate to use the combined interchange stations of the subway, performed on a low-subsidence construction technology. This design will allow construction in the central part of the city, near ground objects of historical and cultural value and other structures, that are very sensitive to the displacement of the earth's surface.

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PRESERVATION OF UNDERGROUND CULTURAL HERITAGE WITH INTEGRATION OF MODERN AND CLASSICAL SURVEY METHODS

Advances in the knowledge about the Cultural Heritage (CH) in the recent years, made people notice the need of protection or conservation of a long historical development. Cultural Heritage distinguished in build environment (buildings, townscapes, archaeological remains), natural environment (landscapes, coasts and shorelines, agricultural heritage) and artefacts (books, documents, pictures) is unique and irreplaceable. Undeniably, a special place in the field of the Cultural Heritage should have historical underground objects. There are many underground objects all over the world – both of natural (caves, grottes) and anthropogenic origin (mines, military objects) which had an enormous influence on the development of underground construction and architecture. Over the centuries, several generations of miners shaped an amazing underground world of excavations and drifts. Each of these monument has significant historical and aesthetic values. Moreover, an increase in interest of the underground mining heritage is noticeable. More and more mines and decide to make their excavations

available as museums which results in a need of special process of preservation and making it available for safe tourism [2].

Nowadays, innovative and wide understood geotechnologies have proven their usefulness in the field of recording, modelling, visualizing, conserving and protecting objects of historical significance [1, 4]. Additionally, current and fast developments in heritage (Historical) Building Information Modelling (HBIM), which enables storing of spatial information and metadata and provides the means of documenting changes that such structures undergo, allows for rapid exchange of information and data between specialists in various fields - surveyors, geotechnicians, designers, architects, archaeologists [3].

In this paper, authors focused on the process of using classic geodetic methods (precise geometric levelling, precise polygonization enhanced by gyroscopic measurements) and modern Terrestrial Laser Scanning (TLS) in preservation of underground cultural heritage. The measurements were conducted in Wieliczka Salt Mine (The Chapel of St. Kinga - the world's largest underground temple and Nature Reserve Crystal Grottoes) inscribed on the UNESCO World Heritage List and in natural environment of Nietoperzowa cave in Poland (accurate caves inventories has always been fundamental to understanding their origin and provide tools and information to predict their future). TLS measurements have provided collection of a huge amount of precise data in a really short time. This provides flexible procedures that make it adaptable to suit different geometric conditions in caves and underground excavation. The final effect of the measurement called point clouds (several hundred million points with known X,Y, Z coordinates) allowed to make spatial models of inventoried objects and further computer-based analysis (precise convergence and displacement determination of mining excavations and mapping the cave in its true 3D geometry).

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THERMALLY STIMULATED ACOUSTIC EMISSION (TAE) METHOD FOR ESTIMATION OF CHANGES IN ROCKS DEFORMED STATE UNDER QUASISTATIC LOADING

At present, a number of deposits of mineral resources which can be relatively easily found be geological exploration tend to deplete. Both first and production mining become deeper and more intensive, which leads to a higher risk of slips, falls, rock bumps and other dynamic

rock pressure manifestations [1]. Mitigation of these risks requires justification and use of efficient preventive measures to ensure control of rock conditions. A precondition to solve the problem is availability of reliable and time-sensitive information on the stress-strain behavior (SSB) of geological environment. Geo-control methods [2], existing and available at present, although having some benefits, are also not free from disadvantages, among which labour intensity of measurements and interpretation ambiguity can be identified and highlighted.

Practically, these disadvantages result in poorer informational efficiency of geo-control and higher risks of overlooking the signs of hazardous geodynamic conditions. In this connection, a critical task is to improve existing methods and create new ones, which could be used both individually and in conjunction with conventional geological, geo-mechanical and geo-physical methods to control SSB. Recent research work bears evidence of prospects of solutions to this and other geo-control-related problems, based upon analysis of informative parameters of the acoustic emission, thermally stimulated within geo-materials subject to research [3, 4].

In view of the above-mentioned, the purpose of the present paper is to experimentally determine and theoretically justify patterns of changes to parameters of thermally stimulated acoustic emission of rocks, subject to dynamics of their deformed state.

For experiments, limestone was used, originating from the Sary-Tash deposit, samples of which were in the form of square cross section parallelepipeds with ground end faces. In the course of the experiments, the samples were exposed to thermomechanical loads, which were of mechanical nature and incrementally increasing to values of 4, 7, 10, 14, 18, 21 MPa, subject to fast heating to 180°C with further convectional cooling at each increment of load. The samples were subjected to thermal impacts upon stabilization of a spike in activity of acoustic emission (AE), following the mechanical loads as above, which permitted to separate a useful signal from interferences.

The following informative parameters were used: AE activity $\dot{N}_{\sum}$ and pulse duration D_{imp}, which were averaged by time marks. The parameter D_{imp} characterizes an average duration of TAE signals. Under other similar conditions the structural bonds are able to emit a proportionally longer signal. Therefore, a value of D_{imp} enables to separate those TAE signals in a signal stream that relate to strong bonds. Apparently, the latter determine the strength properties of rocks to a far greater degree, and information on their destruction is of vital importance of evaluation of residual strength of geo-materials. Against this background, for quantification of residual strength of rocks by the example of limestone samples test results, the following acoustic-emission criterion R was suggested:

$$R = \frac{N_{\sum}^{A} \times D_{imp}^{A}}{N_{\sum}^{B} \times D_{imp}^{B}},$$

where $\dot{N}_{\sum}{}^{A}$, $D_{imp}{}^{A}$ and $\dot{N}_{\sum}{}^{B}$, D^{B} are values of $\dot{N}_{\sum}$, D_{imp}, averaged by the time of "A" (time domain of AE signals on, stimulated by a field of thermal gradient) and "B" (time domain of AE signals generation, stimulated by a field of stationary temperatures with samples, heated to a maximum temperature) domains, correspondingly.

Physically, the criterion R is meant to reflect a degree of rock resistance to external factors. In this particular case, the only variable factor was a value of mechanical load. Thermal impacts in all experiments were the same, and the identity of the samples in the structure and properties was validated with the use of visual, optical and ultrasound methods. Therefore, the criterion R can be reasonably considered as a criterion to evaluate the residual strength of limestone, exposed to increasing quasi-static mechanical loads. Figure 1 presents a cloud of R-values obtained, as a function of mechanical loads P, used for obtaining these values.

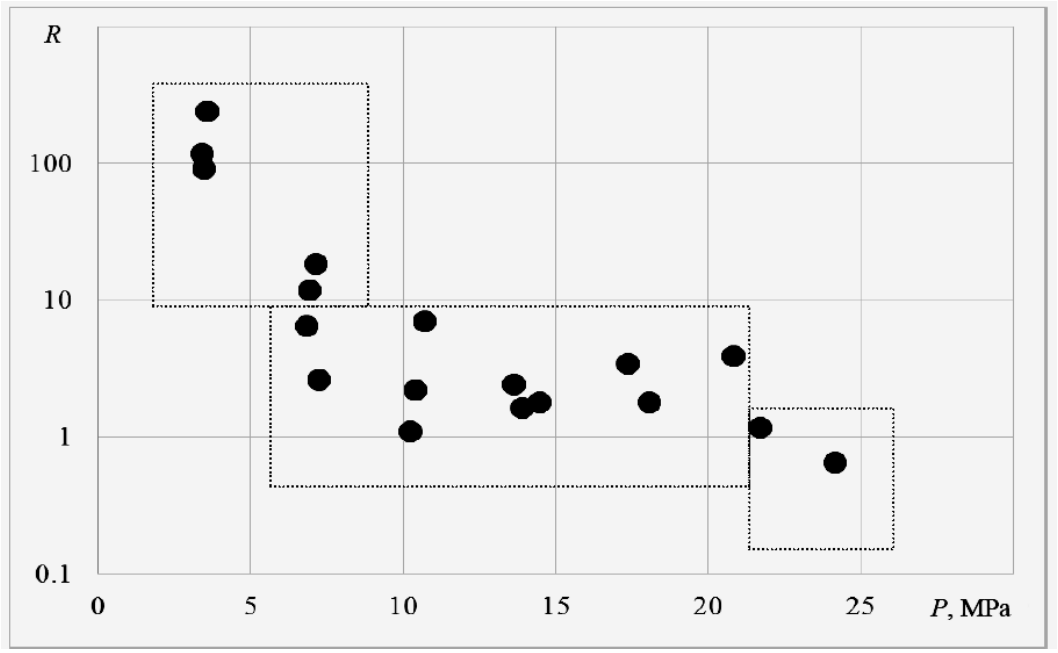

Figure 1 - Relationship between the acoustic-emission criterion R and values of mechanical loads P, with which the values of R were obtained

Presented and theoretically justified is an experimentally proven relationship between TAE parameters in the limestone samples and the evolution of their deformed state, when exposed to increasing quasi-static mechanical loads. Physical preconditions, underlying this relationship, are interpreted, and they enable to justify the new acoustic-emission criterion R for quantification of the residual strength of rocks. A possibility in principle was shown, how this criterion can be used for detection of a sign of fast fracture of an object tested. The results obtained may be used both for developing a new acoustic-emission related method to control strength properties of rocks and finding solutions to forecast problems related to assessment and evaluation of hazardous geodynamic conditions during performance of primary mining (expensed development), underground extraction of mineral resources and other mining operations.

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MATHEMATICAL REPRESENTATION OF DEFORMATION AND DESTRUCTION OF ROCK SALT AT MICRO LEVEL

It is known that rock salt is the most favorable rock for the placement of various underground storages of natural gas (Liu et al., 2019), crude oil (Zhang et al., 2017), and

compressed air energy (Bérest et al., 2014), due to such properties as: low porosity, low permeability and high ductility. But over time, excessive deformations of the pedigree contour of the proposed storages can occur, and hence the loss of the effective storage volume (Yang et al., 2016). The main cause of high deformations is the creep of rock salt itself, as well as the oscillatory process caused by the operation of the structure. Thus, for the correct assessment and prediction of the behavior of the rock mass around the facilities under construction, whether it be a chamber or small wells, it is necessary to have a clear understanding of the creep process of rock salt under various loading conditions and temperature exposure. At the moment, the experimental method for determining the mechanical characteristics of rock salt is the most common and relevant. However, the duration of the experiment to determine the creep parameters is from several days to several months (Zhou et al. 2011), which is much shorter than the period of operation of the structure. Similar. Such an approach may lead to an inaccurate forecast of prolonged deformation, and therefore to problems in the operation of structures, up to emergency incidents. Based on existing theoretical principles and experimental data, geomechanical models are created to study the long-term behavior of rock salt massif.

There are currently empirical models, combined component models, and constitutive models of continuous damage. Empirical models are usually selected from experimental data with a small number of parameters and are widely used to predict the behavior of rock salts. Combined models are based on a combination of simple theoretical principles, such as Newton's dashpot, Hooke's spring and friction element. The difficulty in using example models lies in the difficulty in determining the parameters. Creep models based on evolutionary traits, initial damage parameters in the constitutive creep model (Ma et al., 2017). This category of models is more suitable for determining the degree of macrodamage of rock salt. This type of model allows a more reliable description of the tertiary creep stage.

An alternative and promising approach to studying the mechanical behavior of rock salts is numerical modeling. To date, this approach is widely used to assess the degree of creep of rock salts. In my work I use a synthetic model of rock salt behavior.

Studying the mechanical behavior of rocks at the microstructural level allows us to clarify the actual nature of their deformation and fracture, forms a new idea of the work of such media, and the knowledge gained can be used to predict the development of geomechanical processes in the construction of underground structures. The paper presents a new approach to the formation of a microstructural mechanical model of salt rocks, which includes the formation of a polycrystalline structure and a finite element calculation model. To accomplish this task, it is necessary to describe the structure of salt rocks and the main features of the mechanical behavior of salts at micro and macro levels.

The growing power of computing technology allows more and more to introduce the method of discrete elements in engineering calculations. The prospect of technology development has an exponential dependence on time, which means that in the near future the power of computer technology will increase by an order of magnitude

In conclusion, it should be noted that the main stages of the formation of the polycrystalline structure of salt rocks and the preparation of the finite element model are briefly presented in the work, and numerical simulation of the deformation and fracture of salt samples is performed. The result of this work is to find the relationship between the number of grains in the salt sample and the nature of its deformation. The number of grains has a clear effect on the dependence of normal stresses on axial deformations, only under triaxial loading. In the course of further studies, the numerical model will be improved, it is planned to calibrate the values of stresses characterizing destructive cohesive bonds. In the future, we should proceed to a three-dimensional formulation and assess the need for its use. The obtained numerical model can be used for the most accurate modeling of excavation of mine workings, holes and wells, forecasting the massif VAT and localizing areas of possible collapse.

Further development of the deformation model will be directed to the field of modeling the long-term deformation of rock salt (rheological processes) at the micro level and the

application of this approach for predicting the stability of rock outcrops in the vicinity of boreholes, wells and other small geotechnical objects.

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EVALUATING THE EFFECTIVENESS OF THE ROLL PREVENTION METHOD IN ZONAL MINES

For effective operation of a mining plant, it is necessary to ensure the normal operational condition of a mine. At a depth of more than 500 m, roll becomes one of the predominant indicators of the mountain pressure, and accounts for the largest share of the total enclosing roof-and-floor faulting [1]. In order to reduce faulting, various methods and means are used. The most of them are aimed at preventing roll and at eliminating its consequences [2]. One of the most effective methods is the use of relieve slot. The use of this method is aimed at reducing the stress in the rock mass round the workings, which leads to a roll decrease during the operation of the zonal in-seam workings [3].

Justification of the effectiveness of the roll preventing method was performed according to the mining and geological conditions of the 7 Western slope of the K_6 bank of the Nikanor-Novaya mine. When operating the mine, the section loss reaches 50% of the original value. Basic geological and mining conditions of mining are: the depth of the working of 550 m, the capacity of a coal bed 1.0 m, seam inclination 5 deg. the width of the slant 4.75, height 3.44 m, the method of protection of slop – the coal pillars, the method of controlling the face roof – cave-in. The research method is numerical modeling with the finite-element technique. To analyze the stress-strain state of the rock mass round the 7 Western slope, a three-dimensional model l was compiled. The grid size of the array model directly around the workings is 0.4 m (figure 1). Relieve slot of 1.5 m was modeled in the mine soil.

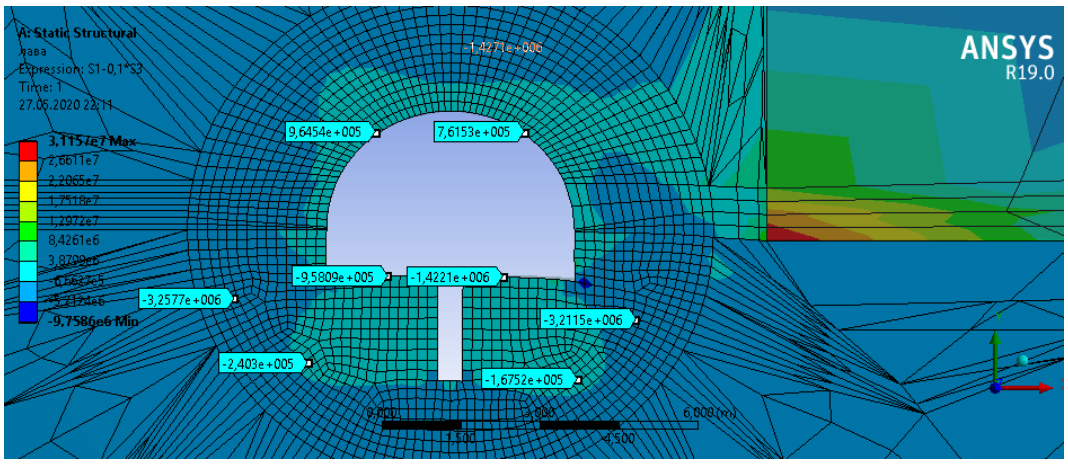

Figure 1 - Cross section of model 7 of the Western slope

Based on the model solution, we determined the stresses and deformations of soil rocks of the 7 Western slope. In the sides of the workings, there are tensile stresses, and in the soil – compressive, which are the main cause of destruction and squeezing of rocks into the cavity of the workings. Figure 2 shows graphs of soil displacement along the length of the workings; without taking any measures (1) and after creating a relieve slot (2). According to line 1, active roll occurs at a distance of 10 m ahead the face, due to the action of reference pressure. After the face, the roll activity decreases slightly, and the total roll is about 320 mm. Line 2 characterizes the roll after the application of relieve slot.

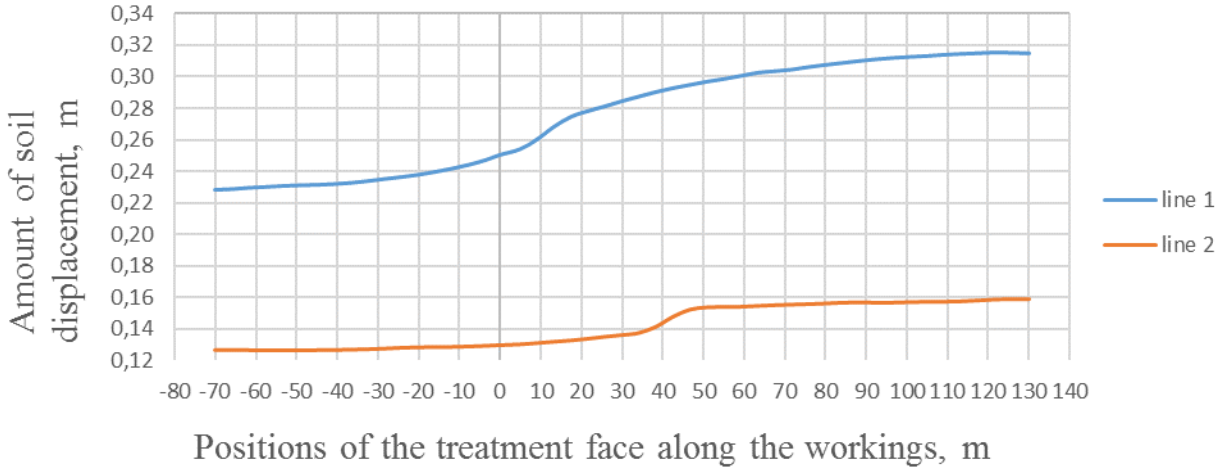

Figure 2 - Roll along the length of the 7Western slope

The use of relieve slot leads to a redistribution of the stress-strain state of the rock mass. Due to the formation of a balance slot, the stresses in the mine soil are reduced from 7.4 MPa to 3 MPa. The roll is reduced from 320 mm to 160 mm.

Numerical modeling with finite element method was used for the evaluation of the efficiency of the roll preventing method by relieve slot in the 7 West slope of the K6 bank of the Nikanor-Novaya mine. Soil displacements are reduced by 50%, and total lateral rock displacements are reduced by 28 %. Thus, the application of this measure will ensure the normal operational condition of the zonal workings and increase the efficiency of the mining plants.

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IMPROVING OF THE QUALITY OF PHOTOGRAMMETRIC SURVEY AT THE CLOSE-RANGE DICTANCES

Nowadays trend of geodetic measures and mine surveying is aimed at remote sensing methods [1]. The most dominating methods today are LiDAR method and photogrammetric survey [2, 3].

The work shows main results of the research, connected with the determination the quality of photogrammetric models and ways of its improving by variation the texture of the shooted object.

To differentiate the results of the experiment from other factors, the test model was taken with the most identical other parameters. The experiment itself has been divided into three series of shooting:

A. In natural light

B. In artificial light

C. In the infrared mode(without any light)

The result of the researching shows that 3D-models were constructed incorrectly, with distortions and deviations in natural light and in infrared mode of shooting. The results were satisfactory in a series of captures using an artificial light with projecting onto the object the television test table.

When comparing models with different textures, a direct dependence of the quality of the resulting models on the entropy of the projected textures was obtained. It was founding that even if the object has a bright, contrasting, but systematically repeated texture, program’s algorithms for automatic orientation of digital images implemented in existing software products are not able to correctly perform their functions.

This experiment demonstrates the fundamental differences between analog and digital approaches to image processing [4]. Moreover, the revealed regularities of influences of object texture content on its resulting model increase a priori and a posteriori estimates of its accuracy.

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CURRENT TRENDS IN LAND SUBSIDENCE OF THE NORTH-CENTRAL PART OF POLAND USING D-InSAR TECHNIQUE

Generally, the change of elevation expressed on the surface is known as land subsidence. There are two type of land subsidence causes: a natural cause related to geological activities such as sinkholes and thawing permafrost, which are rarely occurred; and an induced cause related to human activities linked to mining such as groundwater withdrawal, oil and gas exploration, geothermal exploration. Land subsidence typically occurred when a large amount of fluid has been withdrawn from the underground, while the overburden weight above the reservoir is relatively the same or even increased due to some infrastructures on the surface and therefore leads to compaction.

There are couple of records of historical land subsidence related to human activities such as the one that happened in Goose Creek oil field in 1925, where the entire Gaillard Peninsula parcel was submerged by water [1]. Also, a land subsidence of 14m related to high demand of groundwater and geothermal water production, near to high density populated area was recorded at Wairakei geothermal field in New Zealand [2]. Besides, the rapid increase of industry related to development of urban area was causing a land subsidence of 20 to 200 cm in Jakarta between 1982 and 1997 [3].

This paper presents the current trends of land subsidence case of Gdansk and its vicinity. The area of interest is chosen due to the fact that it is among the most populated area in Poland and dedicated to unconventional as well as conventional exploration of oil and gas, which is part of the onshore of the Baltic Basin [4]. Multiple wells with depth more than 1000 m were drilled in the concerned area. The assessment of subsidence of Gdansk and its vicinity is done using InSAR (Interferometric Synthetic Aperture Radar) images taken from two-different observation times (April 2018 and April 2020). InSAR satellite transmits radar electromagnetic waves that can penetrate clouds even in a very bad weather condition and bounced back by Earth's surface to the space and recorder by the same satellite, and these echoes contain the phase or deformation and therefore can be used to monitor land deformation.

D-InSAR is the technique used to acquire information phase between two images in order to obtain the deformation of the Earth [5,6]. Any movement happened between these time intervals is being recorded and measured by the captured satellite images. A land subsidence map of the concerned has been generated, which shows the actual subsidence in Gdansk, Gdynia, and Wejherowo, where the highest subsidence of the region happens in Lebork town. The possible reason of such subsidence is the increased infrastructure as the oil and gas production area does not show any significant change. Such result is necessary for future investments in the concerned area.

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ANALYSIS OF POSSIBLE LOADS ON COUPLING LINING OF SAINT-PETERSBURG METROPOLITAN BY MEANS OF NUMERICAL SIMULATIONS

Subway pairing is a relevant topic for research. Pairing is an inalienable part of metro construction. For example, pairing tunnels with a shaft, pairing track tunnels, exit bord – without these elements, the functioning of underground transport structures is impossible. At the same time, the accuracy of existing methods for determining the stress-strain state support lining is quite low. The calculation is performed by the analytical method. However, analytical methods for calculating conjugations taking into account the stress-strain state array include a number of assumptions, because of which it is not always possible to solve the problem accurately, unlike numerical methods. The development of geomechanics in accordance with modern requirements for the construction of underground structures is impossible without the development of numerical methods for studying the stress-strain state of the array and lining.

Scientists Minin V.A., Mirzaev G.G., Pershin V.V., Pavlova L.D., Syrkin P.S., Trushko V.L. and others highlighted the problem of ensuring the stability of mines in mine workings.

The calculation of the lining of the pairing is usually carried out by the analytical method, taking into account the height of the arch of the collapse, so the load on the underground transport structures is usually calculated [1]. In this case, the width of crut is taken as the width of the pairing. This method is reliable, however, its result can be an overestimation of the stress indicators in the lining, and, consequently, an overspending of the material, which negatively affects the economic side of construction.

Numerical modeling allows you to see the real picture of the stress distribution in the array and to obtain more accurate stress results in the lining. In the work of P.V. Deev, A.V. Krupoderov [2], a comparison was made of the analytical and numerical methods of calculation. Normal tangential stresses on the contours of rings and contact stresses were compared. When comparing the two solutions, it turned out that all the values of the stresses that influence the further calculations in the calculation by the analytical method are somewhat overestimated. The values of normal tangential stresses on the outer contour of the cross section obtained using the finite element method are significantly less than the values of stresses obtained using the analytical method. The maximum compressive stresses on the inner contour of the tunnel lining cross section also differ significantly. Otherwise, the stress values obtained by different methods are almost completely consistent [2]. Since the strength stock of the underground structure is determined by the values of the normal tangential stresses in the lining, the numerical method can be the solution to the issue of overuse of material.

All other things being equal, the displacements of the rocks and the load on the lining of the mates are significantly greater than in each of the mating workings [3], therefore an accurate

calculation is important, taking into account all the factors affecting the mating. In the tunnels of the St.-Petersburg metro, the rheology process leads to characteristic maximum lining loads. Since the subway structures in St. Petersburg are mainly laid in cambrian clays, it is the process of prolonged deformation that leads to additional loadings on the lining. Collapse in this case is a rather rare occurrence. Therefore, in the proposed numerical model, the loads caused by rheological processes are taken as the main risk factor. In this paper, the numerical modeling tool is the ABAQUS software package. The object of study is the lining of the interface between the trunk and the tunnel. Stages of the study:

- building a model;
- obtaining data on the stress-strain state of the massif and lining during mining operations;
- taking into account the development of rheology in the model.

The work aims at collecting data on the development of loads over time and processing the results, as well as determining the qualitative relationships between the calculated data and field studies in the sections of the St. Petersburg metro. It is also possible to further deepen the research by solving problems with different construction conditions and lining parameters to obtain statistics on the development of loads over time for various conditions.

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FEASIBILITY STUDY OF THE CHOICE OF THE METHOD OF ARMATURE TENSION DURING THE CONSTRUCTION OF REINFORCED CONCRETE SILOS

The purpose of this work is to select the most profitable variant of armature tension in such complex engineering structures as silos, which have become more popular in modern construction. The method of tensioning rebar "on concrete" used in silos has just begun to gain popularity in industrial construction both abroad and in Russia, so the stated topic is particularly relevant at the present time.

The paper lists the main methods of armature tension in round monolithic silos. Of these, the most promising is the tension of jacks on the stops-pilasters, which allows you to significantly increase the length of the rebar bundle and simplifies their installation. However, in this method, there are three variants of armature tension: for two anchors, for one anchor, and for one anchor, but with a change of the heavy end in the height of the silos.

Based on the calculation of the pre-stress losses of the armature in these three variants, performed in tabular form for each section of the silos wall, the stress diagrams in the armature were constructed, on the basis of which the most economical option was identified, which will reduce the number of armature in the section and the number of equipment used simultaneously on the site.

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MESO-SCALE MECHANICAL PROPERTIES OF MUDSTONE INVESTIGATED BY NANOINDENTATION

In geotechnical and hydraulic engineering fields, the widespread occurrence of mudstone is a major bottleneck restricting both the efficient construction and safe maintenance of argillaceous projects [1,2]. The mechanism of deformation and failure of argillaceous engineering tightly depend on the mechanical properties of mudstone. However, the complex nature of heterogeneous mudstone has challenged researchers to understand how mudstone behave mechanically [3,4]. Consequently, observing the structures of the mineralogical compositions in mudstone and researching their mechanical properties are hot topics and can support understand the failure mechanism of argillaceous engineering and reveal the heterogeneity of mudstone.

Herein, an experimental method coupled the nanoindentation technique, SEM-EDS, XRD, and MIP was used to observe the structures of mudstone and research the mechanical properties of its mineralogical compositions. The observed morphology and mineralogy information of mudstone through XRD, SEM-EDS, and MIP were used to establish the multiscale structure model for determining the length scale of the nanoindentation technique and revealing the multi-scale nature of mudstone. Setting nanoindentation peak loads as 1 mN, 5 mN, 10 mN and 30 mN, the heterogeneous properties of mudstone and the influence of experimental protocols on mechanical properties were analyzed; Statistical analysis results showed the correlation between mechanical parameters and mineralogical compositions of mudstone and illustrated its soft mechanism. And the values of the elastic modulus of mineralogical components were compared with macro-scale uniaxial compression results to discuss the influence of macro- and meso-scale pores and cracks on the mechanical properties of broken mudstone.

Based on the observation through SEM-EDS, XRD, and MIP, heterogeneous mudstone can be considered as a multiscale, multiphase and compositionally diverse material. The mineral compositions in mudstone can be divided into two constituents: clay matrix and silt inclusions; the multiscale structure model of mudstone includes macro-scale, meso-scale and micro-scale. Meso-scale mechanical properties of mineralogical compositions in mudstone can be investigated by utilizing nanoindentation techniques. Results show that the strength and stiffness of clay matrix are much smaller than that of silt inclusions in mudstone, inducing the soft properties of mudstone and argillaceous engineering. Based on nanoindentation and conventional uniaxial compression results, the macro-scale elastic modulus of mudstone is smaller than that of both clay matrix and silt inclusions in mudstone due to macro-scale and meso-scale pores and cracks in it.

For the mudstone, the difference of mechanical properties between mineralogical composition should be investigated in future studies to reveal its heterogenous properties.

Besides, the upscaling method to macro-scale and the downscaling method to microscale for heterogeneous geomaterials should be proposed.

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STUDY ON VIBRATION PROPAGATION LAW OF LARGE SECTION HIGH-SPEED RAILWAY TUNNEL UNDER BLASTING CONSTRUCTION

As a traditional tunneling method, blasting is still the most commonly used tunneling method due to its low cost and strong adaptability, especially under the rock geological conditions. For the development of traffic, blasting excavation is very common in subway and tunnel excavation.However, blasting has also brought many problems and hazards, especially some effects on the surrounding environment, such as blasting seismic wave effect.These damage will be critical to the safety of people's lives and property, and it is easy to cause conflicts .At present, scholars have done a lot of research on blasting vibration control and monitoring attenuation law, K.O.Halalehto [1] obtained the attenuation law of front wave in rock stress experiment.Yan Yongfeng [2] used MATLAB software for numerical calculation and analysis, and nonlinear analysis method for derivation, which made the formula calculation more effective. After application, he found that the formula was more accurate than the traditional sadofsky formula, and proposed to modify the national standard.Wang Liu [3] proposed to use EEMD decomposition method to improve the accuracy of the conclusion, so as to obtain more optimized data and blasting vibration waves.Wu Yubin [4] used LS-DYNA software to simulate the tunnel lining connection under high strength blasting load, and proposed a new pipe segment modeL. This thesis combined with the blasting construction project of Nankou tunnel with large section of Beijing-Zhangjiakou high-speed railway, the vibration theory, attenuation law and construction method of blasting excavation are studied.

