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«INNOVATIONS IN GEOLOGY, GEOPHYSICS AND GEOGRAPHY–2019»

Sevastopol Branch of Lomonosov Moscow State University
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Contents

4TH INTERNATIONAL SCIENTIFIC-PRACTICAL CONFERENCE
“INNOVATIONS IN GEOLOGY, GEOPHYSICS AND GEOGRAPHY 2019”:
RESULTS .................................................................................................................. 7
  N.V. Lubnina, O.V. Krylov, A.Yu. Bychkov, M.L. Vladov, N.I. Kosevich, I.N. Modin,
  V.O. Osadchii, I.L. Prygunova, I.Yu. Khromova

INNOVATIVE EDUCATIONAL CENTER OF EARTH SCIENCES ON THE
BASIS OF BRANCH OF LOMONOSOV MOSCOW STATE UNIVERSITY IN
THE CITY OF SEVASTOPOL ................................................................................. 12
  A.Yu. Palenov, E.V. Kozlova, N.I. Kosevich, V.O. Osadchii, A.D. Skobelev,
  I.L. Prygunova, I.Yu. Khromova

APPLICATION OF GIS TECHNOLOGY IN THE STUDY OF THE RELIEF OF
THE REPUBLIC OF KARELIA ............................................................................... 19
  Agayan A.S., Kosevich N.I.

SEISMICITY AS AN ADDITIONAL FACTOR IN ANALYSIS OF GEODYNAMIC
CONDITIONS OF THE BARENTS-KARA SHELF .................................................... 20
  Basakina I.M., Antonovskaya G.N.

FRACTURE STRUCTURES OF MUD VOLCANOES AND HOST STRATA OF
THE KERCH-TAMAN MUD VOLCANIC REGION ..................................................... 22
  Beloborodov D.E., Tveritinova T.Yu.

DEEP GEOFLECTRIC RESEARCH IN CRIMEA ....................................................... 25
  Desyatov D.O.

HISTORY OF CHOKRAK LAKE DURING LATE HOLOCENE (KERCH
PENINSULA) ........................................................................................................... 27
  Dikarev V.A.

HYDROTHERMAL BIOMASS CONVERSION OF ALGAE CHLORELLA SP.
AND THE STUDY OF THE REGULARITY OF FORMATION OF SYNTHETIC
OIL ............................................................................................................................ 30
  Ermina O.S., Bychkov A.Yu.

ADSORPTION EQUILIBRUM IN THE SYSTEM "MERCURY (II) - SILICONE
SORBENT" .............................................................................................................. 32
  Fiaizullina R.V., Kuznetsov E.V., Salavatova D.S.

RANKING OF THE HYDROCARBON TRAPS IN THE KERCH-TAMAN REGION 35
  Gayazova E.N., Krylov O.V.

MUD VOLCANOES OF LAKE BAIKAL AND OF THE BAIKAL REGION ............. 37
  Isaev V.P., Korolkov A.T.

3D INVERSIONS OF POTENTIAL FIELD DATA: AN ATTEMPT OF GUIDED
CLASSIFICATION IN ORDER TO DERIVE PSEUDOLITHOLOGY ...................... 40
  Kaminsky V.F.

FRACTURE CORRIDORS AND THEIR ROLE IN HYDROCARBON FIELD
DEVELOPMENT .................................................................................................... 41
  Khromova I.Yu.
ELECTRIC CONDUCTIVITY OF THE BASEMENT OF THE EAST EUROPEAN PLATFORM IN THE SOUTH-EAST OF LADOGA REGION ACCORDING TO MAGNETOTELLURIC SOUNDINGS .......................................................... 44
Kulikov V.A., Sokolova E.Yu., Ionicheva A.P., Pushkarev P.Yu., Yakovlev A.G.

ENERGY BUDGET OF GEOMORPHOLOGICAL SYSTEMS OF HIGH-ALTIMETRICAL AREA ........................................................................................................................ 45
Kuznetsov A.S.

SEARCHES FOR GROUNDWATER FLOWS IN STEPPE AND MOUNTAINOUS CRIMEA, CONFINED TO ENDODRAIN DRAINAGE SYSTEMS, USING THE NPEMFE METHOD .......................................................... 47
Kuznetsov I.V., Tarasenko V.S., Ozykin M.K.

NEW METHODS AND APPROACHES IN GLOBAL GEODYNAMIC RECONSTRUCTIONS .......................................................................................................................... 49
Lubnina N.V.

KARELIAN PROTOCRATON DURING PALEOPROTEOROZOIC TIME: NEW KEY PALEOMAGNETIC POLE FOR THE VODLOZERO AND CENTRAL-KARELIAN TERRANES .......................................................................................... 52
Lubnina N.V., Tarasov N.A., Stepanova A.V.

BIOCHEMICAL ROLE IN THE FORMATION OF BAUXITE EXTRACTABILITY IN THE LATERITE WEATHERING CRUST .......................................................... 54
Makarova M.A., Boeva N.M., Bochannikova Yu.I., Shipilova E.S.

METAMORPHIC ROCKS FROM ISLANDS OF THE KANDALAKSHA GULF OF THE WHITE SEA AND THEIR PETROGRAPHIC CHARACTERISTICS ...................................................... 57
Myshenkova M.S., Kosevich N.I., Bagdasarian T.E.

Nikolaeva S.A., Savchuk D.A., Kuznetsov A.S.

DENDROINDICATION METHODS OF HAZARDOUS GEOMORPHIC PROCESSES .............................................................................................................................. 61
Nikolaeva S.A., Savchuk D.A.

EXPERIMENTAL STUDY OF THE PHOSPHORUS VOLATILITY IN HYDROTHERMAL SOLUTIONS ....................................................................................................................... 64

FEATURES OF GEOMORPHOLOGICAL PROCESSES OF COASTAL-MARINE SYSTEMS OF THE SOUTH-EASTERN PART OF THE CRIMEAN COAST .................................................................... 66
Pashkova N.G.

BRECCIAS, SHEAR AND FRACTURING ZONES OF THE MIDDLE STRUCTURAL FLOOR OF THE HERACLION PENINSULA, CRIMEA .................................................................................. 68
Promyslova M.Yu., Demina L.I.

ELECTROMAGNETIC SOUNDINGS FOR SEDIMENTARY BASINS EXPLORATION. HISTORY AND STATE OF THE ART ............................................................................... 70
Pushkarev P.Yu.
PHYSICAL MODELING OF STRUCTURAL DEFORMATION ON THE EARLY STAGES OF IBERIA AND NEWFOUNDLAND CONJUGATE PASSIVE MARGINS FORMATION ................................................................. 72
Rashchupkina A.O., Dubinin E.P., Grokholsky A.L., Agranov G.D.

SEAWATER INTRUSIONS INTO COASTAL WATER INTAKES ................................................................. 74
Rastorguev A.V., Levitskaya E.V.

EFFECT OF TEMPERATURE AND PRESSURE ON PHASE RELATIONSHIPS AND DISTRIBUTION OF SCANDIUM, YTTRIUM AND RARE EARTH ELEMENTS IN THE GRANITE SYSTEM (SI-AL-NA-K-LI-F-O-H) ................................................................. 76

INVESTIGATION OF KARST AND SUFFUSION PHENOMENA BASED ON TEMPORAL VARIATIONS OF MAGNETOVARIALTIONAL PARAMETER ................................................................. 78
Ryabova S.A.

STUDIES OF THE SPECTRAL CHARACTERISTICS OF REFLECTED SEISMIC WAVES IN CONDITIONS OF DISTURBED CONTINUITY OF ROCKS ................................................................. 79
Semerikova I.I.

PETROLOGICAL AND EXPERIMENTAL STUDY OF SYENITIZATION OF TONALITE GNEISSES EXAMPILED BY THE MADIAPALA COMPLEX, LIMPOPO BELT, SOUTH AFRICA ................................................................. 81
Selyutina N.E., Safonov O.G.

THE APPLICATION OF DYNAMIC CHARACTERISTICS OF SIGNALS IN SEISMIC SURVEY FOR ESTIMATION OF DISTRIBUTION OF INHOMOGENEITIES IN BLOCKS OF ARTIFICIAL AND NATURAL GROUNDS ................................................................. 83
Shmurak D.V.

CORRELATION OF RECENT DANGEROUS GEOLOGICAL PROCESSES AND NEOTECTONICS ACCORDING TO THE RESULTS OF STRUCTURAL-GEOMORPHOLOGICAL AND MORPHOMETRIC ANALYSES ................................................................. 84
Simonov D.A., Bryantseva G.V.

APPLICATION OF PETROMAGNETIC ANALYSIS IN THE STUDY OF SECONDARY PROCESSES IN THE PALEOPROTEROZOIC IGNEOUS COMPLEXES OF THE KARELIAN CRATON ................................................................. 87
Tarasov N.A., Lubnina N.V.

EXPERIMENTAL STUDY OF FLUORIDE COMPLEXES STABILITY OF ZIRCONIUM AND HAFNIUM IN HYDROTHERMAL SOLUTIONS ................................................................. 89
Tarnopolskaia M.E., Bychkov A.Yu.

DISTRIBUTION OF REE AND TRACE ELEMENTS IN THE ROCKS OF THE RHYTHMIC STRATIFICATION OF KIVAKKA INTRUSION ................................................................. 91
Tskhovrebova A.R.

ON THE AGE OF MUD VOLCANOES ON THE KERCH PENINSULA ................................................................. 92
Tveritinova T.Yu., Beloborodov D.E., Simonov D.A., Bryantseva G.V.

VELOCITY MODELS OF THE CRUST AND LITHOSPHERE IN THE PITKARANTA SEISMIC STATION AREA IN KARELIA ................................................................. 95
Vaganova N.V., Meshcheryakova V.A.
MÖSSBAUER SPECTROSCOPY OF GLAUCONITE AS A SOURCE OF INFORMATION ABOUT THE REDOX CONDITIONS OF SEDIMENTATION........97
Voronin M.V.

CONDITIONS AND FEATURES OF THE METAMORPHIC COLLISIONAL ROCKS EXHUMATION IN THE PALEOPROTEROZOIC TIME .........................99
Zavyalov S.P.
ABOUT THE CONFERENCE

4th INTERNATIONAL SCIENTIFIC-PRACTICAL CONFERENCE “INNOVATIONS IN GEOLOGY, GEOPHYSICS AND GEOGRAPHY 2019”: RESULTS

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The 4th International Scientific-Practical Conference “Innovations in Geology, Geophysics and Geography-2019” was held in the first days of July, 2019 at the Branch of Lomonosov Moscow State University in the city of Sevastopol. The main purpose of this conference was to create a platform for the exchange of experience and knowledge, and to cover the innovative achievements in the integrated application of methods at the intersection of different scientific fields of Earth Sciences. The conference was initiated by the Faculty of Geology of Lomonosov Moscow State University, its Branch in the city of Sevastopol and Innovative Educational Center of Earth Sciences.

One of the important tasks of the conference was to develop modern approaches, proposals, methodology for the application of integrated research methods for environmental management and sustainable development of the coastal zone of Crimea and Sevastopol.

The participants of the conference were addressed with a welcoming speech given by the head of Branch of Lomonosov Moscow State University in the city of Sevastopol Olga Alekseevna Shpyrko, deputy chairman of the legislative Assembly of Sevastopol Alexander Andreevich Kulagin, head of Institute of Natural and Technical Systems Veronika Nikolaevna Maslova, head of the Department of environmental management and licensing of the Main Department of natural resources and ecology of the city of Sevastopol (Sevprirodnadzor) Yulia Anatolyevna Gavrilova, representatives of the Institute of Biology of the South Seas named after A. O. Kovalevsky RAS.

The state of the Crimean seashores was discussed at the plenary session (Yu.N. Goryachkin), prospects of groundwater search in Steppe and Mountain Crimea (I.V. Kuznetsov), as well as marine expeditionary activities of Sevastopol State University (M.I. Silakov) and Irkutsk State University (A.T. Korol’kov).

I. N. Modin presented a report on the prospects of combining the results of electrotomography and seismotomography, A.D. Skobelev and D. O. Desyatov for the first time in the framework of the conference held a field demonstration of the method of electrotomography.

In 2019, in addition to the traditional plenary session, round tables were organized in the following areas:

- New methods and approaches in geodynamic studies;
- Geophysical methods of research;
- Fracturing in rocks: modern methods of study, data processing and analysis;
- Geology and evolution of sedimentary basins;
- Mud volcanism as an indicator of the processes of formation of oil and gas;
- Assessment of the relief and dangerous exogenous processes;
Modern geological-geomorphological processes and dynamics of coastal landscapes.

The main purpose of the round table "New methods and approaches in geodynamic studies" was to show the importance of an integrated approach in the construction of global and regional geodynamic reconstructions, while the primary role in such constructions is played by the correct correlation of geological, geochemical and geophysical data with supercontinent cyclicity. It is shown that the knowledge of the tectonic evolution of a particular block and its place (spatial position) in the supercontinent in a particular period of time greatly facilitates the interpretation of regional materials, and the correlation with the same age blocks, which are now part of various modern continents, opens up new opportunities, including for the search for mineral deposits (N.V. Lubnina). At the same time, in Precambrian correlations there is a problem of correct identification of the same-age events manifested in different cratons. Limitations and features of such correlations in the Paleoproterozoic according to supercomputer modeling were considered in the report of S. P. Zavyalov, and the conditions of secondary transformations of Precambrian complexes-in the report of N. E. Selyutina. The new integrated Petro-paleomagnetic approach to reconstruct trends of secondary transformations of Precambrian rocks were shown by N.A. Tarasov.

The problems discussed in the framework of the round table «Geophysical research methods» were directly related to the main theme of the round table «New methods and approaches in geodynamic research» – the relationship of tectonic structure of the region with the geophysical information. Heterogeneity of the lithosphere of the Svecofennian belt of the East European craton was shown according to magnetotelluric sounding data (P.Yu. Pushkarev), as well as velocity models of the earth's crust and sub-crust lithosphere in its Eastern part (N.V. Vaganova). V. F. Kaminsky discussed the issues of three-dimensional modeling and inversion of gravitational data and aeromagnetics, and the use of magnetic variation parameter in the study of karst and suffosion phenomena was reported by S.I.Ryabova.

In recent years, unconventional traps in fractured reservoirs have attracted increasing interest in the search and exploration of oil and gas fields, with special attention paid to the correctness of the allocation of structural parageneses according to 3D seismic data, VSP and special GIS methods: Imagers, broadband acoustic logging, etc. Global attention is also focused on methane recovery technology from coal seams and shale, which is closely linked to the study of the permeability of these rocks. The distribution of zones of high fracture and as a result, the fluid permeability depends on the newest geodynamic activity of the area, which appear on the surface of the Earth in the latest dispositions, reflected in the topography, high heat flow, seismicity and often are accentuated by accumulation of oil and gas fields.

In the framework of the round table “Fracturing in rocks: modern methods of study, processing and analysis of data” we discussed new methods and approaches to identify areas of concentration of cracks in rocks, which circulate fluids. Special attention was paid to numerical and physical modeling of deformations in various geodynamic settings (A.F. Vasilevsky, A.O. Raschupkina). One of the highlights of this round table was the laboratory demonstration “Tectonophysical modeling of inhomogeneous media” given by A.F. Vasilevsky. During the experiment the importance of correct recognition and diagnostics of crack systems (or structural
parageneses) arising at the same stage of tectonic activity was shown. Topical issues of petrophysical studies of coal fracturing were presented by I. V. Kuvínov and co-authors.

The role of fractured corridors in the development of hydrocarbon deposits was discussed during the round table "Fracturing in rocks: modern methods of studying, processing and analyzing data" (I.Yu. Khromova), as well as studies of spectral characteristics of reflected seismic waves in conditions of discontinuity of rocks (I.I. Semerikova). The importance of the connection between the neotectonic activity of the region and the predictions of various scenarios for the development of dangerous geological processes (landslides, landslides, microseismicity, karst processes, etc.), as well as mud volcanism was discussed in the reports of G. V. Bryantseva and D. E. Beloborodov.

Within the framework of the round table "Geology and evolution of sedimentary basins" the main stages of structural and tectonic reconstructions and stages of formation of sedimentary basins in various geotectonic areas were considered. A number of invited reports in this section were devoted to modern methods of studying the Geology of oil and gas basins of the land and shelf, special attention is paid to the history of geological development, the directions of structure-forming movements at different stages of the basin formation, discussed the emergence of regional melange, thrusts, overflows, landslides (V.V. Yudin).

Considerable attention in the section were paid to the conditions of sedimentation within sedimentary basins, the material composition of the formed rocks, time and nature of tectonic movements. Several reports were devoted not only to the study of structural forms, but also to the analysis of the structure of the basins according to electromagnetic and geoelectric measurements, the use of an additional factor of seismicity in the analysis of its geodynamic situation (I.N. Modin, P.Yu. Pushkarev, A.D. Skobelev, D.O. Desyatov). The existence of multi-age oil systems in the basin has also been highlighted in a number of reports. They considered the data on the magnitude of the thermal heating of the entire basin, the degree of catagenetic transformation of oil and gas parent strata, the history of the formation of hydrocarbon traps and the possible time of their filling (O.V. Krylov, A.Yu. Bychkov, I.V. Kuvínov, O.S. Ermina, I.M. Basakina). Consideration of the whole complex of problems is closely linked with modern computer technologies aimed at solving problems of basin modeling.

The round table "Mud volcanism-an indicator of the formation of oil and gas" was devoted to a unique natural phenomenon, widely developed in the Kerch-Taman region. Various geochemical indicators of conditions of formation of the mud volcanic fluids – water, hydrocarbon and non-hydrocarbon gas and oil, the adsorption equilibrium in the system "Mercury (II) – silicon organic sorbent" and the problem of the age of formation of the volcanoes of the Kerch Peninsula and their disappearance was discussed in the papers by V.Yu. Lavrushin, D.S. Salavatova and G. V. Bryantseva. One of the key issues was the connection between active and "inactive" mud volcanoes and the oil and gas potential of the region. The forms and structures of mud-volcanic structures, as well as discovered and developed oil and gas deposits in the Maikop series sediments, as well as in terrigenous and carbonate reservoirs of Neogene sediments were discussed (O.V. Krylov, A.Yu. Bychkov, N.V. Lubnina and others).

In response to the great interest in the mud-volcanic provinces of the Kerch-Taman region, manifested during previous conferences, a field school "Unconventional hydrocarbon sources: multidisciplinary research" was held with a visit to a number of mud volcanoes. During this field
school, participants were able to observe active manifestations of mud volcanism on the Kerch and Taman Peninsula, their confinement to oil and gas fields, oil source rocks of the Maikop series and oil-bearing rocks of the flisch and delta complex. Report of the leading specialist in Geochemistry of mud volcanism, prof. V.Yu.Lavrushin, served as a basis for discussing the features of this process during field trips. Other reports presented new results of geophysical studies of mud volcanoes, the content of trace elements in the mud-volcanic breccia, experimental modeling of oil formation processes. The discussion within the section and the field school showed the increased interest of researchers in the mud-volcano process and the great possibilities of modern methods for solving the problems of genesis and evolution of mud-volcano and oil-forming systems. The participants of the conference were able to observe with their own eyes the interrelation of hydrocarbon generation and the stages of formation of mud volcanoes and their manifestations during the field tour and discuss at the round tables "Mud volcanoes of the Taman Peninsula" and "Traditional and non-traditional oil and gas reservoirs of the Taman Peninsula".

During the round table "Dangerous geological processes" the manifestations of dangerous exogenous processes and their impact on the relief of a territory of the globe were considered. The section presented reports on the formation of relief within different geomorphological settings: coastal areas of the South-Eastern coast of the Crimean Peninsula and Alpine areas within the Altai Mountains, etc. A.S. Kuznetsov in his report paid attention to the energy potential of high mountainous areas from the geological and geomorphological point of view. S. A. Nikolaeva and A. S. Kuznetsov presented the results of a study of dangerous slope processes (debris flows, avalanches and rockfalls) by dendroidal methods in various geomorphological environments of the highlands.

At the round table "Modern geological and geomorphological processes and dynamics of coastal landscapes" the main problems of transformation of coastal and inland landscapes of the Crimea and the black sea coast of the Russian Federation were considered. Due to the increasing frequency of catastrophic natural phenomena, the report of the leading expert of GAU “Ecocenter” Roman Andreev on the problems of transformation of the seaside landscape in the coastal zone of Sevastopol aroused great interest. No less urgent were the issues of monitoring of geological and geomorphological transformations of internal landscapes, considered on the example of a specially protected natural area of the reserve Castel, as well as the impact of climate trends on the transformation of landscapes of the Crimea. A senior researcher of IBSS, Oksava Vyalova, gave a talk on the insufficient use of the black sea coast of Russia for aquaculture production and the prospects of this industry. A particularly interesting problem is the intrusion of seawater to coastal water intakes, leading to deterioration of water quality and failure of water intakes. This issue was considered on the example of the Orel water intake of the city of Sevastopol by a graduate of the Faculty of Geology of Lomonosov Moscow state university Kate Levitskaya.

During the discussion the participants of the round table agreed on the need for a comprehensive study and monitoring of any changes in the coastal landscapes of the coastal zone of Sevastopol. Any uncontrolled local transformations of the landscape of this zone are associated with uncontrolled natural risks both now and in the future. Career, active construction in floodplains in the vicinity of the rockslide abrasion amphitheatres of Lubimovka group are invalid, since they initiate landslides and avalanches that are dangerous to tourists and constructed
facilities. The already existing load (TSN, ST, Belbek airport) exceeds the carrying capacity of coastal geosystems, and further work only stimulates and accelerates the adverse natural processes characteristic of this area, which complicates the further development of the coastal areas of Great Sevastopol and is fraught with huge economic costs. To attract public attention to these problems, as well as to train young professionals capable of solving the tasks of studying and monitoring landscape systems, it is proposed to organize a field landscape-geo-ecological school.

128 participants took part in the conference in 2019. In addition to representatives of the Faculty of Geology of Lomonosov Moscow State University and the Faculty of Geography of Sevastopol Branch of Lomonosov Moscow State University, the conference was attended by young employees, graduate students and students of V.I. Vernadsky Crimean University (Sevastopol), Kazan Federal University, Permian State University and Kaluga State University.

The conference was attended by experts and young professionals from the institutes of the Russian Academy of Sciences: Institute of Physics of the Earth, Geological Institute, Institute of Geography, Institute of Geology of Ore Deposits, Petrography, Mineralogy and Geochemistry, V.I. Vernadsky Institute of Geochemistry and Analytical Chemistry (Moscow), Institute of Earth Crust (Irkutsk), N. Laverov Federal Center for Integrated Arctic Research (Archangelsk), Institute of Monitoring of Climatic and Ecological Systems (Tomsk), Mining Institute of the Ural Branch RAS (Perm), Institute of Experimental Mineralogy (Chernogolovka).

Leading experts of Rosneft, Skoltech, Geomedg.ru, I.E. Khromova I.Yu. and Aerogeology supported the conference and participated in the round tables.

The conference was also attended by experts from Branch of Lomonosov Moscow State University in the city of Sevastopol, Institute of natural and technical systems RAS, Marine Hydrophysical Institute RAS and Institute of marine and biological studies RAS, Main Department of natural resources and ecology of Sevastopol (Sevprirodnadzor).

The results of the conference are published in a special collection of scientific papers and covered in the media.

The papers presented at the conference were partially implemented with financial support RFBR, projects №18-45-920073 (Geodynamic aspects of fracturing of the coastal zone of the Sevastopol region of South-Western Crimea: comprehensive studies, monitoring and technogenic risks, headed by O.V. Krylov) and 18-05-00818 (Physico-chemical model of mud volcanism of Kerch-Taman region, headed by Prof. A.Yu. Bychkov).
The Innovation Center of the Earth Sciences was established on October 15, 2016 by the decision of the Scientific Council of the Branch of Moscow State University named after M.V. Lomonosov in the city of Sevastopol (Protocol No. 5-1) for the coordination and interdisciplinary integration of the educational, research and innovation activities of the Moscow State University divisions and enterprises established by the Moscow State University aimed at solving urgent and promising tasks.

The work of the Innovation Center of the Earth Sciences is mainly attended by staff and professors of the Geology Department of Moscow State University named after M.V. Lomonosov and Geographical Department of the 1Branch of Moscow State University named after M.V. Lomonosov in the city of Sevastopol, conducting scientific research, educational process and innovative activities on the themes of the Center.

At present, within the framework of the work of the Innovation Center of the Earth Sciences, there are five main research areas:
Geodynamic aspects of fracturing (supervisors: Prof. N.V. Lubnina and Associate Professor O.V. Krylov);

Mud volcanism as an indicator of the processes of formation of oil and gas (headed by Leading Researcher E.V. Kozlova and Associate Professor O.V. Krylov);

Hydrothermal processes and fluids in the Earth's crust (headed by Prof. A. Yu. Bychkov);

Geophysical research and geomonitoring of hazardous processes (supervisors Prof. I.N.Modin and Prof. M.L.Vladov).

Modern geological-geomorphological processes and dynamics of coastal landscapes (supervised by associate professor I.L. Prygunova and assistant N.I.Kosevich).

To highlight innovative achievements in the integrated application of methods located at the junction of various scientific directions, the Innovative Education Center of the Earth Sciences jointly with the Branch of the Moscow State University named after M.V. Lomonosov in the city of Sevastopol has been holding International Scientific and Practical Conferences "Innovations in Geology, Geology and Geography" for four years, with more than 100 participants annually.

One of the important tasks of the scientific and practical conferences was the development of the main approaches, proposals, methodology of application of complex research methods, innovations in geology, geophysics, geography for rational nature management and sustainable development of the coastal zone of the Crimea and Sevastopol. Over three years of work, more than 450 scientific articles have been published in conference proceedings in Russian and English, 3 teaching aids and 5 guidebooks for field excursions have been published.

Training of students, graduate students and young employees is one of the main areas of work of the Innovation Center. For three years, five field schools have been conducted to train regional staff and increase the level of training of profile students in leading Russian universities: "Magmatic complexes of the south-western Crimea: multidisciplinary research" (2016), "Geomonitoring of natural processes" (2016), "Oil and gas potential of the Crimea: a multidisciplinary approach" (2017), "Coastal areas: monitoring and innovative complex research" (2017), "Fractured collectors: innovative complex research" (2018), and «Unconventional sources of hydrocarbons: multidisciplinary research» (2019), as well as one sightseeing tour this "Fracturing of the rocks of the Heraklei Plateau (south-western Crimea: a multidisciplinary approach" (2018–2019.). Within the framework of these schools, participants got acquainted with new methods of studying the declared processes, as well as with real geological objects. Among these objects were the folded-block structures of the Heraclea plateau, the Inner ridge of the Crimean Mountains (mount AK-Kaya), the development of mud volcanism within the Kerch and Taman peninsulas, underwater ridges and strata of modern sediments of the coastal regions of the Crimea.

An important achievement of the Innovative Educational Center of Earth Sciences are studies of fractures and monitoring of hazardous exogenous processes within the Herakleian plateau (South-Western Crimea) associated with high fracture zones held in 2016–2019 and headed by Prof. N.V. Lubnina and associate Prof. O.V. Krylov. These studies included tectonic,


The second direction of scientific research conducted by the Innovative educational center of Earth Sciences is the study of oil systems of the Mesozoic-Cenozoic sedimentary cover of the Black sea-Caucasus region. In the course of field research in 2016-2019 the relationship of
elements of oil systems with tectonic features of development and modern structural plan of the Steppe and Mountain parts of the Crimea was studied (E.V. Kozlova, O.V. Krylov, N.V. Lubnina, A.V. Murovskaya, A.Yu. Bychkov, N.S. Frolova, G.V. Bryantseva, V.O. Osadchii).

For the most representative sections of the 3 structural plans, oil source formations, reservoir horizons and covers in sediments from the Triassic to the Neogene were identified. An important aspect is the prospects for the discovery of deposits in the depths of the Black sea, the analogues of natural reservoirs of which were investigated in the course of land field trips (2016–2019).

Special attention is paid to the natural phenomenon of mud volcanism, which is widely developed within the Kerch-Taman region and is a direct evidence of oil and gas subsoil. The types and structure of mud volcanoes, hydrocarbon composition of eruption products, lithological characteristics of mud-volcanic breccia, mud-volcanic provinces of the black sea region are considered.

As part of the study of the manifestations of mud volcanism on the Kerch Peninsula in 2017-2019, comprehensive geological and geochemical studies of the mud volcano on the shore of lake Tobechik, Kostyrinto village, were carried out (O.V. Krylov, E.V. Kozlova, N.V. Lubnina, A.Yu. Bychkov, G.G. Akhmanov, G.V. Bryantseva, V.O. Osadchii). An oil field in the Neogene sediments of the Chokrak formation has been developed here since the beginning of the last
century. Oil generation took place in the sediments of the Maikop Paleogene–Neogene series, one of the main oil-producing formations of the Black Sea oil and gas basins. Due to a number of technical reasons, the field was closed in the 60s of the XX century, the existing wells were plugged.

In the vicinity of the oil field there is a mud volcano, the active force of which is the thermo-baric transformation of the mineral matrix (represented mainly by mixed-layer clays) and the organic component of the deposits of the Maikop series.

To assess the feasibility of seismic geophysical methods in the study of mud volcanism, in 2019 on the shores of lake Tobechik under the guidance of Prof. I.N. Modin, assistant A.Yu. Palenov, senior researcher T.B. Sokolova, associate professor I.V. Lygin, associate professor L.A. Zolotaya, senior geophysicist A.D. Skobelev, engineer-geophysicist D.A. Kvon, ingineer S.A. Akulenko, D. Arutyunyan, T.P. Shirokova, V.A. Lobkov and D.A. Nelogov a
complex of surface geophysical methods, including electrical survey (electrical resistivity tomography, method of natural electric field resistivimetry), magnetic (area imaging of magnetic field, cappamore), gravirazvedka (profile observation of anomalies of gravity field) and other geophysical surveys (radiometry, registration emanations, thermometry) were applied. Comprehensive studies have allowed to identify unconsolidated mud-volcanic deposits embedded in the limestone massif by the system of tectonic faults.

Participants of the field school "Oil and Gas potential of Crimea: multidisciplinary approach" on the Bulganak mud-volcano field (2017 г.).

Samples of oil films and oxidized bituminous substance were collected directly in the mud flows and on the sides of the mud lake in the North-Eastern part of the village and studied in the laboratory (E.V. Kozlova, I.C. Balakin). The density of the isolated bitumen was estimated using special pyrolytic studies and is 0,89–0,92 g/cm3. According to elemental analysis bitumen contains a significant amount of carbon (36-51%), hydrogen (5-5,76%), very little nitrogen (0,17-0,57%) and sulfur (0,14-0,34%). The group composition is dominated by naphthenic hydrocarbons, there is a small amount of asphaltene component.Petroleum hydrocarbons are subjected to strong oxidation, normal and ISO-alkanes are not found in the composition of oil films, which indicates a high degree of biodegradation. Among the aromatic components identified alkyl naphthalenes and alkyl-diamantanes and alkyl-diamantanes-diamond-like film, in its hardness only three times inferior to diamond. Adamantanes are a valuable raw material in
medicine, used for the production of thermostable lubricants and polymers, have a bactericidal and antistatic effect.

Scientific studies were implemented with financial support RFBR, projects №18-45-920073 (Geodynamic aspects of fracturing of the coastal zone of the Sevastopol region of South-Western Crimea: comprehensive studies, monitoring and technogenic risks, headed by O.V. Krylov) and 18-05-00818 (Physico-chemical model of mud volcanism of Kerch-Taman region, headed by Prof. A.Yu. Bychkov).

In the near future, the work of the Innovation Center on Earth Sciences will be aimed at creating Programs of additional professional education in combining geological and geophysical research:

- Courses of retraining of personnel (500+ hours) with MSU diploma on professional retraining with the assignment of additional qualifications;
- Courses for the re-qualification of staff (144-250 hours) with MSU diploma about re-qualification;
- Scientific and practical seminars (24-40 hours) with the certificate of the MSU responsible structural unit (Department) MSU about the course.
APPLICATION OF GIS TECHNOLOGY IN THE STUDY OF THE RELIEF OF THE REPUBLIC OF KARELIA

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The relief of the earth's surface is the result of the interaction of multidirectional modern geological processes - endogenous and exogenous. The most important role is played by endogenous processes because they form “primary” relief forms (morphostructures), which are complicated by various denudation and accumulative forms (morphosculpture) [1].

The region of this study is located within the Republic of Karelia, on the territory of the Baltic Shield. The study of platform complexes is of interest from a geological and tectonic point of view, since they are characterized by low speed of vertical movements, weak seismicity, the absence or rare manifestation of volcanic activity and low heat flux. Currently, the use of specialized software systems in research allows for research at a new level.

The aim of the work was to characterize the structural and geomorphological structure of the Republic of Karelia using GIS technologies. The initial data for the study were SRTM 4 (Shuttle radar topographic mission) radar interferometric satellite imagery data with a spatial resolution of 3 angular seconds (90 m), having a square shape of 5x5 degrees, and generalized with a resolution of 30 angular seconds [2]. The morphostructural analysis of the relief was carried out in the software package ArcGIS 10.3 on the basis of the morphometric method of searching for tectonic structures [1, 3] and structural and geomorphological analysis [5]

As a result of the study, derived morphometric maps of the main indicators were obtained: the steepness of the slopes, the exposure of the slopes, the depth of the dismemberment of the relief, the density of the dismemberment of the relief and the total index of the dismemberment of the relief. With a spatial and thematic analysis of the maps obtained, a map of the morphometric complexes of the study region was constructed.

The following maps were obtained and analyzed within the framework of the structural-geomorphological analysis: flow direction, total flow, permanent and temporary water flows, orders of watercourses, basic surfaces of various orders, differences between the basic surfaces. As a result of the analysis, a map of the morphostructures of the Republic of Karelia was compiled.

The study was carried out with the financial support of the Russian Foundation for Basic Research in the framework of the research project No. 18-35-00666.

Literature

The development of seismic networks in the Arctic gives us additional opportunities to representation extension of geodynamics of this region. Seismic monitoring of the Western Arctic sector of the Russian Federation, in particular, the Barents and Kara seas is carried out according to the Arkhangelsk seismic network data with addition data from foreign seismic networks. The installation of seismic stations on the Arctic Islands and obtaining new data on seismicity, primarily there are low-magnetic earthquakes (M<3), allows us to identify not only seismic areas, but also passive one. It is significant that single earthquakes occur in the areas of oil and gas fields [1].

The correlation of modern seismic data with oil and gas fields of the Barents and Kara seas shows that these areas are seismically passive but outside them we observe weak seismicity including in the sedimentary cover. Thus, the additional factor in the allocation of possible formation of hydrocarbon deposits areas appears.

Currently, the method of seismotectonic imaging and its connection with geodynamics is not fully developed. Thus, the study of the seismic regime of oil and gas provinces is an important step in the assessment of the geological environment stress-strain state.

The basin of the Barents-Kara shelf began to form as a continental rift, and then, having experienced a short-term spreading, filled with sediments. Oil and gas provinces of this region have multifactorial formation, complex stages of petroleum generation which causes their spatial distribution and the difference in the properties and ages of geological structures including hydrocarbon complexes. They are difficult to link to key geodynamic processes. Geophysical fields such as seismic, gravitational and geothermal form the structural and density heterogeneity of the basement and sedimentary cover and show the nature of the junction of heterogeneous blocks of the crust, mark the suture zone of the basement [2]. Areas of possible formation of hydrocarbon deposits are distinguished by the coincidence of use of several factors.

The first factor is allocation of zones of development of deep thrusts and subduction zones (concealed seams of collision plates). It is in the areas of development of deep thrusts, subduction zones associated with sedimentary basins especially during their fast immersion, the energy influent occurs for activation of oil formation in oil source rock and removal of hydrocarbons formed by an upward flow of fluids [3, 4, 5].

The second factor is the allocation of rift zones (rifts, deflections, depressions, inversion inter- and inside rift shafts, anticlines) [6]. The maximum oil and gas accumulation is expected over the buried rift zones [7, 8].

The third factor is the allocation of abnormally high heat flow [9].

The fourth factor is the allocation of seismically passive areas.

...
At the same time, the assessment of the seismic regime before the start of large-scale industrial exploitation of hydrocarbon deposits will allow timely detection of potential areas of critical changes in the geological environment stress-strain state caused by man-made impact. Thus, seismicity is an important factor in the complex of geological and geophysical surveys to analyze the oil and gas provinces geodynamic situations of the Barents and Kara seas.

The work was partially supported by Russian Foundation for Basic Research grant № 18-05-70018 "Geodynamic situation of oil and gas provinces of the Barents and Kara seas according to the latest seismotectonic data" and the project for the implementation of the state task "Development of seismic methods for forecasting and reducing the consequences of natural and man-made disasters in the Western Arctic sector of the Russian Federation", AAA-A18-118012490072-7.

Literature

Mud volcanism is genetically related to the areas of development of Late Cenozoic sediments and recent and modern tectonic movements [1,2,3], representing a natural element of the spatial-temporal geological system of active orogens at their intersection with transverse interpericlinal troughs. A typical example of such a structural element is the Kerch-Taman interpericlinal zone with the complex of the latest Late Cenozoic sediments and the manifestation of active Late Cenozoic tectonics against the background of the formation of the modern relief.

Mud volcanism is manifested both by the readily observable in relief positive and/or negative systemic structures of the central type, formed in the Cenozoic deposit's sections and near-surface zone, and by their accompanying formations in the form of breccia – dried mud-stone mass.

In the mud volcanoes, as well as in the "real" volcanic objects, there are neck and flow (cover) facies of mud breccia. The neck facies have crossing contacts with the enclosing stratified strata. Cover facies are marked by complex facies relationships with normal sedimentary rocks.

The morphology of mud volcanoes is varied – from large conic complex structures, that form under conditions of effusion or extrusion of mud-stone masses, to flat mud-volcanic fields and salt-water lake basins with a weak manifestation of mud volcanism during degassing in a wide area. The impulsive nature of the mud volcanic process leads to subsidence and collapse of the roof over the devastated foci and the formation of the structures of the “pressed synclines”. This process can be carried out in the case of underwater eruptions against the background process of normal sedimentation.

Competent rocks of the near-surface zone are usually characterized by the development of fracturing. Mud volcanoes, including even large mud volcanic structures, are unfavorable objects of study in regard to fractures, since they are mainly composed of clayey strata of breccia. Moreover, extensive mud volcanic fields are practically devoid of cracks. However, fractures in the breccia have been observed. First of all, these are contractional cracks, which are the most characteristic fracture systems of clay strata, developing on the drying surface of clays. The distribution of such cracks reflects all-round stretching during the dehydration of the clayey strata, but at the same time indicates the morphology of the original basin: in the orientation of the separation cracks regarding the basin elongation, the ones having the longitudinal and transverse direction will especially stand out. This property can also be used in the study of the fractures within the mud breccia of mud volcanic structures. The uneven development of small near-surface contractional cracks may reflect the presence of large disjunctive structures hidden under clayey strata.
The second important source of information about the disjunctive structures distribution that determine the manifestation of mud volcanism is information about the chains of mud volcanoes. Mud volcanoes are localized at the intersection points of the weakened (disjunctive) zones, so the chains of mud volcanoes can account for the presence of disjunctive structures poorly expressed in clay strata. In some cases, it is possible to observe fracturing in competent rocks (sandstones, carbonates) of lithologically contrasted Cenozoic deposits with mud volcanoes on the wings of folded structures and faults that complicate them. In addition, there are other rocks characterized by intense fracturing – these are carbonate rocks of pressed synclines, which are overlapping breccias.

The results of the study on fracturing and latest disjunctives in mud volcanoes breccia and their surrounding geological objects are considered on the example of some mud volcanoes of the Kerch-Taman zone: Shugo, Karabetova Mountain, Peklo Azovskoye (Taman), Bulganak, Dzhau-Tepe, Dzhardzhava (Kerch).

Fracture of mud volcano breccia. Concentric “plastic” compression rollers and radial extension systems predominate in mud volcanic structures of the central type. The distribution of extension structures is not chaotic. Often they are concentrated in characteristic zones of shear deformations parallel to the frame structures. The direction of the shear displacements corresponds to the regional stress fields detected by the systems of destruction of the enclosing strata. Local degassing centers and griffins are arranged in chains of regional structural directions. In extended streams of mud breccia, the paragenesis of flow patterns is expressed; the flows themselves are oriented in accordance with the directions of the frame structures. The different distribution patterns of the disjunctive structures of uneven-aged covers and flows of complex polyphase mud volcanoes can be used to determine the change in the stress state during the formation of a mud-volcanic structure.

Fracture frame. All mud volcanoes are associated with tectonically active compression zones – diapiric, often supra-fractured anticlines. These structures are fixed by rapidly changing orientations of the lamination from flat to sub-vertical. At the same time, fracture structures of various kinematic types develop in lithologically diverse strata. There is characteristic formation of reverse-fault rotational belts. Lamination is disturbed mainly by located transversely to it two main systems of fractures across its strike (mainly steeply falling extension structures) and along the strike (inclined fractures, complementary to the normal-and-reverse fault rotation zone on the wings of the folded structures). Most fracture systems show signs of shear displacement. In the areas of flat bedding in the places where competent rocks are present, sub-layer slip mirrors are characteristic, indicating concentration of displacements at abrupt lithological contacts. With the development of mud volcanic processes, sharp lithological contacts can play the role of shielding structures.

Conclusions. Despite the generally unfavorable objective conditions for the manifestation of disjunctive structures in the mud breccia of mud volcanic structures, the use of actualistic and paragenetic approaches to the study of the objects under consideration and their environment provides interesting structural information that sheds light on the conditions for the origin and formation of this interesting geological phenomenon. The fracture of the enclosing mud volcanic structures of the Cenozoic deformed strata reflects the complex multi-stage history of the
formation of diapir anticlines and the fold-fracture structures that complicate them. Contraction cracks of mud breccia correspond to the features of the structure of mud volcanoes and the dynamics of their development, as well as indirectly indicate the structural organization of rock massifs enclosing mud volcano channels.

**Literature**

DEEP GEOELECTRIC RESEARCH IN CRIMEA

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In connection with the active development of infrastructure in the Crimea in recent years, research into the deep structure of the Crimean Peninsula has not lost its relevance. The development of the southern coast, the laying of transport routes in an active geodynamic environment requires studying the structural features of the region, monitoring the fluid and rheological regime of the subsoil.