Field survey and design aspects: (1) Summed up the Beijing-Zhangjiakou high-speed railway the geographical location of the tunnel, the basic geology, adverse geological features and construction environment, at the same time, analysis of the blasting excavation methods and types, including whole section method, steps and division method, also has carried on the induction summary of these three measures, it also compared the advantages and disadvantages of these construction method and using condition of surrounding rock. (2) Thesis summarizes the surrounding rock conditions, construction period and other practical influencing factors, designs how to choose the blasting scheme of nankou tunnel construction, and draws the basic schematic diagram.And the choice of explosive. (3) The conditions affecting blasting are discussed. At the same time, the blasting hole depth, hole position, hole diameter, charge quantity, minimum resistance line, initiation sequence, hole spacing and material flow are designed according to the national standard and the experience parameters in the standard. (4) At the same time, according

to the national safety regulations, this paper proposes the flying stone blasting distance, air shock wave noise protection, and calculates and analyzes the blasting safety distance.

Field monitoring: (1) The basic scheme of field monitoring and the use of instruments are designed, and the basic principle and connection mode components of TC4850 are explained. A brief diagram of blasting monitoring in the tunnel is drawn, showing how to monitor blasting vibration in the tunnel, how to arrange points and how to protect. (2) Through the observation of the maximum vibration velocity, it is found that there are many corresponding variables in the blasting vibration with complex changes, which are no longer the same time dimension and cannot control a single variable. In order to more macro Analysis also use of Blasting Vibration Analysis to map the relationship between the Blasting Vibration velocity and time. At the same time, the different characteristics of overlapping and non-overlapping of different hole blasting under the action of micro-difference blasting and non-strict micro-difference blasting as well as their vibration patterns are analyzed. (3) Use FFT method and MATLAB to solve problems. The frequency domain of blasting vibration in the tunnel is analyzed and plotted, and the main frequency of blasting in the tunnel is obtained. (4) Use of Steve sadove formula and field measured data, and the least square method and the linear regression equation, the Origin of application software for drawing and get the parameters K and α, and regression formula is obtained, the maximum speed of blasting vibration attenuation process, engineering blasting scheme of tunnel safety distance formula is verified the correctness of the calculation parameter selection.At the same time, the calculation method of drug limit value within safe range is proposed.The peak attenuation of vibration velocity in the tunnel is analyzed by using the reference value of proportional distance, and the variation formula is obtained by fitting.

Numerical simulation ways: (1) try to use different ways of dividing grid, contain intelligent classification, sweep and mapped, got the pros and cons of different grid features, and to adapt to the method in the project, intelligence division is very simple, strong adaptability, but divided error will increase, some place to go, increased the calculation difficulty, and parts of the grid is too big, cause error, mapped to demand is higher, the classification of grid sweep in meshing for irregular graphics, and which has more reasonable accuracy. (2) to the existing data to simulate material selection as well as the model, at the same time is obtained by simulation to solve the macro image of blasting vibration wave transfer, at the same time, the different location of the medium vibrate maximum velocity attenuation of the waveform in time dimension, and the simulation of vibration velocity and the measured results, found the error meets the requirements of field data and simulation result is reasonable.

Through literature research and field investigation, the blasting scheme design of Nankou tunnel of Beijing-Zhangjiakou high-speed railway is carried out, and the safety protection measures are put forward. Through theoretical analysis and on-site monitoring method, the blasting vibration monitoring system was established to monitor the blasting vibration at different distances from the palm surface and the variation law of peak seismic velocity. Using time-frequency analysis method, the vibration frequency range of main shock frequency and wave was calculated by FFT method, and the parameters of sadovsky equation and the regression equation and image of the attenuation process of peak blasting velocity were obtained by linear regression method, and the attenuation law and characteristics of blasting vibration wave were obtained. ANSYS-DYNA is used to carry out numerical simulation of blasting engineering, and the simulation results are compared with the field monitoring data.

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COMPUTER SIMULATION OF THE STRUCTURE OF ARTIFICIAL CONGLOMERATES

Today, there is the problem of controlling the dangerous state of an array of rocks [1]. The materials studied actively form their properties during operation, and the changes that occur have both positive and negative effects on their structure at different scale levels. When studying the formation of internal defects of agglomerates, it is important to pay attention to its structure. The authors created a virtual model of the structure of the cement composite tested in [2].

Actual studies show that a significant impact on the change in the strength and deformation properties of concrete is exerted by micro-destruction of its structure under the influence of force factors. It has been established that the process of micro-destructions begins when the stresses in concrete are much lower than its tensile strength and can decay or develop over time [3]. It is believed that the cause of the first microcracks is the concentration of stresses near structural defects: pores, inclusions, dislocations. The study of the physical processes causing the development of micro-destruction is of both scientific and practical interest.

According to modern concepts, microcracks appear at low stress levels - **σc = 0.3fcm.** The destruction of concrete begins with the development of cracks in the contact zone (matrix - aggregate) with their subsequent exit into the matrix. Contact cracks develop under the action of shear, and cracks in the matrix develop tensile stresses [4]. All these cases are caused by expansion or contraction of the intra-pore phase, which leads to deformations of the structure, then to stresses, at a critical value of which cracks form in the structure [5].

Considering the structure of cement stone, V.N. Jung [6] called it micro-concrete, in which the resulting cement gel acts as a binder, and unhydrated clinker grains as a filler. Structural models of cement stone look like porous concrete. They contain cement grains with unhydrated cores and shells of neoplasms that grow together in contacts.

To simulate the microstructure of concrete was used Virtual Concrete and Cement Testing Laboratory (VCCTL) [7]. This program was developed by the National Institute of Standards and Technology (NIST), USA. The program models 3D - microstructures of cement systems and allows predicting the final properties of the resulting composite.

The hydration of these microstructures can be modeled according to different hardening conditions, and the resulting hardened material can be analyzed for a number of properties, including linear elastic moduli, compressive strength and relative diffusion coefficients. 3D - packaging of small and large aggregates in mortar and concrete mixtures can also be created.

The authors created a virtual model of the structure of the cement composite (W/C = 0,4). Also, 3D packaging of the final solution was created by converting 3 planes into one cube. The final structure is shown at Figure 1.

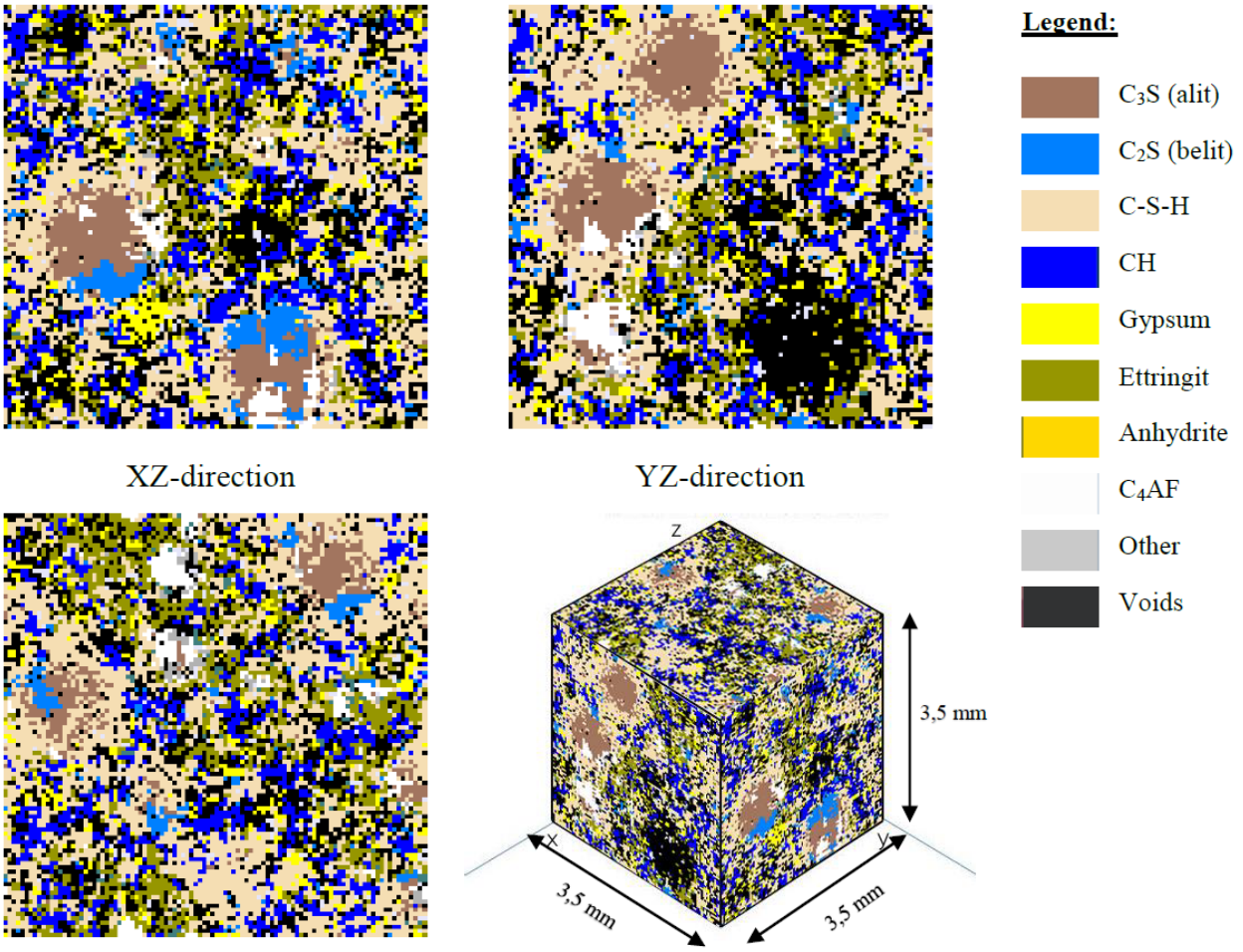

Fig. 1 – Virtual modelling of the cement solution structure (after 28 days)

Studies carried out in [2] should be supplemented with computer simulation results, which will give a broader picture of the processes occurring in concrete structures and will allow optimizing the data already obtained taking into account their structure at various levels of organization. Further tests are planned to be carried out in accordance with the most promising areas of concrete structure simulation.

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INFLUENCE OF GRAIN SKELETONS ON MECHANICAL PROPERTIES OF ROCK: A MICROMECHANICAL NUMERICAL ANALYSIS

Rock is a heterogeneous material due to its internal microstructure. It has been widely accepted that heterogeneity of microstructure plays an important role in controlling the macroscopic mechanical properties of rock. One main reason is that the process of crack initiation and propagation is primarily caused by tensile stresses [1,2], while the heterogeneity is the origin of local tensile stresses even when the rock is only under compressive loading [3]. At the grain level, rock is composed of grains of different size and shape in a certain packing scheme. Many studies on the effect of heterogeneity in terms of grain size or shape have been conducted and macroscopic mechanical properties of rocks with different heterogeneity degrees have been obtained [4]. However, there is a knowledge gap on a quantitative characterization of the packing scheme. The still open key question is: how does the grain skeleton at the microstructure influence the macroscopic behaviour and how can we simulate this. The aim of this study is to establish a link between the spatial distribution of grains and the mechanical response of rocks, and to find some useful functions to characterize the grain spatial distribution and grain skeleton, respectively.

To realise our aim, the main idea is to compare the mechanical response of models with different grain packing schemes by simulating uniaxial compression tests. A particle-based modelling approach is used for this study. In order to avoid any disturbance induced by other parameters on the calculation results, each micro-parameter at the model contacts as well as ball radius are kept constant. Thus, the grain spatial distribution (skeleton network) is the only variable. Firstly, several models with different grain packing scheme were generated to preliminarily explore the effect of geometrical heterogeneity. Uniaxial compression tests were conducted and macro-mechanical parameters, such as UCS and Young's modulus, were obtained. The results show that there is a big difference between the different models, especially in terms of UCS. This means that the heterogeneity of grain spatial packing has an obvious influence on the macro-mechanical properties. Besides, it seems that those models, where grain bond network is denser at the loaded boundaries, have larger values of UCS and Young's modulus. After that, four kinds of regular models with different schemes of grain distribution were chosen to explore the effect of grain spatial packing in detail. The basic structures in each model are rhombus, hexagon (Figure 1a), combination of rhombus and hexagon, and combination of rhombus and octagon. An angle α (Figure 1b) is defined to describe loading direction and contact orientation and several with different angles are set-up. Because of the symmetry of the model geometry, the calculated results (UCS and Young's modulus) also show a symmetric distribution. For each kind of model with same minimal structures, the differences are caused by the different angle α and the level of aggregation. Different α leads to different distances between particles which has influence on the macroscopic behaviour.

Some scalar parameters, such as porosity and coordination number, are normally used to characterize the grain structure, but they reflect only the overall situation and cannot explain differences in strength and stiffness. Several more complicated or advanced functions are needed to reflect the spatial heterogeneity of micro-structures. In this study, bond angle distribution function and pair correlation function are tested to characterize the spatial characteristics of the skeleton network. The pair correlation function can describe how density varies as a function of distance from a reference particle (Figure 1c, Figure 1d). The bond angle distribution was

defined in this study as the angle between the grain bond and the loading direction. The results show that these two functions correspond well to the variation of mechanical properties. According to relevant studies about pair correlation function: this function can reveal the possibility of forming direct contacts of force transmitting chains and further, whether the structure is more stable or not, which supports the results in this study. In respect to the bond angle distribution function: many publications document that tensile cracking plays an important role for crack initiation, propagation and coalescence. It can be assumed that when the bond angle is small, the tensile stress on relevant bonds are also smaller and it is less possible that tensile cracks are generated. Thus, structures where most bonds are parallel to the loading direction can bare larger external forces.

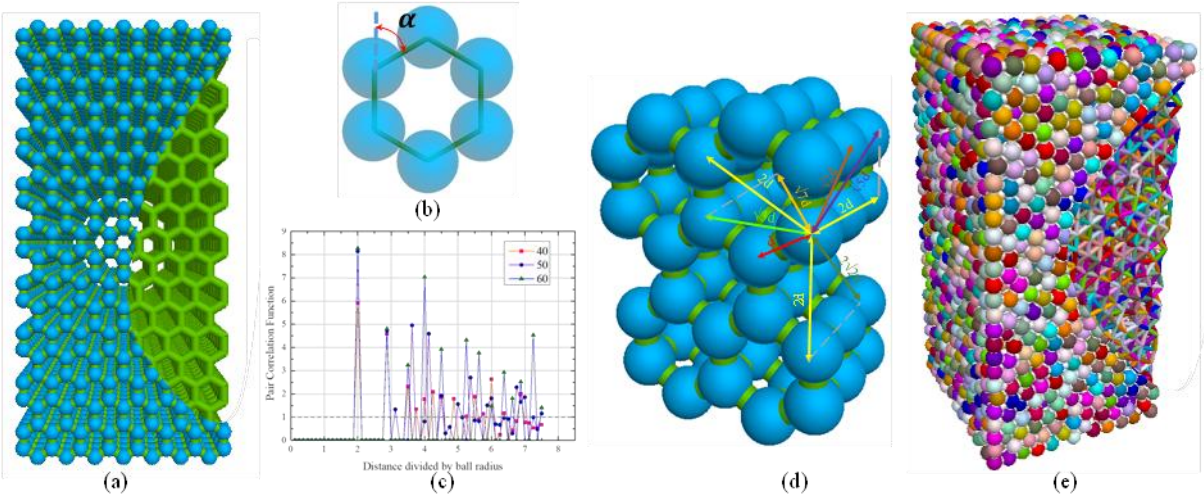

Figure 1 – (a) Models with hexagonal basic structures; (b) The angle α; (c) the calculated results of Pair Corelation Function; (d) The distance distribution from a reference particle; (e) Models with randomly distributed particles

The spatial distribution of grains has an obvious influence on the macro-mechanical properties of rocks. Bond angle distribution function and pair correlation function are good indicators to measure the spatial heterogeneity of grain networks.

In future, more functions in respect to topology or statistics will be tested to characterize the bond chains or force transmitting chains. Also, besides structured models, also models with randomly distributed grains (Figure 1e) will be created and used to test the validity of these functions.

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THE ACCURATE DETECTION TECHNOLOGY AND APPLICATION OF IN MULTI-LAYER GOAF WATER AREA WITH DOUBLE-PERIOD COAL SEAM

Datong mining area in China is an old mining area where Jurassic and Carboniferous double series coal seams occur and have been exploited for a hundred years. The buried depth of Jurassic coal seams is relatively shallow, 240 ~ 350 m from the surface, and the buried depth of carboniferous coal seams is relatively deep, 400 ~ 800 m. The thickness of the main coal seam of carboniferous coal seams is 6 ~ 20 m. Due to the large thickness of Carboniferous - Permian coal seam, the overburden migration range is wide and the influence area is large. Once the Carboniferous - Permian thick coal seam mining caused double system (Jurassic - Carboniferous) fracture connectivity, Jurassic coal mined-out area through the fissure or drainage water to the carboniferous coal face, the goaf water drainage and a series of security technology problem, bring a big increase in mine disaster severity, and seriously restricts the safe and efficient mining.

In view of the above problems, the paper systematically studied the law of water accumulation in the goaf, the height of water-conducting fracture zone and other key technical issues, and established a three-dimensional comprehensive detection technology system of multi-stage, multi-method and well up-down combination in the multi-layer goaf, which realized the fine exploration of the multi-layer goaf and ensured the safe and efficient production of the mine.

Main conclusions:

1. A comprehensive three-dimensional detection method combining ground detection with downhole detection, transient electromagnetic method with direct current method, geophysical exploration interpretation with mining and water extraction and release data, and multi-parameter qualitative interpretation with quantitative interpretation are proposed.

2. A detection system is formed for the water-filled areas in the mined-hole by combining up detection by mtem and down detection by ground tem and ground induced polarization, and a joint interpretation method and quantitative interpretation standard for geophysical data of different detection directions are defined.

3. It has realized the accurate detection of long-distance and multi-layer water logging zone, reduced the multi-solution of geophysical data, improved the accuracy of prediction results, optimized the drilling position and workload, and improved the water drainage effect.

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NUMERICAL SIMULATION OF VERTICAL SHAFT SINKING USING ARTIFICIAL GROUND FREEZING

For decades, Artificial Ground Freezing (AGF) has been effectively applied for a vertical mine shaft sinking under hard hydrogeological conditions. The aim of the technique is a formation of a temporary ice-soil retaining structure is formed around a projected excavation. The structure restrains of rock pressure and eliminates groundwater seepage into the excavation. However, AGF is an expensive technology. Therefore, an application of the technique for building of mine shafts leads to a significant rise of expenses of mining companies. In order to optimize freezing regimes and reduce risks of conduction of excavation works, at the present time fully coupled thermo-hydro-mechanical models are developed. In [1] a model of artificial freezing of a rock mass taking into account heat transfer, water migration and an evolution of elastic stress-strain state was developed. The developed model allowed one to define a time period required to a formation of an ice-soil wall and to estimate a thickness of the wall in each soil stratum. In [2] a coupled model was adapted to a large-scale simulation of response of a rock mass to AGF and excavation works. The numerical predictions of the model were shown good agreement to field measurements of temperature and frost heave displacements. Thus, thermo-hydro-mechanical models allow one to predict an effectiveness of AGF, a process of formation of an ice-soil wall and a stress-strain state of a rock mass in depending on natural hydrogeological conditions and engineering decisions.

The present study is devoted to development of a theory of application of the artificial freezing technique of a rock mass and a shaft sinking under protection of an ice-soil wall. For this purpose, a thermo-hydro-mechanical model of freezing of water saturated soil has been developed. The governing equations of the model consists of the energy conservation equation, the balance equation of mass and the mechanical equilibrium equation. The equation is derived using a macroscopic continuum-mechanics approach. Heat transfer mechanisms by thermal conduction and convection are taken into account in the energy conservation equation. Also heat sources related to the latent heat of the phase change of water into ice and heat generated by deformation of the solid skeleton. According to [3] the balance equation of mass is written with respect to the porosity of the freezing soil. Pore water transfer in the equation is governed by the Darcy law. The ice pressure in the frozen soil is determined through temperature and water pressure using the Clausius-Clapeyron equation. The mechanical behavior of the saturated soil is described within a theoretical framework of the thermo-poro-mechanics and using the effective stress concept. The approach allows one to express the pore pressure through the porosity and the volumetric strain and to estimate an influence of a freezing process on evolution of mechanical properties. to determine the relation between temperature, ice pressure and water pressure in the frozen soil. Besides viscoelastic strain is incorporated in the model to describe the rheological properties of the saturated soil. The equations for the strain is based on the Vyalov's constitutive relations [4]. The developed thermo-hydro-mechanical model has been implemented in the Comsol Multiphysics® software. Numerical solution of the nonlinear equations of the model has been performed using the finite element method.

The proposed model has been applied to large-scale numerical simulations of an ice-soil wall formation by the artificial freezing technique and a stress-strain state of the unsupported excavation wall during a shaft sinking under protection of the formed ice-soil wall. The simulation has been carried out for a silty sand stratum in a potash deposit in the Republic of Belarus. The numerical results have shown that distribution of the ice volumetric content throughout the ice-soil wall is nonhomogeneous. Near the outer side of the ice-soil wall the ice content is higher because of more intensive water migration from the surrounding unfrozen soil. The artificial freezing induces an intensive processes of frost heave of the soil in the frozen zone and consolidation of the soil in the unfrozen zone. Due to frost heave the porosity increases and the mechanical pressure reduces in the frozen zone. At the same time consolidation leads to decrease of the porosity and rise of the mechanical pressure in regions adjoining to the sides of the ice-soil wall. Besides the shear stress raises at the freezing front. As a result, a redistribution of stress and strain fields in the soil stratum is observed. Numerical simulation of the stress-strain state of the excavation wall during a shaft sinking allows one to conclude that the high

mechanical pressure near the inner side of the wall causes a movement of soil into the excavation. On the other hand, the significant mechanical pressure near the outer side of the wall opposes an effect of the rock pressure on the ice-soil wall, that reduces a risk of fracture of the ice-soil wall and, as a consequence, water and soil inrush into the excavation.

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Session 4. GEOLOGICAL MAPPING, EXPLORATION, AND PROSPECTING OF MINERAL RESOURCES

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BAZHENOV FORMATION PHYSICAL MODELING

Nowadays the most part of oil companies in Russia are interested in development of new technologies to predict properties of Bazhenov formation. Unfortunately, only seismic data doesn't show convincing results in prospecting Bazhenov formation's properties. In this case the decision was made to use both seismic + electric data to predict properties of Bazhenov formation. In 1990s the Controlled Source Electro Magnetics (CSEM) method was developed and used for marine oil deposits properties prospecting. CSEM has shown convincingly results after marine works and that is why it was decided to use this method in West Siberia for Bazhenov formation properties prospecting after mathematical and physical modeling in laboratory. The main economic aims for today, due to hard situation in oil sector, are to reintroduce CSEM to reduce costs on field works and more accurate evaluating risks.

The main goal of the current research is to evaluate the effectiveness of using CSEM exploration for the area forecast of the properties of the Bazhenov formation. The main objectives of physical modeling in this research are: creating an isotropic physical model corresponding in electrical and elastic parameters to the section of the studied area, and performing 3D modeling on it with survey parameters that reproduce real seismic and CSEM surveys; to convince that the contrast of the elastic properties and the ratio of the resistivity of the target interval Bazhenov formation and overlying rocks in the created physical model corresponds to the real petrophysical characteristics of the section of the studied area; obtaining initial data for testing the algorithms of synchronous inversion of seismic + electric and testing various approaches to the processing and interpretation of CSEM and 3D seismic data.

The main criterion for choosing materials for the modelling was the preservation of the relations of the electrical and elastic properties of the layers during the transition from real object to the model[2]. The basic model consists of 4 layers and basically corresponds to the geological section of the research area: from top to bottom - 1) sedimentary cover, 2) Bazhenov formation (BS), 3) Jurassic deposits, 4) high-speed basement [1].

The argumentation for the use of frequency sounding (CSEM method): 1) To predict the properties of the Bazhenov formation and to identify the areas in which oil deposits are localized the use of electrical prospecting methods is promising. 2) The magnetotelluric and near-field time-domain electromagnetic sounding methods are not very suitable for studying the rocks of the Bazhenov formation. These methods use an induction method of structure excitation and the response from the rocks of the Bazhenov Formation of high resistivity can not be reliably recorded [4]. 3) A prospective method for mapping the Bazhenov formation and identifying oil deposits is the method of frequency sounding with a controlled source of electric type - a horizontal electric dipole. According to the terminology adopted in foreign countries, the name for this method is Controlled Source Electro Magnetics (CSEM). When working in the intermediate zone of the source, the galvanic excitation of the structure plays a significant role. Anomalies associated with the vertical currents of the source crossing the horizontal layer of high resistivity are quite large. 4) A similar approach has been successfully implemented in offshore surveys [3]. The high efficiency of the CSEM method has been convincingly shown in mapping thin subhorizontal formations of high resistivity - hydrocarbon reservoirs.

Big amount of data was collected in open sources as a result of the study. An assessment of the quality of the data obtained. The choice of materials for creating a physical model was made, field measurements of their elastic and electrical properties were carried out. An isotropic physical model was created from the selected materials, which, taking into account scaling and similarity conditions, corresponds in electrical and elastic parameters to the section of the studied area (Vashkevich, 2016). A physical simulation of CSEM seismic and soundings was performed with the configuration and operating parameters of the arrays, reproducing, taking into account scaling, the parameters used in real field surveys on the studied area. An array of high-quality seismic and electromagnetic data has been obtained, which can be used to test algorithms for synchronous inversion of the results of seismic + electric and to test various approaches to the processing and interpretation of CSEM and 3D seismic data. Inhomogeneities of the physical model are clearly manifested in the data of both seismic and electromagnetic modeling. In the case of pronounced three-dimensionality of the medium during CSEM sounding, maps and graphs of effective parameters give only an approximate idea of the shape and position of geoelectric inhomogeneities. To restore the geology aspects of the structure according to CSEM data, it is necessary to use seismic information in the form of setting structural boundaries or a joint inversion of seismic and electromagnetic data.

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DEVELOPING NEW PERMEABILITY PREDICTION CORRELATION USING GEOMETRIC PROPERTIES OF MICRO COMPUTED TOMOGRAPHY IMAGES

Absolute permeability is a petrophysic propertie of porous media depends on its microscopic properties. Topological and geometrical properties and their relation with permeability is so important. There are different methods have been developed have kinds of disadvantages to characterize porous media [1]. Estimation of permeability using rock properties was started by Kozeny-Carman equation and have been developed in recent years when some parameters such as porosity or tortuosity included [2].

Minkowski geometric measures for 2D images parameters are the area, the perimeter and the (2D) Euler Number and for 3D images parameters are the volume, the surface area (called surface), the mean breadth (also known as integral of mean curvature) and the (3D) Euler Number [3]. An algorithm given by Legland (2007) called imMinkowski can help to calculate Minkowski properties [4].

Based on the evaluated data of some micro-CT images an equation is being developed that is correlation to predict variety of rock absolute permeabilities very well. In order to cover the full range of permeabilities two set of coefficient parameters were generated are shown in table-1. One set of coefficients is related to rocks with permeability less than 2 Darcy and the other above 2 Darcy. In case of 2 Darcy both sets can be used.

$$K\,(md) = a1 \times porosity + a2 \times bw2a + a3 \times A2 + a4 \times P22 + a5 \times bw2p4 + a6 \times B33 + a7 \times NObw3c6 + a8 \times NObw3c18 + a9 \times E36 + a10 \times E326 + a11 \times E24$$

In the above equation, K is absolute permeability, bw2a is 2D area calculated by MATLAB function, A2 is 2D area calculated by imMinkowski, P22 is 2D perimeter of 2 connectivity, bw2p4 is 2D perimeter of 4 connectivity, B33 is 3D mean breadth of 3 path, NObw3c6 is 3D number of objects of 6 connectivity, NObw3c18 is 3D number of objects of 18 connectivity, E36 is 3D Euler number of 6 connectivity, E326 is 3D Euler number of 26 connectivity, E24 is 2D Euler number of 4 connectivity.

The proposed equation with two set of parameter coefficients has shown excellent prediction of absolute permeability from geometric properties for different rock type. Equation is conducted on twenty series of micro-CT images with 0.06 average absolute relative error.

Table 1 - Proposed equation parameter coefficients

Parameter Coefficient	**K<2D**	**K>2D**
a1	2561.601898	166606.9314
a2	0	204150.3261
a3	-107.2069415	-37398.83022
a4	50.22296765	798.0438519
a5	-78.44146504	-3913.780701
a6	-4.48472775	10.4925334
a7	0	-107437068.7
a8	0	-263709565.6
a9	20298580.14	0
a10	0	184072600.5
a11	-15481223.59	0

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THE METHOD OF CORRELATION OF THE PASHISKY HORIZON DEPOSITS IN THE CENTRAL PART OF THE ORENBURG REGION BASED ON THE COMBINED SELECTION OF ELECTROMETRIC FACİES AND LITHOTYPES OF ROCKS

Reducing the active residual oil reserves of large fields is a prerequisite for forced approaches to maintaining the rate of production in regions with developed infrastructure by involving previously unclaimed, small-scale reserves and complex geological formations in the development. One of such promising objects within the well-developed territories of the Orenburg region is the terrigenous deposits of the upper Devonian Pashisky horizon, characterized by heterogeneity of reservoir layers [1]. The identification of regularities and determination of the causes of heterogeneities in the filtration and reservoir properties of the upper Devonian Pashisky horizon on the territory of the Orenburg region, which significantly improve the reliability of the geological model and geometry of the formation in order to optimize its further development, is possible with the use of the proposed integrated approach, even in conditions of low representation of logging and core selection.

The aim of this work is to develop a combined approach to the identification and well correlation of productive layers of the upper Devonian Pashisky horizon in the Central part of the Orenburg region.

The structure of the work includes the following tasks:

1. At the first stage of the work, the method of core and ground analysis is used. On the basis of macro - and micro-descriptions of rocks, structural-textural and lithological-genetic features of deposits are determined, which are an indicator of sedimentation conditions. As a result of a layer-by-layer detailed description of the core, seven lithological and genetic types of rocks were identified, which differ in structural and textural features
2. The second step is the use of field-geophysical methods of well research for the lithological section of wells. The Muromtsev method made it possible to diagnose facies and determine paleohydrodynamic conditions of sedimentation based on positive and negative deviations of the PS curve [2]. Based on the analysis of geophysical data and the selection of lithotypes, it was found that the deposits of the Pashisky horizon formation were formed in the conditions of the sea coast with mixed wave and activity.
3. Identification of the dependence of electrofacies with selected lithotypes corresponding to the idealized facies profile of M. Irwin [3]. Based on the Irwin profile, which describes the conditions and features of deposits of terrigenous rocks of epicontinental formations, the selected facies are linked and the corresponding dependencies are identified. This helped to clarify the conditions of sedimentation and identify transgressive-regressive cycles depending on the alternation of lithotypes
4. Correlation of wells based on the identified dependencies.

The peculiarity of the research is the use of a combined approach to identify productive layers in the section of wells and determine the conditions for sedimentation of deposits. The advantage of this approach is the addition of one method to another, particularly in the absence of core material or well logs curves

As a result, lithological and genetic types of rocks were identified for the study area– sandstones, mudstones, siltstones, limestones, and alternation of siltstones and mudstones. The

analysis of the PS curve allowed us to divide the section of wells, including those not covered by core, into conditional identical units, which were compared with Muromtsev's electrofacies. It is established that the deposits of the Pashisky horizon were formed in the conditions of the sea coast with mixed wave activity. As a sealrock, we consider a pack of mudstones in the upper part of the horizon. As a result, the method has been developed that includes a number of sequential steps for detailed correlation of wells using complementary methods for characterizing well sections and determining sedimentation conditions. The proposed approach has shown a satisfactory result of predicting the filtration-capacity properties of different facies deposits of the Pashisky horizon, which may become a prerequisite for testing the combined method on other deposits of similar genesis.

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IDENTIFYING LITHOLOGIES AND HYDROCARBON USING NEURAL NETWORK

Well Lithology identification is important in oil exploration and development. The identification of lithologies is generally based on core samples and outcrop characteristics. Because available core and outcrop are usually limited, establishing relationships between lithologies and more readily available data sources, in particular well logs, is highly desirable. Currently, in the oil industry, different software's are used to interpret lithology, it requires a human logging expert to carefully analyze these logs to further increase the accuracy of the findings. This is time-consuming and also requires a lot of human effort. Our work ponders to find lithologies from well logs using machine learning with an emphasis on an artificial neural network and later on extended to find hydrocarbon-bearing zones.

For our model to be constructed well logs of different wells were first manually studied and interpreted. Well data collect in las format was converted to excel and later scrutinized to remove any discrepancy in the data. The model was to be later trained, validated, and tested to ensure the system works efficiently and various models were constructed based on different input and output layer functions. To enhance accuracy further hidden layer was also worked on.

For lithology identification, the input logs used are gamma-ray, density log and neutron porosity logs which are trained to get the shale, sandstone, and limestone lithologies. Once the network was trained new well data could be simply be kept in the network to identify similar lithologies at unknow points. The network parameters of the created feedforward backpropagation network for lithology determination are a training function of trainlm, input-tansig, output-linear with 12 neurons in the hidden layer.

In hydrocarbons identification, a deep resistivity log has been added to the above-said inputs and a network has been created which can distinguish the gas zone and oil zone. The network parameters of the created feedforward backpropagation network for hydrocarbon

identification are training function of trainlm, input-tansig, output-logsig with 12 neurons in the hidden layer.

Results were really fruitful with network analyzing different confusion matrix, histograms, and error graphs indicating the accuracy of 98.4% in case of lithology determination and accuracy of 94.7% in case of hydrocarbon identification. The lithology identifying neural network can be further improved by adding more inputs like photoelectric factor log, caliper log, etc., and the network can be modified to give outputs of more lithologies like dolomite, shaly sandstone, dolomitic limestone, etc. Also, we can develop neural network models that assist in predicting reservoir parameters and in history matching arguments.

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PETROLOGICAL FEATURES OF PICROBASALTIC MELTS ON LANZAROTE, CANARY ISLANDS

The occurrence of basic magmatism is characteristic of different geotectonic settings. For volcanic islands basic magmatism is predominant (over 95% of the volume) whereas the generation of melts occurs at mantle levels under the influence of a thermal anomaly (plume). The presence of xenoliths in basalt makes it possible to analyze their relationship with the host magma thus determine the extent of contamination of a primary basaltic magma by melting of rocks hosting the magma chamber. The mineralogy and chemistry of xenolith in basalt from Lanzarote has been extensively studied. Neumann suggested that the modal, mineral chemical, and whole rock compositions of the spinel-harzburgite xenoliths are compatible with an origin as highly depleted suboceanic mantle lithosphere [1]. According to Aparicio and co-authors identical metamorphic and ultrabasic xenolith textures and mineralogies point to a possible metamorphic origin for some ultrabasic xenoliths [2]. Gomez-Ulla with coworkers [3] proposed that inclusion of numerous harzburgites and dunite xenoliths supported limited equilibration and rapid ascent of magma, which is also indicated by the sharp boundary between the xenocryst cores and their overgrowing rims. The object of the study was picrobasalt referred to the third phase of the volcanic eruption on Lanzarote (July 1731 – January 1732).

In order to achieve the assigned goals, the following methods were used. The mineralogical composition of the rocks was studied in transparently polished slides. The composition of the rock-forming minerals was determined using a JEOL (JXA-8200) electron probe analyzer. The content of major and rare elements in the rocks was determined by X-ray

fluorescence analysis (XRF). The determination of the microelement composition of the rock was carried out by inductively coupled plasma mass spectrometry (ICP-MS). The crystallization temperature of the melt was counted by using a geothermometer [4].

Picrobasalt is dark gray rocks with almond-stone, porous texture and contain large xenoliths of peridotites. The porphyry structure of picrobasalts is formed by olivine phenocrysts (30-35 vol.%) immersed in the fine-grained olivine-pyroxene-plagioclase groundmass. Olivine phenocrysts form large (0.3-0.5 mm) resorbed grains of angular and irregular shape. The central parts of the grains are homogeneous and are characterized by high Mg # 89-91 (Mg # = Mg / (Mg + Fe) * 100), Ni and Cr concentrations, low concentrations of incompatible elements (Al, Ti, Mn). The central parts are surrounded by a narrow (less than 0.005 mm) rim of a less magnesian composition (Mg # 85), characterized by a low Ni content and higher contents of incompatible elements. The olivine phenocryst rims contain spinel inclusions with chromium number Cr # 25-45 (Cr#= Cr / (Cr + Al + Fe) * 100). The groundmass of porphyry picrobasalt has a gabbro structure and consists of olivine (10 vol.%), pyroxene (45 vol.%), plagioclase (35 vol.%), and magnetite. Olivine forms small (up to 0.05 mm) isometric grains with Mg # 84-85 and is comparable in composition to the rim parts of olivine phenocryst. Pyroxene forms prismatic grains up to 0.3 mm in elongation, most often smaller (less than 0.05 mm) hypidiomorphic grains and is represented mainly by diopside with Mg # 68-76 ($Wo_{51-54}En_{34-40}Fs_{9-11}$). More rarely diopside is surrounded by narrow (less than 0.005 mm) olivine phenocryst rims. Magnetite is present in the form of inclusions in pyroxene forming veins in it along cleavage cracks. The interstices filled with plagioclase represented by labrador (An_{62-69}). Magnetite forms rounded grains in the bulk of the rock. Mantle xenoliths in the picrobasalt are represented by harzburgite. Large hypidiomorphic olivine grains with Mg # 90-91 are characterized by a high Ni content and low concentrations of incompatible elements. Orthopyroxene forms large hypidiomorphic grains and is represented by enstatite ($Wo_1En_{87-88}Fs_{11}$) with Mg# 92. According to the content of trace elements, xenolithic olivines are comparable with the central parts of olivine phenocryst on picrobasalt.

In accordance with the petrochemical characteristics, the studied picrobasalt correspond to low potassium tholeiitic basalts with a predominance of Na over K (K_2O / Na_2O = 0.3-0.4). According to TAS classification, volcanic compositions are located in the field of basalts, less often basanites. The studied rocks in terms of the content of all petrogenic elements are comparable with the known compositions of picrobasalt of the third phase of the eruption. At the same time, rocks of all phases of eruptions on Lanzarote as a whole have similar variations in the contents of petrogenic and rare elements. The multi-element trace of the distribution of rare-earth elements (REE) of picrobasalt are weakly fractionated and are characterized by enrichment with light ($[La/Sm]_N$ = 1.7-2.3) and heavy ($[Gd/Yb]_N$ = 3.3-3.9) REE and positive anomalies of Nb (Nb/Nb* = 1.7-2.2) and Ti. The REE trace of picrobasalts is similar to those for basalts of oceanic islands.

Considering the significant differences in the content of trace elements between olivine phenocryst and the olivine of the groundmass, as well as the geochemical similarity of olivines in harzburgite xenoliths and central parts of the olivine phenocryst, it can be assumed that olivine phenocryst is most likely the product of harzburgite xenoliths disintegration. Disintegration was accompanied by the resorption of xenolithic olivine which affected its morphology. During crystallization from a melt of liquidus olivine (olivine of groundmass), the central parts of olivine phenocryst were surrounded by narrow rims. This mechanism explains the geochemical similarity of the bulk olivine and the olivine phenocryst rim. The crystallization temperature of clinopyroxene obtained using a geothermometer [4] varies in the range of 1100–1180 °C.

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PETROGENESIS AND SIGNIFICANCE OF MIDDLE DEVONIAN MAGMATISM AT THE XIERQU Fe-Cu DEPOSIT IN THE KALATAG DISTRICT, EASTERN TIANSHAN, NW CHINA

The Central Asian Orogen Belt is commonly interpreted as the largest Phanerozoic accretionary orogen in the world, which is characterised by multiple amalgamation of ophiolitic mélanges, arcs, accretionary complexes and micro-continental blocks during the Paleozoic closure of the Paleo-Asian Ocean (Xiao and Santosh, 2014). The eastern Tianshan Orogen located between the Tarim Basin to the south and Junggar Basin to the north and west of the Beishan Terrane. The orogen is regarded as an important mineralized zone in China (Pirajno et al., 2011). The Dannanhu belt in eastern part of the area is interpreted as a volcanic arc and forms an important mineralized zone.

The Xierqu Fe-Cu deposit, located in the western part of the Kalatag district, is a recently discovered skarn deposit in the eastern Tianshan. It is hosted by porphyritic diorite and pyroclastics rocks of the Devonian Dananhu Formation, mainly presenting as various types of stratoid and disseminated, with well-developed skarn alternation. The I-Fe and I-Cu orebodies are present at the Xierqu deposit, which are structurally controlled, lenticular and strataform. The I-Fe orebody is 400 m long, up to 100 m wide, and dips 20° to 30° NE. The Fe grade ranges from 10 to 55%, with an average of 36% Fe. The I-Cu orebody is 100 m long, up to 100 m wide, and dips 30° NE, with a grade between 0.2 and 3.62% and average of 0.52% Cu. The mineralization processes are divided into four paragenetic stages, based on the mineral assemblages and their crosscutting relationships. These are: (1) prograde skarn characterised by garnet-diopside; (2) a retrograde stage represented by magnetite and epidote; (3) a pyrite-chalcopyrite-quartz stage; and (4) a quartz-chlorite-carbonate stage.

The porphyritic diorite is grey to white in colour and consists of euhedral 1-2 mm long plagioclase, euhedral amphibole up to 0.5 mm across, and a small amount of subhedral to allotriomorphic quartz up to 1 mm in size. The matrix contains the same minerals as the phenocrysts with accessory magnetite, titanite and zircon, and secondary sericite, chlorite, and epidote. Sensitive High-Resolution Ion Microprobe (SHRIMP) U-Pb dating of zircons indicate that the porphyritic diorite is 391 ± 3 Ma. Major element geochemistry show the diorite is calc-alkaline with high Al_2O_3 contents of 16.7-19.0 wt.%, $Mg^{\#}$ values of 56.8-67.1 and Na_2O/K_2O ratios of 2.51-4.58, and $Al_2O_3/(CaO+Na_2O+K_2O)$ (A/CNK) values of 0.55 to 0.94. Trace element characteristics of the diorite show it is enriched in Ba, K and Sr, and depleted in Nb, Ta, Ti, similar to adakites with positive Eu (1.18-1.44) anomaly and high Sr/Y (84.2-139.1) and $(La/Yb)_N$ (5.61-6.97) ratios. Sr-Nd isotopic analyses of the diorite show positive $\varepsilon_{Nd}(t)$ values ranging from 7.1 to 9.8 and low $I_{Sr(t)}$ ratios of 0.703806 to 0.703856 with very young $T_{DM2}(Nd)$ ages of 565-336 Ma. These geochemical and isotopic characteristics indicate that the adakite-like diorite, was emplaced in an island arc setting and resulted from partial melting of subducted oceanic crust in a mantle wedge.

The proposed Devonian island-arc in the Kalatag district offers an opportunity to unravel the nature of the genesis of the magma and the geodynamic evolution in eastern Tianshan. However, the tectonic setting of the Late Cambrian to Middle Devonian magmatism is still under debate with two confronting interpretations: (1) a north-directed subduction of the Kanggur ocean beneath the Dananhu arc (Li et al., 2006); and (2) a south-dipping subduction of the Kelamaili ocean beneath the Harlik-Dananhu arc (Xiao and Santosh, 2014).

Considering the Ordovician-Devonian Formations and volcanic rocks are only developed in the northern Dananhu arc, magmas become progressively younger southwards consistent with the gradual southward migration. In addition, the ca. 420 Ma granodiorite in the Tuwu district of the Southern Dananhu arc is enriched in LREE, depleted in HFSE, has a low $I_{Sr(t)}$ ratio (0.704149-0.704520 and high $\varepsilon_{Nd(t)}$ values (4.05-4.07) (Xiao et al., 2015). It is likely that the magmatism and mineralisation are related to the northward subduction of the Kanggur Ocean beneath the Dananhu arc during the Middle Devonian.

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PROSPECTIVE PETROLEUM ACCUMULATION AREAS IN THE UPPER PERMIAN SEQUENCES OF THE SOUTHERN PART OF THE VILYUY SYNECLISE (EASTERN SIBERIA)

The current issue in the east of Russia - in Yakutia - is certain risks associated with the provision and refill of the energy and industrial sectors of the national economy with petroleum resources [1]. One solution to this problem is exploration of new accumulation areas in Central Yakutia. Vilyuy Syneclise is one of the areas in Eastern Siberia, where researchers expect discovery of new petroleum accumulations in the Upper Paleozoic formations. The petroleum potential of the Permian section of the Vilyuy Syneclise is confirmed by the presence of accumulations in the Upper Permian formations (gas and gas condensate fields in the central part of the syneclise - within the Khapchagay Uplift Area), as well as oil and gas occurrences within the syneclise. Different researchers have repeatedly pointed out the possible oil and gas prospects of the Permian section in the south of the Khapchagay Uplift Area [2, 3]. The geological and geophysical studies recently conducted by JSC “Yakutskgeofizika” and JSC “VNIGRI” in the southern part of the syneclise confirm the prospects of Permian formations in this area.

The studied area is about 12 thousand km2. In general, the Permian structural plan of this territory is the southern monoclinal slope of the Vilyuy Syneclise. It is complicated mainly by structural elements such as structural noses, flexures, etc. The Permian formations are widespread throughout the studied territory. Their thickness varies from 3.6 km in the central

part of the Tangnaryn Depression to wedging-out closer to the sides of the syneclise. These formations are dominantly composed of sandstones, layers of interbedded siltstones and mudstones [4]. They were formed in continental sedimentation environments.

The oil and gas accumulation zones within the studied area can be primarily confined to non-anticlinal traps. Favorable factors for their formation are the presence of interbedded sand and clay rocks, large regional Pre-Triassic and Pre-Jurassic erosion, on the surfaces of which the porous and impermeable rocks come into contact, the development of facial substitution areas and regional wedging out of sequences that are characterized by oil and gas potential.

The identification of promising zones of oil and gas accumulation was preceded by a detailed correlation of productive levels , structural and tectonic studies based on seismic, electrical, and gravimetric surveys, which allow us to clarify the structural plans for prospective petroleum bearing areas within the territory and to update the pinch-out line of the Permian sequences.

As a result of research, promising oil and gas zones were localized in the upper part of the Permian section. In the eastern part of the research area, a promising prospecting object is limited from the northwest by tectonic fault traced along seismic sections. The level of oil and gas content was taken at an absolute depth (TVD) of -1190 m, corresponding to the top of water-saturated reservoirs according to well log data in Andreevsk 2 well (2_Andr) located nearby. In the south the perspective zone is limited by the wedging line of the Taragay Formation, traced on seismic surveys sections and deep well drilling data. In the western part of the site, the prospecting object is bounded from the southwest by the pinch-out line of the Permian sequences, and by tectonic faults that limit the Suntar Arch from neighboring depressions. The probable oil and gas content level has an absolute depth, which corresponds to the top of the water-saturated reservoir in the nearest well.

The Permian oil and gas structure is associated with certain prospects for the discovery of hydrocarbon accumulations in the southern part of the Vilyuy Syneclise. Non-anticlinal traps are expected there. They are controlled by the surfaces of erosion, limiting the Permian sequence from below and above, as well as by the development of weakly permeable or impermeable rocks below the surface of the Pre-Permian erosion. Other factors are the distribution of clay rocks above the Triassic erosion surface and facial variability within the Permian section. As a result of the studies conducted by VNIGRI specialists on the basis of complex geological and geophysical surveys, the perspective objects in the Upper Permian were localized within the research object and the pinching out boundaries of the Permian formations were clarified. The traps in the selected zones are assumed to be of non-structural type and will be confined to the zones of pinch-out of productive reservoir rocks and controlled by regional lithological screens. The types of deposits associated with these traps are stratigraphic, lithological and strati-graphic with elements of tectonic shielding. The obtained geological results indicate the need for further study of this territory.

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LITHOLOGY OF THE RESERVOIR ROCKS IN THE EOCENE-PALEOCENE DEPOSITS OF THE EASTERN CAUCASUS REGION

The Ciscaucasia is one of the oldest Russian petroleum region. Data of oil-wells has centuries-old history, but namely late 18-th and early 19-th became the start point foe scientific research in the Caucasian region. Nowadays, geological and seismic exploration works have been carried out on this territory gives us to assess the discovered deposits. The relevance and novelty of this work lies in a detailed examination of the most common stratigraphic and oil and gas complexes in the Eastern Ciscaucasia: the Goryachy Klyuch Suite, the Cherkesskaya, Kumsko-Kerestinsky, Beloglinskaya and Khadumskaya suites, which are related to the reservoir rocks of the Prikumsky system.

The deposits predominantly consist of multicomponent siliceous-carbonate-clayey rocks, mainly containing in situ hydrocarbons. The section is built up of thin-layered mudstones partly with calcareous admixture in lower part, clayey and bituminous globigerina limestone, and laminated silty mudstones intercalation.

A mineral component prevalence determinate the pore shape: isometric micropores up to 5 microns in the carbonate matrix and slit-shape micropores up to 30 microns in the siliceous-clay matrix. A rock structure and texture control the pore distribution.

The most of pores do not have connection and it is provided only by the fractures. The fractures are developed at any hierarchical levels (micro-, macro- and meso), and their presence is often confined to increase of carbonate and siliceous component in the rock composition. When the clay component predominates, fracture attenuation is observed.

The detailed lithological characteristic of this section makes possibility forecast hydrocarbon migration and accumulation for this polygon.

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THE IMPACT OF THE EARLY CRETACEOUS IGNEOUS INTRUSIONS IN THE FALKLAND PLATEAU BASIN

The Falkland Plateau Basin is a sedimentary basin to the east of the Falkland Islands. The basin was created during the Gondwana breakup, on the Middle Jurassic, and was exposed to extensional forces during the South Atlantic Ocean opening [3]. A system of magmatic intrusions are affecting the basin and date from the Early Cretaceous [4]. According to literature these intrusions are affecting a succession of source-rocks [2] high petroliferous potential with a TOC ranging between 3-8% [1]. The study of these features allows the comprehension of the basin formation as well as assess about the implication on the petroleum system.

Eight horizons were interpreted and there were identified 92 magmatic intrusions forming sills. All the surfaces were converted into depth using a velocity model based on literature. The geometries of the intrusions depend on the depth of emplacement. In greater depths, more planar tend to be the sills. The intrusions are aligned with the fault planes, being these the principal pathway for magma migration. The magma is thus intruding and exploiting faults to get to upper levels of stratigraphy. It is also possible to see two points where the magma extrudes, covering most part of the South-East area of the seismic volume. On top of the intrusions, it is found an accumulation of fluids in the upper layers, this can be due to intrusion of magma in high petroliferous layers. The heat can have impacted the maturation and expulsion of hydrocarbons

Since these intrusions are contained in a package of black shale with a highly petroliferous potential dated from Upper Jurassic to Early Cretaceous, they could have contributed to the maturation of the source rocks in the basin. To infer about that possibility it was performed a Basin modelling study, by using a 1D basin model. The model was fitted to a set of pseudo-wells inside the seismic volume, in order to infer the maturation of the source rock for the entire area. After run each model from each pseudo-well, the maturation data from the source rocks were used as input to a Sequential Gaussian Simulation (SGS) in order to interpolate the values for all the area. The resulting maturation cubes correspond to continuous values of Vitrinite Reflectance (%Ro). It is notorious an overmaturation of most of the volume in layers older than the Valanginian. Although in the shallower parts (younger than Valanginian) to the NNW there are still oil from the first and second stage. Dry Gas is the second category most probable to be found to the SSE of the volume, shallower in that part is probable to find Wet Gas.

The intrusions present on the basin are gathered to the SSE of the interpreted volume. They are probably dispersed and also present beyond the interpreted volume (observed on the 2D lines). It is evident an Overmaturation of the deepest source-rocks. It is more probable to find Wet gas (to the NNW) and Dry gas (to the SSE) near the Valanginian layer, and the first stages of oil (to the NNW) and Wet gas (to the SSE) near the Aptian layer.

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RETROGRADE METAMORPHISM AT CORDILLERA REAL, ZUNAC, MORONA SANTIAGO, ECUADOR

The Cordillera Real, is a mountain ridge 650 km long, with NNE-SSW trend. The Basement of the Cordillera consists five lithological belts delimited by regional fault systems, and west to east direction are the Terrains: Guamote, Alao, Loja, Salado and Zamora [1]. However, regional geological mapping scale does not resolve the lithological and stratigraphic details in each terrain. In this investigation shows the results of the detailed geological survey of a segment of the Loja Terrain in the Zuñac sector, Morona Santiago. In general, the Loja Terrain consists of quartzites, and schists: biotitic, pelitic and graphite [1], however, new geological data indicate the presence of a mafic affinity lithology within the Loja terrain, which has not been reported in previous works , and in this work is called "Zuñac greenstone".

The rock samples (5) were analyzed in the petrography laboratory of the UCE Geology Department. In Zuñac greenstone, the macroscopic analysis showed the dominant presence of two minerals: chlorite and garnets. The structure is massive without foliations presence, unlike the quartzites and schists reported for the Terrain Loja. Furthermore, a cross-correlation of microscopic mineral paragenesis with paragenesis obtained by X-ray diffraction (D8 ADVANCE PLUS) was performed. X-ray mineral paragenesis consists: plagioclase + magnesihornblende + tremolite + chlorites + quartz + muscovite + garnet + diopside.

The presence of plagioclase, diopside and garnet, suggests a mafic protolith (basaltic) [2]. Microscopic analysis revealed that has porfiroblastic texture the garnet at its edges is partially replaced by a corona-shaped chlorite. Replacement of pyroxene for amphiboles in water presence, in this case, diopside for tremolite, suggests a uralitization process, consequently, anhydride and higher density minerals (garnet and diopside) are considered relict minerals. [3]

With the above mentioned, it is concluded that the green rock with garnets reached metamorphic facie of amphibolite, which suffered a process of retrograde metamorphism until reaching the epidote-amphibole facie. further, it is suggested the presence of a new belt with this lithology, based on that previous studies to southwards along the Paute River are reported rocks with similar characteristics, but is found in Salado Terrain.

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GEOCHEMICAL DIAGNOSIS AND GEOLOGICAL-STRUCTURAL RELATIONSHIP FOR THE DELIMITATION OF THE MACHALA'S METALLOGENIC BELT BETWEEN 3°20'- 4°00'S

In Ecuador, through geological studies carried out by different missions over the time (1969-present), the Andes mountain range is known as the main geomorphological structure in the country, characterized by NS and N15 ° E faults. However, in the south of the country there are also transverse structures with a SE-NW direction, which favor the intrusion of intramineral plutonic bodies and allow the opening of mineralizing fluids [1].

This research focuses on the delimitation of the Machala metallogenic corridor and increasing scientific knowledge between 3°20' - 4°00' S, since previous studies show regional guidelines, which are closely related to intrusive pulses favorable to mineralization, generating geochemical anomalies along the corridor [2].

In the study area, the major anomalies are located in the northwest of the study area, mainly along the Salado, Bono, Palto, Zaruma Urcu, San Luis, Piñas, Daucay rivers; close to the towns of Zaruma, Portovelo, Piñas, Saraguro, Chilla and Gualel; a marked trend is evident in the NW-SE direction, possibly related to the Portovelo and Jubones faults, crossing the Celica, Chinchillo and Tahuín Group Formations.

Taking into account the geochemical threshold values, the study area was zoned according to the association of these elements, obtaining 7 areas of interest.

Based on the map reduced to the pole, the interpretation of possible anomalies associated with lithologies or structural controls were performed. The anomalies are in the north central part of the study area, forming elongated bodies with direction NNE-SSW and E-W. It should be noted that these structures reach 29681nT.

For the analysis and interpretation of the magnetic anomalies, it was classified by the degree of magnetic susceptibility associated with the type of rock. Values with high magnetic susceptibility (> 29,300 nT) are correlated with rocks from the Celica, Chinchillo, Saraguro and Gneiss formations of the Tahuín Group, within this group andesitic, rhyolite, tuff and multiphase intrusive rocks emerge, establishing that geological bodies associated possess enrichment of magnetic minerals; it is also importante to note that there are metallic projects in this area in the exploration stage (Tioloma, Santiago, Caña Brava, Piñas, Angelina, Chilla Norte, among others).

The area with medium magnetic susceptibility is characterized by rocks: rhyolites, tuffs, quartz porphyry, shale, andesites and alluvial deposits, corresponding to the Tarqui, Saraguro, Tahuín Group formations and their lithology is associated with paramagnetic minerals due to their lower degree of susceptibility (29108 to 29300 nT).

Finally, the low magnetic susceptibility (29108 nT) is associated with rhyolites, tuffs, shales, limolites and phyllites, corresponding to the Sacapalca, Ciano and Grupo Tahuín Formations.

The results obtained with the 2DV map, allowed to identify structural guidelines with preferential NE-SW directions, associated with the Andean heading, which are displaced due to the predominantly NW-SE fault system (Piñas-Portovelo fault and Tenguel River fault) and at the same time they are related to WE systems, the Huancabamba Deflection and the Amotape Tahuín Block, creating the geological-structural environment which allows to lodge deposits with significant metallogenic interest.

It is concluded that, the interpolation developed by the Ordinary Kriging method allowed to define geochemical anomalies in 13 elements: major elements (Ag, Au, Cu, Pb and V), pathfinder (As, Co, Fe, Sb and Zn) and indicator elements (Cd, Cr and Ni), which form

elongated bodies in the NW-SE (predominant), NE-SW and WE direction and are located close to the towns of Zaruma, Piñas, Portovelo, Saraguro, Chilla. The geochemical association of the elements is associated with porphyry-epithermal type deposits.

According to the analysis, the multiphase intrusive bodies are aligned NW-SE (predominant direction), they are associated with the Jubones fault, Portovelo fault and with the regional structural control of the Huancabamba Deflection [3]; In addition, the geochemical anomalies have the same orientation, as well as the magnetic highs located in the north central area, which allowed the delimitation of the Machala Metallogenic Corridor (NW-SE), located between 3 ° 20 '- 4 ° 00'S, with a dimension Approximately 75 km long and 35 km wide, making it a potentially prospective metallogenic belt.

Carry out detailed geology and systematic sampling of fluvial sediments in target 5, because of the reason that it does not have information, along the San Luis River and the Chuchillo, Trencilla, Barro Negro, La Palma and Santa Fe quebradas, soil sampling, to define mineralogical bodies and contrast it with the information obtained in this investigation.

Propose exploration works for the projection of the Machala Metallogenic Corridor towards Peru, in order to confirm its continuity.

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THE METHOD FOR RANKING HYDROCARBON DEPOSITS USING STATISTICAL DATA ANALYSIS

In recent years the situation in oil and gas industry leaves much to be desired. The 2020 pandemic worsened the sitution. The biggest hydrocarbon (HC) producing regions have a hard time. On the one hand, it is the natural decrease of the HC producing owing to entry of HC fields to the late stage of field development. On the other hand, it is the globally decreased HC demand all over the earth. HC market structure was broken in few days, but recovery will take years. Russia, as one of the biggest HC producing countries, has small advantage and big disadvantage in comparison with some other countries. Russian HC producing enterprises are state and always can count on government, certainly it is a advantage. However, once they limit the HC production, stopped wells are unable to recovery their work like before. There are couple of reasons, these some of them: high parafine concentration in oil, severe climate conditions in northern areas, high water cut in producing liquid and etc. One of many decisions of industry problems may be in temporary replenishment of the lost recoverable reserves by HC reserves in undeveloped deposits of HC field in the late stage of development. There are lots of wells, which penetrate the undeveloped small deposits, which were left to the better days. Consideration of the case shows, that it may be short-term profitable owing to presence of wells, so capital expenditures of development will allow us to increasre recovarable production to 1-5% and get extra free cash flow, what can help enterprises to survive in such adverse situation. But we have

lots of unanalysed data, which we need to take into account. We do not have much time to rebuild geological models, so the first priority is to choosing the deposit with the highest reserves and the lowest uncertainties [2]. The article describes this approach.

For deposits ranking the input geological data for reserves calculating was checked. Ranking techmique was done by using results of 2D geological modeling which were done before research [3]. For these models statistical analysis were done and key assessment parameters were choosen. It was decided to use 2 parameters, which were named geological complexity and data volume. They can help us to choose the deposits for initial development using geological criteria [1].

Geological complexity is the complex parameter, which takes into account how geological conditions are complicated. For instance, there could be continental facies, shaling out, pinching out, diagenesis, tectonic destructions, high spatial and vertical heterogenity, uncertaint fluid contacts and fluids and etc. All of these parameters were analysed and geology assessment criterion was carried out: if geological parameter has the positive influence on geological complexity – it gets 0 mark, if there is unconsequential infuence to reservoir geology – it gets mark 0.5, if there is remarkable complication – it gets 1. Then, we found the arithmetical mean of them and get the result: if it is closer to 1 – reservoir geology complicated, if it is closer to 0 – there is no problem with geology. Nevertheless, there were used weight coefficients in case of one parameter has higher influence.

Data volume was assessed like geology complexity, but there were used different type of data: seismic data, hydrodynamic researches, laboratory fluids analysis, petrophysics and core data. All parameters were assessed by data quality, data quantity and interpetation quality. For example, parameters answer the questions: in there any core data, how many wells have core, is there any well logs, was there any hydrodynamic logging and etc. If there was no data – mark is 0, if there are low accurate data – mark is 0.5, if there are high accurate data – mark is 1. Subsequent acts are the same as for geological complexity.

As a result we get the bubble chart (Fig. 1), on which deposit ranking is shown. The diameter of the bubbles correlates with reserves quantity, arrows shows the sequence of deposit development. The deposit on the top left is the first to development owing to big data volume and low geological complexity. The second and the third are bubbles with black arrows, which have moderate geological complexity and data volume but we can increase the data volume by well tests or well logging. Bubbles with orange arrow are the rest ones, which we will concern from top to the bottom of the chart.