One of the main methods of electrical prospecting for in-depth studies is the method of magnetotelluric sounding (MTS).

For a long period, the Crimean Geophysical Expedition, the Dneprogeophysics Trust and the Institute of Geophysics of the Ukrainian Academy of Sciences conducted a study of the deep structure of the Crimean Peninsula by electrical prospecting methods [Rokityansky, 1975; Kulik et al., 1984; Buryanov et al., 1985].

In 1979, the association "Ukrgeofizika" were carried out regional electrical exploration research method DMTS on the profile of Kerch - Dzhankoy - Tarkhankut [Borodulin et al, 1980].

In the period 1959 - 1965 Department of Geophysics, Faculty of Geology, M.V. Lomonosov Moscow State University carried out work by the method of the DES on the profile of Yalta - Novopavlovka under the leadership of V.K. Khmelevskoy [Khmelevskoy et al., 1997]. The work resulted in a geoelectric cross-section with a depth of about 6 km.

Starting from 2007 to 2013 Institutes of the National Academy of Sciences of Ukraine carried out modern experimental MT / MV research in the Crimea. Anomalies of high electrical conductivity in the Earth's crust and upper mantle confirm the connection between the seismicity of the Crimean region and the manifestation of collision processes [Burakhovich et al., 2016].

A new stage of in-depth studies of MTS in the Crimea began in February 2016, when the geophysical company North-West, together with the Department of Geophysical Methods of Earth Crust Study, faculty of Geology, M.V. Lomonosov Moscow State University, carried out experimental work using magneto-telluric sounding (MTS) in Crimea [Desyatov et al., 2019]. Soundings were carried out on reconnaissance profile Yalta-Novoselovka in the amount of 30 physical points. The equipment used in the course of the work, methods and programs for processing and analyzing MT data, as well as for solving direct and inverse problems, meets the modern world level. The aim of the study was to study the deep geological structure of the Mountain Crimea. According to the results of the study, geological and geophysical interpretation of MT data was carried out using a priori geological and geophysical information [Desyatov. et al., 2018].

One of the main results of the MTS in the Mountainous Crimea in 2016 was the refinement of the structure of the Bodrak Fault (dumping). Previously, this structure was traced from geoelectrical data to depths of 4–5 km, and the fault of the high-resistance Paleozoic rocks of the
Lozovoe zone was lowered by 1 km relative to the Mountain-Crimean zone [Khmelevskoy et al., 1997]. According to the new MTS data, the fault can be traced to a depth of over 30 km, it falls steeply to the north-west at an angle of 80-85°.

At the depths of 4–15 km in the Lozovoe zone near the Bodrak fault, an electrical conductivity anomaly was found, presumably associated with the fractured zone saturated with fluid.

The report presents the results of the above electrical exploration. Based on these data, a map of the total longitudinal conductivity for the entire territory of the Crimean Peninsula was constructed.

Literature

HISTORY OF CHOKRAK LAKE DURING LATE HOLOCENE (KERCH PENINSULA)

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Introduction

About 8000 years ago, the Black Sea was reconnected with the Mediterranean via the Bosporus to put the water balance of the Black Sea in equilibrium with the world ocean. Hence, the worldwide Holocene sea level rise also affected the Black Sea, where it involved massive changes to the coastal configuration by the flooding of the Black Sea shelf and the initiation of coastal erosion. The shallow Sea of Azov, in particular — which is surrounded by unconsolidated sediments — underwent considerable alterations in terms of its coastal morphology.

Geological setting and Historical background

In the northern Black Sea region, the Crimean Peninsula separates the Sea of Azov from the Black Sea. Today, both seas are connected only by a small opening, the so-called Strait of Kerch (formerly the Kimmerian Bosporus), which is also the border between Asia and Europe. The west coast of the marine passage belongs to the Kerch Peninsula, which is the easternmost part of Crimea.

Numerous ancient and prehistoric settlements on the Kerch Peninsula show that the area has been occupied and strongly influenced by humans for millennia. The earliest human settlements date back to the late Palaeolithic and Mesolithic epochs. These small settlements are generally situated inland in the central area of the Kerch Peninsula. However, further prehistoric sites may also be located on the Black Sea shelf, which was flooded by the postglacial sea level rise.

Material and Methods

In this study, we focus on the salt lake of Chokrak which is situated in the northern part of the Kerch Peninsula in Crimea. A small peninsula stretches into the lake, which today is totally disconnected from the open Azov Sea. At the tip of “Chokrak Peninsula,” an ancient Greek settlement was founded during the 1st millennium B.C. We reconstructed the palaeogeographic and environmental evolution of Lake Chokrak during the mid- and late-Holocene. This record has been evaluated in association with a regional archaeological data set to explore human–environment interactions over this period. The results show major changes in the palaeogeographic setting since the 3rd millennium B.C., when the postglacial marine transgression had started to fill the study area. Microfaunal analyses reveal the long persistence of an open marine embayment that only became separated from the Sea of Azov when a sand barrier developed during the late 2nd millennium B.C. When colonizing the Black Sea region after the 8th century B.C., the Greek settlers erected a fortification with a small settlement on a promontory that was by then a peninsula-like headland extending into the lake [5]. The colonists abandoned their settlement at the end of the 1st millennium B.C. when the depth of the surrounding lake decreased from 1.5 m to less than1 m. The results are based on sedimentological investigations of vibracorings carried
out on the sand barrier separating Lake Chokrak from the Azov Sea, and in the adjacent lagoon. This research was carried out in cooperation with the archaeological research Professor Maslennikov’s excavations in the northern part of the Kerch Peninsula [4].

**Holocene Sea Level Change**

Sea level history of the Black Sea and the Sea of Azov has many contrasting opinions in the literature. For the Black Sea, curves are published with several major regression/transgression cycles during the Holocene. Some of the cycles were given names, for example, the “Phanagorian regression” (during the 1st millennium B.C.) is followed by the “Nymphaean transgression,” which is said to have occurred over the last 2000 years. However none of these fluctuations have ever been found in the Mediterranean and both seas have been connected since approximately 8000 years B.P. [2,3].

Position of the many Greek settlement sites along the shores of the shallow Sea of Azov approves sea presence during 1st millennium BC. Otherwise sea level fall would have forced the settlers to shift their harbor installations at least several hundred meters (perhaps even kilometers) seawards due to the extremely shallow shelf of the Sea of Azov. This has never been evidenced in archaeological excavations or surveys nor has it been reported in historical accounts. In the study region, recent investigations on sea level changes have focused mainly on the Taman Peninsula, that is, the eastern side of the Strait of Kerch. Sea level evolution around the Kerch Peninsula was investigated by Porotov (2007) and Danovskiy et al. (2009), but only to a limited extent [1]. A relative sea leve (RSL) curve can now be reconstructed based on the results of the core sediment records from Lake Chokrak.

As can be stated so far from the coring results, around 3000 B.C. sea level was approximately 7 m lower than today at the Chokrak sand barrier. By then, shallow marine conditions prevailed that lasted until the beginning of the 1st millennium B.C. Thereafter, the sand barrier formation was initiated, most probably during the 8th century B.C. It ended during the 5th century A.D. Sea level reached its highest position at the present day. Since the 3rd millennium B.C., sea level continuously rose, without any of the previously postulated regression/transgression cycles. The RSL curve indicates differential subsidence rates within short distances in relatively stable areas, exceeding 40 cm per 1000 years [3].

**Conclusions**

Summarizing the results, we are able to reconstruct palaeogeographic for several time slices. Around 3000 cal B.C., the postglacial marine transgression reached the area of Lake Chokrak. The ancient coastline was situated somewhere between the Chokrak Peninsula and the sand barrier, adapted to the palaeotopography. After 2000 cal B.C., the decelerating sea level rise led to sand spits and bars formation to the north of the marine embayment. Around 1000 cal B.C., the ongoing transgression and cliff erosion led to the formation of the Chokrak peninsula. When the Greeks erected their settlement in the middle of the 1st millennium B.C., the peninsula was surrounded by the sea with water depth not exceed 1.5 m. The marine inundation of Lake Chokrak was not permanent. The small navigable connections to the Sea of Azov were closed rapidly by the sediment supplied by the coastal long-shore drift. In the following millennium, until the 5th century A.D., the water depth became more and more shallow; during the summer it probably

28
dried out—as it does today. Torrential rains triggered erosion that supplied the lake with sediments, which led—and still does so today—to siltation. This evolution explains the abandonment of the settlement on the Chokrak Peninsula. Due to the ongoing siltation process, the site lost its initial strategic advantage. Other settlements along the northern coastline (e.g., at Cape Zuk) took over its function.

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HYDROTHERMAL BIOMASS CONVERSION OF ALGAE CHLORELLA SP. AND THE STUDY OF THE REGULARITY OF FORMATION OF SYNTHETIC OIL

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Recently alternative energy sources have been actively studied. In this regard, a lot of works were carried out to convert algae into oil. The optimal temperature of hydrothermal treatment [3-5], effects of added catalysts [1], increased oil output by risen heating rate [2] were studied, also oil production from different algae species and differences of output were investigated [7] and the gas phase was studied [6,8]. For the hydrocarbons obtained in this work, the term “oil” is used, but the composition of the organics of the products obtained has not yet been studied in detail. Chlorella sp. algae were selected as the initial biomass. This type of algae is easily cultivated, and the algae themselves are in nature a source material for oil. The purpose of the work is to identify patterns of oil and gas formation from the biomass of algae Chlorella sp. during hydrothermal transformation, as well as to study the distribution of elements in the water-biomass-oil system and the isotopic composition of carbon in the algal biomass and in the resulting oil.

A total of 5 series of experiments on hydrothermal transformation of algae Chlorella sp. in tablets at different temperatures (from 250 to 350°C) and pressure of saturated steam of water were conducted. The first series (C-1) was kinetic, the second (C-3) - with different mineral phases, the third (C-5) - with a multi-element standard solution for ICP: ICP-MS-68A-A, Solution A, the fourth (C-6) - with an acidified solution of nickel chloride and the fifth (C-7) - was kinetic series at different temperatures and with the selection of the gas phase. The content of the elements was determined on the Niton FXL-950 for the oil of the C-5 and C-6 series, as well as the algal biomass. An isotope analysis of the carbon of the C-3 oil series and alga biomass was carried out.

All experiments were conducted using 20 ml titanium autoclaves in the laboratories of the Department of Geochemistry, Moscow State University. Aqueous solution and algae tablets (in some experiments with mineral phases) were placed in autoclaves. Then they were closed and placed in the oven at a certain temperature for a certain time. After which they were taken out, cooled and opened. Extraction of oil for the series was carried out in different ways. In the C-1, C-3, C-5 and C-6 series 5 ml of hexane was poured into the autoclave, after it their contents were transferred to a separatory funnel where the organic layer with hexane was separated from the aqueous solution. Then it was transferred to 15 ml glasses and evaporated. Further the mass of oil was determined. In some experiments of the C-7 series chloroform was poured into autoclaves instead of hexane, then the same actions were carried out. In the remaining experiments the contents of the autoclave were poured into a sample bottle, the residue was poured 5 ml of chloroform and also transferred into a sample bottle. Then water solution was taken with a syringe from under a layer of hydrocarbons with chloroform and the residue was evaporated under fume hood, weighed and transferred to caddies for storage. Gas sampling for this series of experiments was performed as follows under water. A funnel was put on the autoclave, and a test tube which
the released gas was put on it. The volume of gas was measured with the test tube. Then it was moved to the test tube with brine for storage and examination with a syringe. After it autoclaves were opened and oil was extracted. For the C-1 and C-3 series the ratio of maltenes and asphaltenes in oil was determined. For this the forty-fold volume of hexane was first poured into glasses of oil, after a day everything was filtered through a paper filter into a sample bottle — the maltenes were obtained in this way, and the residue was filled with chloroform and filtered into another sample bottle — that was how asphaltenes were obtained. Next, the extracts were evaporated and the amounts of maltenes and asphaltenes were determined by the gravimetric method.

The results showed that as the duration of the experiment increases, the yield of oil decreases, but its quality improves (the number of maltenes increases). Mineral phases accelerate the process of oil ripening. The decrease in oil yield is probably due to the sorption of oil on the surface of the mineral phases. The carbon isotope composition showed that both maltenes and asphaltenes are enriched in a light carbon isotope relative to the initial biomass, but maltenes are more. Elemental analysis of oils showed that Zn, Ni, Fe, Ca, K, S and sometimes Cu are distributed into oil. Tablets of algae Chlorella Sp. contain Zn, Fe, Ca, K and S. Consequently, Ni and Cu are concentrated in the oils from the solution. The amount of Ni in the oils increases as the amount of Ni added in the solution increases. With an increase in the duration of the experiments, the amount of oil output decreases, while that of gas increases. The oil yield increases in the series: 350> 300 ≥ 250˚C, and gas in the series: 350> 250> 300˚C.

*This work was supported by the Russian Foundation for Basic Research, project 18-05-00818.*

**Literature**

Mercury and its compounds are an integral part of the environment, where they are usually found in extremely low concentrations. Analytical chemistry of mercury has visibly made a step forward over the last fifty years. However, there still exist natural reservoirs in which concentrations cannot be directly determined. In such cases, one solution is to use various kinds of synthetic sorbents that significantly lower the detection limit for mercury. An additional advantage of their use is the possibility of transporting accumulated mercury on the sorbent from the sampling site directly to the measurement site, i.e. in an equipped analytical laboratory. In areas with increased anthropogenic load, another problem is particularly acute, associated with elevated concentrations of this element. A large amount of data on the negative effects of mercury on the environment, including ours [4], indicates the need for industrial and wastewater treatment. In the absence of control and reliable protective devices, it enters the soil, surface and groundwater, and bottom sediments, having an extremely negative impact on the environment. In particular, entering the aquatic ecosystem, mercury accumulates and transforms in each subsequent link in the food chain, reaching the maximum content at its top. Analysis of currently existing methods of purification of natural and wastewater from heavy metals showed that one of the most promising is the sorption method. The synthetic sorbent PSTU-3F, synthesized by a group of scientists from the A.E. Favorsky Irkutsk Institute of Chemistry SB RAS under the leadership of academician M.G. Voronkov, fits the role of a sorbent capable of providing a solution to these two diametrically opposite problems. The sorbent is a spatially linked silicone polymer with thiocarbamide groups - (C$_7$H$_{14}$N$_2$O$_3$SSi$_2$)$_n$ - poly bis-(3-silsesquioxanilpropyl) thiourea (PSTU-3). Its distinctive feature is increased thermal and chemical stability, which allows operation in aggressive environments. High chemical stability allows this sorbent to function in a wide range of acidity of the medium: from pH 12 to strong concentrated acids [2]. Thus, the purpose of our work was to study the sorption properties of the PSTU-3F silicone sorbent on mercury. A number of factors can influence the course of adsorption: the amount of the adsorbent, the time of its contact with the solution, the temperature and the pH value. The laboratory air temperature throughout all experiments was 23.5±1.5 °C. To measure the equilibrium concentration of mercury, the “cold vapor” method was used with an atomic absorption spectrometry using Portable Mercury Analyser PMA-1 (EcON, Moscow) with a PAR-3m attachment. The reducing agent was a 1% solution of sodium borohydride in a 1% solution of sodium alkali. To control the acidity of the solutions, the pH meter Expert-001 (Econix-Expert, Moscow) was used. A combined glass electrode “EGC-10601” (Measuring equipment, Moscow) was used as a pH electrode. The concentration of adsorbed mercury was determined by the difference of concentrations in solutions.

Effect of pH. The acidity of the solution is one of the most important parameters controlling the absorption of heavy metals. In the case of PSTU-3F, we have shown that the process of mercury
adsorption is most significant in the region of more acidic pH values. This is due to the dominance of the cationic form of mercury-divalent mercury $\text{Hg}^{2+}$ in the area of strongly acidic solutions. This fact can be judged from the book [3] on the hydrolysis of metal ions in highly diluted solutions. It should also be noted that $\text{pH}_{\text{PZC}}$ (points of zero charge) is probably in the near neutral medium, and the PSTU-3F sorbent, in the area under study, is a cation exchanger, i.e. negatively charged.

Therefore, $\text{Hg}^{2+}$ cations are involved in the formation of the electric double layer, occupying the absolute majority of adsorption centers as a result of competing adsorption. The decrease in the amount of adsorbed substance, when shifted to the near-neutral and weakly alkaline zones, is associated with a decrease in the concentration of the $\text{Hg}^{2+}$ particle, and in the region around the pH value equal to 3, the isoelectric point is located, in which the dominant form changes: the concentration of mercury (II) $\text{Hg(OH)}_2^0$ increases, having no charge, and, therefore, not able to be sorbed on the negatively charged surface of the sorbent. It is shown that with an increase in the amount of sorbent in solution, the acidity of the latter shifts to a more alkaline region. This can be explained by the formation of a double electric layer from the negatively charged surface of the sorbent, and positively charged protons attracted to it. It is obvious that with an increase in the amount of sorbent in the solution, the adsorption also increases, due to an increase in the sorbing surface. Consequently, due to the increase in the content of OH– groups in the solution, the pH shifts to the alkaline region.

Adsorption kinetics. It should be noted that all the adsorption experiments described in this work were carried out under static conditions (without using shakers, i.e. without active mixing). Samples were mixed by hand for 2 minutes once a day. Under such conditions, equilibrium was achieved in less than a day, and the degree of mercury recovery from solutions in this case was more than 95%.

Adsorption isotherms. Analysis of adsorption isotherms allows you to set the features of the process, to assess the feasibility of the practical use of the sorbent for the absorption of any substances. In the present work, the analysis of isotherms was carried out using well-known equations: Langmuir and Freundlich.

From the data obtained, it becomes obvious that the most accurately studied adsorption process describes the Freundlich equation, as indicated by the value of $R^2$, greater than 0.99. It was shown that the value of limiting adsorption ($\Gamma_{\infty}$) was not achieved during the experiment, and its value significantly exceeds 15 mg/g, which indicates an impressive sorption capacity of the sorbent under study. The maximum adsorption value obtained from the Langmuir equation, corresponding to 5.57 mg/g, does not correspond to reality - it is significantly underestimated, which indicates the inapplicability of the theory of monomolecular adsorption in the case with the sorbent chosen by us. Freundlich’s equation most accurately describes the process of adsorption of mercury (II) on the silicone sorbent PSTM-3T. The resulting parameters of the Freundlich equation were: $n = 1.51; K_F = 0.1025$.

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Literature


RANKING OF THE HYDROCARBON TRAPS IN THE KERCH-TAMAN REGION

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This work is devoted to the description of various classifications of oil and gas traps, and to revealing of their principal differences.

The reservoir trap is the element that holds the oil and gas in place so that they do not escape until released by drilling [1]. That means that a trap filled with hydrocarbons is an oil and gas deposit. Petroleum reservoir is a geological body which is formed from reservoir rocks and covered with the seal rock, and in case of proper conditions there can exist an oil and gas deposit. [1]

The target of the exploration and appraisal phase is discovery of the new oil and gas fields or new deposits within existing field and evaluation of reserves. During this phase leads and prospects are identified and evaluated. The main studied objects are geological structures and oil and gas traps.

Numerous classifications of reservoir traps have been proposed by large amount of soviet or foreign explorers during 60-90 s of 20th century. All of the classifications are unique due to the main feature which this classification was based on.

In this work 5 classification of oil and gas traps are being studied, according to:
I. O. Brod (1951) [2] which is based on the type of the natural reservoir;
A. A. Bakirov (1960) [3], the main feature here is the genesis of the traps;
A. Levorsen (1970) [1], traps are divided according to structural-stratigraphic principle;
V. B. Olenin (1977) [4], types identified by morphology of the traps;
O. K. Bazhenova, Y. K. Burlin, B. A. Sokolov, V. E. Khain (2004) [5], the genetical classification, but it differs from the classification by A. A. Bakirov (1960).

The main subject of the work is the classification by A. A. Bakirov (1960), which was thoroughly described and illustrated. The geologist distinguishes 4 trap classes according to their genesis: structural, lithological, stratigraphic, reef. There are types inside the groups, which in the same time are the smaller units of the classes.

This classification has been chosen to rank traps and deposits of the West Kuban Oil and Gas Region of the Azov-Kuban Oil and Gas Basin. The oil-baring capacity of this region is associated with Cenozoic sandstones and siltstones. The deposits are mainly associated with buried salt domes of Paleogene formations, which are often complicated by tectonic faults; with wedging out of the sandy rocks in the lower part of the Maikop suite (Oligocene); with lithological replacement of Miocene sand layers on the slopes of the domes structures (clay diapirism of the Maikop layers) [6]. Structural and lithological traps are widely spread in the Cenozoic rocks. Within the class of structural traps, the most significant role is played by traps connected with anticlinal structures (undisturbed or complicated by faults and diapirism or mud volcanism). For
lithological traps, the main ones are the traps which belong to the zone of the reservoir rocks, in places where are the changes of facial conditions exist. Among the most outstanding oil fields with deposits connected with structural traps are Abynskoye, Azovskoye, Krymskoye, Ilskaya Dolina, Novoiiske (the anticline deposits), Vostochno-Chumakovskoye, Abynko-Ukrainskoye, Novodmitrovskoye, Zybza – Glubokiy Yar (tectonically distracted deposits), Zapadno-Akhtanizovskoye, Bely Khutor, Zapadno-Neftyanoe, Kurchanskoye, Anastasievsko-Troitskoye (salt domes structures). As for field with deposits which are connected to lithological traps, there are Asphaltovaya Gora, Neftegorskoye, Kurskoye (wedging-out).

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Literature

MUD VOLCANOES OF LAKE BAIKAL AND OF THE BAIKAL REGION

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The outputs of combustible gases have been known at Lake Baikal for a long time. It was not accidental that Buryats, who had lived on its shores before the arrival of Russian pioneers, called it "Baigal", which means "standing fire" [1]. Apparently, the locals have repeatedly seen catastrophic emissions of methane, which in such cases ignites itself. The most recent evidence refers to the 10-point earthquake recorded in the book of V. P. Solonenko, A. A. Treskov "Mid-Baikal Earthquake of August 29, 1959"[1]. The Oymur village dwellers pointed in the direction of the epicenter, and said: "The sky was shining over there".

Various research teams of Irkutsk, Moscow, St. Petersburg, Novosibirsk and foreign scientists started recording of mud volcanoes at the bottom of the lake, along its shores and in all the Baikal-type gorges from the late 90's and in the 2000's. The first detailed article on this topic was published in 2001 in the journal "Geology of oil and gas" [2].

At present, thanks to the works of Limnological and Geochemical institutes of SB RAS, Irkutsk State University, Siberian branch of RosGeolFond, Russian Geological Research Institute VSEGEI (St. Petersburg), more than 50 mud volcanoes and more than a hundred bottom craters with methane outputs have been recorded at the bottom of Lake Baikal.

The largest volcanoes are Posolskaya Banka Seamount, Chelninskiy, Novosibirsk, Saint Petersburg, and a group of Kokuisky volcanoes. Most of them are confined to the delta front of the Selenga River, where the maximum thickness of sediments (about 10 km) got accumulated and where the maximum number of thawing holes was discovered by Irkutsk State University scientists in the ice of the lake in late 20th century.

Apart from the lake itself, the mud volcanoes were registered at other depressions of Baikal Rift System (BRS): in Barguzin and Tunka. Their presence is also assumed in other BRS depressions: Upper Angara, Muya, Chara, Hubsugul. Large fields of sand among continuous forest have been observed at satellite images of some of these depressions.

Four gas-mud volcanoes were found in the Barguzin depression. Two of them are represented by low-slope hills, with diameters at the base up to 15-20 km. The other two are smaller, up to 2-4 km in diameter. Let us consider the Lower Kuytun volcano, which is better surveyed than the other three. It is a huge, completely treeless hill, the slopes of which fall both to the West towards the Barguzin river and to the North towards the Argada river. The height of the hill relative to the river Barguzin is 130 m. On the map, the entire surface of the hill is dotted with winding contour lines. At the site itself, there is a large number of alternating rises, depressions, hills and pits tens and hundreds of meters in diameter.

The main and very interesting geomorphological feature of Kuitun is the presence of a deep drainless hollow (depression) in its central part. Its closed contour at 500 m has the dimensions of 4 x 1 km. The hollow extends from North to South, there are two lakes called Nuhe-Nur (“Nuhe”
means “pit” in the Buryat language, and “Nur” means “lake”). Their actual elevation on the map is 487.7 m. It turns out that the lake level is only 5 m above the level of the Barguzin river, and the depth of the depression from the top edge of the surrounding rise is 75.6 m. The water in the lakes is saline. The composition of positively charged ions is dominated by sodium, potassium and magnesium. Calcium is very low, which is unusual for surface waters. Anions of bicarbonate, sulfate ion and chlorine are observed (in descending order of concentrations). It is notable that the chlorine content exceeds 1.5 g/l, and the total mineralization is more than 16 g/l.

Facts established while surveying the depression:

1. The sediments composing the depression are not lake sediments, as there is no horizontal stratification.
2. The depression is an endorheic basin. Its depth relative to the surrounding terrain reaches 120 m, with 75.6 m directly in the lake part.
3. Water supply to the lake most probably comes from underground sources at its bottom. This is evidenced by the composition of water and the presence of abnormal concentrations of helium in the gases. Atmospheric precipitation is a small fraction of the water balance and is completely evaporated.
4. No fish is found in the lake due to increased salinity of water and gas emissions.
5. We view the basin of Nuhe-Nur Lakes as a crater of a "mud" volcano. Lakes are confined to the vents of the volcano.
6. The Lower Kuytun Hollow is the dissemination site of the mud volcanic streams of clay and sand, which covered all the swamps and pushed the river Barguzin to Barguzin ridge.
7. Within the Upper and Lower Kuytun river basins, the rivers behave the same way, deviating from the shortest direction to the Barguzin river and flowing around the fields of volcanic sediments, as if these sand and clay hills were an obstacle for them. The same is observed in the valley of the Ulan-Burg River.

The presence of "mud" volcanoes is considered to be the most important sign of high oil and gas potential of the territory (or water area). Theoretical justification of the "mud" (gas) volcanism is reduced to the presence of the following geological criteria: high power of weakly lithified sedimentary rocks, high gas-generating potential of the subsoil, the presence of modern tectonic processes expressed through seismicity. All these features are found at Lake Baikal, they are assumed in all depressions similar to Lake Baikal type (Isaev, 2001), as well as in some intermountain basins of Transbaikalia [3].

Mud volcanoes in the BRS depressions are genuinely mud-bearing only at the bottom of lake Baikal. In almost all of the dry-valley depressions similar to Lake Baikal type, the alluvial cones of the volcanoes are represented mainly by light sand. Inclusions of clay and silt were encountered only in the Lower Kuytun volcano. These clays are characterized by the presence of pyrite. This prevents us from calling these volcanoes in the basins of the Baikal type "mud volcanoes”. It is therefore proposed that volcanoes in Baikal-type depressions formed by the catastrophic release of gas are called gas clastic volcanoes or gas arenaceous volcanoes.
Literature

3D INVERSIONS OF POTENTIAL FIELD DATA: AN ATTEMPT OF GUIDED CLASSIFICATION IN ORDER TO DERIVE PSEUDOLITHOLOGY

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The study is describing the results of airborne magnetic and ground gravity data inversions. The data were acquired in Northern Kazakhstan in 2016 within the area of interest (1790 km²), which is approximately 50-52 km long and 52-53 km wide.

The terrain in the area under study is mainly shallow plane with several known AU deposits and mineralizations. The known mineralizations are predominantly Au-quartz-sulphide type with Au-arsenopyrite-bismuth sulphides. The main known deposit is controlled by a contact between porphyroblastic granodiorites and granites.

There were legacy gravity data available over the general area under study, covering 2500 km² with 500 m line spacing and along-profile sampling rate of 250 m. The legacy data were sampled into a digital format and inverted. The magnetic data available over the area included airborne set, flown at 100 m altitude with 250 m line spacing and covering 1630 km² with an infill flown in the middle of the block with double line-spacing (125 m) covering 725 km². A total of 8983 line km of airborne magnetic survey were flown.

The data were further processed and inverted using mag3d algorithm [1] in order to acquire 3D models of magnetic susceptibility, which were in turn used for automated, then user-guided cluster analysis based on petrophysical and other apriori information. The results of cluster analysis were used to derive a 3D pseudolithological model, which, in turn, was used to delineate some areas favourable for mineral exploration and follow-up UAV studies at deposit scale (<=1:10000).

We thank Kazzinc Exploration for allowing to show some results of the study.

Literature

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Fracture corridors are extended linear or curved fracture zones formed by one or more fracture systems; they intersect series of deposits and make a single permeable geological object with pressure communication and, consequently, it contains and conducts fluids. Fracture corridors may have a regular structure in the case they are composed of one system of fractures, which is parallel to the principal direction of a fracture corridor, or random structure in the case they are composed of two or more systems of fracture at an angle to the principal direction of fracture corridor trend. Lateral boundaries of a fracture corridor, which separate it from a rock base, may be sharp (when the fractures outermost in the cluster of identical fractures form the boundaries) or gradual (if transition to the rock base occurs with a consistent reduction of fracture size and opening). According to the results of numerous investigations, all the fractures irrespective of their size are fractal (i.e., self-similar) objects. At the same time, in accordance with the concept of inhomogeneous geological media having hierarchical structure, which is a sequence of inhomogeneities put one into another, fracture corridors are defined as the parental level in relation to both single fractures and systems or fracture clusters. Therefore, properties of fracture corridors, on the one hand, are similar to the properties of single fractures (since they are an element of a fractal tree), but on the other hand, some of its properties have their own features (as they are an element of the higher hierarchical level). The common property for all fractures may be dimensions proportionality, i.e., length is by several fold greater than height, and length many times greater than aperture. The property of fracture corridors, which distinguishes them from single fractures, is the size of heterogeneities acting as stress concentrators, owing to which the stress at their boundaries exceeds the average stress in a given volume. Despite the attempts of many researchers to identify scale levels of structural arrangement (micro-, mini-, macro-, meso-, mega- levels, etc.) by determining the most statistically probable boundaries of the levels, rigid absolute digital values do not define level boundaries in the real world. It is a hierarchical nesting that determines them. Dimensions of a single fracture in a thick (say, fifty meters) carbonate rock base layer can be many times larger than a fracture corridor in ten meters thick interbedding of one meter thick formations. Based on the empirically derived linear relationship between the formation thickness and the dimensions of fracture that break it, we can see that at the next hierarchical level, where the fracture corridor breaks not a single layer, but a layered sequence or cyclite, dimensions of fracture corridors are linearly dependent on the thickness of formation sequence they break. Since a reservoir thickness varies significantly from one field to another (from West Siberian sand formations the first meters thick to tens-meters thick carbonate reservoirs of the Timan-Pechora region), the frequency of occurrence and size of fracture corridors that break them are different; and, accordingly, the degree of these fracture corridors influence on the hydrodynamic connectivity / isolation of development facilities is also different. It so happened that in the literature there are more frequent references to fracture corridors and related phenomena (abnormal production rates, early water production, high accidents rates during drilling, etc.) in carbonate
rocks than in terrigenous ones. However, this statistics is related to the sample inhomogeneity, because it is in carbonate rocks, often composed of thicker rock series, that the size of fracture corridors is larger, and the phenomena associated with them are more catastrophic. Nevertheless, number of fracture corridors in terrigenous rocks is larger, but they are smaller and their impact is also less. For example, 500 and more meters long fracture corridors are typical of 30-50 m thick Lower Permian carbonate reservoirs; and it is a well spacing of production drilling. If by chance two wells enter one of such fracture corridors, its influence on the production will in no way be overlooked: either the water injected in one well will be “immediately” produced from another well, or pressure in the first well will drop when the second well will be hooked up, etc. Not to mention the abnormally high production rates from these zones, especially in the early stages of development. In a situation with terrigenous reservoirs having thickness of first meters (up to ten meters), the length of the fractured corridors breaking them will be significantly less than spacing of production drilling: 150 to 300 m. Their permeability will depend on density and strength of sandstone being broken (for example, the Pokur sand will simply fill a fracture and its permeability will not differ from the permeability of host rocks). Their influence can only be observed if the aquifers occur so close to reservoir that the fracture corridor height will be enough for the reservoirs to start interference under the pressure difference. We would like to note that the lithology of reservoirs is much less important in determining the degree of fracture corridors influence on production than it may seem at first glance. In fact, it is the thickness of the beds composing the reservoir interval that plays a core role. It is very common for reservoir interval to be composed of thin lamination of permeable carbonate and impermeable rock, for example, Tournaisian formations in the Bavinsky field or Artinskian formations of the Orenburg field. In such cases, the influence of fracture corridors on the production occurs in the same way as in terrigenous rocks: fracture corridors are nonextended, small in height, small in aperture, but numerous. The more such nonextended fractures a horizontal production well faces, the better its production rate. And if the borehole runs parallel to a fracture corridor, whatever its length, the production rate will remain low. In other words, the efficiency of horizontal wells depends to a greater extent on the frequency of occurrence and density of fractured corridors per unit area than on the borehole length. In conclusion, we would like to mention that the role of fracture corridors in field development is significantly underestimated. This is due to the fact that it was almost impossible to determine the patterns of their propagation and to map them before introduction of DWM method. Anomalous events associated with their penetration are rare but systematic, and huge statistics is required to consolidate, systematise, analyse and correlate them.

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ELECTRIC CONDUCTIVITY OF THE BASEMENT OF THE EAST EUROPEAN PLATFORM IN THE SOUTH-EAST OF LADOGA REGION ACCORDING TO MAGNETOTELLURIC SOUNDINGS

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We present the results of magnetotelluric soundings in the south-east of Ladoga region, conducted in 2018-2019 in order to study the deep resistivity structure of the EEP basement in the area of the junction of the Russian Plate and the Fennoscandian shield. The results of robust to industrial noise processing of data obtained along the 180-km profile of the Tikhvin-Vinnitsy and the invariant analysis of the obtained magnetotelluric and magnetovariational transfer operators are discussed. Using a two-dimensional inversion along the profile line, a resistivity model of the crustal cross-section to depths of 50 km was constructed, in which the structures of the SE of the Ladoga anomaly of the crustal electrical conductivity, confined to the extended Ladoga-Botnical tectonic zone on the border of the AR and PR domains of the shield, were clearly revealed. The principal features of the similarity of the new model of the Ladoga anomaly cross section with a model built earlier for the Vyborg-Suoyarvi-2 profile (northern coast of Lake Ladoga) were revealed: a general fall in the south-western direction of the conducting crustal structures and the location of areas of maximum telluric current concentration at depths of 15 - 20 km within the southern sections of the profiles, their preliminary geological interpretation is provided.

The authors are grateful to all members of the LADOGA Working Group and students of the Department of Geophysics of the Geological Faculty of the Moscow State University who took part in the field work in the SW Ladoga region in 2018-2019, as well as to M.Yu. Nilov and N.V. Sharov (GI KarRC). The studies were supported by a grant from the Russian Foundation for Basic Research 16-05-00543 and by North-West Ltd.
ENERGY BUDGET OF GEOMORPHOLOGICAL SYSTEMS OF HIGH-ALTITUDINAL AREA

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Approbation of the method of energy analysis of geomorphological systems was carried out in high altitudinal area, since the processes in these natural complexes have a high speed and their dynamics can be easily compared with each other. The study area covers the northern macroslope (the total area is 175.0 km2) of the Severo-Chuisky Range in the Russian Altai. Within the study area there are 6 mountain glacial basins (Tete, Aktru, Kyzyltash, Yan-Karasu, Korumdu, and Kurkurek). This is one of the largest centers of current mountain glaciation in the Russian Altai.

The average altitude of the area is 3000–3100 m a.s.l., the maximum one exceeds 4000 m (altitude of the Aktru-Bash is 4075 m a.s.l.). As a result of direct parallel observations in the mountain glacier basins, the various meteorological values and indicators of atmospheric phenomena was established in the Aktru basin. All the mountain glacial basins have similar climatic indicators, namely changes in the temperature gradient with increasing altitude (0.7°C/100 m in average), the distribution of precipitation in different altitude, solar radiation, wind mode, etc. [1].

At the first stage of the study, the catchment of the northern macroslope were identified and characterized as geomorphological complexes (geomorphological systems) which include a specific set of interrelated elements with integrity. The classification of current geomorphological processes in the studied area was carried out to identify hazardous processes, their flow rate and spatial distribution. Morphometric characteristics of the sections of the slopes within the basins were determined and mapped [2].

At the second stage, the energy from the sun was estimated. The solar energy is one of the leading factors in intrastructural interactions, the direction and intensity of the migration of matter and energy in the geomorphological systems. The balance characteristics of direct, diffuse and total radiation for slopes of various steepness and aspect were calculated under average cloud and without clouds using actinometric data. The values of the solar energy for the slopes of various aspect and steepness (from 2000 to 5500 MJ/m2) were revealed [2].

Further work is to calculate a contribution of the additional energy that enters with rainfalls to this area. This mass can be expressed in universal energy units in Joule.

It was established by long-term precipitation of the Aktru weather station (2150 m a.s.l.) and on glaciers during snow measurements in the Aktru mountain glacier basin that 1), the average yearly precipitation in the Aktru station is 545 mm and changes year by year, 2) there is altitude differentiation in the precipitation (more than 1000 mm falls in the high-altitude glaciers) [3], 3) 75% of the total precipitation falls in the warm period of the year, and 4) mainly snowfalls up to 1300-1500 mm fall in the zone of the headwaters. The current position of the snow line decoded
on satellite images is at 3000–3200 m a.s.l. [4]. Stable rainfalls in summer is normally observed below 2400 m a.s.l.

Thus, the average precipitation over the entire study area, taking into account their altitudinal differentiation, will be 733 mm and the position of the edge of the lower clouds will be on 486 m above the underlying surface. Thus, geomorphological systems will receive 6.53*10^8 MJ or 3.74 MJ/m² per year of the additional energy on average.

The additional energy can be triggers of geomorphic events on the slopes, for example, debris flow activity, solifluction, etc.

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Literature

SEARCHES FOR GROUNDWATER FLOWS IN STEPPE AND MOUNTAINOUS
CRIMEA, CONFINED TO ENDO DRAINAGE SYSTEMS, USING THE
NPEMFE METHOD

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1. The content of the problem and the rationale for its solution.

Hydrogeological features of the territory of the Crimean Peninsula make it possible to consider groundwater as a stable, but insufficient source of water for modern needs. According to Professor S.V. Albov, in the zones of tectonic disturbances in the steppe Crimea, the prokarsteness of the water-bearing rocks of the main aquifers reaches depths of up to 100-120 meters and averages 20% in the volume of the geological section. From the experience of practical work on the search and extraction of underground water, it has been established that a well that has been passed outside the zone of a watering tectonic disturbance has a flow that is an order of magnitude less than in a water-cut zone.

Consequently, for the effective search and production of groundwater in Steppe and Mountainous Crimea, it is necessary, first of all, to solve the problem of mapping endodrainage systems confined to zones of tectonic disturbances and carded water-saturated strata. A promising region for the search for additional groundwater resources is the Mountain Crimea, where areas of feeding of the main aquifers are formed, and significant areas of groundwater are concentrated in areas of tectonic disturbances and faults in the prokarsted rock mass. The geological and geophysical studies conducted on the search for groundwater in the Crimea and the results obtained here are evidence of the presence of significant water resources in intensively carved strata of rocks confined to tectonic faults.

2. Peculiarities of geophysical research methods for mapping promising aquiferous structures using the NPEMFE method.

Studies on the mapping of promising aquifer structures are carried out using the express method of NPEMFE (natural pulsed electromagnetic field of the Earth).

The groundwater search method is based on the phenomenon of electromagnetic polarization of geological and hydrogeological structures in which filtration processes take place. Polarization depends on a number of factors: the presence of flooded fracture zones, porosity and voidness of rocks, the quantity, composition and ratio of the solid and liquid phases in the rocks, the filtration rate of the liquid, the slope of the filtration flow, which in general creates an electric filtration potential, the violation of neutrality when the underground moves water is a source of electromagnetic radiation (EMR) generation. Detection and registration of anomalous intensity of electromagnetic radiation allows us to diagnose the presence of a water flow in a hydrogeological structure.

The method of groundwater search by the NPEMFE method is based on the mechanism of generation of electromagnetic radiation by watered zones and water flows. At the boundaries of water flows with different filtration rates and slopes, a filtering electric potential is formed, the
change of which during the filtration process generates an EOMEMP anomaly in a certain frequency range.

To register variations of the NPMEFE during field geophysical surveys, area-specific measurements are carried out using microprocessor-based equipment such as Simeiz and EMI & SAR.

NPMEFE parameters are stochastic quantities and therefore probabilistic-statistical data processing methods are used for their analysis. Anomalous parameter values are determined by deviations from the average values, taking into account the permissible limits of deviation. At the same time, background values are recorded, and zones of anomalous manifestations of the geophysical field are determined relative to these values. The presence of zones of water-saturated rocks and water flows is determined by certain amplitude-frequency characteristics of NPMEFE and anomalous values of the parameters of EMR recorded in a given frequency range.

**Literature**

NEW METHODS AND APPROACHES IN GLOBAL GEODYNAMIC RECONSTRUCTIONS

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Traditionally Global geodynamic reconstructions based on the reliable paleomagnetic data – the ‘key’ poles. The similarities of magneto-tectonic data and geological correlations depend on the quality of the unique paleomagnetic poles.

Recently, a large number of reconstructions have been done not only for the Phanerozoic, but also for the Precambrian [5 and references within]. At the same time, in Precambrian reconstructions modern contours of the continents are used. Meanwhile, the boundaries of the lithosphere plates and continental blocks change over time, which is crucial for assessing the nature of connection, the distance between neighboring blocks and the speed of their movement. That is why it is so important to understand for what supercontinent cycle reconstruction is being built and what geodynamic position the block in question occupied at the reconstruction time. In other words, if the continental block is now part of the basement of the ancient platform, it was not necessarily part of that platform in the Paleoproterozoic during the existence of the Nuna/Columbia supercontinent. It is likely that at this time considering the continental block could be terrane, accreted to the Archean-Paleoproterozoic continental core, or in its place was an oceanic basin, a fragment of which – ophiolite complex in the process of oceanic have been obducted to the Archean-Paleoproterozoic continental margin, etc., and only during the next supercontinental cycle as a result of cratonization this unit joint to the continental core, and now he is part of the basement of the platform/craton.