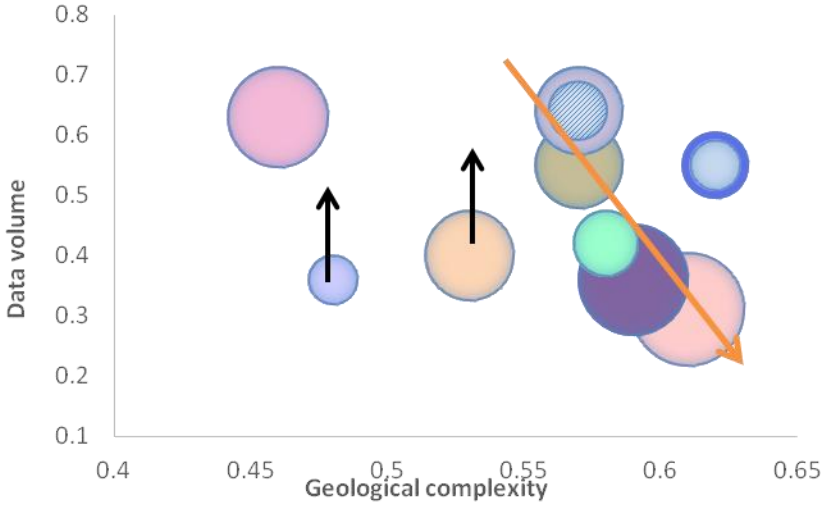

Figure 1 - Bubble are deposits, arrows show moving direction after researches, diameter shows the relative reserves

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COMPREHENSIVE ANALYSIS OF RESERVOIR PROPERTIES OF ROCKS TO IDENTIFY OIL AND GAS PROSPECTS

At the present stage of development of the oil production industry, the study of theories about the origin and migration of oil in the subsurface, the composition of oil source formations, reservoir rocks and reservoir-seal rocks, the paths of oil and gas migration through reservoirs, traps, the formation and destruction of oil and gas deposits is relevant, as the amount of underground resources keep increasing.

This research work is aimed at studying the reservoir properties of rocks to identify promising horizons. The object of the study is the rocks discovered by exploratory well No. P-125, drilled in the northern section of the Rodnikovoye field.

Studies of several core samples of the reservoir were carried out:

1. The study of core samples in the laboratory using a binocular magnifier.
2. The study of pre-granulated particles of one of the core samples to more accurately determine the mineral composition and structure of the rocks that make up the core.
3. Laboratory studies to assess the effective porosity of the sample by method saturation.
4. The study of the mineral composition of a sample by x-ray diffraction method.
5. Generalization and interpretation of the results of the study of reservoir samples.

Mineralogical-petrographic studies consist in a microscopic study of core samples, using the MBS-1 binocular magnifier and include the following: a study of the textural and structural features of core rocks; determination of their mineral composition; determination of the percentage of allothigenic minerals; determination of the content, composition and structural-mineralogical features of the authigenic component.

To determine the chemical composition and content of impurity elements in the core sample under consideration, this sample was subjected to X-ray phase analysis (XRD). To carry out X-ray phase analysis of the core, a sample weighing about 30 grams was taken from it, which was subsequently subjected to appropriate preparation for this type of analysis. The latter was the abrasion of this sample to the desired fraction. X-ray powder diffraction is one of the modern spectroscopic methods for studying a substance to obtain its elemental composition, that is, its elemental analysis. Using it, various elements can be found from beryllium (Be) to uranium (U).

The spectrum arising from the irradiation of the test material with x-ray radiation was collected and analyzed.

When registering the obtained spectrum, the following were used: crystal analyzer (single crystals of certain substances) together with a detector (proportional, scintillation, semiconductor); energy dispersive detectors (distinguish photons by energy). The best resolution of the detector at the moment is the resolution of 123'Dc with the best counting rate of $3 \cdot 10^5$ pulses per second.

The reservoir is granular sandstones with intercalations of clay. The studied samples from the reservoir layer, by field definition, which are sandstones, were taken at an interval of 2870-

2900 m from the YuS1 reservoir. To study the material composition, porosity and mineral composition of the selected samples of the reservoir, the following studies were carried out:

1. Laboratory study of the mineral composition of all samples using microscopic studies with the manufacture of grindings from a single sample;
2. Determination of the porosity of core samples by saturation;
3. To study the elemental composition of the rocks of the reservoir, an X-ray phase analysis of one of the images was performed at the SRSPU (NPI) collective use center.

As a result of the studies, it was confirmed that the reservoir layer is composed of sandstone. Along with this, we found that the sandstone contains a carbonated organic impurity, a certain amount of glauconite, and sulfides in the form of marcasite. By the nature of the relationship between glauconite and marcasite, which the first replaces, it is concluded that the environmental conditions of the diagenetic transformations of the sediment change from relatively oxidative to reducing ones. Studies of the porosity of core images of the reservoir showed a high effective porosity in it, which is a favorable condition for the concentration of hydrocarbons. Also, the data obtained on the effective porosity of the reservoir will be used future we used to calculate the reserves of the field.

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FREQUENCY ATTENUATION OF SEISMIC WAVES FROM BLASTING USING A FULL-FIELD SOLUTION

It is common in the mining industry to measure the frequency content and peak vibration levels from blasting, with an aim to control and prevent any potential damage to structures at some distance from the blast. However, it is less common to perform these measurements in the vicinity of the blastholes, at distances in the so-called near-field range. This work compares the frequency content of raw signals from blasting at different distances, and signals obtained through a vibration prediction model called full-field solution (FFS). The FFS is a semi-analytical and physically sound model whose origin dates back to the mid 1980s and early 1990s (see e.g. [1] [2]). It has had certain impact in the last 10 years (see e.g. [3] [4]), but it is still far from having the same level of implantation as the well-known Holmberg-Persson (H-P) approach and its derivates. This is mainly due to the FFS's calculation complexity, implementation difficulties and longer calculation times. The FFS predicts the behaviour of an isotropic medium upon detonation of a cylindrical explosive charge of finite length. The

displacement field from an element of charge can be represented by three displacement potentials, one of them corresponding to a longitudinal or primary wave and the other two to transverse or shear waves. To model the detonation, the strategy to follow is to superimpose elements of small length in a way that they apply a load to the blasthole wall one after the other with a time difference equivalent to the detonation travel time.

Seismic records were obtained experimentally using high-range accelerometers, which were arranged in vertical orientation and located at distances from the blasts from 2.7 to 28.3 m. The parameter chosen to characterize the frequency content of each signal is the median frequency instead of the often used dominant frequency. It could be defined as the frequency that divides the total power of the frequency spectrum in two parts of equal power. We use this value because it is less affected by random noise, particularly at high frequency levels. To calculate the median frequency of a signal, we take its accumulated frequency spectrum and look for the frequency value that has an ordinate half of the maximum value.

As rocks do not behave as purely elastic solids, we should incorporate a single parameter dependent viscoelastic attenuation model into the FFS. This is the Kjartansson's constant-Q (CQ) model [5]. It is commonly used because it provides a realistic description of intrinsic attenuation in dry crystalline rock [6]. In this case, we did not know this Q-value beforehand. Consequently, a calibration of Q with distance to the source was made taking advantage that peak vibration levels are proportional to the Q-value. Once the Q-law was obtained, we are able to obtain the full waveforms at the same locations where sensors where placed. This allowed us to calculate the frequency spectrum of the signals obtained from the FFS. Once the median frequencies of the raw signals and the ones obtained through the FFS are calculated, these may be compared in a distance to the source versus median frequency plot to analyse the differences between them.

The results show that the FFS overestimates the median frequency in the entire frequency domain if we compare them with those obtained for the raw signals, despite accurately predicting peak vibration levels. This can be explained by some reasons. The first one is that the FFS does not allow for free surfaces or discontinuities in the rock mass, such as fractures, voids, faults, etc. This is a difficult, if not impossible, problem to solve analytically and it plays in favour of numerical models. The second one is that the attenuation Q-model does not consider the attenuation due to elastic scattering, whose effects may be significantly greater than viscoelastic attenuation.

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ANALYSIS AND DESIGN OF THE EXPLORATION NETWORK IN THE CONDITIONS OF ITS IRREGULARITY ON THE EXAMPLE OF THE GOLD-SILVER DEPOSIT DREAM (MAGADAN REGION)

This work opens a part of opportunities of the Micromine software package in the design of exploration work using the "influence fields" method of mine workings. An example is the exploration project for the flanks of the Dream deposit.

Many of the features of this software are elaborated upon in a number of scientific writings, such as: “Block modeling as a tool to assess structural factors mineralization at the stockwork gold field” [1], “The use of scripts in the study of conditions in the software package Micromine” [2], “Estimation of the accuracy of constructing contours of gold zones using GGIS Micromine” [3]. These and other papers were presented at Micromine user Conferences.

The relevance of the work is due to the fact that in real conditions, for various reasons, the factual network in most cases is not regular. Therefore, many mining companies are forced to design exploration work taking into account already existing mine workings. The novelty of the work is that when designing exploration work to achieve a regular network, the work uses conditional fields of influence of the factual mine workings.

From 1977 to 1980, a number of exploration work was performed at the Dream deposit. As a result, two morphological types of ore bodies were identified - ore zones and veins. Ore zones are linearly elongated mineralized structures with a thickness of 1 m to 15 m. Ore veins have a thickness of 0.2 m to 2.0 m. The fall of ore bodies is 55-85º. The main ore controlling factor is the network of submeridional faults.

Category of exploration flanks C_2 (Inferred by JORC). The task of exploration is to study the flanks of the field to category C_1 (Measured by JORC). The western flank is an ore zone. The flank is explored by trenches across 40-50m. Wells drilled over a network of 100 to 100m. The eastern flank is the ore vein. The flank is explored by trenches across 25-50m. Wells drilled over a network of 100 to 200m. For exploration by category C_1 (Measured by JORC), the exploration network is accepted with parameters of 50 by 50 m, for category C_2 - 100 to 100 m. The ratio of C_1 reserves to C_2 equally 50 to 50 percent.

The following data is necessary for work in the Micromine program - spatial coordinates of wellheads, data on the curvature of wells at depth, and the file at trial intervals. As a result of importing this data, a common database is created. Spatial visualization begins with the display of well trajectories, then the contours of ore bodies in sections are constructed. Next, the contours are combined into a closed framework of the ore body. Frames are indicators of volume. Inside the frame is not filled with anything.

Due to the curvature of the axes of the trajectories, the actual workings are located on an irregular network. Therefore, new workings will be located on projections taking into account the "fields of influence" of the actual workings. For clarity, in the projection shows the middles of the ore intervals that crossed the actual workings.

The “Influence fields” method allows you to place design wells on a regular network in the presence of actual wells located on an irregular network using the Micromine program.

For exploration of flanks up to category C1, it is necessary to place wells and trenches on 50% of the estimated ore body. With an exploration network of 50 to 50 meters (category C1), the radius of action of each working is 25 m (Figure 1, 2).

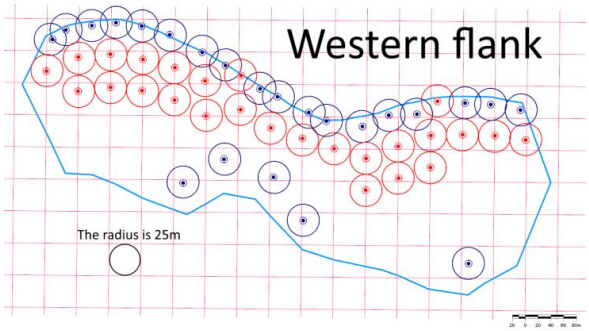

Figure 1 - The vertical projection of western flank

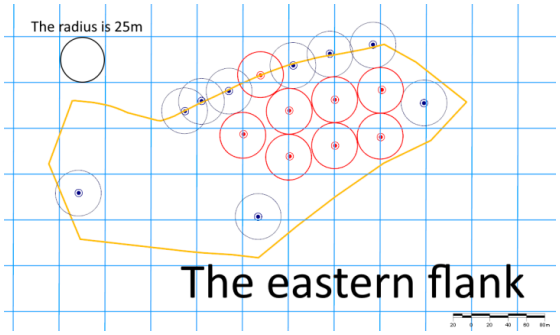

Figure 2 - The vertical projection of eastern flank

The projections show the influence fields of all actual (blue circles) and design workings (red circles). The fields of influence of the design wells are located so that they minimally intersect the fields of the actual. The red dots indicate the estimated midpoints of the ore intervals to be crossed by the design workings.

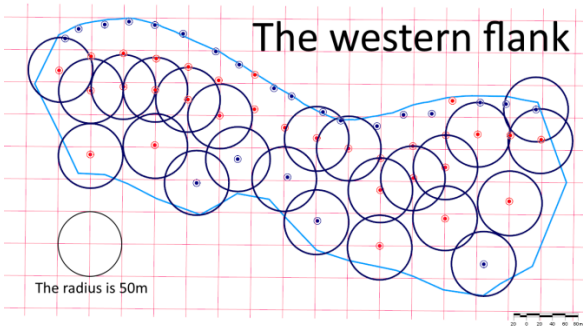

Figure 3 - The vertical projection of western flank

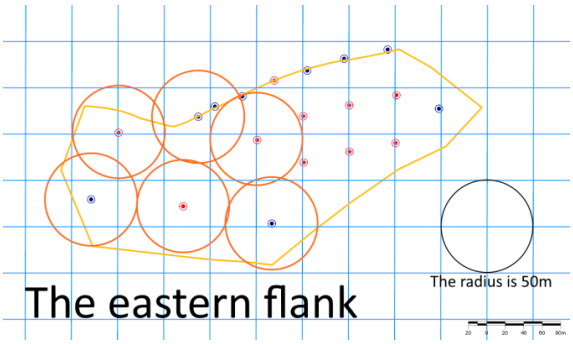

Figure 4 - The vertical projection of eastern flank

When exploring the flanks up to category C2 (network 100 to 100m), the field of influence of the well is 50m (fig. 4, 5). It is important to take into account the fields of influence of project wells located on the 50 to 50m network. Fields of influence of wells of C2 blocks in ore bodies are shown by yellow circles. The centers of influence fields of project workings are also the midpoints of the ore intervals they must cross.

In conclusion, I want to note that this method not only greatly simplifies the process of designing exploration work in the Micromine program, but also allows you to identify insufficiently explored areas within the geological block.

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PRELIMINARY ANALYSIS ON ROLES OF METAL-ORGANIC COMPLEXES IN FORMATION OF "INVISIBLE GOLD"

The purpose in this work is to understand roles of organic matter in mineralization of invisible gold-bearing arsenian pyrite and arsenopyrite.

Invisible gold has difficulties to detect (Volkov et al., 2006) especially, with unsuitable analytical techniques, because many authors reported that even the most sensitive microbeam techniques had minimum detection limits for invisible gold in arsenian pyrite with SIMS in 0.4 ppm (Chryssoulis eta l., 2004; Martin et al., 2005) and PIXE in 21-26 ppm (Louis, 1990). Therefore, to override detection difficulties in the current study another method has been selected to detect invisible gold: four acids digestion (HCl, H_2O_2, NaOH and aqua regia) to dissolve arsenian pyrite and arsenopyrite and then measure the solutions by ICP-OES. Experiments and other analyses for petrographic characterization such as XRPD, XRF, FTIR, EMPA, ore microscopy, organic petrography and organic elemental analysis (OEA) were carried out at the University of Miskolc for 12 samples. The samples had been collected from two black shale mineral deposits: Western Mecsek (Hungary) and Bakyrchik (Qazaqstan). The mineral deposits related to a black shale formation containing different carbonaceous-terrigenous host rocks for the invisible gold-bearing arsenian pyrite and arsenopyrite. The host rock in Western Mecsek is a fine-grained sandstone containing in average (wt%) pyrite 2.4 and amorphous matter 4.6 and in Bakyrchik it is a siltstone including arsenopyrite 6.6 and pyrite 12.2, and amorphous matter 10.7 (result by XRPD).

The four acid digestion removed invisible gold from the sulfide minerals (ppm) minimum 0.2 (in chloric solution), maximum 3.28 (in alkaline solution) and average 1.45 in Western Mecsek while Bakyrchik has (ppm) minimum 0.04 (in chloric solution), maximum 4.0 (in aqua regia solution) and average 2.8. The gold is not detectable by optical microscopy and electron microprobe. It reveals that the gold is of invisible gold type. The gold concentration is increasing with the rate of arsenian pyrite and arsenopyrite minerals in the samples (results by ICP-OES and microscopic observation). It shows that the invisible gold impregnated within a crystal structure of arsenian pyrite and arsenopyrite minerals for both mineral deposits. More gold is included in arsenopyrite than in arsenian pyrite. The gold concentration in arsenian pyrite is increasing proportionally with its arsenic element content. EMPA-EDS (mineral grains) and XRF (powder samples) results show that average arsenic concentration is 3.06 wt% in pyrite grains with maximum value of 10 wt% in the samples of Bakyrchik.

Invisible gold-bearing arsenian pyrite and arsenopyrite associates closely with organic matter. The organic matter content decreases with decreasing the arsenian pyrite and arsenopyrite minerals, and it impacts on the content of the invisible gold as well. Total organic carbon (TOC) of the samples is up to 1% in Western Mecsek and 0,5% in Bakyrchik (result by OEA). The organic materials in Western Mecsek is composed of bituminous coal with vitrinite maceral and in Bakyrchik it is solid bitumen (pyrobitumen) with bituminite (oil-prone) and fusinite (coal-prone) macerals (results by organic petrography). Both of them have fissure-filling textures impregnating veinlets and quartz veins. The organic materials of both mineral deposits have similar organic matter composition and organic matter structure in the samples (result by FTIR). The organic matter composition includes more aromatic compounds than aliphatic

functional groups. Hydroxyl and methylene groups appear like anti-symmetric stretching at peak 2932 cm^{-1} and stretching at peak 2854 cm^{-1}, and carboxyl group is absent. The organic acid corresponds with humic acid in organic matter structure. It means the organic matter in the samples of both deposits is of humic source.

In conclusion, the results reveal that organic matter favors in mineralization of invisible gold on the following: (1) appearance of invisible gold detected in coexistence of organic matter and arsenian pyrite of host rocks is confirmed in Western Mecsek (where invisible gold type was a new discovery); (2) organic matter associates with invisible gold-bearing arsenian pyrite and arsenopyrite; (3) concentration of invisible gold in the minerals correlates positively with increasing TOC in the samples (from 0.2 ppm Au with C_{org} 0.1% increasing gradually to 3.2 ppm Au with C_{org} 1% in Western Mecsek and similar up to 4.0 ppm Au with C_{org} 0.47% in Bakyrchik); (4) organic matter of two deposits reveals that it is of humic origin, where likely humic acid was responsible in mobilization of the gold (5). most of the organic matter was destroyed by thermal degradation (decarboxylation) during hydrothermal mineralization removing the gold from organic matter to pyrite and arsenopyrite in the deposits. (6) the gold likely was in complex of carbonyl fraction before decarboxylation.

The research was carried out within the framework of the „Improved exploitation and utilization of subsurface natural resources" (TUDFO/51757-1/2019-ITM) Thematic Excellence Program of the University of Miskolc, financed by the National Research, Development and Innovation Office of Hungary

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REDUCING UNCERTAINTY IN THE DEEP-GEOLOGICAL CHARACTERIZATION OF ROCKS IN THE INTER-WELL AREA BY USING MATHEMATICAL AND STATISTICAL TOOLS IN THE PROCESSING OF GEOPHYSICAL AND WELL DATA

Proper assessment of the distribution of lithological composition in the subsurface is one of the key elements when evaluating the hydrocarbon potential of an area, as well as geothermal potential and possibility for the CO_2 geological storage. Spatial definition of lithology distribution is the only one step in the characterization of the subsurface.

Incompatible data are usually obtained in exploration of surface outcrops (hard data) and in the subsurface characterization (very little hard data is available, e.g. core material). The lithological composition in the inter-well area is conventionally evaluated on the basis of data obtained from the surrounding wells (cuttings, cores, logs) using either the conventional lithofacies mapping approach [1] where interpretation depends solely on the experience of the interpreter, or by making use of mathematical algorithms [2]. Such procedures have high dose of uncertainty in regional surveys where wells are widely and irregularly spaced and comparatively

smaller uncertainty in the areas of hydrocarbon accumulations with large number of relatively closely spaced wells. Following the trend of technological development, it is needed to turn to mathematical and statistical tools to eliminate subjectivity when interpreting lithology, although general understanding of the geology is always invaluable [3]. In every subsurface exploration, one of the most important assignments are determing key factor—age, structural settings and lithology [4]. These have a very large influence on scientific results, as well as economic implications if the results are applied to any type of resource estimates.

The purpose of this paper was to analyze the data using both geostatistics and geological knowledge as objectively and realistically as possible. For this purpose, a small area covering a depleted oil field located within the Drava Depression of the Pannonian Basin (northern Croatia) was selected for the process. This object was chosen due to available data for lithology interpretation in the wells and 3D seismic coverage needed for the definition of lithology throughout the seismic volume. Clastic Pannonian interval (CPI) was selected for the analysis as the lithology of this unit can be generalized to three classes-sandstones and marls that occur through the whole interval and coals that are most often found in the top of the interval. Subsurface lithology was simplified in accordance with the general geological composition of the Pannonian age sediments in the research area.

For the purpose of lithology modeling, selected seismic volume was analyzed by using artificial neural networks. Two approaches to artificial neural networks (ANN) were used to observe the influence on result prediction of changing the type of the approach. First approach (DAANN) used a large number of different architecture networks, regarding different number of neurons in the hidden layer and different activation functions. Second approach (SAANN) employed the same architecture network but with different distribution of cases within the training, test and selection datasets, and with a different starting point (case) for the analysis. Out of a 1000 total cases, 100 realizations of each approach were singled out upon which the data points with probability of 50%, 75% and 90% of occurrence of certain lithology category were upscaled in the model. Six models were generated by indicator kriging.

Although in theory, the higher accuracy data should provide a more accurate result, the geologically most sound results were obtained by 50% accuracy data. In higher accuracy results, sandstone lithology was unrealistically over emphasized as a result of the upscaling process, variography and statistical analysis. Considering that majority of hydrocarbon reservoirs discovered so far are in clastic sediments, the methodology presented in this paper represents one of the possible ways of determining subsurface lithology, that can lead to new discoveries not only in the study area, but also in other sedimentary basins. Presented research can be used in all geoenergy-related subsurface explorations, including hydrocarbon and geothermal explorations, and subsurface characterization for CO_2 storage potential and underground energy storage potential as well.

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GEODYNAMIC FEATURES OF SOUTH TORGAI BASIN

There are 18 sedimentary basins on the territory of Kazakhstan, which are divided into two regions – Western and Eastern Kazakhstan. The main oil and gas bearing regions of the country are the basins of Western Kazakhstan – the Caspian, Mangyshlak and Ustyurt-Bozashinsky. Within the limits of Eastern Kazakhstan, only in the South Torgai basin industrial accumulations of oil were found [1]. When forecasting and evaluating the oil and gas potential of basins at the current stage of development, it is important to take into account the geodynamic conditions of basin development, which are currently relevant. The geodynamic model of East Kazakhstan development represents the interaction of two East-European plates in the West and Kazakhstani (G. Zh. Zholtaev, T. H. Paragulgov, H. H. Paragulgov, etc.) – in the East and various microcontinents of the Kyzylkum, Ustyurt, Syrdarya, Torgay, etc. Within them are sedimentary basins formed by rock complexes in the stratigraphic range from Devonian to Quaternary deposits.

The Riphean-Vendian stage of rifting, which covered the entire Kazakhstan continent with the formation of a volcanogenic-terrigenous complex and the formation of these diverse microcontinents with the completion of consolidation by the end of the Silurian, was followed by the formation of a sedimentary basin. The borders of ancient massifs are mapped by zones of Caledonian folding [2].

The first collision of the East European and Kazakhstan plates occurred probably in the late Silurian-early Devonian with the closure of the Eastern branch of the Ural paleoocean and the formation of island arcs of complex structure, as well as the activation of deep faults. At the same time, intra-continental rifts are laid within the microcontinents, over which sedimentary basins are later formed [3].

At the famenno-early Carboniferous stage of development of the Kazakhstan Caledonian massif, its territory is generally submerged with a transgressive development style and accumulation of marine and coastal-marine carbonate-terrigenous sediments [4]. Since the end of the early Carboniferous period, the territory of the Kazakhstan Caledonian massif enters the era of compression, which sharply increased by the end of the Hercynian stage of tectogenesis and led to the fragmentation of the Kazakh continent into various blocks. These processes are completed by the design of the North-Torgay, South-Torgay, and Aral Paleozoic sedimentary basins, in contours that almost correspond to their modern outlines.

In particular, the South Torgai basin has undergone a full cycle of geodynamic evolution. In the early divergent period of the cycle, sedimentation and, consequently, oil and gas formation processes took place in rifts, above-drift bending zones, and on passive continental margins [3]. The South Torgai intracontinental rift structure was formed during the final period of the geodynamic cycle, namely, as a result of isostatic alignment of various structural elements of the Eurasian lithospheric plate, formed after the closure of the Ural ocean at the end of the Paleozoic [4].

The geodynamic position of large tectonic elements regarding to the Ural paleoocean in the third cycle of development, which resulted in the formation of the now well-known oil and gas bearing Paleozoic basins, was determined based on the opening of Paleozoic deposits by wells [3].

When predicting and evaluating the oil and gas potential of basins at the current stage of development, it is important to take into account the Genesis of basins, their geodynamic conditions of development, the conditions and speed of sedimentation, and the degree of warming.

It follows from this that a comprehensive approach to the history of basin formation and reconstruction of the features of the conditions for generating and accumulating hydrocarbons allow us to more reasonably identify priority areas for searching for new accumulations of oil and gas in each basin.

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3D STRUCTURAL MODELING INTEGRATED WITH SEISMIC ATTRIBUTE AND PETROPHYSICAL EVALUATION FOR HYDROCARBON PROSPECTING

Hydrocarbon exploration is increasingly entering into more complex geological conditions, so systematic operations are needed to optimize oil production to meet global energy need [1]. Three-dimensional geological modeling is needed to express geological characteristics (e.g., shapes of geological structures, relationships among geological bodies, spatial distributions of geophysical and geochemical properties of geological bodies) in an appropriate computer data structure [2-4] . Therefore, the use of integrated methods, e.g., digital elevation model (DEM), surface slope analysis, 2D seismic interpretation, 3D structural modeling based on seismic interpretation, seismic attribute and petrophysical analysis of reservoirs can identify geometric features, understand internal and external reservoir structures, and quantitatively evaluate reservoir properties (e.g., lithology, porosity, permeability, net pay zone thickness, water saturation and hydrocarbon saturation) [4]. Understanding these information can be applied to increase productivity, revitalize oil fields, predict future reservoir productivity, and bring accurate financial consequences for oil and gas companies [5,6].

Understanding the subsurface geological structure, stratigraphic characteristics, and reservoirs properties is an essential issue in hydrocarbon development. This study aims to evaluate the surface and subsurface geological structural trend, stratigraphic features, and reservoirs properties to ascertain the residual hydrocarbon potential. For this purpose, we have integrated several software to analyze the structural behaviour and reservoir petrophysical properties. Consequently, a workflow has been built utilizing a combined analysis of seismic structural interpretation, seismic attribute, and petrophysical analysis, which yields the best results for hydrocarbon prospecting. Surface structures were identified through the digital elevation model (DEM). Based on the synthetic seismogram, seismic interpretation makes a representative two-dimensional evaluation of subsurface geological structure complexity through time/depth contours models. In order to confirm this result, three dimensional (3D) geological structural modeling based on seismic interpretation was carried out. The analysis of trace envelope, instantaneous frequency, and average energy attributes were utilized to resolve spatial

prediction of the subsurface structure, formation extrusion, and reflector continuity. Based on the qualitative interpretation of well logs data, petrophysical parameters for the formation were evaluated. The overall predicted average porosity (Φ), permeability (md), water saturation (Sw), and net to the gross ratio (NTG) for Chorgali formation were evaluated The initial hydrocarbons of the reservoirs were estimated respectively.

The result of this integrated study shows that there are N-E to S-W (fold axis) broadens anticline structure bounded by two thrust faults on its limbs in the region, which confirms the presence of tectonic compression. The thrust faults have fold axis trending from ENE to WSW. According to the petrophysical analysis, the mapped reservoir is of good quality and has essential hydrocarbon potential, which can be exploited economically.

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DEVELOPMENT OF A METHODOLOGICAL APPROACH FOR INTEGRATING MULTI-SCALE STUDIES IN THE GEOLOGICAL-HYDRODYNAMIC MODELING OF COMPLEX CARBONATE RESERVOIRS

Today geological-hydrodynamic modeling is an important part of the design process for the development of oil and gas fields. The hydrodynamic model allows you to predict many technological indicators for the short and long term, such as oil and gas production, watering rates, reservoir and bottom-hole pressures and many others [1]. One of the main advantages of using geological-hydrodynamic models in predicting of field development is the consideration of geological heterogeneity, which allows to accurately predict the filtration and physicochemical processes occurring in reservoirs.

The reliability and accuracy of the forecast done with the hydrodynamic model directly depends on the quality and quantity of the initial information taken into account in creating the model [2]. The assessment and accounting of the results of various methods of reservoir analysis is often carried out separately from each other and at different times of model creation. Using this approach, in particular for deposits with a complex geological structure, the degree of uncertainty of the reservoir properties remains high, even with a sufficient information, which negatively affects the technological and economic projections of field development. Therefore, to ensure the high quality of the predictive ability of the hydrodynamic model, a comprehensive analysis of all initial information is necessary.

In modeling one of the most important properties of the reservoir is absolute permeability, because this property determines the dynamics of reservoir pressure, the rate of watering of wells, and also has a high degree of uncertainty, which does not allow to predict technological and economic projections of field development with an acceptable accuracy [3].

This article presents the methodological approach that allows to combine the results of multi-scale studies in creating and refining the absolute permeability of the formation in the geological-hydrodynamic model on the example of the priority multilayer field characterized by a complex geological structure.

The methodological approach includes four basic steps: 1. Accounting of the standard complex of geophysical studies. In this stage for each well studied using the petrophysical dependence of permeability-porosity synthetic absolute permeability logging curves in the LAS format were created. 2. Accounting of direct core research. In this stage the synthetic logging curve of permeability is refined according to the core data. 3. Accounting of the results of hydrodynamic and flowmetric studies. Under the stage the working thickness is clarified according to flowmetric studies, the average phase permeability for each working interval is determined. Then the phase permeability is converted to absolute and the permeability logging curve is calibrated according to hydrodynamic studies. 4. Interpolation of synthetic permeability logging curves through all geological-hydrodynamic model. Interpolation is based on seismic attributes.

To evaluate the effectiveness of the proposed methodology, it was carried out the comparative analysis of the results of reproduction of the history of field development obtained from models created by using the standard method and by integrating multiscale information. The application of the aggregation of research results made it possible to reproduce the actual accumulated liquid and oil withdrawals in general for the studied field with greater accuracy. The hydrodynamic model with integration was taken as the basis for further tuning of the performance of each well.