The second important aspect of geodynamic reconstruction is the time. It is necessary to understand what was happening on a global scale at this time-the assembling or break-up of the supercontinent. Accordingly, which complexes-indicators and geological correlations will serve as proof of the proposed model. The experience of reconstruction of the Neoarchean supercontinent Rodinia allowed Svetlana Bogdanova and her co-authors to classify the main tasks of break-up and assembling of the supercontinents [1]. The assembling of the supercontinent is characterized by: (1) close-in-time collision events, manifested on most continents; (2) high peaks of juvenile crust growth, due to intense subduction; (3) lithological and biochemical indicators indicating the existence of large continental masses; (4) high degree of erosion and low sea level; (5) changes in the chemical and isotopic composition of water, associated with a significant introduction of continental material into the ocean; (6) climatic changes in the direction of cooling and (7) slow evolution of life forms. During the breakup of supercontinents occurs: (1) the formation of large trap provinces and swarms of mafic dikes; (2) abrupt climate change; (3) the increase in the level of the World ocean due to the emergence and growth of long ocean ridges; (4) intense transgressions and the formation of intercontinental depressions; (5) a sudden increase in the area of distribution of carbonate and SiO₂-enriched sediments; (6) intensive burial of organic matter and (7) a sharp increase in biotic environments [1].
Almost simultaneously Walter Bleeker and Richard Ernst suggested to correlate coeval "bar codes" – a major magmatic event (LIP) for different cratons [3]. In this case, the relative position of the continental blocks is reconstructed based on the geometry of swarms of the radial mafic dykes. Also a new approach to the interpretation of paleomagnetic data is a method of correlation of pairs of coeval ‘key’ poles for different cratons [4], allow to quantify the displacement of the continental blocks as part of a single lithospheric plate, optional adjoining/neighbor between them. In addition, Brendan Murphy and Domian Nance proposed to divide all the ancient boundaries between cratons on extroverted and introverted [7]. In the case of extroverted articulation, the full Wilson cycle is assumed, in the case of introverted – "truncated". In the same case, two or more of the craton can over a long time interval (longer than the duration of the supercontinental cycle ~ 400 Ma) to form a stable configuration – megacontinent. Examples of such megacontinent is Archean of Vaalbara (formed Kaapvaal and the Pilbara cratons); Paleoproterozoic NENA (North Europe – North America), lasted until the final collapse of the Neoproterozoic supercontinent Rodinia ~ 550 Ma, then re-formed in Phanerozoic ~ 400 Ma ago and called Euramerica (Laurussia); and, of course, the Neoproterozoic – Mesozoic megacontinent Gondwana.

But there are the other methods and approaches in the regional correlations (in addition to the previous methods):

(A) Studies of Anisotropy of magnetic susceptibility (AMS) for typification of primary/secondary different ages processes overprinted and fixed by magnetic carrier minerals. The results allow to reconstruct the distribution of secondary processes, the degree of their occurrences;

B) Studies of secondary processes, their separation and typification in the time and occurrence based on petro-paleomagnetic studies (typification of remagnetization depend on geodynamic setting – chemical or viscous) [2 and references within].

C) Determination of remagnetization trends contributes to better understanding of geodynamic processes and recognizing of geological history for a specific time interval within the global geodynamic cycle [6 and references within].

Thus, it is the correlation of secondary same-age processes on different cratons, leading to partial or complete remagnetization of rocks, can be the basis for recognizing of geodynamic events in the past.

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Literature


KARELIAN PROTOCRATON DURING PALEOPROTEOROZOIC TIME: NEW KEY PALEOMAGNETIC POLE FOR THE VODLOZERO AND CENTRAL-KARELIAN TERRANES

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Years of paleomagnetic studies of the Archean – Early Paleoproterozoic complexes of the Karelian proto-Craton indicate the presence in the high-temperature interval the characteristic components of NRM in almost all objects. Thus in the Early Paleoproterozoic mafic complexes in the Northern and Eastern parts of the Karelian proto-Craton (Paanajarvi structure of the Central Karelian and eastern part of the Vodlozero terranes) are the two characteristic components of magnetization D-component of southeast declination and moderate positive inclination and D’-component south–southeast declination and low-positive/negative inclination. Initially D-component attributed to age 2.45 Ga, and component D’ – 2, 505 Ga [3].

Recent paleomagnetic studies of Paleoproterozoic mafic complexes Iisalmi and Kianta terranes indicate the presence of D’-components in mafic dikes 2.4 and 2.3 Ga, with the initial selected components of the magnetization is proved based on a positive contact test [5]. However, the paleomagnetic pole recalculated from the mean direction D’-components coincides with the paleomagnetic pole 1.75 Ga for the Karelian proto-Craton [see review 1]. It should also be noted that mean directions of D-component separated in Paleoproterozoic mafic complexes of the Karelian proto-Craton "scattered" over the Great circle in the first and second rumbas, indicates an incomplete separation of both Precambrian and Phanerozoic ("Devonian" and "Caledonian") component of the magnetization [1]. Moreover, dolerite dikes 2.1 Ga of the northern part of the Central Karelian terrane contain the characteristic component of the south–southwest declination and low-positive inclination. The paleomagnetic pole calculated from the mean direction of this magnetization component, are also close Paleoproterozoic pole 1.75 Ga for the Karelian proto-Craton.

To proof the primary origin of the D-component of magnetization and evaluate the contribution of different ages of the secondary component applied another test of the paleomagnetic reliability – conglomerate test.

The main objects of paleomagnetic studies were Sariolian (2.4 to 2.3 Ga) conglomerates of Paljeozoero and Penza suite of the Onega structure and Paanajarvi structure of the Central Karelian terrane of the Karelian proto-Craton. The choice of objects is unconscious – in pebbles of conglomerates are present both fragments of NeoArchean basement granitoids and Sumian underlying andesites and andesibasalts. Moreover, to identity of the magnetic record in rocks and pebbles we used data from paleomagnetic studies of Archean granitoids of the Deda and Gorely Isles, intruded into the Shala Neo-Archean dykes of gabbronorites [6], Burakovka [4, 6] and Kivakka (unpubl. authors data) Sumian layered intrusions, as well as Sumian mafic dikes of the Paanajarvi structure.
As a result of paleomagnetic studies of the Sariolian (2.4-2.3 Ga) conglomerates of the Onega structure two characteristic components of magnetization have been separated. The first, medium-temperature magnetization component demonstrates cluster on sphere. The mean direction of this component correspond to the direction Svecofennian remagnetization within the Karelian proto-Craton. The directions of the high-temperature magnetization components separated in the conglomerates have a significant spread, indicates the primary nature of this magnetization component (the conglomerate test is positive). The obtained result testifies in favor of the partial preservation of the primary magnetization components in the Paleoproterozoic complexes of the Karelian proto-Craton. Two clusters of high-temperature components associated not only with the composition of protoliths, but also with different conditions of rock, transformations, including their fluid saturation, are identified.

Comparison of mean directions of high temperature component of magnetization for the Vodlozero and Central Karelian terranes of the Karelian proto-Craton indicates a possible rotation of these two terranes during Early Paleoproterozoic time.

Correlation of coeval pairs Early Paleoproterozoic poles for Superior and Karelian proto-Cratons testifies to their joint move up to 2.3 Ga. However, the relative position of these two proto-Cratons are different from reconstruction based on correlation of radial dikes swarms ("bar codes" method) [2].

The proposed a new reconstruction of the Vodlozero and Central Karelian terranes of the Karelian proto-Cratons as a part of the Neo-Archean supercontinent Kenorland.

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Literature

BIOCHEMICAL ROLE IN THE FORMATION OF BAXITE EXTRACTABILITY IN THE LATERITE WEATHERING CRUST

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There are many hypotheses of the formation of genetic types of bauxite: laterite, laterite-sedimentary, sedimentary, volcanogenic-sedimentary, terra rossa, biogenic, infiltration-metasomatic, etc. However, none of them are able to explain the origin of specific deposits of bauxite. The hypothesis of bauxite origin as a result of chemical weathering does not fully meet modern ideas about the mechanism of biochemical destruction of minerals, the chemical properties of aluminum and the natural conditions of laterization. According to numerous literature data, complexation processes, in particular chelation, play a huge role in the development of weathering [1-8]. The significant role of microorganisms in rock weathering and formation of minerals in WM was noted by I.I. Ginsburg (1952). Laboratory experiments: by Reesman (1968) and Keller (1970, 1971) showed that alumina can be leached from aluminosilicate minerals, including clay, diluted with organic acids at room temperature. These experiments explain the mobilization of Al in laterization in the presence of biota. These experimental data are in good agreement with the data of Heydeman et al. (1983), which proved microbiological leaching of Al from laterite samples taken from geographically remote locations. They proceed with participation of various organic compounds, mainly carboxylic acids and phenols. Aristovskaya, T.A. and Zykina, L.V. [10] have formulated a biological concept of bauxite formation. It essentially does not contradict the prevailing ideas in geological science about the genesis of bauxite ores, but only makes some additions to it. The biological concept considers lateritic soil formation as an initial stage of bauxite formation. In recent years, when analyzing the process of bauxite formation, the microbiological factor has attracted much attention of researchers. It was confirmed that the activity of microorganisms accelerates processes of weathering tens or even hundreds times [11]. There is an active interaction of the substrate with bacteria, including the effect on minerals of metabolic products (organic acids and different forms of carbon dioxide). Many types of microorganisms, such as fungi, heterotrophic and autotrophic bacteria and yeast, live in bauxite ore deposits. This leads to biogenesis and biomineralization. The use of Paenibacillus polymyxa in the effective removal of calcium from low-grade bauxite is demonstrated by bioreactor technology [12]. Similarly, iron-deficient bacteria can be used to remove iron from bauxite (Hanumantha Rao et all, 2010). Silicate bacteria help in the selective solubilization of silicon dioxide to control the ratio of aluminum oxide to silicon dioxide [13, 14]. Microorganisms living in bauxite ore deposits can be effectively used for bio-enrichment. Many types of oxidation-reduction reactions with bauxite minerals, such as calcium carbonate, silicon dioxide, silicates and iron oxides, may be caused by local bacteria [15]. Thus, bacteria (e.g. Paenibacillus polymyxa) can be used for selective removal of iron, calcium or silicon dioxide from bauxite ores. Presence of various microorganisms in light bauxites and transition zones between red and white bauxites along faults was established [12]. It was attempted to study silicate bacteria and bioleaching silicon from bauxite using Bacillus mucilaginosus and Bacillus circulans to control the ratio of Al2O3: SiO2 (silicon module). Organic
acids such as citric acid and oxalic acid produced by several fungi such as Aspergillus sp., may lead to the reductive dissolution of iron oxides (Papassiopi et al., 2010). Direct bioreduction of iron oxides using the metabolism of iron-reducing substances can also be achieved. Several iron reducers, such as Shewanella, have contributed to the reduction of iron hydroxides and oxides in both amorphous and crystalline states. In a study of the metabolic activity of Desulfituromonas palmititidis, it was found that up to 29% Fe2O3 present in the bauxite samples was removed together with the EDTA chelator. Amorphous ferrihydrite was almost completely converted into a solution in contrast to the crystallites of goethite and hematite. Iron and silicon release in the interaction of bauxite with P. polymyx. Because of bacterial adhesion and the formation of acid metabolites, iron can leach effectively. The removal of iron from bauxite by selective bio-modulation using adapted cells of the polymyx (pH 7-9, 5 min at a density of 5% of the pulp) is described in the work of Namita Deo, 1998. It is known that fungi Cladosporium are good solubilizers of aluminum oxide and iron reducers, whereas Pseudomonas anaerobically reduces iron oxide. Silicon and iron are actively derived from the rock by yeast Yarrowia lipolytica, and importantly, aluminum is practically not washed away. An even greater degree of extraction of silica was achieved by the treatment of bauxite by microvilli Aspergillus niger - more than 800 mg/l silica extraction and 620 mg/l iron extraction, with aluminium washed about 100 mg/l. Metabolites of micro-fungi Penicillium simplicissimum (can be obtained on glucose) are used for leaching of aluminium from bauxite. Bacteria such as Bacillus coagulans, and Paenibacillus polymyx, through the provision of exopolysaccharides can separate between oxides of iron, aluminium oxide and calcite. Micro-organisms can also be used to provide environmental control for the disposal of red sludge using bioremediation technology [16]. Bioextraction / microbial uptake of trace metals from bauxite-red sludge has also been attempted [6]. To understand what processes lead to the concentration of useful components in the supergene zones and what the role of organic matter in them is, it is necessary to study in detail the modes of occurrence of useful components in the supergene zones of deposits, their structure and composition. The research team includes highly qualified specialists on the subject. The professional level of the research team is consistent with the objectives of the project. Comprehended for the first time will be results of the study of main formation stages of bauxite and related iron, titanium, and rare earths elements, taking into account the influence of organic matter on these processes. Based on this knowledge experiments on biochemical beneficiation of bauxite will be conducted. These results will become a new contribution to the modern mineralogy, geochemistry and biogeochemistry of bauxite hypergenesis. The research team includes highly qualified specialists on the subject. The professional level of the research team is consistent with the objectives of the project. Comprehended for the first time will be results of the study of main formation stages of bauxite and related iron, titanium, and rare earths elements, taking into account the influence of organic matter on these processes. Based on this knowledge experiments on biochemical beneficiation of bauxite will be conducted. These results will become a new contribution to the modern mineralogy, geochemistry and biogeochemistry of bauxite hypergenesis. The research team includes highly qualified specialists on the subject. The professional level of the research team is consistent with the objectives of the project.

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METAMORPHIC ROCKS FROM ISLANDS OF THE KANDALAKSHA GULF OF THE WHITE SEA AND THEIR PETROGRAPHIC CHARACTERISTICS

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The study is aimed at determining the relief’s formation mechanism on isolated land areas - the islands, which are located within the water area of the Kandalaksha Gulf of the White Sea. In tectonic plan the research region is located within the Belomorian Mobile Belt (BMB). BMB is presented by large tectonic covers, such as Kovdozersky (tonalite-trondhjemite-granodiorite gneisses), Chupinsky (paragneisses) and Hetolambinsky (metabasites) [1]. The main task of this research is the age correlation of the rocks composing the islands of Kandalaksha Gulf and also the study of the horizontal tectonic movements’ processes of the large blocks of the earth crust.

In 2018, we implemented the petro-paleomagnetic studies of the outcrops on the islands of the Rugozersky Bay (Velikiy and Vysokiy), the Kislaya Bay (Olenevsky), and the Krasnaya Bay (Asafiy, Bolshoy Kemludsky). Hetolambinsky complex includes the rocks of Vysokiy island and southwestern part of Velikiy island; Keretsky complex – rocks of islands Olenevsky, Bolshoy Kemludsky and Asafiy; to the border of these two complexes - the southern coast of the central part of Velikiy island. On the border of the Hetolambinsky and Keretskiy tectonic complexes, intensively migmatized gneisses are observed [2], within the Hetolambinsky complex there are gneisses and, less commonly, melanocratic garnet gneisses, as well as amphibolites [2, 3]. For the Keretskiy complex, gneisses are characteristic, turning into garnet gneisses and migmatized gneisses.

A microscopic study of rocks in thin sections was carried out in the Petromagnetic Laboratory (Department of Dynamic Geology, Faculty of Geology, Lomonosov Moscow State University) using a polarizing microscope POLAM R-211. The study using a polarizing microscope is complemented by the study of transparent polished thin sections using a JEOL JSM-6480LV scanning electron microscope in the Laboratory of Local Methods of Matter Investigation (Department of Petrology, Faculty of Geology, Lomonosov Moscow State University). Quantitative ED analysis was obtained with an accelerating voltage of 20 kV and a current of 10 nA, the accumulation time of the spectrum was 70 sec. Analyst – Koshlyakova N.N.

To date a microscopic study of the rocks selected on the islands of Asafiy, Bolshoy Kemludsky, Velikiy and Vysokiy has been carried out.

Melanosome of migmatites on the southern coast of Velikiy island are represented by amphibolites with small- and medium-grained, lepidogranoblastic texture and weak-gneissosity structure, composed of partially sausuritized plagioclase (47%), pargasite and ferropargasite (35%), magnesian biotite (10%), quartz (5%), epidote (2%), zonal sphene (1%). Single grains of ore minerals about 0.3 mm in size are represented by rutile and pyrite with inclusions of chalcopyrite, containing, in turn, inclusions of nickeline and galenite.

The tested rocks on Asafiy island are biotite, epidote-containing amphibole-biotite and amphibole-pyroxene-biotite gneisses with fine- and medium-grained texture. Amphibole-biotite
Gneisses are characterized by a banded structure, expressed in the alternation of bands with granoblastic and lepidoblastic textures and generally composed of partially sausuritized andesine An30 (45%), biotite (25-30%), quartz (10%), ferropargasite (8%), epidote (5%), nonzonal sphene (3%). The content of ore minerals represented by pyrite in these rocks is also small (≤ 1%), their distribution is uniform, but in the amphibole-biotite gneisses, within certain areas at the micro level, the content of pyrite grains reaches 3%. This difference is also characterized by the presence of the largest pyrite individuals - up to 0.8 mm - among all the rocks tested in the framework of petro-paleomagnetic studies. Pyrite grains contain inclusions of magnetite, copper sulfide and chalcopyrite, as well as magnetite crust.

Samples from the Bolshoy Kemludsky island are represented by similar rocks, as well as amphibole gneisses, garnet-containing and garnet gneisses. The garnet-containing amphibole gneisses are characterized by a fine-grained granoblastic texture, the garnet gneisses are characterized by medium- and fine-grained poikiloblastic, symplectic texture and a massive structure. This difference is composed of atoll form garnet crystals (38%), quartz (10%), replaced by actinolite omphacite (8%), oligoclase (4%), pargasite and chermakite (4%), symplectic fusion of clinopyroxene and plagioclase (36%). Ore minerals in the rocks are evenly distributed, their content is ≤ 1%, and only in the garnet gneisses, where they are represented by ilmenite, within some areas does it increase to the first percent.

Samples of rocks from Vysoki island are represented by meta-ultrabasic rocks with medium and fine-grained, kelyphitic texture and massive structure, serpentinized to varying degrees with magnetite release. Secondary magnetite is developed through cracks in olivines, where it performs them in whole or in part along the axial parts. In the most intensely serpentinized varieties, magnetite in some places replaces the central parts of relict fragments of olivine grains. The rocks also contain aggregates of chromite and ilmenite, which are xenomorphic with respect to the now altered grains of primary minerals, often surrounded by phlogopite rims. The overall distribution of ore minerals is uneven, at the micro level in places reaching 10%.

To solve the problems posed, it is further planned to complete the study of the tested rock differences using a scanning electron microscope and to compare the results obtained with the data on anisotropy of magnetic susceptibility.

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Literature


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The Aktru headwater (the Severo-Chuisky Range, the Russian Altai Mountains) is a high altitudinal area with constantly mass movement, including debris flows, snow avalanches and rockfalls. Regular monitoring of them are not available and information about them is very fragmentary. Therefore, indirect dendrogeomorphological methods of their identification and dating [1] become important. The goal is the identification, dating and spatial reconstruction of debris flows, snow avalanches and rockfalls in the Aktru headwater by the dendrogeomorphological methods.

In the Aktru headwater slopes up to 2300 m a.s.l. occupied by Siberian larch and Siberian stone pine forests. The mountain tundra locates higher. There is a forest-tundra ecotone between them with single trees or tree groups [1]. Model (key) sites with a predominance of the same type of mass movement on them are selected on the left gentler and right steeper slopes of the Aktru river valley. Cross-sections and cores were taken from the trees along the periphery of the sites. The control trees were growing in the lower forest. The tree ring width (radial increment) on the cross-sections and cores was measured on the LINTAB device with an accuracy of 0.01 mm. The obtained individual tree ring width series were cross-dated both among themselves and with the reference series [2]. Dating and reconstruction of geomorphic events (avalanches, debris flows and rockfalls) was carried out using traumatic, dendrometric and anatomical dendroindications and eyewitness accounts and image analysis of the area were also used [see Nikolaeva, Savchuk, this book]. We used the temperature and precipitation series of Aktru and Kosh-Agach (70 km away from Aktru) weather stations.

Debris flows. Due to injuries on the trunk and changes in the radial increment in trees on the left debris flow fans for the last 55 years, the large debris flow occurred on June 24, 1984 is well dated. Single trees were found to have injuries after the 1993 and 2004 growing seasons which could date the debris flows in 1994 and 2005. The summer of 1994 was rainy which is one of the conditions of the debris flow. The debris flow injuries of the trunk as well as the presence of an erosion hollow in the satellite image of 2001 and its absence on the aerial photograph of 1975 showed that in 2005 the debris flow stopped at the upper forest line in the first left fan while it reached to the valley bottom in the adjacent left fan. The large debris flows occurred on July 14-16, 2012 recorded by video on the right slope but did not reach the upper forest line on the left slope. No injuries from these debris flows were found in the trees. On the left slope the debris flow of 1998 was possible. We thought so because the surfaces covered by the mud and clay which have already begun to overgrow with grassy and herbaceous vegetation were detected. That summer the precipitation was increased and the Aktru river water level was very high.