Since the main task of geological-hydrodynamic modeling is forecasting field development indicators, at the final stage of work, in order to assess the predictive ability of the model, the retrospective forecast was made that showed acceptable convergence of calculated and actual field development indicators [4].

The proposed approach of integrating multiscale permeability studies allowed to create a geological-hydrodynamic model that complies with the regulations and is able to predict the development of a priority oil field with acceptable accuracy. Taking into account all borehole studies allows to reduce the degree of the uncertainty of permeability and assess the filtration processes occurring during field development more accurately.

The proposed integration technique is universal and can be replicated for all oil fields with various level of knowledge.

ACKNOWLEDGEMENTS

The research was carried out with the financial support of the Ministry of Science and Higher Education of the Russian Federation as part of a government assignment FSNM-2020-0027.

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DEVELOPMENT OF 3D MODELS OF COAL DEPOSIT

Three-dimensional modeling is one of the ways to visualize the geological conditions of the field, which allows us to understand their structure, as well as to plan development and forecast the behavior of the rock massif under various options for mining the selected subsurface area.

One of the structural features of coal deposits is the presence of relatively clear contacts between the coal seams and the host rocks, the presence of a contrasting border greatly simplifies their modeling and the design process of mine workings. Since coal characteristics do not have extreme variability within a single seam, for the model under consideration, we operated on their average values. The thickness of the host tocks is considered as a homogeneous lithological properties, which is determined, inter alia, due to sedimentary origin.

The section of the Taldinsky coal deposit, located in the central part of the Erunakovsky geological and economic region of Kuzbass, we accepted for consideration as the most interesting in its structure, since its layers lie in the form of a brachisynclinal fold.

The selected software for modeling a field, the Micromine Mining and Geological Information System (GIS) refers to general-purpose systems and includes modules: geological modeling, reserves estimation, mining design and planning, scheduling and mine surveying [1]. GGIS Micromine also allows you to visualize geological data for greater visibility of the construction process (Figure 1, 2)

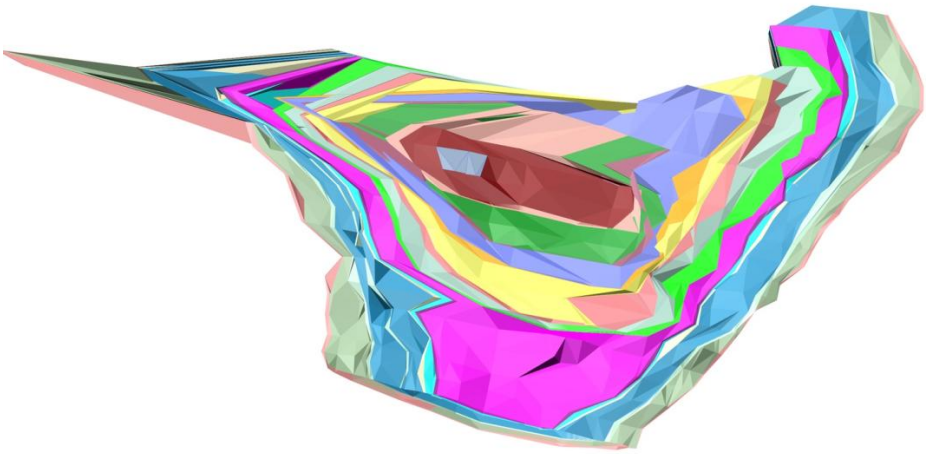

Figure 1 - Visualization of lithological differences of the Taldinskoye deposit site (each layer, interlayers and combinations of mudstones, siltstones and sandstones are painted a certain color)

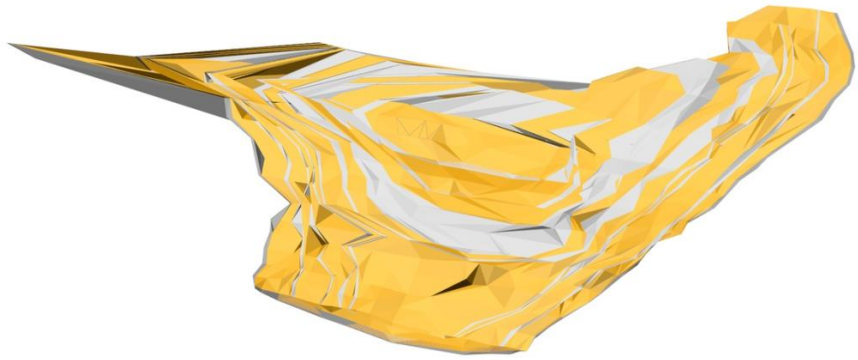

Figure 2 - Visualization of lithological differences of the Taldinskoye deposit site (all layers are colored in gray, and interlayers and combinations od mudstones, siltstones and sandstones – in orange)

The developed geological model can be used to solve several problems, the main ones are the calculation of reserves and geological support for the development of the field [2].

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BASTNASITE NANOPARTICLES IN CARBONATITE-SYENITE-HOSTED REE DEPOSIT

Mineral nanoparticles have been documented in many geologic environments such as geogas, groundwater, fault gouge and ores (Cao et al., 2009; Liu et al., 2019; Reich et al., 2011). Among them, nanoparticles in ores have great effects on the field of mineralogy. However, little concern on these mineral nanoparticles was reported during mining and mineral processing. Maoniuping rare earth elements (REE) deposit, Panxi, SW China, contains abundant bastnäsites that are the main REE-hosting minerals in this deposit (Liu and Hou, 2017). High-resolution transmission electron microscopy observations revealed that there are large nanoparticles occurred in the surface of bastnäsite crystal. As REEs are of high economically significance and supply risk values, these nanoparticles are particularly important. On one hand, REE-bearing nanoparticles were small in size and will be readily overlooked during industrial process, leading to a certain resource waste (Liu et al. 2020). On the other hand, anthropogenic processes such as mining can efficiently decompose host minerals. Therefore, a certain amount of REE-bearing nanoparticles can be released and threaten our ecological environment. As a result, REE-bearing nanoparticles of ore deposits deserved attentions, and this study provided insights on recovery technology of rare earth metals and environmental effects of REE deposit.

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SOME EXISTENTIAL FEATURES OF EARTHQUAKES DISTRIBUTION IN THE TERRITORY OF CHECHEN REPUBLIC (RUSSIA)

It is known that the indices of solar activity are solar stains. The intensity variation of solar stains is subject to 11-year recurrence (a cycle of Shvabe-Volfa) though it is discovered also a 80–90-year (secular) cycle of solar activity. Solar stains are active areas of the Sun, areas of strong horizontal and vertical currents of the gases which are in a vortex motion. Eruptions of gases from Sun bowels transmit the strengthened stream of ultra-violet rays and streams of space rays to the Earth and make significant impact on some terrestrial phenomena (bright polar lights are observed, intensity of telluric currents increases, intensity of radiowaves increases). According to researches of the International Geophysical Year (1 July, 1957 – 31 December, 1958, when 67 countries carried out geophysical observations and studies under the uniform program) belts of the charged particles are an intermediate link in all interactions between the Sun and the Earth.

Magnitude-frequency relationship (and accordingly to the Omori's law) is an essential feature of a seismic condition and one of prognosis indications. The magnitude-frequency relationship represents a statistical cumulative distribution function of frequency – N number of earthquakes to the power classes K = LgE.

In this case it is defined by three principal parameters of a seismic activity:

- Changes in magnitude-frequency relationships, $\gamma = dLnN/LnK$.
- Seismic activity, A_{10}.
- Magnitude of the greatest possible earthquake of K_{max} which defines the right ending of the magnitude-frequency relationship. There are examples that the graph of earthquakes occurrence reflects a series of the general regularities of rock fracturing (Riznichenko 1985).

To construct the magnitude-frequency relationship for observed region the seismicity data for 52 years (from 1960 to 2012) was studied, with $K_{min} = 9$, which coincides with representative class was used, by definition within each class ($K \pm 0.5$) numbers of earthquakes.

After reducing it is visible that (as the first approximation) this graph has the linear form. The straight line received by the least squares method characterizing the law of earthquakes occurrence is given by:

$$\lg N = 7.83 - 0.54K. \quad (1)$$

For this graph parameter γ is equal to -0.54. This value correlates with the data received for the Caucasus region (Riznichenko 1985). The obtained outcome allows assuming that for

rather small regions the declination of the graph of earthquakes occurrence keeps the mean value as a 1 for Caucasus, which, apparently, is fair only for big enough intervals in time.

Analysis of the data testifies that the graph has the step-like form. For the territory authentic distinctions can be established between values: 9 and 10, 10 and 11, 12 and 13, 13 and 14 classes. Distinctions between values of recurrences of earthquakes of 14 and 15 classes are not authentic. Comparative analysis of graphs of earthquakes occurrence for Caucasus as a whole and for studied territory shows that the first has the two-stage form, and the second is characterized by presence of only one step.

Seismic activity (A) is one of the key parameters characterizing the seismic situation of a territory. Seismic activity in some point is understood as a number of the centers of earthquakes in the set range of a power class which arise in a neighborhood of this point in space unit per unit of time.

Now in our country the greatest distribution was received by seismic activity $A = A_{10,}$ which represents number of the centers of earthquakes $K = 10 + 0.5$ ($M = 3.3 \pm 0.3$), referred at the time of 1 year and to the square of 1000 km^2. Seismic activity A_{10} is widely applied in regions with moderate seismicity to which the investigated area is concerned, where earthquakes of $K = 10$ are usually the most typical. In some areas the seismic activity $A = A_7$, and in areas of especially high seismicity the level of $A = A_{15}$ is applied.

There are several ways to calculate seismic activity such as summation with constant detail, summation with constant accuracy, the combined mode or the distributions mode (Kerimov et al. 1992).

Mode of summation with constant detail is carried out by summation of number of earthquakes of all power classes more than the minimum representative average in the fixed zone. In order to calculate, the Riznichenko[1985] formula was used, which for an amount of earthquakes within 1000 km^2 and within 1 year, gives the following:

$$A_{10} = N_{\sum} \frac{1-10^{-\gamma}}{10^{\gamma(\min-10)}} \cdot \frac{1000}{S \cdot T}, \qquad (2)$$

where N_z – a number of earthquakes epicenters in a zone of average square of S km^2, K_{min} – the least of the representative energy class and γ – declination of the occurrence graph.

The mode of summation with constant accuracy allows defining seismic activity with the set accuracy. This mode assumes presence of a constant amount of epicenters at each zone in average. Combined mode implies a combination of two previous modes.

In connection with the stated above the preference was given to calculation of seismic activity by a mode of distribution of epicenters in each zone in average. The analysis of map shows considerable non-uniformity of seismic activity in the area. Territorially zones of the raised seismic activity correspond to epicenters of strong earthquakes and known tectonic faults.

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GEOLOGICAL STRUCTURE AND ESTIMATION OF OIL AND GAS POTENTIAL OF SEDIMENTARY BASINS OF THE CONTINENTAL MARGIN OF THE EAST SIBERIAN SEA BY BASIN MODELING

The East Siberian sea, which is a part of Russian Arctic shelf, is located between the Novosibirsk Islands and Wrangel Island. This area is poorly studied, and there are no wells drilled offshore the East Siberian sea. To be able to assess the oil and gas perspectives of the north-western part of East Siberian continental shelf (Figure1), the authors implemented basin modeling method, which has never been used in studied territory before.

Geological structure data is mainly obtained from adjacent onshore survey results and the interpretation of seismic data. Based on Lomonosov Peninsula deep-water drilling results, the lithological composition of rocks had been studied. On the Novosibirsk Island two strata of dark-colored clays are distinguished within the Mesozoic deposits, which are characterized by an increased content of organic matter (OM) [1], which allows them to be attributed to potentially oil and gas- producing layer.

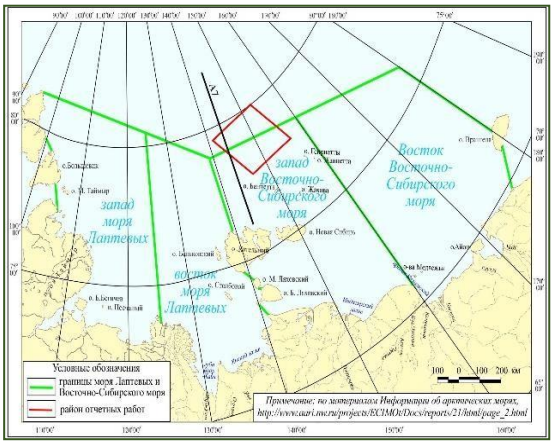

Figure 1 - Overview map of the area studied

The modelling of generation, migration and accumulation of hydrocarbons within the study area was based on the results of interpretation (JSC" mage", 2011-2012) [2] of a series of seismic profiles. Modeling of hydrocarbon systems has been carried out using the PetroMod software package. To build models, the following source data was used [3]:

- the depth of the reflecting horizons on the seismic profile and age of stratigraphic horizons;
- lithological composition of deposits;
- the boundary values of the heat flow;
- geochemical characteristics of oil and gas reservoirs.

As mentioned above, there are two strata of dark-colored clays: the lower Cretaceous and upper Cretaceous potential oil and gas-producing strata (source rock). The lower Cretaceous potential source rock is characterized by a content of about 2% REPRESENTED by type III kerogen, which indicates their gas-generating potential [4]. For a potential upper Cretaceous source rock the OM content is >2% represented by type II kerogen and may be potentially petroleum-derived (Figure 2).

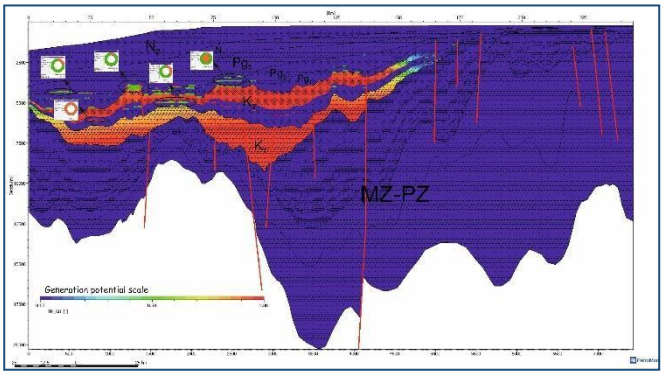

Figure 2 - Model of Organic Matter (OM) generation potential

Upper Cretaceous-Paleogene strata may be favorable for searching for stratigraphic hydrocarbon traps (Figure 3) in case of presence of clay and volcanogenic fluidores. The late Oligocene-early Miocene strata is associated with regional unconformities and might be a regional fluid support.

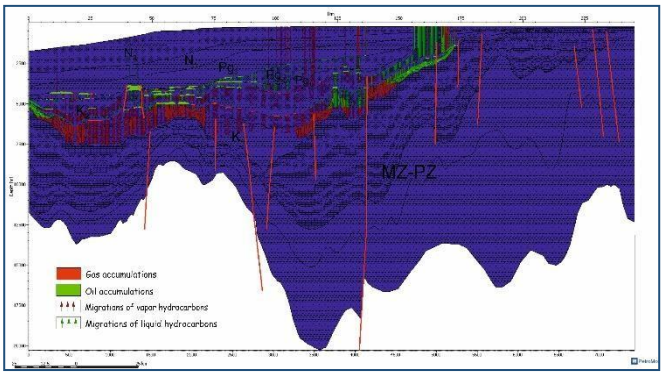

Figure 3 - Model of hydrocarbon (HC) migration and accumulation processes

Thus basin modelling allowed us to come to the following conclusions:

- two oil and gas-producing strata have been identified: lower Cretaceous and upper Cretaceous source rocks;
- 5-7 large accumulations of oil and gas deposits have been identified in the upper Cretaceous- Paleogene APGK and accumulations of hydrocarbons are presumably present at a depth of 3500- 5500M;
- regional fluid seal has been identified.

The analysis shows a high hydrocarbon potential and allows us to identify the most promising sites and objects, as well as to outline directions for further research.

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TYPOMORPHIC FEATURES OF PLACER GOLD IN THE KENKEME RIVER (EAST OF THE SIBERIAN PLATFORM). RUSSIA: IMPLICATIONS FOR THE LATE MESOZOIC GOLD ORE PROCESS

Gold placers are usually not typical for platform areas composed of strong sedimentary strata. However, aurigerous placer occurance in the East of the Siberian platform have been established since the beginning of the XX century. Until now, the root sources that caused the formation of such a vast halo of gold dispertion have not been identified. Earlier two types of gold were identified on the territory of the Lena-Viluy interfluve by Z.S. Nikiforova [3], the potential sources of which she refers to the Pre-cambrian and Mesozoic stages of ore formation. However, the question of Mesozoic gold presence in this area remains open, as there are no geological and geotectonic processes with which it can be linked. The problem of identifying gold-ore sources of Precambrian and younger age is that the studied territory of the rivers of the Lena-Viluy interfluve is covered by a powerful cover of loose mesocainozoic deposits. On the territory of this region there are no products of medium and acid magmatism, which are the main sources of gold deposits, such as in Southern and Eastern Yakutia. This is the reason for the need to study in detail the typo-morphic features of placer gold and the patterns of its distribution in this region. In this regard, new data obtained on the typomorphic gold features from the alluvium of the Kenkeme river are of particular interest.

The research object (the territory of the Kenkeme river) is located in the Eastern part of the Siberian platform. The geological area structure includes rocks of the Archean crystal-line basement, represented by gneiss and granite-gneiss, which are overlain by a powerful Paleozoic sedimentary sheath. Paleozoic deposits break through dikes of the main composition of the Charo-Sin dolerite complex. Everything is blocked by Mesozoic terrigenous rocks, sandstones and mudstones with stratigraphic discordance. Cambrian, Vendian and Archean rocks are wedged at the foot of the Yakut buried uplift, located 40 km South-East of the Kenkeme river, and over-lapped with stratigraphic and angular discordance by Mesozoic rocks, which indicates a long break in sedimentation and a long stay of the territory in continental conditions. The excess of the Yakut buried uplift in relation to the Pre-Verkhoyansk deflection and Viluy syneclise reaches several kilometers on the foundation surface. The foundation depth on the Yakut dome (near Yakutsk) does not exceed, as established by drilling 560-600m. Paleozoic deposits are completely wedged out and Jurassic deposits are directly laid on the foundation. The river Kengkme erodes only Mesozoic and Cenozoic deposits. However, A. V. Okrugin noted the presence of gold indicator minerals of kimberlites (chromium py-rope, chrome spinelides) and platinum-group minerals [4] in the modern al-luvium of the Kenkeme river. In his opinion, the gold-platinum mineralization entered the modern alluvial deposits from the basic-ultrabasite magmatites of the Yakut buried uplift through a series of intermediate reservoirs. According to morphology, the gold of the Kenkeme river is represented mainly by small, well-rounded lamellar grains of scaly shape, the transverse dimensions of which rarely exceed 1-2 mm. The thickness of the main mass of scales is less than 0.1 mm. The main impurity elements are silver (up to 5%), copper (up to 0,02 %), mercury (up to 0,05%), iron (0,01%), palladium and platinum (less than 0,01%) [4].

This work was carried out on the basis of material collected in the course of field re-search by the employees of the Aldan party «VSEGEI» as part of the work on compiling a state geological map of a scale of 1:1 000 000. Five placer samples from the middle course of the river

Kenkme were investigated. The fractionation of the concentrates was carried out according to the standard method: mag-netic and electromagnetic separation, separation by heavy liquids and sieving. Gold mon-ofractions were distinguished from the heavy non-magnetic fraction with a size of -0.16 mm and from -0.315 to +0.16. A total of 188 gold grains were isolated from 5 samples. The morphology and composi-tion of gold particles were studied using Tescan Vega 3 scanning electron microscope with the Oxford Instruments Ultim Max energy dispersive spectrometer (VSEGEI).

Based on the study of morphology and composition, two types of gold were identified. First type placer gold is represented by well-rounded lamellar, toroidal, flattened and spherical forms. There are often impressions of other min-erals on the gold surface of gold. There are lines of plastic deformations and dragging scars.

The gold sample on the surface of gold grains is 1000, that is due to the presence of high-grade edges, indicating a long finding of gold in the placer. Gold has a size of 0.16-0.315 mm.

In the internal structure of gold grains belonging to the first type, there is an almost simple cross-section and the sample inside of which is 1000. This is due to the fact that gold is recrystallized not only on the periphery, but also in the central part. However, while analyzing the internal structure, there were also identified a small number of gold grains with a high-grade border along the periphery and relics of primary gold in the central part with a low sample and an admixture of silver up to 23.11% .

Second type placer gold is represented by cementation aggregates that have preserved mul-tiple impressions of vein minerals. There is often hatching on the prints, which may be induction. The gold rolling is almost zero, there is only a weak rolling of the edges and mechanical bends. The gold sample from the surface varies from 856 to 994. There are impurities of silver from 0 to 13.34% and copper from 0 to 3.36%. The internal structure of gold grains be-longing to the second type is almost simple.

Conclusion

1. There are two types of gold in the modern alluvium of the Kenkeme river: 1) well-rounded lamellar, toroidal, flattened and spherical golds in which there are powerful high-grade rims (1000%) with relics of primary gold (769%), but more often the gold is homo-geneous (1000%); 2) non-rounded cementation aggregates that preserved multiple impres-sions of vein minerals with a gold sample varying from 856 to 994 with silver impurities from 0 to 13.34% and copper from 0 to 3.36%.

2. First type gold is ancient and belongs to the Precambrian era of ore formation. It has been repeatedly re-deposited and transferred. Second gold type belongs to the Mesozoic era.

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COMPARATIVE TESTS OF PORTABLE X-RAY FLUORESCENT SPECTROMETERS RPP – 12T AND SPECTROSCAN – GEO

Due to the fact that the front of treatment works at the mines of Zhezkazgantsvettsmet mines on the flanks of ore deposits, the copper content in the mined ore decreased. The loss of profits from a decrease in the quality of mined copper ores is partially offset by the associated silver mining. For this reason, the task of "online monitoring of the contents of copper in ores" has been replaced by the task of "online monitoring of the contents of silver and copper in ores". The solution to this problem required updating tools for online monitoring of ore quality.

Portable energy dispersive X-ray fluorescence (EDXRF) spectrometers RPP-12T (4 elements: Cu, Pb, Zn, Fe) and RPP-12RI (12 elements: Cu, Zn, Pb, Fe, Ba, K, Ca, Ti, Mn, Ni, As, Sr), which are the main tools for online monitoring of ore quality in mines of the Zhezkazgantsvetmet mines, cannot solve the problem of "online monitoring of silver and copper contents in ores", since they do not determine the silver content.

LLP "Aspap Geo" the main developer of nuclear-geophysical equipment in Kazakhstan, on the terms of reference of Kazakhmys Corporation LLP has developed a portable RPX-12T EDXRF spectrometer that allows online monitoring of ore contents of 34 elements (Cu, Zn, Pb, Ag , Cd, As, Se, Ba, Fe, Mo, Mn, Ti, V, Cr, Co, K, Ca, Ni, Ga, Br, Rb, Sr, Zr, Y, In, Pd, Nb, Sn, Sb , Te, Bi, W, Th, U), including silver. RPP-12T was also designed to solve the problem of X-ray fluorescence testing (RFT) of high (up to 7m) production faces, which is a specificity of RFO ore at Zhezkazgan mines. The RPP-12T spectrometer sensor (mine version) weighs 1.16 kg. The RPP-12T spectrometer passed several test cycles and was recommended for widespread use in the mines of the IO "Zhezkazgantsvettsmet".

The appearance of the RPP-12T spectrometer (shaft version) is shown in Figure 1A. The XRD of the bottom faces in the mine using the RPP-12T spectrometer is shown in Figure 1B, and the XRD of the ore faces at the quarry using the RPP-12T spectrometer is shown in Figure 1C (ZAO Magadan Silver). In RPP-12, a regular smartphone is used as a handheld computer.

A. Mine

B. RFT mine faces

C. RFT in a career

Figure 1 - RPX-12T EDXRF spectrometer

The Spektron NPO (St. Petersburg, Russia) developed the Spectroscan – Geo wearable EDXRF spectrometer, which makes it possible to conduct RFO of core samples, geological samples, faces, ores in bulk of broken rock mass to silver (Figure 2). Weight Spectroscan – Geo 2.4 kg. The device is controlled by a portable personal computer, which is shown in Figure 2. Two rods allow you to raise the Spectroscan – Geo to a height of 2.5–3 m, but no more.

Figure 2 - Spectroscan – Geo EDXRF spectrometer

The Spectroscan – Geo spectrometer was brought to Zhezkazgan and joint tests were conducted on the core of exploratory wells at Zhezkazgangeologiya JSC. But the studies were not completely equal: with the RPP-12T RFO, the core samples were carried out as shown in Figure 3A and 3B, and with Spectroscan-Geo using a special attachment (Figure 3C). The test results are given in Table 1.

A. RPP–12T (core)

B. RPP–12T (mine)

C. Spectroscan–Geo

Figure 3 - RFO of core samples during testing

Table 1 - Comparative tests of RPP-12T and Spectroscan Geo

№№	Interval, m		Item Content					
	from	to	Cu, cond.unit			Ag, cond.unit		
			Ch/a	RPP–12T	GEO	Ch/a	RPP–12T	GEO
1	131,3	132,4	0,93	0,848	0,83	50,7	49,7	46,7
2	135,4	136,4	0,50	0,443	0,45	20,8	19,4	21,3
3	136,4	137,5	0,46	0,432	0,47	21,3	20,9	23,2
4	137,5	138,5	0,43	0,419	0,43	16,8	15,7	19,4
5	138,5	139,5	0,34	0,316	0,34	17,8	18,5	17,3
6	139,5	140,5	0,22	0,231	0,27	6,1	6,1	8,0
7	140,5	141,5	0,12	0,418	0,56	2,6	2,4	3,2
8	141,5	142,5	0,37	0,579	0,40	20,7	23,7	21,2
9	142,5	143,5	0,44	0,449	0,45	24,6	24,1	25,5
10	143,5	144,5	0,20	0,204	0,23	6,8	5,9	7,3
average			0,431	0,434	0,431	18,82	18,64	19,.31

RPP-12T and Spectroscan Geo for copper and silver gave similar results, but RPP-12T: it is easier, it can conduct RFO of faces up to 7 m in height, cheaper and is produced in Kazakhstan.

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SUB- AND SUPERCRITICAL WATER IN THE PROCESSES OF DOMANIC ROCK ORGANIC MATTER CONVERSION

On the territory of the Republic of Tatarstan, the Domanic strata are represented by high-carbon carbonate-siliceous rocks with limestones and dolomites, containing sapropelic dispersed organic matter (OM) of up to 20% [1]. These high-carbon thin-layered formations are capable of both producing hydrocarbons with their own oil and gas source strata, and concentrating them in separate layers and zones [2]. At present, in many oil and gas bearing territories, a spatial relationship has been established between the location of oil and gas fields and the permeable zones of the earth's crust - deep faults and rifts [3]. The formation of Domanic deposits with a high OM content is also associated with the occurrence of tectonic and volcanic processes in the Volga-Ural region. This contributed to the accumulation of huge layers of organic matter in the depressions and depressions and penetration into them. hydrothermal fluids and deep heating in sedimentary strata [4]. The main components of deep fluids are carbon dioxide, methane, water and hydrogen. At high reservoir pressures and temperatures, methane, carbon dioxide, and water can become supercritical and exhibit enhanced chemical activity in the processes of OM transformation. It was shown in [5] that water under supercritical conditions at temperatures above 374.3 ° C and pressures above 22.1 MPa is able to penetrate the structure of kerogen and break its structural skeleton, leading to the formation of bituminous substances. Therefore, studies aimed at the extraction of hydrocarbons from low-permeability rocks by supercritical fluids are important and relevant not only from the point of view of studying oil formation processes, but also in terms of developing technologies for the development of oil source Domanic sedimentary rocks.

The purpose of the work is to obtain new data on the processes of conversion of organic matter of Domanic rocks in sub- and supercritical water and the subsequent extraction of converted mobile hydrocarbons from them to develop the scientific basis for creating technologies for the development of Domanic strata.

The paper presents the results of a study on the conversion of organic matter of the Domanic high-carbon rock of the Romashkino field in a sub- and supercritical water environment at temperatures of 320, 374 and 420°C and pressures of 17, 24.4 and 24.6 MPa. The initial siliceous-clay carbonate rock is rich in organic matter consisting of bitumen and kerogen. Bitumen is characterized by a high content of resins and asphaltenes and a low content of saturated and aromatic hydrocarbons. Distinctive features in the yields and compositions of extracts from rocks were revealed depending on the temperature of the experiments. The highest yield of the extract was observed in the experiment with subcritical water at 320°C as a result of degradation of resins and more complete extraction of asphaltene and high molecular weight n-alkanes of the C_{22}-C_{30} composition from the rock. Supercritical water at 374 and 420°C leads to an intensive decomposition of the kerogen structure and the separation of aliphatic chains from condensed structures of asphaltenes with the formation of low molecular weight n-alkanes of the C_{12}-C_{21} series and carbonaceous substances such as carbene-carboids. According to IR spectroscopy, the structure of asphaltenes and carbene-carboids becomes more condensed and oxidized. Structuring of asphaltenes during their carbonization leads to a decrease in their paramagnetic properties and the removal of metals from the structure of porphyrin molecules. After the experiment at 420°C, the structure of the asphaltenes revealed splitting of the superfine spectrum from the ^{14}N nitrogen nuclei on the line of the vanadyl complex, which indicates the probable conversions of alkylporphyrins to monocycloalkylporphyrins in the processes of

dealkylation, demetallization, and hydrogenation. In addition, phase changes in the mineral composition of mica were discovered due to the isolation of a separate phase of montmorillonite from it. Thus, the research results showed that the effect of sub- and supercritical water on domanic high-carbon rock is reflected not only in the hydrocarbon part of the experimental products, but also in the change in the high molecular polycondensed structures of asphaltenes and carbene-carboids, as well as their paramagnetic properties.

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COMPOSITIONAL TRENDS AND RARE METAL (TA-NB-SN) PEGMATITES OF EDE-AWO AREA, SOUTHWESTERN, NIGERIA

Rare-element pegmatite is a source of strategic metals such as Ta, Nb, Sn, Li and Be. This study involves the petrography and geochemical evaluation of pegmatite veins intruding the migmatitic gneiss, banded gneiss, granite and syenogranite around Ede-Awo area, Southwestern Nigeria. This is with a view to determine their compositional characteristics and rare metal Ta-Nb-Sn potential. In Nigeria, the study of pegmatites had aroused interest over the years. Workers like [1] studied the pegmatites of Nigeria and vividly demonstrated that it occurs mostly in the Western half of Nigeria along a NNE-SSW trending belt. However, studies such as those of [2], have shown that they also occur on a minor scale in Southeast and North-eastern part. [3] defined the metallogeny of the rare metal Ta-Nb pegmatites of Nigeria outlining seven (7) broad fields namely Kabba-Isanlu, Ijero-Aramoko, Nasarawa-Keffi, Lema-Share, Oke Ogun, Ibadan- Osogbo and Kushaka-Birnin Gwari.

Petrographic studies revealed the preponderance of microcline and plagioclase (albite) with subordinate muscovite and quartz. Accessory minerals include garnet, tourmaline and beryl. 7 whole rock pegmatite, 5 feldspar extract and 4 muscovite extract samples were analysed for major, trace and rare earth elements using combined Inductively Coupled Plasma Mass Spectrometry (ICP-MS) and Inductively Coupled Plasma Atomic-Emission Spectrometry (ICP-AES) analytical methods.

Geochemical analysis revealed that Ede-Awo whole rock pegmatite is highly siliceous with SiO_2 mean value of (73.91%) which is higher than muscovite and feldspar extracts (47.33%; 56.21% respectively). Al_2O_3 with a mean value of (16.08%) in the whole rock samples is lower than those of the muscovite and feldspar extracts (22.79%, 28.30% respectively). The trace element analysis revealed that the feldspar extracts are more enhanced in Ta with a mean value of (30.40ppm) compared to the muscovite extracts (27.13ppm) and the whole rock (12.91ppm). The muscovite extracts are predominantly enhanced in Nb and Sn with mean values (336.53ppm,

274.00ppm respectively) compared to feldspar extracts (144.28ppm, 18.40ppm respectively) and the whole rock pegmatite (50.74ppm, 11.29ppm respectively). The Ta-Nb-Sn values in the muscovite extracts are comparable with those of the richer Keffi-Nasarawa and Kushaka Ta-Nb fields of Nigeria.

Rare-elemental plots indicate the whole rock, extracted muscovite and feldspar extracts of Ede- Awo have low to moderate level of rare metal mineralization potential with the enrichment between muscovite and feldspar extracts samples. The rare metal enrichment pattern is in the sequence of Nb>>Sn>>Ta.

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NEAR-SURFACE ELECTROMAGNETIC METHODS' COMPLEX INTEGRATION TO OPTIMIZE SEISMIC SURVEYS IN THE AREAS WITH HETEROGENEOUS NEAR SURFACE ZONE

Due to the trend of geophysical prospecting works increasing in the Arctic Zone, we deal with various subsurface heterogeneities, so nowadays new technologies introduced to solve the kinematic inversion problem there, associated with seismic and non-seismic methods. Dolgikh et al. (2019) showed the importance of their integrated use. 3D seismic, focused on deep reservoirs, have major errors in near-surface zone. Shallow transient electromagnetic method (sTEM), which became the most common alternative technology, allows quantitatively supplementing the saturation forecast with a satisfactory horizontal resolution (Shelokhov et al., 2018). sTEM gives corresponding to real, but only averaged spatial conductivity distribution; further resolution increasing is unable because it is not wave-based method. It became possible by combining with the unique ultra-wideband georadar radiometry (GPR) technology, which is actively developing last years (Gulevich, 2015, Dolgikh et al., 2019). The wave nature expands method's potential: besides signal propagation velocity, conductivity is measured.

Methods' comprehensive approbation (Volkomirskaya et al., 2015) on the giant crater (Yamal peninsula, Western Siberia) became the assumption of this study. sTEM data showed detailed horizontal separation by electrical properties (resistivity and its multiplicative inverse – electric conductivity). With an averaged dielectric constant eps=5, the permafrost bottom corresponds to a depth of 145 m. A layer with higher conductivity was identified below it, where horizontal change was also observed with a clear-out increase towards the funnel. GPR measurements were carried out with 2 m long rigid antennas at the funnel bottom using a 15 MW transmitter. Radarograms processing realized using specific procedure for extracting layers having different permittivity that allowed recording reflections in permafrost layers to the contact point with its bottom boundary around 140-150 m. The set of reflected signal representations is tracing the kinematic characteristics and fixing the layers with various

electromagnetic properties and analyzing the amplitude & waveform behavior. By the results comparison, the reflected signal behavior shows a significant vertical heterogeneity, typical for tectonic disturbance zones. Bottom permafrost boundary presence marked at a 145 m depth was confirmed by further nearby drilling. So methods complexing allowed more accurately interfaces distinguishing (particularly, the permafrost bottom area).

Several works were conducted at complexing the sTEM with seismic in Eastern Siberia (Shelokhov et al., 2018). One of the examples shows the combined seismic & geoelectric profile. According to 3D seismic data, the spread of the Parthenian reservoir, the drilling of two wells showed the presence of a gas-saturated reservoir; it was completely absent in the third well area, after conducting sTEM, an area of high resistance values associated with secondary changes that led to a deterioration in reservoir properties was revealed. So sTEM allows us to achieve accurate geometrization of the research object and anisotropy & lithology assessment in the near-surface zone. But on the other hand method has rather poor vertical resolution. This drawback can be visible is about only averaged resistivity value given inside the particular geoelectrical horizon.

The wave nature of the georagar radiometry neutralizes that drawback. Measurements were held at the northern part of Eastern Siberia in the area associated with high amount of subsurface heterogeneities identified by sTEM profile: the traps and water-saturated rocks stand out quite confidently, blocks different in tectonics are also zoned well. But still we see the same drawback with the vertical resolution. Increasing working depths with no quality lose and high resolution (both vertical & lateral) of ultra-wideband GPR made it possible to provide experimental works. On given radarograms the timeline here is already in ns, in contrast to the traditional ms for seismic exploration. Satisfactory quality of the material is also visible - reflections are traced ill the at depths range of 120-160 m. Analyzing the results of sTEM and ultra-wideband GPR individually and summarizing the effect, we can see that determination both electric permittivity & resistivity distribution can be realized in the same area. So methods' joint use is significantly expanding the solving problems range, including providing parallel geological engineering solutions.

Combination of sensing by the field formation (sTEM) and ultra-wideband GPR survey allow supplementing seismic data in the near-surface zone, complementing each other's data. It is possible to increase the reservoir properties & saturation forecast accuracy and reliability level which was still unattainable at the current technological stage. The complex integration effectiveness is actual at all stages of exploration, development and operation of deposits. Technology allows carrying out two types of work in the same time that justifies complex survey from both geological & economic points of view. Also, electromagnetic methods are environmentally friendly and do not harm the Arctic nature because of using ungrounded coaxially-spaced loops (sTEM) and mobile radio-radars (GPR).

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INSIGHTS INTO ORE OCCURRENCE AND GENESIS OF THE POST-GONDWANA SUPERGENE MANGANESE MINERALIZATION IN THE HIGHVELD REGION OF THE NORTH WEST PROVINCE, SOUTH AFRICA

The North West Province of the Republic of South Africa was not considered industrially mineralized until recently. The region hosts small scale supergene Mn deposit in a weathering crust of the Neoarchean manganiferous dolostones of the Malmani Subgroup, Transvaal Supergroup. The mineralization predominantly occurs as Mn nodules, wad and crusts and is confined to regional karstic depressions which resulted from the weathering and dissolution of the underlying Malmani dolostones. The early prospects of manganese mineralization in this region were carried out in 1960 by Dr. De Villiers of the then Geological Survey of the Union of South Africa. His work documented the small scale occurrence of manganese wad on the dolostone sections west of Johannesburg into larger portion of the former Transvaal (North West). About 30 years later few researchers documented the occurrence of Mn wad across the area and attributed its origin from manganiferous dolomites and/ Ecca strata of the Karoo. Our recent paper was devoted to understanding the ore body occurrence and distribution which led to the documentation of the local stratigraphy of the ore deposit. Westwits alluvium) which overlies the saprolite with a distinctively sharp erosional surface. The deposit is characterized by high valence state (Mn^{4+}) Mn oxide minerals which are well known to scavenge relatively high concentrations of trace (TE) and rare-earth elements (REE) during precipitation in geologic environments. The coherent behaviour of these elements in natural environments has led them to be inherently robust in discriminating sources of various Mn ore precipitates. The present work is therefore intended to apply the TE and REEY geochemistry to constrain the genesis of the Supergene North West Manganese Deposit. Post Archean Astralian Shale and Chondrite-normalized trace element patterns of the ore samples indicate enrichment in the assemblage of Ba, Y, Cu, Sc, Ni, Cu, Co and other TE such as Ce, La and Zr and depletion in elements Zn, Nb and U.

The PAAS and chondrite REEY anomalies of the ore samples further indicate enrichment of light rare-earth elements and a notably pronounce positive Ce and negative Y anomalies indicative of hydrogenetic precipitation of the ore deposit. This was supported by the observation on the high field strength (HFS) element discriminating plots; Ce anomalies and YSN/Ho_{SN}, Ce anomalies and Nd concentrations and the Fe+Mn+(Co+Ni+Cu)*10 which effectively discriminates between hydrogenetic, hydrothermal, diagenetic and mixed source ore precipitates. The overlap of the REEY patterns for Mn nodules and Malmani dolostones suggest the existence of close genetic relation. In contrary REEY patterns for Mn wad reflect negative Ce and positive Y anomalies indicative of hydrothermal source.

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GEOLOGICAL AND STRUCTURAL CONDITIONS OF FORMATION AND ORE CONTENT OF DEVONIAN VOLCANOGENIC COMPLEXES OF RUDNY ALTAY

According to modern representation, Rudny Altay present an active continental outskirt of the Altay-Sayansk folded area. In average Paleozoic, under the influence of tectonic stresses directed from the north-east to the south-west, Rudny Altay was a mobile belt of the tectonosphere with a special deep architecture of structures. These data are based on the results of gravimetry, magnetometry, seismology, seismic exploration, electrometry and geothermy. Along the southwestern edge of the Altay microcontinent, a system of adjacent subparallel and oblique deep-seated faults formed, falling to the northeast at angles of 60-70º. They contributed to the formation of a tectonomagmatic lithospheric block of the Rudny Altai linearly elongated in a northwestern direction, enclosed between the Irtysh and Northeastern crumple zones [1,4].

In Silurian-Devonian, the inland Continental riftogenic zone functioned on the site of the Irtysh deep fault. Rudny Altay was located in the northeast of the rift zone and was a zone of basalization of the sialic crust. At the stage of zone closure in Famennian time, an ensialic island arc was formed here, fixed by the volcanic-sedimentary dacite-andesite formation of the Pikhtov suite (D3fm1). In the Beloubinsko-Sarymsaktinskaya zone in the northeast side of the riftogenic zone on the border with Gorny Altay, a linear inland continental Northeast rift was formed. Pyrite lead-zinc deposits (Nikitinskoye, South Altay group, etc.) were formed here.

The Rudno-Altai metallogenic zone is characterized by a mosaic-block structure of riftogenic zones, within which volcanotectonic uplifts were formed (Aleyskoe, Sinyushinskoe, Revnyushinskoe, etc.). They were areas of intense manifestation of predominantly Middle Upper Devonian acidic (rhyolitic) volcanism. Volcanic rocks belong to the Devonian subvolcanic complex. A study of the chemical composition of volcanics shows that they have a predominantly rhyolite composition (TAS, Fig. 1). According to the AFM diagram, they fall into the field of calc-alkaline and supersaturated with aluminum series, diagram A / NK = Al2O3 / (Na2O + K2O) and A / CNK = (Al2O3 / (CaO + Na2O + K2O) in mol% (Shand (1943), Maniar and Piccoli, 1989).

Subsequent tectonomagmatic processes in the Carboniferous and Permian significantly complicated the riftogenic structures, causing the movement of individual blocks along sub-latitudinal and northeastern faults and the introduction of giant granitoid intrusions, which caused the absorption of a significant mass of polymetallic ores [4]. The main industrial pyritic deposits of the Rudny Altay were formed in a riftogenic geodynamic setting and, according to metallogenic zoning, are combined into a large Rudny Altay copper-polymetallic belt of regional significance, which is part of the general geostructure of the Bolshoy Altai.

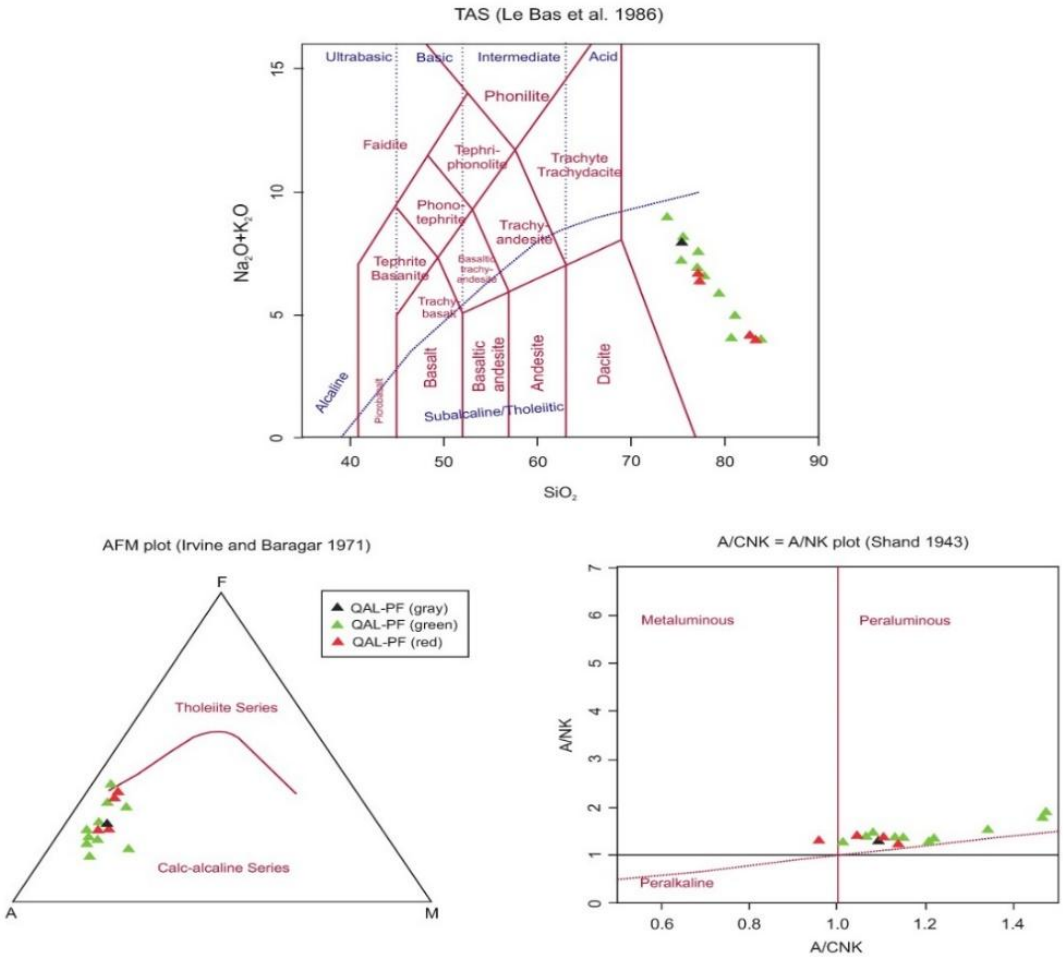

Figure 2 – Diagrams TAS, AMF and A/CNK-A/NK rocks of Devonian subvolcanic complex of deposits of the Priirtyshsky ore area

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PRELIMINARY RESULTS OF FOSSIL REMAINS FROM HOLLIN FM NAPO - ECUADOR

The study of fossil plants in the Lower Cretaceous is relevant due to the appearance and subsequent radiation of angiosperms, which is one of the major biotic alterations in life evolution and has significant repercussions of terrestrial ecosystems.[1] The knowledge that we have about

cretaceous flora of America mostly corresponds to the northern hemisphere.[2] According to the paleobiology database, in South America during Aptian - Albian there is a few fossil evidences, most of them corresponds to mollusks, reptiles and pollen.

Therefore, there is a lack of knowledge about macroflora and any contribution will be useful to understanding the neotropics which currently is the most diverse place in the world. In order to filling that gap, this research presents a stomatic analysis of fossil leaves, as well as a description of seeds and remain fossils found in sandstones and mudstones from Hollin Formation, Oriente Basin of Ecuador that corresponds to Aptian – Albian in age (see Fig.1). The systematic analysis is based on the description of these fossils considering mainly the morphology of subsidiary cells, guard cells and stomata distribution of cuticles. Based on these characteristics, it proceeded to made an assignation to the possible families of cretaceous plants.

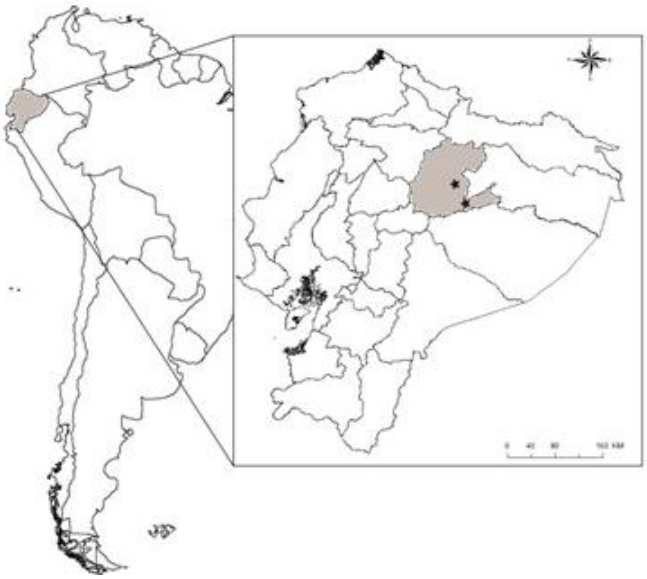

Figure 1 - Location of the study area in Napo province, Ecuador

The methodology applied consists in six steps:

1. The disintegration of rock sample with H_2O_2.
2. The picking process to extract the fossil remains.
3. The assembly of the samples in a slide with a gelatin-glycerin solution in order to avoid the dryness of cuticles.
4. The photoprocess using Olympus DP73/BX63 Microscope, Nikon Eclipse E600 Microscope, the confocal Olympus Fluoview FV1000 and SEM. It is necessary to consider the ultraviolet light of microscopes for cuticles from rocks which are not too highly affected diagenetically because will often show autofluorescence under illumination with ultraviolet light. [3]
5. The categorization of photographs considering the morphology of subsidiary cells, guard cells and stomata distribution of cuticles.
6. Interpretation of the stomatal development in terms of its primary morphogenetic factors and place it in a phylogenetic context.[4]

As a result, the fossils described in this research certainly indicate that in the middle cretaceous of Hollín formation there was a strong predominance of gymnosperms plants like gnetales, cladophlebis, podozamites, ginkgoales, pinnales and glossopteris. There is a possibility that angiosperms plants could also exist in this period like magnoliales but it is necessary more investigation using scanning electron microscopy to asseverate this statement.

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STOCHASTIC SEISMIC INVERSION OF A NORTH SEA RESERVOIR

This is a geostatistical seismic inversion study of an exploration block in the North Sea. Seismic inversion aims at characterizing a high-resolution model of impedances or petrophysical properties of a reservoir based on the available seismic image. Geostatistical seismic inversion uses the stochastic simulations and co-simulations as a perturbation technique and an optimization method, based on genetic algorithms, of a convergent iterative process [1], [2], [3], [4].

There are different types of seismic inversion such as deterministic inversion and stochastic inversion. On the deterministic methods, only one solution is reproduced, and it is based in the minimization of the error between the convolution model of reflectivity and observed seismic amplitudes [1]. One alternative to the deterministic inversion is the stochastic inversion which consists in the generation of realizations with the same probability of petrophysical properties, acoustic impedance in this situation, using the information of wells and seismic information between wells in order to reduce the uncertainty of these properties [2]. Geostatistical seismic inversion is divided in two steps: first the values of acoustic impedance are simulated in every cells of the study area based in the well data and the spatial continuity pattern given by the variogram. In the second step these acoustic impedance values are convolved, with a known wavelet, giving rise to a synthetic seismic amplitude which is compared to the real seismic. The best acoustic impedance, synthetic seismic and correlation value is generated after each iteration replacing the previous value with the best one. When the iterative process converges to satisfactory objective function, the best simulated values for acoustic impedance, synthetic seismic and correlation area the main results of the inversion process [3].

In this study the geostatistical seismic inversion method was applied using and comparing two different procedures, one assuming regional stationarity of the acoustic impedance model and one assuming stationarity only inside a zone created from the seismic interpretation done prior to the seismic inversion study.

The first inversion was made considering a homogeneous volume. As a final result, acoustic impedance models as well as synthetic seismic cubes were obtained. Knowing the acoustic impedance is inversely related to the porosity it was possible to identify clearly potential reservoir zones with low acoustic impedance which means zones with high porosity. At the end a correlation pattern was shown in order to identify the zones of with higher correlation and the result was very satisfactory. Statistical analysis was made at the end of the inversion analyzing histograms of acoustic impedance data in the well and acoustic impedance after the inversion.

In the second test the volume studied was divided in two parts assuming two zones with different behavior. Looking at the results of this second inversion a similarity between the synthetic seismic and the real seismic was evident showing a good match; the acoustic impedance models show a change of spatial behavior between the different zones; statistical analyses of histograms about acoustic information in the well and after inversion was discussed.In conclusion, it is possible to say that both seismic inversions performed well since both synthetic seismic matched pretty well the real seismic. The second inversion had a lightly superior

correlation value what shows that the more different zones are interpreted and inverted, the better the final obtained models are, given the heterogeneity of the Earth's subsurface. For a further development, in order to obtain better results, it would be better to integrate more geological information in order to divide the volume in more zones, extract a better wavelet and do seismic inversion with more simulations aiming an optimization in the results.

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COMPARATIVE ANALYSIS OF ORE FORMATION OF ZHAILMA SYNCLINE

The Zhailma syncline is main structure in the Atasuy ore district. It concentrates industrial deposits with rich and easily ore-rich iron and manganese ores, which represent the main raw material base of Kazakhstan's ferrous metallurgy. Subsoil wealth is not limited only to iron-manganese ores. The lead-zinc and barite-polymetallic ores lie together with them. A comprehensive study of the allocated areas should result in the discovery of new and expansion of prospects for already known deposits. In this regard, the article considers the deep geological structure of The Zhailma syncline in detail. The epochs of ore formation in different structures are distinguished.

A significant role in the study of the Atasuy ore region, in particular the Zhailma syncline, which closed from the surface by Mesozoic-Cenozoic deposits, and the identification of integrated mineralization here belongs to geophysical studies. Its characteristic feature is the joint occurrence of hydrothermal - sedimentary iron, iron-manganese, manganese and syngenetic polymetallic ores of the first stage of ore formation and hydrothermal-metasomatic barite, sulfide-barite and lead-zinc ores of the second stage of ore formation in the deposits [1]. At the same time, iron and manganese ores prevail in some deposits, such as Western Karazhal, and lead, zinc and barium in others, for instance Zhairem. The prospects of the Atasuy district to search for the Atasuy type of mineralization have been identified, and drilling has confirmed the industrial value of a number of areas.

Analyzing the distribution of metallogenic elements, distribution regions of ore-bearing rocks of the Upper Devonian, ore abnormal (magnetic, gravitational) fields, secondary dispersion halos of elements, we can notice their linear arrangement. So, for example, the ore fields of the Karazhal deposits (Western, Southern, Northern, Eastern), marked by elongated or chains of maxima of local gravitational anomalies and secondary dispertion of halos of lead, zinc, manganese and other elements, make up a band more than 15 km long, confined to areas of development of volcanic-sedimentary ore-bearing deposits of the Famennian stage of the Upper Devonian.

The inconsistent overlapping of the Middle Paleozoic effusive rocks (probably spilled) into the more ancient strata along the lines of deep faults, as well as the presence of numerous hidden faults revealed by geophysical data, suggest that the role of discontinuous disturbances in the formation of the modern tectonic plan Atasuy district is very significant [3]. The basis of this plan, according to geological and geophysical data, is a framework formed by systems of deep

regional faults of submeridional and sub-latitudinal directions. There are Atasu-Tselinograd, Kyzylzhar, Kyzmolinsk, Koskara Kuvlinsk.

Atasuy-Tselinogradsk and Kyzylzhar pass through the Zhailma syncline. The listed systems of the main faults are accompanied by second-order faults that form a distinctive lattice. Not excluded, that the main faults are long-lived and non-renewable. In the area, traces of activation of the Hercynian epoch of tectogenesis are most evident [1]. Deep faults in the foundation of the Zhailma syncline and in the rocks composing this structure played an important role, such as the structure-determining and ore-bearing [2].

In the areas of intersection or conjugation of distinct bands of sub-latitudinal and submeridional directions, group localization of ore occurrences is observed, including those of industrial importance. Such, for example, are the Karazhl group of deposits in the central part of the research territories, Zhumartskaya in the western, and Ushkatynskaya in the northwest [4]. The Zhairem ore-bearing zone, the main part of which is the ore field extended in the latitudinal direction of the Zhairem deposit, is located within the Zhairem block structure.

When comparing the available materials on metallogeny and the structural and tectonic conformation of the region, it turned out that the ore-bearing bands under consideration gravitate to the near-fault activated sections of block structures, located along the strike of linear deep faults [4].

Analyzing the distribution of metallogency elements in the compilation with the deep geological structure of the Zhailma syncline region, one can notice that in most cases mineralization is carried out by graben synclines, which complicated by higher order folding, made by ore bearing Famennian deposits and necessarily confined to the fracture parts of block structures that are characterized by the mosaic foundation structure, composed of rocks of high density.

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POSSIBILITIES OF GEOPHYSICAL METHODS FOR SEARCHING AND DELINEATION OF SULFIDE MINERALIZATION ZONES AT THE NURKAZGAN FIELD

Geophysical methods are one of the most progressive and modern means of studying the earth's interior, they are widely used in the search and exploration of coal, iron, copper and other ores, rare and precious metals, etc. but their role is especially great in the search and exploration of oil and gas fields.

The effectiveness of exploration geophysics in solving a particular problem is determined by the correct choice of a method (or a set of methods), a rational and high-quality technique and

technique of work, the quality of both the geophysical interpretation and the geological interpretation of the results [1].

Field geophysical methods constitute a set of methods used for the search and exploration of mineral deposits by studying geological sections from the surface of the land (land), sea (sea) and from the air (aerospace methods). Depending on the nature of the physical fields used, they are divided into gravimetric exploration (gravity exploration), which studies the Earth's natural gravity field, magnetic exploration (magnetic exploration), based on the study of the distribution of the natural geomagnetic field, electrical exploration (electrical exploration), using artificial and natural electromagnetic fields, seismic exploration (seismic exploration), studying the field of elastic vibrations, artificially excited by explosions, impacts, mechanical vibrations, etc [2].

The Nurkazgan field is located in the Bukhar-Zhyrau district of the Karaganda region, 30 km north of the city of Karaganda. This deposit has the prospect of an ore field for gold-polymetallic and copper-porphyry mineralization. At this field, detailed exploratory geological and geophysical work was carried out [3].

As a result of the work, gold-polymetallic mineralization in the western part of the ore field (Northern gold-polymetallic section), copper-porphyry mineralization in the Central part (Western and Eastern sections), copper-porphyry mineralization in the Northern part of the ore field (Northern copper section) were revealed.

Of the surface ground-based geophysical work at the Nurkazgan field, the following were performed:

- detailed high-precision magnetometric (network 25 × 5 m) and gravimetric (network 100 × 100-50 m) surveys over an area of 15 square meters. km;

- electrical exploration by the method of induced polarization in the modification of the median gradient (HPSG) over a network of 200 × 25 m on an area of 13.1 square meters. km and sounding by the transient method (ZMPP) over a network of 200-50 × 50 m (15 sq. km);

- pilot production electrical exploration studies using methods of sensing the formation of a field in the near zone and remote sensing of induced polarization and resistances.

Based on the magnetic survey materials, a map of ΔT isolines was constructed, which was used to compile a geological map of the ore field of the Nurkazgan deposit.

According to gravimetric survey data, a preliminary map of the isanomal Δd (conventional) with a cross section of 0.1 mH was constructed.

Electrical exploration studies of the ZMPP were conducted with the aim of searching for well-conducting sulfide ores. Based on the results of the work, a map of the electrical conductivity of the rocks in the depth interval 300-400 m from the surface was compiled.

Electrical exploration by the HPSG method was carried out in a pulsed modification with the aim of searching and delineating sulfide mineralization zones (mostly streaked-disseminated), with which copper-porphyry mineralization is mainly associated with the Nurkazgan site.

Geophysical surveys of wells at the Nurkazgan field were carried out starting from the stage of exploration. Copper ore zones are characterized, in general, by favorable conditions for the use of well logging, the most effective of which for exploration purposes is X-ray radiometric logging for copper.

Based on the results of tele-logging, stereographic projections of ore veins for all examined wells were calculated and the elements of their main systems were estimated.

Flow measurement was carried out in wells of hydrogeological purpose, and was performed by the filling method in two stages - survey and detail. Based on the materials of the survey stage, the interval of depths was determined along the wellbore, in which the dynamics of groundwater were noted, and when detailing, the boundaries of the dynamic regime change and the sections of its constant values were specified. As a result of studies, water-permeable intervals were identified for which filtration coefficients were calculated.

Thus, a fairly wide range of logging and downhole electrical exploration was tested at the Nurkazgan field, which allows us to solve specific geological problems at the stage of

prospecting and exploration for copper-porphyry ores: clarifying the boundaries of lithological differences, boundaries of ore zones and crushing zones, verification of core sampling data, determination of permeable intervals for calculating the filtration coefficient. For exploratory purposes, the most effective should be recognized as the use of X-ray radiometric logging (RRT) to determine the contents of copper and other elements in the walls of the wells and flow metering to solve hydrogeological problems.

All surface and borehole geophysical surveys were carried out by standardized equipment in accordance with the requirements of the instructions applicable to each method, provided with the necessary volume of independent control observations and, according to their data, permissible values of measurement errors are characterized [4].

Geophysical exploration methods use spatio-temporal changes in geophysical fields in the earth's crust to search for and explore useful more often, control over the operation of their place.

The intensive development of field geophysics methods in recent decades is due to the rapid progress of their theory and methodology, as well as electronics and computer technology, which allows us to record, process and interpret in a limited time a huge amount of geophysical information collected on the Earth's surface.

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GEOCHEMICAL ANALYSIS OF OIL SEEPS, CONDENSATES AND TAR SAND IN THE COASTAL BASIN TANZANIA AS A TOOL FOR OIL EXPLORATION AND GENERATION POTENTIAL

Surface indications of oil and gas seepage have been noted for thousands of years, and such seeps have led to the discovery of many important petroleum producing areas (Abraham, 2005) Oil and gas seeps, if present, are also valuable analogs because they permit direct correlation of seeping hydrocarbons with soil gas and fluorescence data as well as other microbial or geochemical data (Horvitz, 1969)

Hydrocarbon exploration like in any other basin depends essentially on the presence of petroleum source rock (oil and/or gas-prone) which should have generated and expelled hydrocarbons given the right maturity (Tissot and Welte, 1984). Petroleum source rocks are the primary component of the petroleum system concept introduced by Magoon and Dow (1994). They constitute the precursors of petroleum which, under favorable conditions, may subsequently migrate to reservoirs and be trapped to form accumulations. Oil seeps provide the petroleum systems analyst critical information about source (organic matter type), maturation (organic maturity), migration (migration pathway delineation), and in selected geologic settings, specific prospect hydrocarbon charge, (Abraham, 2005).