Snow avalanches. The avalanche magnitude and extent were determined by the tree damage and their spatial distribution on avalanche fans. The powder avalanche on December 31,

**Rockfalls.** The most notable rockfalls identified by tree injuries are caused by the powerful Chuya earthquake of August 27, 2003 and its subsequent aftershocks. The other rockfalls are more probable (by injuries with addition to climate and earthquake data): in 2007, 2002, 1990, 1985 and 1966.

Thus over the past half century, the Aktru headwater has been characterized by low debris flow, low rockfall and rather high avalanche activity.

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**Literature**

DENDROINDICATION METHODS OF HAZARDOUS GEOMORPHIC PROCESSES

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Hazardous geomorphic events (debris flows, snow avalanches, rockfalls, landslides, and other mass movements down the slope) destroy the infrastructure, lead to the people losses and change landscapes and ecosystems. When geomorphic monitoring is irregular or absent, the dendrogeomorphological methods become to be perspective. Since the beginning of the current century, such studies in Western Europe have intensified considerably, while in Russia, on the contrary, have sharply declined. The goal is to provide an overview of the dendrogeomorphological methods of identifying, dating and reconstruction of hazardous geomorphic events (debris flows, snow avalanches and rockfalls) at different stages of the study.

Dendrogeomorphological studies are based on the J. Schroder’s concept: “process - event - response” [1]. The study is divided into several stages, each of which includes its own approaches and methods outlined below which make it possible to identify the influence of geomorphic phenomena and minimize the influence of climatic and other factors. At the preparatory stage non-dendrogeomorphological methods and at the subsequent ones dendrogeomorphological methods are used.

The preparatory stage of work includes: identifying features of the geomorphic processes in the selected area and factors contributing to their activation, image analysis of the area for different years (maps, aerial photographs, satellite images, and images from unmanned aerial vehicles), analysis of vegetation characteristics and distribution, including trees, the collection of evidence of geomorphic events (own observations, literature, archive data, the internet, and an interview of eyewitnesses), the choice of model (key) sites. In dendrogeomorphological studies, additional information is useful for identifying and assessing geomorphic activity: the vegetation composition and structure (phytocenotic indication), the characterization of layers of debris flow deposits (sedimentation-stratigraphic indication), the age of fossil wood (radiocarbon analysis).

At the stage of field work, trees with external disturbances are selected and mapped, taking into account the different types of the disturbances, the type of wood samples and the sample height on the trunk, the number of disturbed and undisturbed (control) trees. Such selection in dendrogeomorphological studies is differently made than in dendroclimatic studies [2], and depends on the type of the mass movement and the presence of injuries in trees. In the study of debris flows and avalanches, a predominantly targeted method of the selection was used; in the study of rockfalls were used transects [3].

As a control, tree ring series is used obtained from undisturbed trees growing (1) on adjacent undisturbed slope sites or (2) on the same sites where the geomorphic process is studied. In the second case, the injured trees, in which (3) tree ring series were obtained from intact trunk sectors or (4) a part of the series is taken corresponding to the time when the factor studied was absent can also used as the control.
For the analysis of growth reactions, three types of wood samples are used: cross-section or disc, wedge and core. On the cross-section (disc) there is all available information but it leads to the tree death. In the case of core, some of the necessary information may be lost but the tree continues to live. The cores are normally taken from living trees and the cross-sections (discs) or wedge do from the dead ones.

The minimum sample size varies greatly from 20 to 100 trees. The general empirical rule is “the more the better”. In case studies, the minimum sample size is 6–35 trees. But the frequency of events reconstructed from them is considered incomplete and the spatial reconstruction is fragmentary. The number of control trees is normally from 15 to 30.

Then, at the laboratory processing stage, standard preparation and measurement of woody samples, their cross dating, dating of mechanical damages and growth reactions, standardizing (normalizing) and analysis of tree-ring series, determination of tree age and the time of establishment of their main generations, assessment of the tree reaction rate are made.

Traumatic dendroindication is determination of the time of mechanical damage to the tree. Indicators are injuries (wounds), mainly of the trunk, and callus tissue. The determination of the year of the tree death can also be conditionally referred to this dendroindication. Indicators are standing dry or lying trunk and stump.

Dendrometric dendroindication is determination of the time of effect (impact) to geomorphic events from changes in absolute or relative tree ring width. Indicator is a sharp, significant and sometimes relatively long change (decrease often) in the width.

Deformation dendroindication is determination of the start time of an eccentric growth of a tree trunk when it bended or tilted. Eccentric growth is an indirect indicator of the slow mass movement (landslides).

Anatomical dendroindication is determination the time of changes in the anatomical structure of wood. Indicators are traumatic resin ducts and reaction wood. Such ducts appear in the wood in Larix, Picea and Abies, and did not in Pinus [4].

Age dendroindication is determination the time of establishment of the main tree generations. If the geomorphic event was strong enough to kill the trees, its assessment can carried out according to the age of the generations established as a indicator. The uncertainty of dating by this method is associated with difficulties in determining the exact tree age by tree rings which only increases with age and the species specificity and locality of the time when a tree established an area after a destroying geomorphic event.

In general, the accuracy of dating the tree reactions is usually 1–2 years by the traumatic dendroindication indicators, 1 year by dendrometric ones, a month or a season (but the tree can be late to react to an event) by the anatomical ones, from 1 to several years by the deformation ones, and approximate (from 1 to 100 years) by the age ones. To date avalanches, debris flows and rockfalls, the main are the indicators of the traumatic and dendrometric dendroindication and additional are the indicators of the age and deformation one. The indicators of the anatomical dendroindication are good to show in a monsoon climate. Dating the geometric event was considered more reliable if it was confirmed by different dendroindication indicators and in several trees.
As a result, spatio-temporal reconstructions of geomorphic events at specific sites are performed, i.e. assessment of the extent and frequency of the events and intensity of the process. The advantages and limitations of each method are discussed, poorly developed or unsolved problems of dendrogeomorphological studies are considered.

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Literature

EXPERIMENTAL STUDY OF THE PHOSPHORUS VOLATILITY IN HYDROTHERMAL SOLUTIONS

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Phosphorus is the most important biophilic element and in many ecosystems limits the development of life. Phosphorylated biomolecules play a major role in replication and information (like RNA and DNA), metabolism (like ATP, NADPH and other coenzymes) and structure (like phospholipids). Several key properties of phosphorus as phosphate make it beneficial for biological systems, including thermodynamic instability combined with kinetic stability, state of charge and coordination, and a constant state of oxidation under typical redox conditions. These features are especially important for the formation of large informational polymers and, therefore, are very important for the emergence and development of life on Earth. However, in natural geochemical processes, phosphate activity is determined by the saturation of relatively poorly soluble calcium phosphate (apatite), which determines the low concentration of this element in natural waters. From the point of view of the origin of life, the stability of apatite creates problems with the explanation of the appearance of prebiotic precursors for the synthesis of phosphorus-containing organic molecules [1].

In redox conditions on the Earth’s surface, orthophosphate strictly dominates, which is determined by the thermodynamic properties of phosphorus compounds [2]. Phosphates are the main forms of this element, other compounds with a low degree of oxidation of phosphorus are not stable. In iron meteorites and rarely as a result of geological processes, low-valent phosphorus compounds occur, but they are oxidized to form orthophosphate under the conditions of the Earth’s surface. Compounds of low valence states of phosphorus can occur in hydrothermal processes, a phosphite ion has been detected in a number of modern thermal systems [3]. The study of the distribution of liquid-gas for modern hydrothermal systems provides information about the new poorly studied forms of transfer of elements in gases. Phosphoric acid is a non-volatile compound, but in the gas phase of thermal springs of Kamchatka, noticeable concentrations of phosphorus are constantly determined, which gives a liquid / gas distribution coefficient close to 100. Such volatility cannot be explained by the distribution of phosphorus (V) and forms with low valences can be assumed. Based on this assumption, thermodynamic calculations were made in the HCh program for all the gas particles of phosphorus available in the database.

The results showed that the gas molecule PO₂ will prevail. To verify the calculations, an experimental study of the transfer of phosphorus in the gas phase in an autoclave with a valve was performed. The experiments were carried out at temperatures of 200 and 250 °C and the pressure of saturated water vapor. A sample of a 3% phosphoric acid solution was input into the autoclave. A sample was taken through a valve with a capillary into a test tube with distilled water. The phosphorus concentration in the samples was determined by the colorimetric method. In direct determination, phosphorus concentrations were extremely low, but after oxidation, the results were much higher.
The phosphorus concentration in the condensate does not depend on the duration of the experiment, but depends on the temperature. In the experiment, it was not possible to specify various redox potentials of the system by adding different components. Probably, in the experiment, titanium plays a significant role in determining the degree of oxidation of phosphorus. Therefore, further study was carried out in autoclaves with PTFE inserts by the static method with the addition of various metals.

An experimental study of the transfer of phosphorus in the gas phase by the static method was carried out at 150 and 200 °C and the pressure of saturated water vapor. To this end, a PTFE glass with concentrated phosphoric acid was placed in titanium autoclaves with a 180-mL volume. Double-distilled water was added to the volume of the autoclave to provide a saturated steam pressure at the temperature of the experiment. Directly before the autoclave was closed, weighed amounts of various metals (Zn, Co, Fe, Ni, Ti, Al) were added to phosphoric acid.

0.1-30 mg/l of phosphorus was found in condensates in the insert volume. The addition of various metals contributes to the transition of phosphorus to the gas phase. For titanium, we obtained similar values with an autoclave experiment with a valve. Placing the metals in order of decreasing electronegativity, no obvious dependence is observed. However, there is a tendency to increase the phosphorus concentration with increasing electronegativity of the added metal, but comparing the angle of inclination with the calculated one, it is obvious that the angle of inclination does not coincide.

Based on the research, we can draw the following conclusions:

Phosphorus is transported in the gas phase under reducing conditions in the presence of metals. In the series of decreasing electronegativity of metals from Co to Zn, the distribution coefficient increases. Experimental results indicate the possibility of phosphorus transfer in hydrothermal gases in the form of low-valence compounds.

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Literature

FEATURES OF GEOMORPHOLOGICAL PROCESSES OF COASTAL-MARINE SYSTEMS OF THE SOUTH-EASTERN PART OF THE CRIMEAN COAST

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The natural conditions of the southeastern part of the Crimean coast, combined with human activity, create an environment that determines the nature and intensity of the latest physical and geological phenomena. The coast of the south-eastern part of the Crimean Peninsula, as an object of geomorphological study, has significant value associated with a special complex of coastal processes that determine the dynamics of coastal development. The territory is characterized by a certain development of exogenous processes that determine the peculiarities of the relief, the main of which are abrasion, gravity (scree, landslide and other) mudflows, as well as the processes of accumulation, erosion and weathering.

Processes of abrasion actively occur in the area from the village Morskoe to village Semidvore, which is caused by the predominance of low-strength rocks of the flysch and flyschid formation, as well as a large number of landslides, reaching the water's edge [1]. The processes of abrasion stimulate the development and activation of alongshore landslides. The speed of retreat of the edge of the abrasion ledge in areas of landslide development reaches at least 0,6 m/year; the rate of erosion of mudstones in the bedrock does not exceed 0,04 m/year [2]. East of the village Morskoe coastline becomes heavily dissected and winding, with many small and larger capes and bays. This is due to the rather diverse composition of the deposits of different strengths. Abrasive processes are characterized by intensive development in areas of tectonic movements, which are characterized by a high degree of fracturing of rocks [3]. Selective abrading of the coastline, depending on the lithology of the composing rocks, leads to the formation of capes, protrusions, benches or small bays, niches with characteristic microsculptures.

Landfall-scree processes are widespread in the area, which is due to the strong dissection of the relief with steep slopes. The most intensive scree processes are developed on slopes with a steepness of from 25 to 50°, slopes with a steepness of more than 50° are characterized by the predominance of landslide processes [1]. Clay, flysch and flyshoid deposits, which are easily weathering and extended areas with steep gradients of 25 to 50 °, cause the scattering processes above the landslide to prevail in the study area. Destroyed and showered material contributes to the formation of scree plumes at the base of the slopes. Landfall processes are less developed and confined to the places of formation of rocks and ledges, composed of rocks (sandstones, limestones, conglomerates), and may also be confined to fractured zones. Under the action of landslide processes in the beach strip are formed block piles, especially pronounced in the area of Cape Meganom.

Landslide processes - according to the geographical distribution of landslides 2 plots were allocated - from village Semidvore to village Privetnoe and from the village Morskoe to the village Kurortnoe. Both sites are characterized by the presence of the following types of landslides: abrasion, erosion, mixed and artificial, the first two of which are predominant. By age and activity landslides are divided into: 1) ancient, stabilized; 2) modern: a) temporarily stabilized b) active c)
regressive. All types of landslides are widespread in the coastal strip from the village Morskoe up to the city of Alushta. In places of activation of landslides, the width of the beach is measured by several meters and is characterized by an uneven, rough surface, which was formed due to the collapsed sides of landslide rocks.

According to the degree of mudflow activity, the studied territory can be divided into two sections: the western - from the village Semidvore to the city of Sudak and the east - from the city of Sudak to the village Kurortnoe. The westernmost section is the most mudflow hazard [1]. The first type is characterized by frequent medium-sized selenium manifestations (valleys of the Shelen and Voron rivers), and for the second type, the nature of selenium manifestations depends on the rates of rock destruction and accumulation of loose material in the lower parts of the slopes (valleys of the Kutlak and Ai-Serez rivers), from where it can be involved in the mudflow. The outflow cones formed during the mudflow processes are deposited in the sea, their maximum height reaches 3 m, on average, the height of the outflow cones ranges from 1,4 to 1,6 m.

Erosion processes in the study area are developed everywhere, which is facilitated by significant angles of inclination of the relief (from 25° and more), sparse vegetation, a significant overall slope to sea level. The most intensive horizontal division is confined to the areas of the river basins Shelen and Voron. For the study area is characterized by the presence of both side and bottom erosion. On average, ravines in flysch and clay sediments grow at a speed of 0,2 – 0,3 m/year, with a maximum increase in the length of the ravine of 1,5 – 6 m [2]. The most intensive ravines grow during heavy rains. Accumulative processes are noted in bays. They are expressed in the formation and reformation of beaches, braids, underwater shafts (bars). Weathering processes are most active on watersheds and slopes composed of limestone under a thin eluvial layer.

As a result of research and analysis of the state of the coastal zone of the southeastern part of the Crimean peninsula, it was determined that the main factor causing the destruction of the slopes is abrasion, which develops in a transgression environment. The erosion of the coastline in these geological conditions is accompanied by landslide processes. The geomorphological mapping of deep landslide deformations of meotic sediments is a landslide amphitheater. Mudflow processes are widespread, which distinguishes the studied area from the adjacent territories.

**Literature**

BRECCIAS, SHEAR AND FRACTURING ZONES OF THE MIDDLE STRUCTURAL FLOOR OF THE HERACLION PENINSULA, CRIMEA

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There are three structural floors can be distinguished in geological structure of the Heraclion Peninsula, South-Western Crimea. The upper structural floor is composed of limestones and Neogene clays lying subhorizontally and forming a plateau. They are underlain by a thin layer of Cretaceous and Paleogene wedged out to the south-west. Formations of the middle structural floor are exposed in the coastal cliffs of the Cape Fiolent area and represent a melange consisting of clastolites and a matrix of Jurassic magmatites. The lower structural floor, distinguished by geophysical data, is represented by a layered sedimentary stratum, crushed into a large Heraclion anticline [4].

In the Cape Fiolent area as part of the middle structural floor there are all members of the ophiolitic association section, formed in the back-arc spreading basin over the subduction zone. [1]. The formation of this basin is associated with strata of breccia of volcanic-sedimentary nature, whose number increases markedly to the south-east.

Boulder breccias composed of large (up to 0.8–1 m) fragments of dolerite-basalt parallel dikes are exposed in the cliffs of the western part of Marble Bay. In addition to the rocks of dikes, the cement includes serpentinitized rocks and carbonate material.

Ophiocalcitic breccias occur to the west of the exposures of boulder breccia. They contain both angular and rounded, to varying degrees, debris of different rocks (serpentinite, serpentinitized ultrabasite, dikes, basic lava); the size of some of them is up to 0.5–0.8 m. The rock debris is cemented by carbonate material with a small share (up to 3%) of the siliceous component.

Ophiocalcites are covered with a layer of pillow lavas, single flows of which are separated by layers of their breccias, also cemented with carbonate material [2].

Two formations of breccia are exposed to the west of Aiya-Burun Cape. The formations differ in the size and composition of debris. The contacts of the formations with the surrounding rocks are completely covered by the erosion products of the Neogene limestone. The first formation of breccia consists of large boulder breccia, with blocks of several tens of centimeters in size, reaching 1 m and more. The debris is basically presented by basaltic lavas and sometimes by separate lava pillows. The large fragments are in a fine clastic mass with silt and pelite particle size and with clayey-siliceous cement; there is no carbonate material in the cement. The coarse clastic breccia overlaps the pillow lavas, which is clearly observed in the southwestern cliff of the small cape. It can be assumed that lavas build up the large clastolith buried in breccia. A similar clastolith, composed of metamorphized green (probably ultramafic) rocks with a lenslike shape, is observed in pillow lava at the cliff of the small bay located to the west of Marble Bay.

The second formation of breccia is divided from the first one by a rupture and significantly differs in the size of the debris (from fractions of mm to 10 cm). This formation is characterized by a mixed composition; basaltic and silicic lava, sedimentary siliceous rocks, chlorite slate,
ultrabasite, and other rocks present in the debris. In this breccia the amount of the cement of the clayey-siliceous composition is much higher.

Breccia, exposed in the cliffs of Cape Lion is composed of angular and poorly rounded fragments of mafic and ultramafic rocks and less frequent terrigenous rocks cemented by the matrix consisting of micro- and fine-clastic material of the same rocks and light blue to green jasper. The tabular fragments in breccia are composed of hyaloclastites, which were formed due to cracking of lavas rapidly cooled under submarine conditions. The breccia was metamorphosed under conditions of high-temperature greenschist facies.

Plagiorhyolite breccias are widespread in the framework of extrusive bodies (domes of the Monakh). They are formed as a result of cracking of viscous magma during the dome growth. The fragments are variable in size and shape from large blocks to fine-clastic cement. All fragments are identical in composition, which is the same as the extrusion as a whole [1].

Beside the primary breccia, in the Cape Fiolent area breccia of a tectonic nature is widespread. The breccia is attributed to numerous fault and shear zones, including thrusts. The rocks in the fault zones are brecciated, affected by cataclastic metamorphism and mylonitization, and replaced by secondary minerals: albite, quartz, chlorite, carbonates, actinolite, epidote, zeolite, iron oxides and other minerals.

Such zones of predominantly northeastern strike are exposed to the west of the Iron Rock, directly on Cape Fiolent, in the cliff of Jasper Bay, on the east side of the Monakh dome, to the west of Aiya-Burun and other places. Shear, fault and fracturing zones of the north-west strike are clearly visible in the rocky cliff of Cape Vinogradny and the cliffs of Cape Bronevoy area. These structures are related to the formation of the late Jurassic – early Crataceous Predgornaya Collision suture, dedicated by V.V. Yudin [4].

Movement in the shear and fracturing zones occurred in the Quaternary, which is fixed in the overlying Neogene limestones and identified by the methods of structural-geomorphological analysis of the Heraclion peninsula [3].

The most intensive destruction processes and the collapses of the Neogene limestones of the Heraclion Plateau are confined to the areas of breccias, shear and fracturing zones development of the middle structural floor, which must be taken into account in economic activities.

**Literature**

Electromagnetic soundings (EMS) of the lithosphere are low-frequency methods of electroprospecting. They include methods using a natural alternating field (magnetotelluric sounding, MTS) and methods using artificial fields, among which are those working in the frequency domain (frequency sounding, FS) and in the time domain (transient sounding, TS).

EMS methods are based on the principle of the skin-effect: the longer is the oscillation period of the field (or the transient time), the deeper it penetrates into the Earth. EM field on the Earth's surface depends on the electrical resistivity of rocks. Thus, gradually increasing the period of the field oscillations (or the transient time), we can observe how the resistivity changes with depth.

The resistivity of rocks depends on a number of factors, but clay content and fluid saturation, as well as the type of fluid (oil, fresh water, salt water) are most significant. However, oil-bearing strata have a small thickness and occur at a large depth, creating anomalies that are hardly noticeable from the surface. Larger anomalies are connected with the top of the crystalline basement and the boundaries between the complexes of rocks that make up the sedimentary cover, as well as lateral changes in the resistivity of these complexes, which may have a different nature.

The methods of EMS began to be applied to the study of sedimentary basins in the 1950s. They replaced the methods of electrical prospecting with direct current, the effectiveness of which in deep studies was low. Later, using the EMS methods, important information was obtained about the structure of the sedimentary cover of the East European Platform, West Siberian Plate, East Siberian Platform and other regions. At first, 2-3 layers were distinguished in the sedimentary cover, the position of their boundaries along profiles was traced; in the presence of a profile system, depth maps to the foundation and other parameters were constructed.

In the 1990s, due to appearance of portable, productive geophysical equipment, the development of computer technology and software, the detail of studies both in lateral and vertical directions significantly increased. On the resistivity cross-sections along the profiles, consisting of many dozens of sounding sites, up to 10 layers were distinguished in the sedimentary cover, which allows detecting local uplifts and faults, as well as changes in lateral properties. Interpretation has become possible to perform in the framework of 2D and even 3D models of the Earth, which is important in the presence of significant horizontal inhomogeneities.

In recent years, there have been examples of the application of EMS methods to assess spatial changes in reservoir properties and oil and gas saturation of individual layers. This became possible in areas with a dense network of observations in the presence of wells with data from electric logging and a structural frame according to seismic data. Another promising direction is marine electrical exploration performed on the shelf with bottom stations or towed arrays. For this purpose, special modifications of ground-based methods of EMS are used, and the successfully
solved tasks also include the mapping of permafrost and gas hydrates in the upper part of the section.
PHYSICAL MODELING OF STRUCTURAL DEFORMATION ON THE EARLY STAGES OF IBERIA AND NEWFOUNDLAND CONJUGATE PASSIVE MARGINS FORMATION

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Revealing the condition of passive continental margins forming and evolution is the current scientific problem. There is a formation of petroleum basins within those margins, and their structure depends on transition from rifting to oceanic spreading. The aim of that work is to reveal and investigate structure formation in the early stages of Iberia and Newfoundland conjugate passive margins formation based on physical modeling.

In this study, we are considering features of structural formation of Iberia and Newfoundland conjugate passive margins based on geological, geomorphological analysis and physical modeling. These margins represent an etalon of passive margins that were formed in conditions of hyperextension of continental crust with an essential asymmetric breakup and big detachment fault. Moreover, such type of margins is lack of magmatism, as well as sin-rifred magmatic formations. They are also characterized by the development of exhumation of mantle serpentinites along the oceanic boundary, continental crust thinning within the margin and significant tectonic differentiation [2]. The development in condition of the long-lasting rifting extension of continental crust that became slow and then ultraslow rifting is essential for hyperextended margins.

There are distinguished four major rift phases during which extensional deformation was accommodated along different parts of the margins and associated with different processes [5]. During the earlier phase, extension led to the formation of half-graben type basins and small detachment faults in domains that are now found in proximal margin positions. The second stage is characterized by thinning of continental crust, rising Moho boundary and formation of large detachment faults that shaping asymmetric evolution of conjugated margins. The third stage is associated with a distal domain that is characterized by significant thinning of continental crust and exhumed serpentinized peridotites. The fourth stage is associated with outer domain characterized by accretion of oceanic crust in conditions of ultraslow spreading with highly differentiated relief. Further, the spreading speed can vary from slow and medium rates that influence on the morphology of the crust and relief.

One of the features in Iberia`s and Newfoundland`s conjugate margins structure is a presence of marginal plateaus Galicia and Grand Banks. They are deep, planar and subhorizontal plateaus that are located between the platform and the lower continental slope. The occurrence of such plateaus is under discussion nowadays.

Experimental investigations of the early stages of Iberia and Newfoundland conjugate passive margins development were conducted with physical modeling in Laboratory of experimental geodynamics in the Earth Science Museum at MSU. The experimental conditions that simulated the spreading met the similarity criteria described in detail in [1, 3]. Liquid (mineral
oil) and solid (ceresin and paraffin) hydrocarbons with different additions were used as modeling materials.

The first and the second stages of extension and amagmatic thinning in experiments were created with artificial thinning of modeling continental lithosphere. The third stage of margin’s development was reconstructed in the experiment with the process of a quite slow extension and ultraslow spreading. Thus, the appreciably differentiated relief was forming in the form of large deformed shafts (вала?) along one or both sides of the margins. On this stage were marked geometric instability of the rift axis accompanied with repeatedly jumps (перескоки) that led to symmetric or asymmetric accretion. That process also reflected in the symmetric or asymmetric structure of the margin.

The fourth stage (the formation of crust in the condition of transition from ultraslow spreading to slow one) was corresponding to increase of extension rate. The new-formed crust was characterized by a differentiated surface with less contrast relief meanwhile asymmetric accretion could be kept.

The experiments also have shown that the formation of marginal plateaus within margins like Galicia Bank and Flemish Cap is possible when two rifted cracks are moving toward each other circumscribing microcontinental block from both sides.

Thus, physical modeling of different types of relief formation in conditions of transition from rifting to spreading with different rates of the extension has allowed to identify the diverse character of structural formations on each stage of evolution of Iberia and Newfoundland transition zones. The comparison between experimental results and relief of fundament that was gained with seismic data provides us with satisfactory results.

The work was supported by the Russian Foundation for Basic Research (project № 18-05-00378).

Literature

Intrusion is the introduction of a salt water wedge into coastal confined or unconfined aquifers [8]. The problem of seawater intrusion is relevant for all countries with access to the sea water areas [2,3,5,6,7,8,11]. In the Netherlands there are known cases of introduction of a salt wedge into coastal aquifers for tens of kilometers [2], which leads to deterioration of water quality and failure of water intakes. Various models play an important role in forecasting the spread of marine intrusions and developing measures to minimize damage associated with them: physical [7], analytical [2,7,8,9], numerical-analytical [4] and numerical [1,2,3,3,5,6,9,10] models. For analytical and numeric-analytical assessment it is often assumed that there is a sharp interface and that there is no mixing between fresh and salt water. Analytical estimation of the limit distribution of intrusion L for a homogeneous confined aquifer characterizing hydraulic conductivity coefficient k and thickness m can be made using the following formula [2,11]:

\[ L = \frac{km^2a}{2q} \]

where \( a \) is the ratio of the difference in the density of salt and fresh water to the density of fresh water; \( q \) is the specific flow rate of groundwater discharged into the sea. This formula allows us to consider that intrusions always exist if there is a difference between the density of sea and ground water. The reduction in sea discharges is associated with groundwater abstraction in the coastal zone because of the partial interception of natural flow, which causes the wedge of saline water to move deep into the aquifer at considerable distances.

Within the Sevastopol city area, laboratory studies have observed exceedances of normative for salinity, chlorides and stiffness in some water wells, which may be due to seawater intrusion. To study this problem the Orlovsky water intake, located in Sevastopol in the estuary part of the Kacha river valley, was chosen. Orlovsky water intake consists of 16 wells (7 mothballed wells, 2 reserve wells). The wells are equipped for the aquifer of the middle-upper Sarmatian deposits represented by cracked limestone. The total water intake is currently 14.8 thousand m\(^3\)/day. We have carried out an analytical calculation of the length of the sea intrusion using the above formula. It turned out that at average values of flow parameters the length of the intrusion in the absence of water intakes would be equal to 70 m and salt water would not reach the area of water intakes. At reduction of sea unloading connected with water intakes operation the intrusion length was equal to 3900 m that explains water intakes quality deterioration.

For more precise consideration of the object peculiarities numerical-analytical modeling of the water intake intrusion spreading by the method of analytical elements (MAE) was carried out. Real location of water intake wells, heterogeneity of flow properties were taken into account in calculations. The Kacha river on the model was realized by the boundary condition of the III type (river level and bed resistance). Data preparation and modeling were performed with the help of GFLOW software. Maximum intrusion advance, obtained by MAE, was equal to 3750 m. The most precise development of the intrusion can be estimated on the basis of linked flow and
convective-dispersion transport models. In order to obtain a related solution to the two models, the results of the groundwater flow problem are taken from the previous time step or specified iteratively [2,3,6]. It requires large computational costs and reliable programs of means. For numerical modeling of seawater intrusion, the most reliable software codes at present are SEAWAT (orthogonal grid, finite difference method) [3], FEFLOW (unstructured grid, finite element method) [1], GeRa (unstructured grid, finite volume method [9]. In this study the intrusion into the water intake was calculated on the basis of the SEAWAT program; the filtration area was divided into 100 x 100 cells in the plan and into 10 layers in the section. In the calculations the value of longitudinal dispersivity was assumed to be 1 m, while the transverse dispersivity was an order of magnitude less. It turned out that the maximum advance of intrusion in the model taking into account the mixing of sea water with groundwater is 3025 m. This is less than with the use of a model with a sharp interface and is consistent with previous studies [6], indicating that dispersion, especially transverse dispersion, reduces the size of intrusion.

To regulate the promotion of intrusion proposed activities, among which: the creation of low-permeability walls [7], water bodies that increase the sea discharge of groundwater [5], etc. With regard to the Orlovsky water intake by the method of analytical elements, the assessment of the creation of a reservoir on the Kacha river to reduce intrusion was made. Calculations have shown possibility of reduction of intrusion up to 900 m at reservoir creation. However, this is a preliminary assessment, which needs to be further developed.

**Literature**

EFFECT OF TEMPERATURE AND PRESSURE ON PHASE RELATIONSHIPS AND DISTRIBUTION OF SCANDIUM, YTTRIUM AND RARE EARTH ELEMENTS IN THE GRANITE SYSTEM (SI-AL-NA-K-LI-F-O-H)

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Experimental data on the distribution of rare earth elements (REE), scandium, yttrium and lithium between aluminosilicate and salt alkaline fluoride melts at a temperature of 1250 °C to 500 °C, a pressure of 1 and 2 kbar and a water content of 2 to 50 wt. % were obtained.

The compositions of the solid charge material for the experiments was set based on the composition of the aluminosilicate melt with defined ratios of Si, Al, Na+K+Li and the fluoride salt phase (cryolite) in an amount sufficient to saturate it the aluminosilicate melt. The initial composition of the silicate melt corresponded to the granite eutectic of the quartz-albite-orthoclase system at 690 °C, 1 kbar H2O, 1 wt. % F [1]. The Li content in the system was 1.5 wt. %.

The experiments were carried out at the installation of high gas pressure (HPC) at the Institute of experimental Mineralogy of the RAS in Chernogolovka. The experimental products were investigated by scanning electron microscope Jeol JSM-6480LV (Japan) with energy dispersion INCA Energy-350 and crystal diffraction INCA Wave-500 (Oxford Instrument Ltd., UK) spectrometer in the laboratory of local methods of research of MSU substance. The main rock-forming and rare-earth elements, scandium, yttrium, fluorine, lithium were studied at ICP MC in the laboratory of the Department of Geochemistry of MSU.

Based on the data obtained, it is seen that the behavior of rare earth elements in the granite system Si-Al-Na-K-Li-F-OH depends on the temperature, pressure and water fluid content.

It is shown that in the granite system Si-Al-Na-K-Li-F-OH at 800 °C and 1 and 2 kbar the equilibrium of aluminosilicate and alkali-aluminum-fluoride salt melts is carried out. REE, Y, Sc and Li are distributed in favor of the salt melt.

When the temperature decreases from 800 to 500 °C, the phase composition of the system changes: at 700 °C and P = 1 and 2 kbar, a partial crystallization of the salt melt occurs with the formation of large crystals of aluminofluorides. The residual salt melt enriched with rare earth elements and lithium, and the aluminosilicate melt are stored in the system up to 500°C.

At T = 600-500 °C and P = 1 kbar, quartz and potassium fluorine-containing aluminosilicate (presumably, lepidolite) crystallize from the aluminosilicate melt (L). The phase composition of the system is as follows: L+LF+Cr+Qtz+KAlSil.

Regardless of the given experimental conditions, all rare earth elements, scandium, yttrium and lithium with large separation coefficients (several times) are distributed in a salt aluminum fluoride melt.
Experimental data confirm the assumptions of formation of cryolite-containing granites at the late stages of formation of large granite massifs as a result of separation from magma of salt melts rich in rare elements.

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Literature

INVESTIGATION OF KARST AND SUFFUSION PHENOMENA BASED ON TEMPORAL VARIATIONS OF MAGNETOVARATIONAL PARAMETER

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The karst and suffosion phenomena which are manifested as the formation of karst craters, basins, wells, underground caves and grottoes are associated with the dissolution of hard (carbonate, gypsum-bearing, salt-bearing) rocks and corrosion of loose rocks by groundwater. Tectonic fracturing of rocks and its increase due to natural and man-made causes, intensive movement of groundwater and changes in the hydrogeological regime favor the development of karst. Since karsts are characterized by an increased amount of water, the electrical conductivity in these places is different compared to the electrical environment conductivity. The magnetovariational parameter (magnetic tipper) calculated from the geomagnetic monitoring data allows determining the distribution of the lithospheric electrical conductivity, as well as identifying its temporal variations, which makes it possible to identify regions with karst processes, estimate the thickness of karst rocks and rock surface, below which there is no karst, and also evaluate the dynamics of karst-suffusional processes. In this research, we study the synchronous variations of the magnetic tipper and the groundwater level at the Mikhnevo Geophysical Observatory of the Institute of Geosphere Dynamics of Russian Academy of Sciences. A feature of the study area is the presence of a multi-layered system of separated aquifers. The monitoring data from the level of the Kashira aquifer is used, the groundwater of which within the study area is free-flowing. The registration of geomagnetic variations at the observatory was performed in the geomagnetic pavilion using a three-component fluxgate magnetometer LEMI-018. The groundwater level of the Kashirsky free-flow horizon, located at a depth of 56.6 m, was determined in an open well with a depth of 31.5 m using the LMR 308i submersible probe. Based on the correlation-regression analysis, a statistically significant correlation was established between the magnitude of the magnetic tipper and the groundwater level of the free-flow horizon, and a linear regression model was constructed.
STUDIES OF THE SPECTRAL CHARACTERISTICS OF REFLECTED SEISMIC WAVES IN CONDITIONS OF DISTURBED CONTINUITY OF ROCKS

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In practice, in the quantitative definitions of complete clarity and uniform positions in the evaluation of seismic resolution does not exist [1, 2]. It must be remembered that each reflection is the result of the complex interference of several simple signals. Physical phenomena such as “scattering” and “diffraction” depend on the ratio of the particle size and the wavelength that falls on the particle. In the case when the particle is much smaller than the wavelength, scattering is a special case of Rayleigh scattering. If the particle size is close to the wavelength, the scattering pattern becomes complex. The interference of waves reflected from different parts of the particle surface is manifested. In this case, the phenomenon is considered from the point of view of the Mie scattering theory. If the sphere is much larger than the wavelength, then the refraction and reflection of the waves, which are described by the Fresnel formulas, occurs.

In this paper, the approach for the spectral analysis of time sections was to calculate and analyze the differential and integral amplitude-frequency spectra. Spectra in a narrow time window sliding along each seismic trace were calculated as the differential characteristics of the seismic record. To study the behavior of the integral characteristics, the total spectra were calculated, the essence of which is in the calculation of the frequency spectrum in a wide time window covering a large depth interval of rocks and the aggregate of seismic traces over a long, wide lateral area.

The studies were performed on a network of profiles in the territory of the Verkhnekamskoye potassium salt deposit. As a result of the analysis of the calculated both integral and differential spectral characteristics on all profiles, the dominant frequency in the band 75-80 HZ, having the largest energy contribution to the seismic recording spectrum, is clearly detected. The behavior of the dominant frequency of the seismic signal is taken as the normal field.

An analysis of the anomalous behavior of the spectral components showed the following.

At this stage of understanding the results of experimental observations, without going into theoretical hypotheses about scattering and diffraction, a number of features should be noted.

It turned out that the high-frequency anomaly is spatially located to the zone of small differently oriented cracks, revealed by us in previous studies [5]. The increase in the frequency coordinate of the centroid in earlier studies has been established by us as a prospecting indicator of fractured zones of this class [3, 4].

Within the area of the anomalies of reduced intensity of the dominant frequency, a low-speed zone in suprasalt rocks and a high-speed "replacement zone of carnallite and sylvinite salts with rock salt" are developed.

On another profile, a local anomaly of energy loss is noted for harmonics with a frequency of 100 Hz. When combined with the situational plan of a mine field 300 meters from the profile,
a vertical mine working was built - "cage shaft". The "cage shaft" is the most complex mining and technical object, changing the natural stress field and determining the technogenic component of the stress-strain state. This object can be represented as a local disjunctive heterogeneity in the earth. Then the wall of the trunk is the most acoustically contrasting boundary in the rock mass, it can be approximated by a "free surface", and the object "cage shaft" can be represented as a fracture of small lateral dimensions. The diameter of the cage shaft is 8 m in the light. Then, the diameter of mine working is less than the diameter of the first Fresnel zone at different depths 17-22 times, while the horizontal resolution of the seismic record is defined as 1/6 of the diameter of the first Fresnel zone. The vertical resolution of the seismic survey is ¼ wavelength, and in our case the barrel diameter is 5-6 times smaller than the wavelength.

It is precisely because the dimensions of this heterogeneity are smaller than the horizontal and vertical resolution, we do not observe the response from this object in the seismic time section. Therefore, the identification of heterogeneity of this class in the spectral parameters is an important prospecting indicator.

Additional evidence may be the fact that this frequency anomaly in the interval below the depth of the cage shaft is not observed.

Studies of the spectral characteristics of reflected seismic waves allow a deeper understanding of the "mechanisms" of wave processes in a fractured earth, improves model ideas about these processes and get new model ideas about the system of fissured rock mass.

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PETROLOGICAL AND EXPERIMENTAL STUDY OF SYENITIZATION OF TONALITE GNEISSES EXAMPLIFIED BY THE MADIAPALA COMPLEX, LIMPOPO BELT, SOUTH AFRICA

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The Madiapala syenite body is located in the western part of the Central Zone (CZ) of the high-grade Limpopo Complex, South Africa. It is situated within the Alldays TTG gneisses with an age about 2600 Ma. According to the SHRIMP geochronological data using the $^{207}\text{Pb} / ^{206}\text{Pb}$ ratio in titanites, Rigby et al. [3] reported an age of the syenites 2010.3 ± 4.5 Ma. This age corresponds to the period of the Paleoproterozoic tectono-thermal activity (D3/M3) in the CZ, which was characterized by massive fluid influx along regional and local shear-zones. Using pseudosection method (THERMOCALC), Rigby et al. [2] estimated 6 kbar and 770°C as peak P-T parameters for the syenites and interpreted them as conditions of metamorphism of pre-existing syenites during the Paleoproterozoic metamorphic stage. Different model for the formation of the syenites within the TTG gneisses is suggested by Safonov et al. [4] on the basis on experiments on the interaction of biotite-amphibole tonalite gneiss with H$_2$O-CO$_2$-(K, Na) Cl fluids at 750 and 800°C and 5.5 kbar [5]. These experiments demonstrated that the leading factor for formation of the syenite assemblages after tonalite gneiss is an increase of potassium activity in a fluid (associated with the salt component of the fluid). Thus, the Madiapala syenites could be a product of the syenitization of the TTG gneisses under influence of saline H$_2$O-CO$_2$ fluids.

The earliest assemblage in the syenites is potassium feldspar + clinopyroxene + titanite ± apatite. In order to estimate the conditions for formation of this assemblage, we constructed the P-T pseudosection for a dry system, for a water-containing system and for a system saturated with a water-carbon dioxide fluid. These graphs showed that the observed association occurs in the water-containing system.

Following to the pseudosection, isopleths for Mg-number and Na content in clinopyroxene in the syenites converge at temperatures 800-850°C and pressures 6-9 kbar

At close pressure conditions, the calculated temperatures are noticeably higher than the temperatures estimated by Rigby et al. [2] for amphibole-containing metasomatic veins in the syenite body (6.4 ± 0.6 kbar, 770°C). However, such differences in the results are quite understandable, as temperatures >800 °C correspond to the conditions of crystallization of the primary association Cpx + Kfs + Sph ± Ap, whereas amphibole-containing associations appeared obviously against the background of the cooling of syenite magma. Estimates of the effect for K$_2$O activity on the Alldays gneisses showed that the formation of the syenite assemblage is possible at increase of the K$_2$O activity.

Geochemical data (ICP-MS, ICP-AES) for syenites, syenitized gneisses and host TTG gneisses indicate the crustal nature of syenites and the close genetic relationship between the
syenites and host Alldays gneisses. The syenites' REE spectra demonstrated the important role of the fractionation for the formation of the syenite assemblage.

Thus, the formation of the primary syenite assemblage occurred at pressures of about 6 kbar and temperatures of 800-850°C. Reactions of Alldays tonalite gneisses with a H$_2$O-CO$_2$-salt fluid in which salt component is rich in potassium, played an important role for the formation of the primary association, while the formation of an amphibole-bearing association, estimated by Rigby et al. [2] occurred during cooling of the syenite magma.

This work was supported by RFBR grant №16-05-00266

Literature

Seismoacoustic methods are widely used for investigations in water-saturated wells. It has a lot in common with marine seismoacoustics, but there are also a few differences for example, a wave front is moving in a symmetrical cylindrical cavity instead of homogeneous space. There are two types of waves in seismoacoustics in wells: faster low-amplitude direct pressure wave and slower high-amplitude Stoneley hydrowave. Along its propagation, the seismic wave energy will decrease due to several factors such as spherical divergent, scattering, reflection and attenuation process. Information about attenuation is very important to be known, not only in the processing but also in the interpretation of seismic data.

Attenuation is usually addressed as quality factor (Q) term which is always associated with its intrinsic properties of medium: pore fluid content and lithology variation. There are two well-known methods of estimation Q-factor: frequency shift method [3] and amplitude ratios method [2].

Even though amplitude ratios method can be more accurate, amplitude information itself is often inaccurate due to noise, geometrical spreading, scattering, and other effects, and it’s even truer in shallow seismic. Another method for estimating seismic absorption is based on the frequency shift observed in VSP data and is better protected from noise at cost of making some assumptions about signal. Assuming that the amplitude spectrum of the source wavelet can be well represented by that of a Ricker wavelet (or another analytical function, for example, Gauss wavelet), Q-factor can be estimated as a function of dominant frequencies of initial and absorbed signal.