Geochemical techniques have contributed significantly to our understanding of petroleum systems globally. However, to meet the increasing challenges of discovering new hydrocarbon resources other analytical method are applied (Lawson et al., 2018), such as integration of seismic and well data to establish stratigraphic framework. Geochemical analysis Permit post seismic high-grading of leads and prospects; generate geochemical leads for further geological or

geophysical evaluation. Use geochemical data to infill between seismic lines and constrain mapping of AVO/amplitude anomalies between lines. Evaluate areas where seismic surveys are impractical or are ineffective due to geological or environmental factors. Provide methods applicable to both stratigraphic traps and structural traps, with the ability to locate traps invisible or poorly imaged with seismic data.

Geochemical analyses of gas seeps, as well as analysis of condensates produced in association with gas at several established gas discoveries, and potential oil-prone source rocks observed at outcrop or penetrated in the subsurface provide the evidence for significant volumes of oil to have been generated.

The high demand for petroleum since the 20th century initiated intensive exploration for hydrocarbon in Tanzania. This led to an extensive study of offshore coastal basin after a long while of non-productive search in the inland basin and with non-commercial discovery at the Songo Songo field (TPDC, 1992; Boote and Downes, 2010). To date, only gas has been found along the coastal margin in commercial volumes (recently in exceedingly large quantities), despite of all the evidence or the presence of evidence that shows existence of oil-prone sources. It was believed that in coastal Tanzania gas was a dominant hydrocarbon (Pereira et al.,2012) and this is confirmed with the commercial gas discoveries that has been made in Lower Cretaceous sands at SongoSongo and in Miocene sands at Mnazi Bay. However, seeps and oil show in wells point to viable, oil prone source rocks (Boote and Downes, 2010). There has been very limited exploration along the whole margin, and this was mainly based on 2D seismic control. Many targets with access to Early Cretaceous and Jurassic sources remain to be tested. (Davison and Taylor, 2012) Said that “to date, only gas has been found along the Coastal margin in commercial volumes, (recently in exceedingly large quantities).

However, despite the success of the recent drilling efforts, it is still universally acknowledged that the East African Basins are massively under explored” and it is true to say that there is still much knowledge to be gained.

Despite the presence of all evidence of evidence from seeps, cuttings, slicks, analogue geological settings, etc., to clearly demonstrate beyond doubt that oils have been generated throughout the region. Very little research efforts have been put on studying of these seeps hence the genesis of these seeps remains poorly known. as a result, very little is understood on coastal basin oil generation potential limiting the understanding of their implications for petroleum geology and hydrocarbon exploration. It is anticipated that this work will provide important information concerning the genesis of the seeps, the geochemical characteristics of their source rocks, and the secondary processes of alteration within petroleum systems with stratigraphic framework. Therefore, this study will be able to use geochemical analysis so as to determine biomarker compounds derived from biological tissue of plants and animals which were fossilized into Hydrocarbon. Biomarkers will be analyzed from oil seeps and condensates then correlated with biomarkers from other oil seeps/known source rocks extracts to determine its similarities in term of deposition environment, maturity level without drilling a well especially in this era of low hydrocarbon costs.

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TWO-LEVEL GROUNDWATER INTAKE WELL

Boreholes are versatile and technically advanced structural type of water intake structures. Currently, in the Republic of Belarus and most European countries, groundwater is extracted using water-supply wells. The extraction of groundwater for water supply of large settlements is carried out using high-yield water-supply wells. In Belarus, the average service life time of high-yield water wells of standard designs is 20-23 years [1]. To ensure uninterrupted water supply to the consumer, it is often envisaged to install two water wells: the main and the reserve one, having separate pump station buildings, that have a zone of sanitary protection, where the special regime of operation conditions of the territory protection are organized [2]. This arrangement of the placement of the working and reserve wells involves significant material costs for the construction of individual wells with pavilions and networks, and also requires the alienation of significant areas under the territory of their sanitary protection zones. With intensive exploitation of wells in most cases, their productivity decreases in due to the chemical and biological origin sedimentation of filters in holes, gravel pores and aquifers. A direct consequence of colmatage is an increase in filtration rates, an increase in input hydraulic resistances and a decrease in water flow to the well. A failed well is plugged back and a new one is built instead, which is not only irrational and expensive, but also unfavorable from an environmental point of view, as corrosive metal structures remain in the exploited underground horizon.

In this article, the author presents the structure of the water intake well with filters on two levels, that can simultaneously perform the functions of working and reserve wells. The use of this structure will reduce energy consumption on lifting water, reduce capital construction costs, as well as ensure uninterrupted water supply. A two-column two-level well design was proposed to increase the reliability and durability of the water well, as well as to reduce the unit cost of water lifting.

The well consists of a conduit with annular cementation, a first borehole consisting of a production string, a filter with a working section and a settling basin, a second borehole consisting of a production string, a filter with a working section and a settling basin, an upper connecting pipe, a lower connecting pipe, gravel package, sand backfill, clay key, injection tubes with perforation, made opposite the working section of the filters.

If one pump fails, another pump runs before it is replaced. In this case of water intake from a two-column design by one pump located in the first barrel, the main flow enters through the filter of the first barrel, the flow from the filter of the second barrel is added to it, which enters through the upper connecting pipe into the first production casing to the pump. Both filters work. Thus, the proposed design is more reliable, since if there is a hydraulic connection between the two columns in case of failure of one filter, you can work with one pump or two at

the same time. Each filter has its own filtration flow from the water-bearing stratum. As the filters are located at different levels of the aquifer column, the fluid flows are separated and they do not significantly affect each other.

The advantage of the two-level well is that the filters are installed in a common water receiver not opposite each other, as, for example, in a two-column well proposed by the authors [3, 4], but at different levels, that increases water intake capacity. Two radial seepage flows are formed along the height of the reservoir, when this installation of filters work with the simultaneous operation of two pumps and with the operation of any of the pumps. It will allow the filtration rate on the way to the filters to be reduced. This will create conditions for reducing pressure losses and will decline of a water table in the well, providing a reduction in the cost of produced water, increase in specific yield of a well and its life time in comparison with a single-column design. Also, the proposed design is more reliable, because if there is a hydraulic connection between the two columns in case of failure of one filter, you can work with one pump or two at the same time.

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PROBLEMS OF DEVELOPING NON-TRADITIONAL SOURCES OF HYDROCARBONS BY THE EXAMPLE OF THE DOMANIKITES OF THE TIMAN-PECHORA OIL AND GAS PROVINCE

The first industrial oil was obtained in 1929. Currently more than 230 hydrocarbon deposits have been explored in the province, a significant part of which are under development. At the same time, the initial total resources have been developed in terms of oil only by 50%, in terms of gas by about 30%. The remaining unexplored part of the initial total resources is forecasted to be in difficult unconventional bedding conditions, in particular, in the «domanikites» of the Upper Devonian period. The so-called «shale oil and gas» are associated with them. The forecasting, exploration and development of oil and gas deposits in the «domanikites» require new methodological and technological solutions. In the worldwide balance of explored reserves and extraction, shale oil plays an increasingly important role, which is associated with unconventional, poorly permeable reservoirs with low levels of oil recovery. In the overall balance of explored world reserves, the share of «shale» oil makes up for almost a half, and the production volumes reach 35%. The role of «shale oil» and gas in the world is constantly increasing. In Russia, «shale oil» refers to «tight oil» [1].

The relevance of the development of «domanikits» is reflected in the government document: «The strategy for the development of the mineral resources base of the Russian Federation until 2035»: «Evaluation and involvement of previously discovered, explored, undeveloped fields and deposits of hard-to-recover oil connected with the bazhenov formation,

domanik horizon and their analogues». Currently, more than 150 wells with various manifestations of oil and gas potential in the «domanikits» have been noted within the territory of the Timan-Pechora province, with industrial oil deposits being discovered in 11 structures.

The analysis of the accumulated geological and geophysical material allows us to compile and justify a geological model of the structure of «domanikoids», to characterize the filtration-capacitive properties of productive deposits, and to identify the features of the formation and the bedding of hydrocarbons in these deposits. «Domanicites» and «domanicoids» occupy a special place in the formation of hydrocarbon deposits in the reef systems of the upper devonian.

First: hydrocarbon generation. The high content of $C_{org.}$ - 5% or more, makes these rocks the main sources of hydrocarbons, and the «fomanicites» themselves are the main oil and gas source rocks in both the Timan-Pechora and Volga-Ural provinces. The generation potential of the «dominicites» is quite high and reaches 700-1000 cm^3/m^3, which is sufficient under certain thermobaric and geological and tectonic conditions to fill the formed traps, in particular, high-capacity rifogenic reservoirs, and due to the vertical-horizontal migration, can be an essential source of hydrocarbons for other oil and gas complexes. Some autochthonous hydrocarbons remain in place in the oil and gas source rocks themselves and fill traps of an unconventional type, that is, they create the so-called «shale oil» and «shale gas». As a result, oil and gas source rocks also become oil and gas containing. This is one of the features of the oil and gas potential of the «domanicoids».

The second feature of «dominicoids» is the lack of structural control over the placement of deposits, in contrast to traditional hydrocarbon accumulations, where the main control factor for almost all types of deposits, except for lithological ones, is structura.

Despite the evidence of the high oil and gas potential of the «dominicites» and «dominicoids», a systematic forecast and searches for oil and gas deposits in these deposits are not carried out. Based on the foregoing, we can draw the following conclusions [2]:

1. The domanik-tournaisan reef system is represented by polycyclic shelf-age depressions of different ages, which include: «domanikites» and «domanikoids», reefs and shelf deposits.

2. «Domanicites» and «domanicoid» deposits are simultaneously in the same system both oil and gas producing and oil and gas containing rocks. The location of deposits in «dominicites» and «dominicoids» is generally not controlled by the structural factor and, as a rule, hydrocarbon accumulations are confined to decompression zones associated with both primary (sedimentation) and secondary (tectonodynamic) fracturing zones.

The analysis of the oil and gas potential of the «domanikites» and «domanikoids» in the domanik-tournaisan rifogenic system allows us to dwell on the main problems of forecasting, prospecting and exploration of hydrocarbon deposits in these deposits [3].

These include - the problem of forecasting and assessing the resource potential of «domanicites» and «domanicoids». To date, the assessment of the resources of various oil and gas complexes in the Timan-Pechora province has been carried out by the standard method of comparative geological analogies (MGA). This was justified for traditional oil and gas complexes, which, especially in the platform part, had a significant degree of exploration (about 50%) and reliable reference ranges (sections). But even under such conditions, the confirmation of the initial total resources (NDS) is very uneven and in the whole province varies from 60 to 100% or more. For the assessment of hydrocarbon resources in the «dominicites» and «dominicoids» of the domanic-tournaisian reef system, which have non-standard conditions for the formation and placement of deposits, as well as due to the lack of sufficiently tested reference sites, some accumulated experience is needed. As far as the authors of this article are aware, there is no such experience either in the Timan-Pechora province or in other similar regions of Russia (the Volga-Ural oil and gas province - «domanicites», Western Siberia - «bazhenites»). For this, it is proposed in the Timan-Pechora province to identify several (at least 3) experimental training grounds, given that rifogenic systems have various morphogenetic forms, such as the most common in the province: atoll, carbonate bank, solitary reef and barriers.

There are structural features of reef systems in the platform part and in the foothill trough of the province.

Therefore, it is proposed that in the platform part of the province in the Khoreyver Depression, the Bagan carbonate bank and Sandivey atoll be selected as a proving ground; in the Pre-Ural marginal trough in the Verkhnepechorsky Depression Vuktylsky autochthon with a barrier reef. These objects have a sufficient amount of geological and geophysical material to justify and develop methodological, methodological and technological principles for the development of domanic deposits of the Timan-Pechora province.

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GEOPHYSICAL METHODS OF STUDYING THE SALINE OIL AND GAS RESERVOIRS OF RUSSIA AND BELARUS

The presence of halite in the pore space is characteristic of subsalt and intersalt oil and gas deposits in the south of the Siberian Platform and the Pripyat Trough. Secondary halite inclusions are also found in productive deposits of the Northwest European Province, the Triassic Province of Algeria and sedimentary basins of Michigan in the USA. Filling the pores and secondary voids with salt sharply reduces the filtration-capacitive properties (FCP) of the rocks. After interacting with the water injected into the reservoir, the FCP of such rocks change significantly due to the dissolution of halite. During well development, calculating hydrocarbon reserves, monitoring, modeling and regulating the development of oil and gas fields it should be taken into account. To take these changes into account it is necessary to have detailed information on the localization and salinity degree of productive reservoirs within the oil and gas horizons; this information can be obtained using the materials of geophysical well logging.

The most complete information on methods of studying salinity degree of rocks by methods of geophysical well logging is available for oil and gas deposits in the south of the Siberian platform. The approaches to studying the saline reservoirs proposed by Russian specialists differ both in the set of geophysical well logging techniques and in the techniques of interpretation of primary materials [1]. Detailed analysis, synthesis of knowledge and knowledge about interpretation of laboratory and geophysical well logging data to allocate and assess the quality of saline reservoirs in Eastern Siberia and the Republic of Sakha (Yakutia), together with information on the reservoirs structure of the Pripyat Trough, made it possible to adapt some interpretation techniques developed in the Russian Federation in relation to the Belarusian oil fields.

One of the approaches proposed in the Russian Federation to the allocation of saline reservoirs is the use of nuclear well logging data (including thermal neutron logging). At the

same time for the geological section of Eastern Siberia a comparison of fictitious values of porosity calculated using different methods was proposed. Since 1984, it was proposed to allocate saline rocks in the carbonate reservoir according to the results of comparing the readings of gamma neutron logging and thermal neutron logging. Later, the allocation of saline rocks was identified according to the thermal neutron logging, gamma neutron logging, sonic logging and density logging data, since the effect of halite on the readings of these methods is different.

Saline reservoirs can be allocated by comparing the results of core-derived porosity and porosity determined by gamma neutron logging in the case when previously drilled wells are characterized by a limited number of geophysical well logging methods. Due to the presence of chlorine in the rocks, the readings of the gamma neutron logging increase, accordingly, the determined porosity index decreases. Comparing the porosity curves according to core and gamma neutron logging data in the rocks without halite, the compared values should be the same, and in saline rocks values should be different ($k_{p.GNL}<k_{p.core}$). To use this approach to the interpretation of gamma neutron logging, large amount of laboratory data on the halite content in the pore space are required.

In recent years, a number of new geophysical methods have been proposed for assessing the degree of reservoirs salinization and determining capacitive properties of these reservoirs:

– by a complex of sonic and neutron logging. For this purpose, a number of crossplots was built to determine the salt content in hydrophilic and hydrophobic rocks according to neutron and sonic logging techniques.

– by combining density logging with neutron logging and sonic logging with neutron logging. This approach allowed us to take into account the degree of salinization and determine the porosity index of the Verkhnechonsky horizon, which is located in the south of the Siberian Platform. The reliability of the proposed algorithms was confirmed by the match of porosity indexes determined by core, nuclear magnetic resonance logging, gamma-gamma logging with neutron logging and sonic logging with neutron logging, when estimating reserves of the Vernechonskoye field.

For the first time, when estimating reserves at the Chayandinskoye oil and gas condensate field, the porosity index was determined by acoustic impedance. In addition, zoning of the territory and revision of the porosity and permeability cutoffs for the zones with different salinization degrees were carried out, taking into account new core data and information on the salinization degree of the rocks. The porosity of the Botuobinsky, Hamakinsky, and Talakhsky horizons was determined according to the sonic and density log data using “core-core” and “core-logging” relations.

Another approach to the study of saline reservoirs is based on a combination of the dual-spacing epithermal neutron logging and dual-spacing pulsed neutron gamma logging techniques, which provide the determination of halite content in the rocks with an error of less than 0.7–1.0%, due to the abnormal high thermal-neutron capture cross-section in halite, as well as lineation of the capture cross-section relative to the volume content of halite. The inclusion of litho-density tool in the complex of equipment allows to reduce the error.

It was also proposed to use the pulsed spectral neutron gamma logging for studying the saline reservoirs, which makes it possible to determine accurately the salt content in the pore space. Using this method in combination with standard and nuclear magnetic resonance logging helps to increase the reliability of determining the porosity and permeability of saline reservoirs.

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APPLICATIONS AND CHALLENGES OF ARTIFICIAL INTELLIGENCE IN EXPLORATION

Machine learning methods deal with the design of algorithms learned from machine-readable data. ML covers the main areas, such as data mining, hard-to-program applications and software applications. It is a collection of multiple algorithms (such as neural networks, support vector machines, self-organizing graphs, decision trees, random forests, hyper cube, case-based reasoning, , etc.), which can provide multivariate, nonlinear, nonparametric regression or classification. The modeling function of the ML-based method has led to its wide application in science and exploration. The Queensland geological survey have done a brilliant work on this methods for the various purposes in the field.

Our focus in this research will be on the application of artificial intelligence and machine learning. Specifically, the role of exploration such as geophysical exploration (gravity electric, magnetic magnetotelluric survey etc), geological exploration (mines and minerals, lithological survey etc) (such as geophysical, geological, mineral), best use of satellite images to gather regional targeted outcomes with highest possible accuracy. The development of intelligent exploration methods using geological and geophysical data in earth science exploration will be given. The most challenging problems in exploration and production may require the application of advanced technology.

Artificial Intelligence (or machine learning) is advanced pattern recognition, not cognition or understanding Decisions on inputs are subjective; actual inputs are largely interpretive Application to poorly modelled data or a small number of input variables yields little benefit over traditional methods (such as map interpretation) Application of new methods of artificial intelligence to well-modelled data sets with large numbers of variables can yield significant insight, identifying associations between input variables and targets.

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INTENSITY OF QUARTZ CATHODOLUMINESCENCE AND TRACE ELEMENT CONTENT IN QUARTZ

Quartz is the second most abundant mineral and is found in many geological environments (Donovan et al., 2011). It is resistant to alterations and weathering(Götze et al.,

2004; Larsen et al., 2009; Müller et al., 2010; Zhang et al., 2019), which permits it to record the physicochemical history of the mineral systems (Götze and Möckel, 2012; Zhang et al., 2019). The internal growth textures and grain size distribution yield valuable information on the nature and evolution of the melt from which the crystal developed (Müller et al., 2000). Importantly, quartz commonly has sink capacity for many trace elements including Ti, Al, P, Fe, Ge, H, Li, Be, B, Na, P, K, Ca, Mn, Fe, Ge, etc. (Müller et al., 2003; Müller and Koch-Müller, 2009). Therefore, trace elements of quartz provided a powerful tool to understand the evolution of various geological processes and the physicochemical conditions during the formation of quartz (Donovan et al., 2011; Lehmann et al., 2009; Thomas et al., 2010). In this regard, a considerable number of researches on magmatic quartz trace elements by laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) combined with the internal texture observation by cathodoluminescence (CL) were conducted to further understanding the forming processes and conditions, and petrogenesis of igneous rocks. For example, identification of multiple generations of scheelite (Ding et al., 2018a), crystallization history reconstruction and quartz generations identification in Schellerhau Granite Complex (Müller et al., 2000), identification of magmatic processes and evolution (Ding et al., 2018a; Müller et al., 2003), and conditions and sequences of magma crystallization and deformation process (Müller et al., 2002). Defects that cause CL and Core-to-rim zoning indicate the physicochemical conditions of quartz growth (Marshall, 1988; Matthews et al., 2012; Rusk et al., 2006).

The Huangshaping Pb-Zn polymetallic skarn deposit, with the total ore reserve of 22.43 Mt Pb-Zn (Ding et al., 2016a; Hu et al., 2017), 74.31Mt W-Mo (Ding et al., 2016a; Li et al., 2016a), and 20.35 Mt Cu (Hu et al., 2017; Li et al., 2016a), located in the central Nanling region, Southern China (Ding et al., 2018b, 2018a; Hu et al., 2017; Li et al., 2017, 2014a). These polymetallic deposits have been classified into two metallogenic systems: W–Mo–Pb-Zn system genetically associated with granite porphyry (Ding et al., 2018b, 2018a, 2016a; Hu et al., 2017; Jiang et al., 2018; Li et al., 2014a; Li et al., 2020) and Cu-Pb–Zn system genetically related with Quartz porphyry (Bai et al., 2007; Jiang et al., 2018; Li et al., 2009; xiaofeng et al., 2016; Li et al., 2020). Different authors reported the crystallization sequence in a different way ranging from dacite porphyry to granite porphyry (Lei et al., 2010; Li et al., 2009; Quan et al., 2012; Li et al., 2020). Based on previous research work, we infer that the crystallization sequence should be dacite porphyry----quartz porphyry----granophyre----granite porphyry (Li et al., 2020). Nevertheless, according to the spatial relationship between mineralization, alteration, and igneous rocks, the metallogenesis is genetically associated with the quartz porphyry and granite porphyry (Ai, 2013; Yao et al., 2005; Zhu et al., 2012; Hu et al., 2017). No mineralization has been found related to the dacite porphyry (Li et al., 2014a, 2014b). Huang et al., 2015 and the O^{18} values in quartz from the Huangshaping granites represented no significant differences, indicating that the isotopic compositions of the original magmas of these granites are not much different from each other and they are possibly related to the same geologic event (Ding et al., 2018b). Recent drilling exploration and petrologic evidence (Hu et al., 2017; Li et al., 2014; Quan et al., 2012) proved that, when we move from shallow to deep, granophyre gradually turned into granite porphyry, indicating that the granophyre and granite porphyry may belong to different litho-facies of the same pluton (Ding et al., 2016b; Hu et al., 2017; Zhu et al., 2012; Zhu et al., 2010).

After the 1970s, a lot of research activities have been undertaken on the Huangshaping polymetallic deposit including fluid inclusions (Ding et al., 2018a; Li et al., 2016b), S and Pb isotopic studies of sulfides (Ding et al., 2016a; Hu et al., 2017; Li et al., 2014a, 2016b), C and O isotopes and trace elements of gangue minerals (mainly fluorite and calcite) (Li et al., 2016b), and Sm-Nd isotopes (Li et al., 2016b), ore genesis (Li et al., 1997; Shen, 1999), studies of mine geology (Deng, 1997; Huang, 1999), and ore geochronology (Lei et al., 2010; Li et al., 2016; Qi et al., 2012). From 2007 a new round of intensive exploration was conducted, and numerous skarn-type W–Mo and Cu orebodies were discovered beneath the Pb–Zn orebodies at deeper levels (Li et al., 2016a). However, the detailed study of magmatic quartz related to these four

types of porphyries is insufficient at Huangshaping. This paper reported new information on the CL-imaged textural features and LA-ICP-MS trace element geochemistry of the ore-related quartz from the Huangshaping deposit. With these data, we discussed the petrogenesis of these four types of rocks and why the two types of intrusive rocks (quartz and granite porphyry) are fertile to mineralization. In contrast, the other two (dacite porphyry and granophyre) are barren, given that these four rocks formed at the close time.

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LABORATORY MEASUREMENTS OF SEISMIC VELOCITIES OF THE MUMBAI HIGH FIELD DRILL CORE SAMPLES, AND THEIR RELATION TO LOG DATA

The mechanical characterization of reservoir rock is essential in the design and development of Geomechanical models. To process such models, lab derived compressional and shear-wave velocities are significant, which provides dynamic and elastic properties to validate and match the field measurements. A study of the variations in the elastic properties from various methods such as ultrasonic, triaxial tests and well logs helps to find the anisotropy of reservoir rock. In this study, rock elastic properties such as Poisson's ratio, Young's modulus, shear modulus, bulk modulus, and uniaxial compressive strength were evaluated using the ultrasonic measurements and triaxial compression loading tests. Laboratory measurements of ultrasonic wave velocity are the well-established method to measure the dynamic elastic properties of the rock samples. This measurement was first practiced as far back as 1951 [1]. To obtain the elastic properties, core plugs have been derived from different wells located in the Mumbai High field, India. Also, the conventional triaxial compression tests were carried out on digital compression testing machine having a load capacity of 1000 KN, where the confining pressures ($\sigma_1 > \sigma_2 = \sigma_3$) were used.

The pressure and shear wave velocities have been evaluated in terms of travel time and length of each core samples using the transducers of 250 kHz and 500 kHz under ambient conditions. This study was performed in congruence with the ISRM methods [2]. Cylindrical core samples were made flat for transducer coupling and prepared geologic samples were tested with Ritec High Power Ultrasonic Pulser Receiver RPR-4000 in the ambient conditions. In triaxial loading test, confining pressures in the triaxial chamber were added in a sequence; Initially, confining pressure applied through the hydraulic-oil system on the core sample placed

in a triaxial chamber, later axial load is applied when the pressure inside the chamber gets stimulated. Axial load continued to apply until the rock fails to take a further increase in load. This study provides rock failure parameters such as cohesion and internal friction angle from the Mohr-Coulomb failure envelopes at various confining pressures. Moreover, 1D Mechanical Earth Models represents the subsurface spatial distribution of rock properties were calculated from wireline logs.

In ultrasonic testing, a significant difference in P-wave velocity was observed in the limestone samples typically ranges from 1140 m/s to 1912 m/s, with an average of 1632 m/s. Average P-wave velocities measured in the shales and basalt samples are 1680 m/s and 1355 m/s, respectively. S-wave velocities in the limestones have an average value of 860 m/s; shale samples have 920 m/s. Also, triaxial loading tests were conducted on the same specimen collected from the same wells. During the triaxial loading test, the cylindrical rock sample first revealed linear-elastic behaviour and then elasto-plastic behaviour. When the maximum compressive force achieved, the crack initiation starts, which reflects in terms of initial damage in the corresponding rock samples. Significant transform in the elastic properties has been discovered in the multilayered shale-carbonate transition zones. More precisely, the integrated analysis and interpretation of elastic properties from different methods provide an inclusive understanding of rock mechanical anisotropy and borehole stability.

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DETERMINING THE PROPERTIES OF A COAL SEAM EXPLORED BY CORE DRILLING

One of the most important, and essential things in the human technological evolution all along the history is the mineral mining. Without it, modern life could be unimaginable, so it is our objective to make all the material accessible for the society. The base of economical, and sustainable mining is the precise models, good estimations about the underground minerals, and geological structures. Determining the required properties for the planning and production management is the key for every successful mine all around the world. In this work my objective was to determine the necessary properties of a coal seam by using the given database, measured during the research phase.

The method of sampling was core drilling, this allows us to examine the geological environment without bigger alteration. The database contains the detailed properties of 30 drilling holes, and nearly 900 samples. The following properties were measured, and recorded: horizontal x and y coordinates; elevation; drill hole depth; sample elevation from-to value; calorific value; sample height; seam top-bottom; ash content, humidity; sulphur content; hydrogen content; burn heat value; density. My goal was reprocessing the information and determine the average values for the production phase, assign the correlations between the properties, depending on the slice thickness. Some of the information were missing, so I had to

complement them with an empirical method, depending on the available data. I made the calculations for 2 m, 2.5 m, 3 m, 3.5 m and 4 m slice thickness.

The first goal was replacing the missing data, because it is necessary at the following calculations. Instead of creating a correlation by the database, I used the empirical equation which was formerly determined by regression method from by over 5700 data, so the level of accuracy is higher than using my 850-sample sheet. After the replacement I started counting the average values for every drill hole. I used Microsoft Office Excel spreadsheet software for the calculations to prepare database for geostatistical estimations. In the software I used the commands to simplify the calculation method, so numerous information can be handled in a relative short time. I measured the slice thickness in every case from the upper surface of the coal seam. The sample heights are usually under 0.4 m, so every thickness contains multiple samples, with different values. I added up the sample heights from above until it reached the required slice thickness, in some cases the lower border of the slice separated the last sample into two parts. Depending on the - upper part height (which is in the slice thickness)/full height - ratio I gave a multiplier value to the separated sample which is equal to the mentioned ratio. With a weighted average formula, I calculated the average properties of the drill holes by considering the sample height, density, and the specified properties (and the multiplier for the last separated sample). For the five different slice thickness the averages were of course different, so in the result of the calculations I created five spreadsheets, every with the drill holes in the rows, and with average values of density, calorific value, humidity, ash content and sulphur content in the appropriate columns.

I edited maps for the different properties of the coal seam using the created spreadsheets. I used Surfer mapping software for creating the maps, and with it I calculated the overall volumes of the coal seam by the five properties listed earlier. Before calculating the volumes, I created a border line around the drill holes, considering the extrapolation and interpolation rules, used in the software calculation method. After I recorded the volumes depending on slice thickness, I created charts with Excel for visualizing the data. The charts show important correlations between the different slice thicknesses and the properties. With all the calculations, map creating and chart making, we received valuable data for further mine planning, and production.

During this work I learned about the data reprocessing and visualization, map creation, and a lot more. All the result can be used in geology, mining, and construction. The information can be important for further geological research, opening the mine, extracting the minerals, or managing the waste dump area. By using the created maps, we can determine the type of the mining method, the starting point of the mining process and the progress heading, the necessary roads, ramps, in case of underground mining the shaft, surface and underground facilities. The maps can be helpful all along the mining activity, but even during reclamation or upgrading the mining area with further geological research. With more calculations, the production rate, the required mining machinery, hauler and reprocess equipment can be chosen. Depending on the resource market value and mining expenses, a financial plan can be created for a sustainable and rewarding mining activity. The created information is key to selecting the mining technology or evaluate the economic properties of the coal seam.

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STUDYING BLOCK MODELS WITH VARIOUS SIZES OF BLOCKS AND THEIR PARTITION IN MGIS

At the moment, the use of digital technologies in many industries has already become commonplace. Nowadays, it is one of the most important ways of efficiency improvement. And for the mining industry this is no exception, while there are still many opportunities for improving the digitalization of the industry.

Leading global mining companies invest heavily in the development and application of modern technologies. One of the key areas of the mining sector in which the digital technologies are being actively introduced are search and exploration of mineral deposits, their economic evaluation, quality management, automatic dispatch and control systems for equipment [1-3]. In the selected areas, a large number of modern technologies and various software are used, the latter include mining and geological information systems (MGIS). Recently, there have been a lot of such systems, the most famous among them are Micromine, Datamine, Leapfrog, Geomix, Geovia Surpac.

With the help of MGIS, a geologist or mining engineer can create frame and block models of ore and non-metallic bodies, coal seams [4]. In most cases, the work is not limited only to the creation of frame models; for certain reasons, the transition to block models is necessary. And at this stage, any MGIS user faces the problem of choosing the optimal block parameters.

The problem is that today there are no specifically prescribed, approved, universal rules for determining the parameters of blocks, specialists from the industry, as well as software developers, only give recommendations on choosing parameters.

Within the course of this project, the task was to develop a block model of a porphyry copper deposit and select the optimal block parameters. Based on the passports of the boreholes, a database of the deposit was created, ore intervals were allocated for the GKZ, and frame models for ore bodies and lithological varieties were built. A comparative analysis of various parameters of block models is carried out. In this work, recommendations for selecting block parameters in the Micromine MGIS are considered, various options for parameters are analyzed based on basic recommendations.

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PIT OPTIMIZATION USING MINING AND GEOLOGICAL INFORMATION SYSTEMS ON THE EXAMPLE OF THE PAVLIK DEPOSIT, (MAGADAN REGION)

The use of mining and geological information systems is becoming more widespread in modern mining enterprises, so the proper use of the functionality of software systems and the development of appropriate techniques is a very important and urgent problem.

One of the most important tasks in developing an open pit mine is to determine the final contours of the pit. The solution to this problem is based on taking into account the spatial distribution of useful components and accepted stable or technologically permissible slope angles of the pit sides. Today, it has become in geoinformation systems, which, make it possible

to build 3D models of the pit and choose the optimal shell. In the Russian literature on geostatistics and modeling of deposits in the works Yu. E. Kapustin a comprehensive review of the application of geostatistics and modeling is given fields, the theory of optimization of quarries, etc. in both Russian and Western practice. Along with the work of Y. E. Kapustina this question is open lesonen M. V. M. V. M. S. and Sen , offering a mechanism for determining the contour of the quarry taking into account the interests of the subsoil user and the state, where the the main criteria of optimization are considered career net present value discounted and budget efficiency. In continuation of this topic, the authors reveal the principles of using quarry optimizers in the technical and economic assessment of deposits, as well as offer parameters of conditions used in the calculation of reserves block modeling methods

This article discusses the possibility of using MICROMINE software in order to obtain optimal quarry shells. The purpose of the study was to develop a project for the rational development of the southeastern flank of the Pavlik deposit (Magadan Oblast) by open pit method using GIS. At the moment, the company is developing the central part of the field, which was explored in the 90s.The objective of the study is to build a volumetric model of career expansion and choose the most rational shell based on the data obtained at the enterprise. All builds will be completed in the Micromine 2018 program.

The Pavlik gold deposit is located in the Magadan region. Pavlik is a stockwork type deposit, which makes it possible to open-cast large-scale gold mining. The initial data are the results of testing wells for exploration and production drilling. The necessary materials were obtained during practical training at Pavlik JSC in 2019. By the service of the chief geologist, I was given the task in a special part of the diploma project to consider the optimization of further development of the field by open pit mining.

Ore zones were identified based on composites calculated along the wells. The deposit has an extremely uneven distribution of the useful component, so it was decided to allocate ore zones whose boundaries correspond to the onboard) content, with a zone thickness of at least 30 meters. Based on the obtained composite intervals, ore zones were outlined in the plane of each section. Depending on the stratigraphic position, 3 ore zones were identified in the section.

For optimization, it is necessary to have a block model of the deposit, as well as the cost of ore extraction and its processing. All of this data is entered into a specific form of Micromine software. Based on the data, a possible quarry shell is automatically selected. At the moment, I have economic indicators, but there is no block model, so it is impossible to show the proposed shell. However, in this software it is possible to build a quarry project manually, which can be further compared with the proposed shell contour shell. The depth of the project quarry is determined by the degree of exploration of ore bodies.

The practical significance of the work lies in the development of an algorithm for selecting the optimal open pit shell using modern digital technologies and its introduction into the production process at the field, as well as in calculating the operational options for changing the open pit contour when specifying mining, geological, technological and technical and economic conditions during operation. In conclusion, I would like to say that the optimization process is complex and its result will depend on the correctness of the source data. But if the operation is performed correctly, then it will help to achieve the most rational operation of the field.

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MOLECULAR SIMULATION OF METHANE ADSORPTION BEHAVIORS ON COAL: EFFECT OF MATURITY AND MOISTURE CONTENT

Coalbed methane is an alternative and valuable non-renewable unconventional gas energy, and an understanding of its adsorption characteristics under the reservoir condition is greatly required for accelerating the process of safe mining, energy structure optimization and reduction of greenhouse gas emission. It has been widely acknowledged that water exist in coal matrix and fractures [1], therefore, clarifying the adsorption characteristics of gas-fluid two-phase in coal shows great significance to evaluate the transfer and flow law. Although many scholars have reported the methane adsorption ability in coal by performing the molecular simulation [2-3], the quantitative impact of moisture content and maturity on the methane adsorption ability has been paid a little attention.

In this work, based on the classical coal structure [4], the effects of maturity (low, intermediate and high rank) and moisture content (0.7wt.%, 1.1wt.%, 1.4wt.% and 1.8wt.%) on methane adsorption capacities and thermodynamic properties are discussed by performing the molecular simulation, where the simulated pressures range from 0 to 16MPa and three temperatures (298K, 323K, and 348K) are included. The determination of temperature and pressure is depending on the actual coal environment.

Initially, the coal structure is conducted by hydrogenation saturation, further relaxed by Geometry Optimization and Anneal simulations. Amorphous Cell module employed first aims to determine the initial density value of coal molecular structure with the periodic boundary conditions, then the molecular mechanics and molecular dynamics calculation are carried out. By adjusting the cell size and repeating above steps, the coal molecule configuration with the lowest energy is ultimately acquired. To investigate the effect of moisture content on gas adsorption in coal, moist coal models with a series of water contents (0.7wt%, 1.0wt%, 1.4wt% and 1.7wt%) are constructed through the fixed loading task in Sorption module. The absolute adsorption isotherms are calculated by using the grand-canonical Monte Carlo (GCMC) method. The fixed pressure task is utilized to simulate the adsorption process of sorption molecules on coal structure. The adsorption amount with different temperature and pressure conditions is determined by Metropolis method. The periodic boundary conditions and Andersen heat bath temperature control are adopted for the simulation calculation.

In addition, the competitive adsorption capacity of water/methane on coal is sufficiently compared and analyzed depending on the competitive adsorption curves of methane and water molecules on coal for different maturity at 298K. Furthermore, the critical moisture content impacting the isosteric adsorption heats of methane in coal is determined. This study provides a quantitative understanding of the maturity and moisture effects on methane adsorption abilities and thermodynamic properties from a microscopic perspective.

Results demonstrate that the adsorption capacity of methane on dry coal increases with pressure and maturity significantly, nevertheless, decreases with temperature and moisture content sharply. Taking the 323K simulated temperature and 16MPa pressure as an instant, the absolute adsorption capacity of methane on coal with the low, intermediate and high maturity are 0.45mmol/g, 0.59mmol/g and 0.71mmol/g, respectively. Compared with the intermediate-rank dry coal, the absolute adsorption capacity of methane molecules on moist coal (0.7wt.%, 1.1wt.%, 1.4wt.% and 1.8wt.%) are reduced by 28.3%, 35.1%, 46.9%, and 62.3%, respectively (at the same P-T conditions). Moreover, during the competitive adsorption process, the adsorption site of coal structure is easier to absorb polar molecules, which leads to the higher adsorption capacity of water molecules than that of methane molecules. When the simulated

temperature reaches 298K and pressure is 16MPa, the competitive adsorption capacity of methane molecules on the low-rank coal is 0.12mmol/g, while that of water molecules is 35.76mmol/g. Furthermore, the value of moisture content 1.4wt.% is a critical point for the isosteric adsorption heats of methane in coal. When the moisture content in coal is less than 1.4wt.%, the average isosteric adsorption heat of methane molecules stays almost stable. Accordingly, when the moisture content in coal exceeds 1.4wt.%, the average isosteric adsorption heat of methane molecules increases obviously with the increase of water content.

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GEOLOGICAL JUSTIFICATION OF URANIUM DEPOSITS DEVELOPED BY UNDERGROUND LEACHING USING THE EXAMPLE OF THE TORTKUDUK DEPOSIT

Due to the growing demand for uranium, the mining industry of uranium as a type of raw material for the nuclear industry is growing and expanding around the world. To date, the uranium reserve in Kazakhstan is about 1.7 million tons. About 80% of them are concentrated in layers of infiltration type, water rocks.

Underground well leaching is a method of exploration of reservoir-infiltration type deposits without lifting the ore to the surface of the earth by selecting natural uranium ions directly into the productive solution. At the same time, uranium-containing ores are considered to be environmentally friendly and more efficient than traditional mining methods (mine and quarry) [1].

The main problem that arises when implementing the method of underground well leaching is the current lack of sufficient reliable information about the construction of the ore body to regulate the technological process in order to maximize the extraction of the useful component and reduce the cost of production.

Positive factors in the development of the field include:

- stability and horizontal occurrence of productive horizons;
- good filtration properties of ores; -good leachability of uranium with weak sulfuric acid solutions;
- relatively high content of uranium in ores
- low acid content of rocks and ores;
- small effective capacity of the productive horizon;
- high drilling speeds for rocks of the III-IV category of drillability;
- absence of interfering factors (karsts, etc.);
- possibility of using polyethylene pipes instead of stainless steel pipes for casing technological wells;

- the ability of deposits of productive horizons to neutralize residual technological solutions;

- semi-desert landscape, not suitable for agriculture;

- absence of any interfering structures and communications[2].

The following features are typical for infiltration deposits: 1. Location in areas of arid climate; 2. Confined to permeable aquifers of sandstones located between reservoirs; 3. Presence of ore-controlling zones of intraplastic oxidation; 4. Presence of ore-controlling redox mineral-geochemical and hydrogeochemical zonality; 5. Localization in places of accumulation of syngenetic organic matter and other reducing agents (bitumen, organic matter); 6. Roll form of ore bodies (Crescent – shaped-in cross-section, ribbon-shaped-in terms of ore deposits); Descending flows of oxygen-containing waters in the artesian system form zones of formation oxidation (ZFO). Oxygen-rich water transfers soluble oxides U6+, V, Mo, Se. deposition of the substance occurs at the reducing geochemical barrier. In the area of mineralization are precipitated metallic selenium, the oxides of uranium (U4+), coffinite, pyrite, molybdenite, pranavanandaji etc. The roll form of ore bodies is very characteristic, due to different rates of percolation of oxidized water [4].

The Tortkuduk Deposit is a typical representative of formation-infiltration uranium deposits with mineralization confined to permeable aquifers, in which oxidative ore-controlling epigenetic zoning develops. The Tortkuduk field is located in southern Kazakhstan, and belongs to the Moinkum group of fields.

The main features of such deposits and sites that determine the method of exploration are:

- subhorizontal and sub-consistent position of uranium ore deposits within the productive horizons;

- large size and ribbon-like shape of ore deposits in the plan with sustained for a considerable distance stretch;

- variability of power of ore bodies and roll-like shape of deposits in sections;

- variability of the uranium content in both the strike and fall;

- occurrence of ores in difficult mining and geological conditions (pressure water);

- control of mineralization by wedging out the formation oxidation zone;

- an alternative method of mining is underground leaching.

According to the " Instructions for the application of reserves classification...", 1986. deposits of this type in terms of complexity of the geological structure belong to group 2 subgroup a and are explored only by vertical drilling wells. For exploration of reserves of category C1 in the fields of this group, the distance between the profiles of drilling wells along the stretch of ore deposits is 400-100m and the profiles between wells are 100-25 m[3].

The purpose of hydrogeological work is to determine the hydrogeological parameters of non-metallic aquifers, experimental pumping for ore-containing aquifers, determination of filtration coefficient, etc. To solve these problems, the following types of work are required: 1. Experimental filtration works; 2. works on studying the regime and balance of underground water; 3. Engineering and geological works. The site provides for drilling wells in hydrogeological bushes and single ones, for conducting pilot filtration works in them. As a result, various hydrogeological parameters will be obtained, which will be necessary for the assessment and operation of the site [2].

Taking into account all the favorable factors such as low carbonation, stability and horizontal occurrence of productive horizons, small effective capacity of the productive horizon, favorable groundwater regime, as well as other factors, it can be considered that deposits of this type are favorable for development by underground sulfuric acid leaching.

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VALIDATING OF STRUCTURAL-TECTONIC MODEL ACCORDING TO WATER CUT ANALYSIS AND TRACER TEST RESULTS

The aim of the work is to update the structural-tectonic model of the V. Filanovsky Oil field taking into account results of applied tracer studies. The work included: -analyses of dynamic parameters of the object of development; -analysis of the results of tracer studies. During the analysis of tracer studies, the possible distribution pattern of tectonic disturbances not detected by seismic surveys was determined. The results of the study can be used to create valid geological model of the V. Filanovsky field. Levchenko V. S. in his work is giving a report about applied tracer studies in injection wells 5-N, 7-N, 8-N, describing the characteristics of applied tracers and analysis of taken samples from production

One of the largest oil fields in Russian sector, Offshore V. Filanovsky Oil field, was discovered in the central region of Caspian Sea in 2005. Ten major hydrocarbon deposits have been discovered in the sediments of the Middle Upper Jurassic and Lower Cretaceous. All reservoir deposits are narrow and extended from west to east. The main industrial reserves are located on the western deposits of the Neocomian sub-layer, on which most of the wells have been drilled. By 01.01.20, there were 16 producing and 3 injection wells in the Neocomian sub-layer. In the initial phases of hydrocarbon extraction, the increasing coproduction of water and high gas factor in numerous wells, together with a significant drop of reservoir pressure were reported. Increasing coproduction of water was notified in wells 4, 4-N, 5, 6, 7, 7-N, 8, 12. Also, a significant number of wells did not respond to water injection from injection wells.

Such uncertainty indicates a lack of understanding of the adequacy of the geological model, in other words, its inadequacy within the development field data. In order to identify the presence of a hydrodynamic connection between injection and production wells, tracer studies were applied. Running tracers can significantly increase the information of characterization of reservoir processes of the studied objects and thereby significantly increase the effectiveness of method used for hydrocarbon recovering.

The tracer was pumped into three injection wells (5-N, 7-N, 8-N), after which the samples were taken from producing wells. An analysis of the samples showed that tracer pumped in 8-N injection well was recorded in 4 production wells: 4, 4-N, 7-N, 12 [1, 2]. It was established that well 4 and 4-N had a good hydrodynamic connection with the 8-N injection well: injection tracers were flowing along decompressed (fractured) zones. A connection between production wells 4, 5, 6, 7, 8 and injection well 5-N was also noticed. Hydrodynamic connection between injection well 7-N and the producing wells 5, 6, 7, 8 was determined. A connection between production wells 4, 5, 6, 7, 8 and injection well 5-N was also noticed. A good connectivity between wells located at a considerable distance from each other (up to 8 km) was establish according to analyses of speed of the arrival of the tracer. Analyzing the change of the tracer concentration over time allowed us to determine that the maximum concentration of the tracer in the wells 4-N (reacted from 8-N) and 6 (reacted from 5-N) is due to high filtration rates, high permeability, and low volumes of the filtration channels. The rapid arrival of a highly concentrated tracer from injected well 7-N to producing well 7 is due to its proximity.

Faults with a large displacement along the fault plane and permeability pitchouts can represent barriers to the flow of fluids perpendicular to their axis. Applying tracer studies can provide a significant help for detecting faults and other kinds of flow barriers. Some of the

examples of fields where tracer studies were used are the Snurre field (a giant Oil field in the Norwegian sector of the North Sea) and the Gullfaks field (the North Sea). In these oil fields tracers have identified unexpected communication paths between the layers. The results of these studies have contributed to methods to improve the efficiency of water and gas injection. Based on the analysis of tracer studies applied in V. Filanovsky Oil field , there was an indication of a possible presence of tectonic deformations (faults) that were not identified by seismic surveys. The obvious factor is the presence of a loose zone along the northern side of the field. Also, the presence of an impermeable fault between the MLSK-1 (marine ice-resistant stationary complex) and MLSK-2 was assumed. A new understanding of tectonic deformations allows updating of geological and reservoir model of V. Filanovsky Oil field (Figure 1). In the future, it is necessary to build an updated structural-tectonic model of the V. Filanovsky Oil field with adaptation of it's hydrodynamic model also.

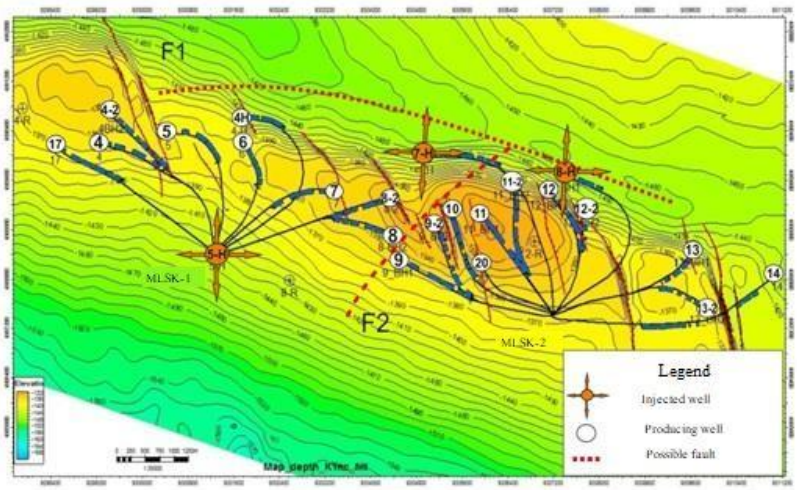

Figure 1 - Structural map of the V. Filanovsky Oil field with faults identified after conducting tracer studies

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CHARACTERIZATION OF NANOSCLE-PORE-NETWORK IN HIGH-RANK COAL - A KEY PROBLEM IN EVALUATION AND EXPLORATION OF HIGH-RANK CBM RESOURCES

KEYWORDS: Nanoscale pores; Anthracite coal; Descriptive classification; Quantitative characterization; PSDs.

Nanoscale pores microstructure of coal reservoirs is an important factor influencing methane adsorption, storage and migration in the matrix. Therefore, their characterization is receiving increasing attentions by geologists as a critical aspect of coal reservoir studies. This includes the types, pore size distribution, surface area, pore network characteristics (how the pores are clustered or arranged) and their connectivity.

In the present study, a series of experimental procedure were designed and applied to the quantitative analysis of the microstructure of anthracite coal samples collected from the

Yangquan mining area in the Qinshui basin, northern China. First, the pore size distributions (PSDs) of coal samples were obtained by combining low temperature nitrogen gas adsorption (LTN_2GA) and high pressure mercury injection (MIP). To determine the pore types over different size scales, an atomic force microscope (AFM) was used to characterize the pores with diameters of less than 10 nm, and an argon ion polishing-field emission scanning electron microscope (AIP-FESEM) was employed to capture images of pores with sizes ranging between 10 nm to micro-fracture scales. Image processing was conducted on the field emission scanning electron microscope (FE-SEM) images to extract the structural information of pores.

Results show that the tested coal samples were bimodally distributed with a major peak present at approximately 20nm-400nm. However, the pore volume determined by LTN_2GA was significantly lower than that by MIP, indicating the destruction of the microstructure and the compression of the sample matrix by high pressure. To better characterize the pore size distribution, the elastic mechanics law combined with a fractal dimension determined by LTN_2GA data was used to correct the MIP volume, and parameter dv/d(logw), where v is the pore volume increment and w is the pore diameter, was used to assess the partial porosity of the samples considering different pore diameter ranges. The results revealed a high proportion of pores with diameters over the range of 3 to 50 nm. According to the FE-SEM and AFM images, two types of pores contributed to the predominant pore-size distribution, including nano-scale pores within or between microscopic organic constituents (10 nm-50 nm) and molecular pores (3 nm-10 nm) (Figure 1). Gas pores, mineral-related pores, and micro-fractures developed over larger scales. The observed meso-porosity was limited. A micro-pore network system in high-rank coal reservoirs was established combining qualitative and quantitative methods (Figure1).

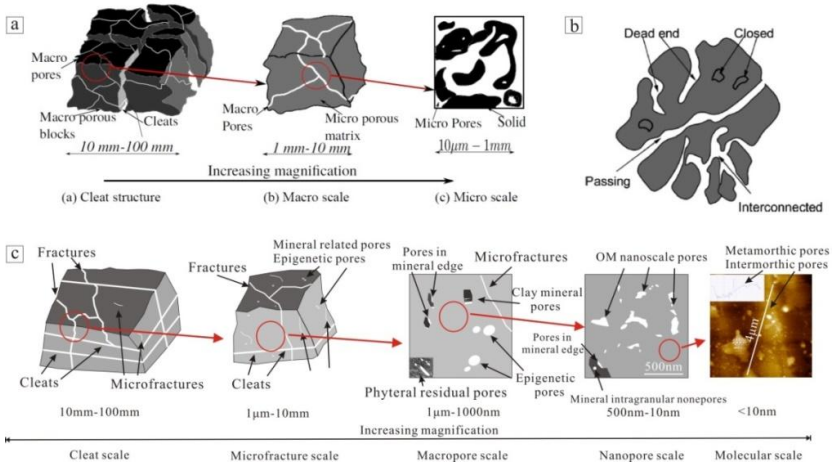

Figure1 - Micro-pore network system in high-rank coal reservoirs

The micro structure controlled the transportation of gas within the matrix. The microscale gas transportation process based on the micro-structure, from the molecular to the fracture scale, such that the methane first desorbs from the surface of the molecular pores (Stage A), and is then gathered in the nanoscale pores (Stage B) (Figure 2). With the decrease of pressure when mining shale gas, the gas is transported from the nanoscale pores to seepage channels (Stage C). It is proposed that the lack of mesopores leads to the low micro-permeability, while the nanopores contribute to the high gas storage capacity of the sampled coal matrix.

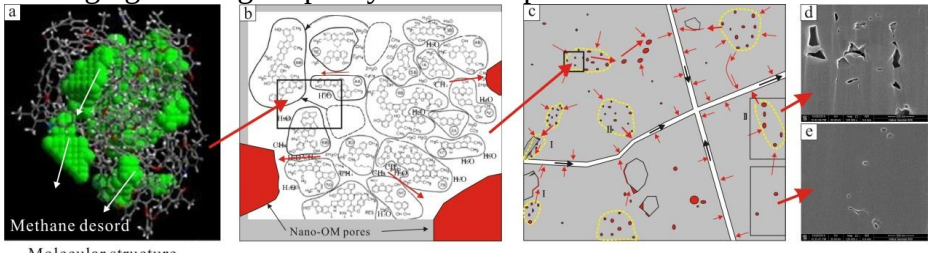

Figure 2 - The microscale transportation process of methane. (a-c) Desorb and transportation from molecular pores to micro-fractures. (d-e) Porous and un-porous regions

ACKNOWLEDGEMENTS

The authors are very grateful to the National Natural Science Foundation of China (No. 41772130), Coal based key scientific research project of in Shanxi Province (MQ201402) and Scientific Research Foundation of Key Laboratory of Coalbed Methane Resources and Reservoir Formation Process, Ministry of Education (China University of Mining and Technology) (No. 2015-007), for funding support. The author Difei Zhao also thanks to the China Scholarship Council (CSC) for providing the CSC scholarship for occupational training at the University of Queensland.

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SEISMIC APPROACH FOR INTEGRATED RESERVOIR CHARACTERIZATION BASED ON A COMPREHENSIVE GEOLOGY STUDY

3D seismic survey is the undisputed leader among tools of identifying potential exploration targets and reservoir characterization. This paper shows surveys that are crucial in the exploration and development of significant amounts of hydrocarbon resources, and can be used by operator companies to map complex geological structures [1] and select better drilling locations. The purpose of research work is to have better understandings of formations and update previous studies in oil field of Mangyshlak Basin [2], Western Kazakhstan. The Main results are the acoustic impedance, Vp/Vs ratio, lithological and reservoir properties data. The quality controls and analysis of results show good match with well logs and good recovery of seismic signal in inversion, but it should be improved in some areas. The results, from a scientific point of view, expand the already known geological and geophysical studies of the reservoir and improve the quality of interpretation using seismic methods [3] in studying the sedimentation environment of the site.

Reservoir characterization [4] is made by correlating seismic properties obtained with values measured in wells and extended wells. It's a process that helps fill our knowledge gaps of properties between wells. The given reservoir characterization technique uses the following procedure: 1. Conducting detailed correlation with the division into 11 groups of oil formations of the field, followed by analysis of stratigraphy; 2. Interpretation of horizons and faults over 11 productive layers and 4 main target horizons in the Triassic and Paleozoic; 3. Compilation of structural maps of the main target horizons; 4. Perform analysis of sedimentation conditions based on updated more detailed logging and 3D seismic data; 5. Creating and performing dynamic analysis of field operation; 6. Reservoir characterization features. Evaluation of the exploration and development efficiency.

Using the sections of deposits and distribution maps of oil and gas regions, we analyzed the features of 11 oil-bearing objects (Figure 4).In the horizon 11, the sections between oil, gas and water are complex, which allows to distinguish 11 systems of oil, gas and water. From the interpretation of the logging data and seismic data, it was noted that the A pack is an oil and gas bearing deposit, while the GOC is -2116.0 m, the WOC ranges from -2121.0 ~ -2136.0 m. Sublayers A is an oil-and-gas bearing reservoir, with a GOC of -2121.0 m and a GOC of -2132.0 ~ -2145.0. Pack A is a reservoir with a gas cap and circulating water. B pack is an oil and gas reservoir, which has a GOC of -2133.0 m, a WOC ranges from -2139.0 ~ -2162.0 m (in the

western part) and 2136.0 ~ -2165.0 m (in the eastern part). The 4-5 pack is a reservoir, lithological and structural oil and gas reservoir, fluid sections in the field are complex. According to the study, it was noted that lithological variability probably occurred in the central and east, north parts. Resulting in the formation of oil and gas deposits with different oil and water systems, which, accordingly, leads to different oil and gas concentrations.

Horizon	Type
1	Layered gas reservoir
2	Layered gas reservoir with oil rings
3	Layered gas reservoir with oil rings
4	Layered oil reservoir
5	Layered oil reservoir with gas caps
6	Layered oil reservoir with gas caps
7	Massive oil reservoir
8	Layered oil reservoir with gas caps
9	Layered oil reservoir with gas caps
10	Layered oil reservoir
11	Layered oil reservoir with gas caps

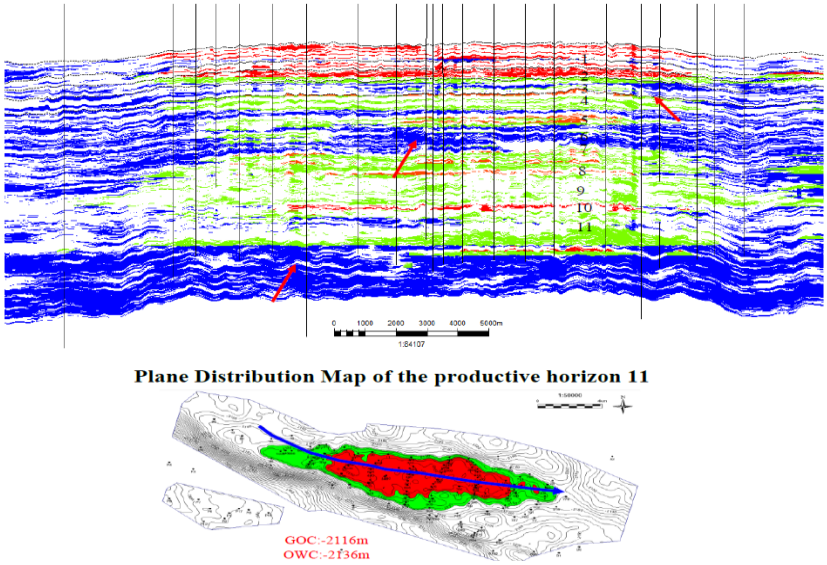

Figure 4. Section of the oil reservoirs along the certain direction

Based on the data on reserves calculation, in accordance with the interpretation of the structure, results of testing and trial operation, and a comprehensive analysis of the distribution of oil reservoirs, it is believed that reservoirs are difficult to distribute at the field, and heterogeneity is intense. In general, they are intact multilayer lithologic-structural deposits with marginal and plantar water; the relationship between oil and water is complex.

The implementation of 3D seismic data by the method of quantitative interpretation is holistic and depends both on the quality of the input data and on the elastic properties of the rocks. Nevertheless, the quantitative involvement of deep trends in the interpretation of seismic data significantly enhances prediction validity and diminishes the uncertainty of the results of a comprehensive characterization of the reservoir. Seismic reservoir characterization data led to have detailed structural construction, the tectonic model of the research area. A comprehensive study showed that the deposit is mainly of the delta type, and the reservoirs are sand bodies of river and branched-channel genesis, while the thickness of the sandstones varies sharply in area and the reservoir connectivity in lateral complex. According to the the reservoir analysis, it is clear that the properties of oil within the deposits are characterized by regular variability with increasing depth. The Oil field has the potential to expand the border, recommendations made for the development of the field. The low-amplitude trap at the edge of the area appears to be the next potential area. It is necessary to drill new wells for the most rapid development of field reserves.

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TOPICAL ISSUES OF RATIONAL USE OF NATURAL RESOURCES: Scientific Conference Abstracts. Saint-Petersburg Mining University. St. Petersburg, 2020. P. 463. (XVI International Forum-Contest of Students and Young Researchers. 17-19 June 2020)

АКТУАЛЬНЫЕ ПРОБЛЕМЫ НЕДРОПОЛЬЗОВАНИЯ: Тезисы докладов / Санкт-Петербургский горный университет. СПб, 2020. 463 с. (XVI Международный форум-конкурс студентов и молодых ученых. 17-19 июня 2020 г.)

М 432

ISBN 978-5-94211-915-7 (Часть I)
ISBN 978-5-94211-914-0

УДК 001:(622+55+669+33+502)=111

ББК 26+33+35.514+34.3+65

Научное издание

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XVI МЕЖДУНАРОДНЫЙ ФОРУМ-КОНКУРС СТУДЕНТОВ И МОЛОДЫХ УЧЕНЫХ

17-19 июня 2020 г.

Тезисы докладов

Статьи публикуются в авторской редакции
Печатается с оригинал-макета, подготовленного в Международном центре компетенций в горнотехническом образовании под эгидой ЮНЕСКО

Лицензия ИД № 06517 от 09.01.02

Подписано к печати 22.07.2020. Формат 60×84/8. Уч.-изд.л. 38.
Тираж 100 экз. Заказ 538.

Санкт-Петербургский горный университет
РИЦ Санкт-Петербургского горного университета
Адрес университета и РИЦ: 199106 Санкт-Петербург, 21-я линия, 2

TOPICAL ISSUES OF RATIONAL USE OF NATURAL RESOURCES: Scientific Conference Abstracts. Volume 1. Saint-Petersburg Mining University. St. Petersburg, 2020. P. 463.(XVI International Forum-Contest of Students and Young Researchers. 17-19 June 2020)
АКТУАЛЬНЫЕ ПРОБЛЕМЫ НЕДРОПОЛЬЗОВАНИЯ: Тезисы докладов Часть I/
М 432 Санкт-Петербургский горный университет. СПб, 2020. 463 с. (XVI Международный форум-конкурс студентов и молодых ученых. 17-19 июня 2020 г.)

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Подписано к печати 22.07.2020. Формат 60×84/8. Уч.-изд.л. 59,6.
Тираж 100 экз. Заказ 538.

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