But is it a correct assumption? This question can be answered by calculating mean absolute error between real amplitude spectrum and closest Ricker spectrum (or any analytical function used in this method).

**Literature**

Modern gravitational processes are widely occured on the Kerch Peninsula. This is due to the geological structure, the wide spread of easily eroded terrigenous rocks, mainly of clay and sand in composition, ann also spread of steep sea coasts. The most dangerous of this processes are landslides, more often of abrasive origin. They carry a certain danger to the settlements located on the coast. Currently, many landslides are in a stable state, but the possibility of new collapses is very high. In this paper, an attempt is made to determine the most dangerous areas using structural-morphological and morphometric analysis of relief.

Structural geomorphological and morphometric methods allow us to consider only those deformations that are currently expressed in relief, i.e. formed during the pliocene-quaternary time. The relief analysis of the peninsula was carried out using the SRTM digital model on a scale of 1: 200,000. The detecting of structures formed in the neotectonic stage was carried out according to the method developed by N.P. Kostenko [2]. This method involves the detecting of the latest deformations and their total uplifts during the erosive stage of development, as well as fractures and fracture zones. According to the structural geomorphological scheme [1], the largest uplift is located in the central part of the peninsula and extends from southwest to northeast. Its strike does not coincide with more ancient structures, for which a sublatitudinal orientation is more characteristic.

The structural-geomorphological scheme reflects the amplitude and direction of tectonic movements for the entire neotectonic stage, and it is difficult to distinguish movements related to different stages of the formation of structures. Therefore, to study the evolution of the latest vertical tectonic movements was used structural and morphometric analysis of relief, developed by V.P. Philosophov [5], which allowed within the latest structures identified in the structural and geomorphological interpretation to determine the area, the most rapidly developing at the present time.

On the Kerch Peninsula the stream network consists of mainly intermittent water flowes, so for morphometric analysis estimated the drainage system was built according to the digital elevation model SRTM using algorithms to detect the direction of flow in the elementary cell according to the model eight directional flow [6], followed by division of streames by orders. Given the specified parameters, on the Kerch Peninsula was identified five stream orders. Moreover, it is consider that the streames of higher orders develop for a longer time, and the streames of lower orders reflect movements for a shorter period of time, and are younger than the streames of higher orders. On this basis, a set of monobasic and difference surfaces [5] for watercourses of all five allocated orders, as well as a residual relief was built according to the algorithm for ArcMap GIS, which allowed us to trace the evolution of the newest tectonic structures [4].
The development of the relief Kerch Peninsula began with the formation of the uplift in the Central part of the Peninsula, the approximate boundaries of which can be traced to the development of deposits of the kuyalnitsky stage, distributed along its periphery. It gradually acquires an elongated form of the East-North-East structure, approximately corresponding to the orientation of the latest structures identified by the structural-geomorphological method. The most intense uplift at this time was in the Central and Eastern parts of the Peninsula. With the beginning of the formation of streams of the third order, the intensive uplift is typical for the Eastern and North-Eastern parts of the Peninsula, while in the Western and Central parts the intensity of uplift falls.

Based on the analysis of the basic surface of the first order, it is found that the Northern and North-Eastern coast of the Kerch Peninsula is currently experiencing an uplift, and in these regions the most active denudation of the coastal zone is revealed. The negative values of the difference surface are observed in the area of Kamensky uplift, on Cape Kazantip, in the Eastern part of the Kazantip Bay, on the North-Eastern tip of the Peninsula, South of Cape Lantern, in the area of Kerch, along the shores of lake Tobechik, South of Cape Takil.

Thus, it is shown that the tectonic processes that have the most effect on the development of dangerous gravitational processes are reflected in the relief formed at the stage of formation of streams of the first order and later. The results of structural-geomorphological and morphometric analysis correlate with field observations carried out by the expedition of Rostov University in the coastal zone of the Kerch Peninsula. They identified areas of development of abrasion-landslide processes between Sivash and Kazantip bays, where the rate of abrasion reaches 0.3–0.4 m per year, and sometimes up to 0.5–2 m per year [3]. The same type of relief is typical of the coastal zone of Kazantip p., where steep slopes formed by numerous landslides, particularly on the North side of the island. In the North-East of the Peninsula in the area of Zyuk cape and in the Reef Bay as a result of active abrasion landslides and blocks of subsidence are formed. Landslide slopes are typical for the coast South of Cape Lantern. In the East of the Peninsula in the area of the lake. Tobechikskoe for abrasion areas characterized by landslides, the occurrence of which is associated with the lithology of coastal ledges, composed of clays and limestones. On the coast from Cape Maly Mayak to Cape Takil significant development of exogenous gravitational processes on the composed of clay coastal ledges. [3].

All these data are in good agreement with the identified as a result of morphometric analysis of tectonic uplift at the stage of formation of the residual relief, and allowed to determine areas of possible development of abrasion-landslide processes within the Kerch Peninsula.

**Literature**


APPLICATION OF PETROMAGNETIC ANALYSIS IN THE STUDY OF SECONDARY PROCESSES IN THE PALEOPROTEROZOIC IGNEOUS COMPLEXES OF THE KARELIAN CRATON.

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The abundance of tectonomagmatic processes in the geological history of the Archean and Paleoproterozoic complexes determines the importance of a detailed study of the secondary processes occurring in them, including those associated with the fracturing of rocks. The paleomagnetic method, in combination with other methods, allows to estimate the distribution of secondary processes over a wide area and estimate the time of mineral transformations. In the case of recrystallization or the formation of a new ferromagnetic minerals at temperatures below the Curie point, the magnetic field is fixed by minerals carrying magnetization, and chemical magnetization occurs. In the case of secondary heating without mineral transformations, a thermoviscous magnetization is created with a corresponding blocking temperature.

The remagnetisation of the Early Paleoproterozoic magmatic complexes of the Karelian Craton was studied in detail. To determine the options for the remagnetisation of different parts of the Karelian Craton, studies were conducted at the territory of three blocks: in the north - Pyaozersky, in the center - Voknavolok, and in the south - Tulos.

Microprobe studies indicate minor secondary changes in dykes. Basically, they have been identified very locally: in the form of amphibolization along thin cracks. In the case of the replacement of primary pyroxene by secondary amphibole, recrystallization of primary titanomagnetite occurs with the formation of ilmenite and magnetite.

As a result of paleomagnetic analysis, three main components of different age of magnetization were identified. It was determined two components of chemical nature and one thermoviscous. The magnetization carrier minerals are close in composition and have a similar size of magnetic particles for rocks carrying different magnetization. For the majority of rocks, they are low titanium magnetites with single-domain and pseudo-single-domain particle size. The degree of fixation of secondary processes by magnetisation depends on the chemical composition of dykes.

The time of secondary transformations is determined by the proximity of the paleomagnetic poles for the obtained components with key poles of the Karelian craton and the apparent polar wander for the East European platform. The chemical remagnetisation of the rocks of the northern part of the Karelian craton occurred 2.4 billion years ago, which is associated with the migration of fluids during the formation of a large igneous province at this time [4]. Thermoviscous remagnetisation of rocks occurred during the Svecofennian orogenesis. At the same time, there is observed a regular rejuvenation of the age of thermoviscous remagnetization fixation from the N-E to the S-W, respectively from 1.86 to 1.70 billion years. The last chemical remagnetisation occurred in the period 280-230 Ma. In [3], a similar remagnetisation of dykes in Finland is associated with intense Permian-Triassic magmatism in the Oslo graben in southern Norway.
The obtained age of the last chemical remagnetisation is similar to the fission-track dating data of the apatite of the eastern [2] and north-eastern [1] parts of the East European Craton.

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**Literature**

EXPERIMENTAL STUDY OF FLUORIDE COMPLEXES STABILITY OF ZIRCONIUM AND HAFNIUM IN HYDROTHERMAL SOLUTIONS

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The stability of the fluoride complexes of zirconium and hafnium at elevated temperatures has not been adequately investigated. At higher temperatures, the solubility of baddeleyite in HF solutions was investigated, and the stability constants of the Zr (OH)₃F and Zr(OH)₂F₂ complexes were determined by Ryzhenko et al. [1] and [2]. In works [3], [4] there are data on the stability of complexes ZrFₙ⁴⁻, where n=1-6 at 25 °C. In [5], the equilibrium constants for complexes of the HfFₙ type were determined, for n = 1–6.

Experimental study of zirconium speciation was studied in the ZrOCl₂-HCl-HF-CaF₂ system at 90, 155, 210 and 255 °C (saturated water vapor pressure). The study was based on measuring the solubility of fluorite in acidic solutions with the addition of a different amount of zirconium. For the experiments, we used fluorite from Kalanguy deposit. We produced cylinders from a single crystal fluorite (diameter-8 mm, height-5 mm and weight about 0.7 g). Before using the cylinders, fluorite was weighed on an analytical balance Mettler Toledo AG204 DeltaRange. We used steel autoclaves with PTFE inserts. Fluorite cylinders was fixed on the cover of autoclaves with the PTFE tape. Autoclaves was placed in a preheated oven lid down for the contact of crystal and solution. The time of the experiment was from 4 to 10 days for different temperatures. Autoclaves were quenched in cold water, pre-inverted lid up. This contact with a solution of fluorite was interrupted to avoid dissolution or deposition of material. Fluorite cylinders was recovered, washed with distilled water, dried to constant weight over silica gel, and weighed [6].

The solubility of fluorite increases with increasing of zirconium concentration. With increasing temperature, the solubility of fluorite also increases (an average of 0.4 logarithmic units with an increase in temperature of 60° C).

By results, it was determined that at a temperature of up to 100 ° C the solubility of fluorite is described by the formation Zr (OH)₃F and Zr (OH)₂F₂ complexes [2]. However, at higher temperatures, under the conditions of our experiments, the ZrF₆²⁻ complex predominates.

The stability constant of this complex was determined using the free energies of fluoride and zirconium ions from the SUPCTR92 database [7]:

\[ \text{Zr}^{4+} + 6\text{F}^- = \text{ZrF}_6^{2-} \]

At 90, 155, 210, 255° C and the saturated vapor pressure of water, the constant of this reaction was \( \text{lg} \beta = 32.53 \pm 0.12, 33.70 \pm 0.030, 40.40 \pm 0.016, 41.7 \pm 0.022 \) respectively.

The study of fluoride complexes of hafnium was carried out on the basis of measuring the solubility of fluorite as a function of the concentration of HfO (NO₃)₂ in HCl ± HF solutions at 100, 150, 205 and 240°C and the pressure of saturated water vapor.
Hafnium was added in the form of a powder of pure HfO (NO$_3$)$_2$. The solubility of fluorite increases with increasing hafnium concentration and temperature (on average, 0.4 logarithmic units with increasing temperature by 50° C). The results were processed using the OptimA program [8]. The hafnium complex formation scheme was adopted similarly to the previously studied zirconium as its geochemical analogue: the formation of Hf(OH)$_3$F(aq), Hf(OH)$_2$F$_2$(aq) and HfF$_6^{2-}$. According to calculations, under the experimental conditions, only 2 complexes predominate: Hf(OH)$_2$F$_2$(aq) and HfF$_6^{2-}$. Therefore, optimization was carried out only these two complexes.

In experiments without the addition of HF, the dominant form is Hf(OH)$_2$F$_2$(aq).

The dissociation constants for the reaction were calculated from the obtained free energies of the complexes:

$$\text{HfF}_6^{-2} = \text{Hf}^{4+} + 6\text{F}^-.$$  

At 100, 150, 205, 240°C and pressure of saturated water vapor, the constant of this reaction was lgβ = 32.53 ± 0.12, 33.70 ± 0.030, 40.40 ± 0.016, 41.7± 0. 022 respectively.

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**Literature**

DISTRIBUTION OF REE AND TRACE ELEMENTS IN THE ROCKS OF THE RHYTHMIC STRATIFICATION OF KIVAKKA INTRUSION

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Deposits of chromium, copper, nickel, and elements of the platinum group are associated with layered basite-hyperbasitic intrusions, and the appearance of ore is often associated with rhythmic layering. At the moment, the mechanism of the formation of rhythmic layering is not clear. We chose the Kivakka intrusion as the object of research.

The intrusion is located in North Karelia. It belongs to the group of layered peridotite-gabbronorite intrusions. Geological observations revealed in the section the Upper and Lower contact zones and the Stratified series. [2] The zones of Olivinites, Norites, Gabbronorites and Gabbronorites with pizhonites stand out from the bottom-up in the Stratified Mass. Between OZ and NZ there is a Rhythmic series, represented by the Bronzitite and Norite interbedding. [1]

In our previous studies, we divided the chemical elements into 3 groups, depending on their degree of fractionation during the evolution of the intrusion. So, we selected elements with coherent, incoherent and mixed behavior [3]. We decided to study the behavior of Cr, Sc, Sr, U, Ni, the total concentration of REE and the value of the europium anomaly (Eu / Eu *). The concentration of Sc turned out to be closely related to the amount of normative pyroxenes in the rock, the concentration of Sr - with the amount of normative plagioclase. There were also deviations from the expected patterns: the expected correlation between the amount of plagioclase and the value of Eu / Eu * turned out to be sharply asymmetric. A significant positive anomaly is observed in rocks rich in plagioclase, and a negative anomaly is weakly manifested in rocks rich in pyroxene. The relationship between the concentration of Cr and the amount of pyroxene in the rock is complicated by a very high range of Cr concentrations in the rocks with the highest amount of normative pyroxene. In the PzPBN rocks, no correlation was found between the total concentration of rare-earth elements and the U content in the rock.

A more detailed and accurate analysis of the identified patterns will allow us to identify the most realistic hypotheses of the formation of rhythmic layering.

**Literature**

ON THE AGE OF MUD VOLCANOES ON THE KERCH PENINSULA

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Among the unsolved problems of mud volcanism history on the Kerch Peninsula there are problems of the attribution of the active and inactive volcanoes to tectonic structures, as well as their age (Shnyukov et al., 2006).

Mud volcanism of the Kerch Peninsula, as well as of the entire Kerch-Taman zone, is primarily associated with development of the recent deposits including thick clay series attributed to the Oligocene – lower Miocene (the so-called Maikop series). Almost all researchers noted that mud volcanism is genetically related to tectonic movements: lateral compression and the existence of faults usually contribute into volcanic activity. Both recently active and inactive mud volcanoes are concentrated mainly within fault-folded zones of anticlinal structure, being situated close to the specific transverse and sloping (in relation to diapir anticlines) faults and the nodes of their intersection. The activity of mud volcanoes leads to the formation of mud domes and vast mud volcanic fields, however, this process is also accompanied by the characteristic development of the negative subsidence structures in the arching of anticlines and mud volcanoes complicating them, - the phenomenon known in the Kerch peninsula as “depressed synclinal fold”.

There are divergent opinions on the issue of mud volcanism activity patterns over time. Several events of mud volcanism were recorded in the Cenozoic section of the Kerch Peninsula [2]. The layers of fossil mud breccia found in the maikop indicate that the beginning of the mud volcanic activity in this region can be attributed to the Miocene or even Oligocene, while this process was most active in the middle and late Pliocene, and it has been virtually uninterrupted starting since the late akchagyl and up till now.

Some information about the age of mud volcanoes is provided by the analysis of their spatial distribution in combination with researching the history of the formation of modern relief which partially took after the more ancient relief structures. The development of the folded structures of the NE orientation is quite characteristic for the southern part of the Kerch Peninsula, while for the non-Parpachian region the latitudinal structures are typical [1]. The arrangement of mud volcanoes following the pattern of diagonal and orthogonal chains, which correspond with the two mentioned relief structures, can be regarded as an evidence of their relationship with regional systems.

According to the structural-geomorphological analysis of the Kerch Peninsula relief, it is possible to distinguish the North-Western, Central and South-Eastern recent structures of the first order [3]. The Central structure is the most elevated and is in the process of active development at present. There can be distinguished structures of the lower rank, sublatitudinal anticlines and synclines. On the basis of the morphometric analysis of the relief it was possible to research the development of the most recent uplifts in time [4]. Thus, it was discovered that the Central uplift, represented initially by the isometric form, was formed in Kuyalnitsk time and was gradually
stretching in the NE direction. In the initial period of the growth, structure’s central and western parts were more active. At present, tectonic activity has shifted to the eastern and northern coasts of the peninsula, and there is a great likelihood that starting from the end of the Pleistocene this is where the most intense uplift occurs, as well as the activation of more ancient faults, expressed in the formation of the sublatitudinal structures of the lower orders.

The evolution of tectonic activity is also expressed in the development of mud volcanism. In the central part of the Kerch Peninsula, the mud volcanism actively manifested itself in the Miocene (possibly, from the end of the Oligocene), during the accumulation of Maikop clay series in the Indol-Kuban and Kerch-Taman depressions separated by the periclinal part of the Mountain-Crimean uplift which was formed under the conditions of transverse compression. In the processes of the growing of uplift and subsiding of adjacent depressions, the folded and discontinuous structures could form, being accompanied by mud volcanism.

Submeridional compression, occurring in the early Pliocene (perhaps late Miocene) against the background of the collisional processes in the Crimean-Caucasian region, resulted in the formation of the system of latitudinal linear and brachymorphic diapir anticlinal folds in the Kerch-Taman zone. Exactly at that time the areas of maximum mud volcanism developed to the East, into the area of the North-Eastern part of the Kerch Peninsula and were associated with the activity of latitudinal structures.

At the same time Mountain-Crimean periclinal of the North-Eastern orientation extending into the Kerch zone, was continuously developing and effecting the growth of the Kerch land at the end of the Pliocene. This dry land was gradually elongating in the North-East direction, but in its depths it concealed continually developing system of latitudinal oriented diapir folds. The evolution of the general North-Eastern orientated elongating of land was accompanied by its breakdown by the North-Western orientated valleys forming along the weakened zones of the breakaway type. Weakly lithified above-maicopian layers eroded easily, but the presence of solid carbonate layers determined the complex relief with denuded carbonate ridges on the wings of the latitudinal diapir anticlinal folds. In addition to the fact that both active and inactive mud volcanoes can be attributed to the axes of the sublatitudinal anticlines, it should be noted that the majority of no longer active mud volcanoes relate to the central part of the ancient Kerch land, that is, to the Central isometric uplift beginning to form in Kuyalnitsk time. Active volcanoes frame this uplift almost from all sides, but the maximum activity is typical of the North-Eastern part of the peninsula.

Thus, the Kerch zone is a complex interference system of the structures characterized by the different age and along different stretches. The location of mud volcanoes, close to the Central uplift of the NE orientation, reflects the presence of the NW orientated transverse weakened zones, which are probably confined to the areas of the much earlier mud volcanic activity. Mud volcanoes along latitudinal directions correspond with the main system of the latitudinal structures represented by the diapir anticlines which were forming at the collision stage of the active compression.
Literature

VELOCITY MODELS OF THE CRUST AND LITHOSPHERE IN THE PITKYARANTA SEISMIC STATION AREA IN KARELIA

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The PITK seismic station is located on the northeast coast of Lake Ladoga (lat = 61°40'13.7, lon = 31°15'57.6") and is included in the Karelia regional network of Institute of Geology of the Karelian Research Centre of the Russian Academy of Sciences. In 2014 it was upgraded with Guralp's CMG-6TD broadband sensors with a built-in recorder. For the determination of crustal and upper mantle velocity structure in the substation area the receiver functions technique of P waves and S-waves was employed [1], which allows to investigate the deep structure at the installation sites of stationary seismic stations.

The receiver functions technique is aimed at the registration, selection and interpretation of converted waves, which spread from the source area as P-waves before being converted into S-waves (PRF) and as S-waves before being converted into P-waves (SRF) at the seismic station area. Data processing includes the following procedures: frequency filtering of source records, rotation of axes to a source, component standardization, obtaining individual receiving functions for each earthquake, summing paths from several earthquakes with a time shift. Processing is carried out using the SeismicHandler software package (www.seismic-handler.org) under the Linux operating system, as well as with the help of the own developments of the staff of the IPE RAS. A detailed description of the processing procedures is given in articals of L.P. Vinnik, G.L. Kosarev, S.I. Oreshin.

P receiver functions (PRF).

A total of 71 earthquake data records were selected, in distances from 35° to 93°, with focus depths extending down to 686 km. The individual P-receiver functions for each event are stacked, for several test depths from 0 to 800 km, with a step of 100 km.

On the PRF stack the following exchange boundaries are well distinguished: 1) the Moho discontinuity with a delay 4.9 s; 2) the mantle discontinuities are 410 km and 660 km with a delay 42.2 s and 66.4 s respectively. According to the IASP91 model TP410s = 44.0 s, TP660s = 67.9 s are considered to be the standard times. The reason for the short delay at PITK can be high Vs velocities in the upper mantle or the upward of the 410 km discontinuity, or the integral effect of both causes. The delays at the PITK station practically coincide with those for the south of the Fennoskandian Shield, obtained according to the data of the SVEKALAPKO project and the Russian Plate according to the data of the KLM station [2]. In the mantle transition zone between 410 and 660 km discontinuities the difference in time according to PITK is 24.2 s, which indicates a standard transition zone.

S receiver functions (SRF).

SRF we calculate by the method [3]. For the study we select 26 earthquakes records in the range distances from 70 to 90 degrees, with depths from 7 to 600 km, magnitudes from 6.0 to 8.1.
We sum up the individual SRF for each event, taking into account weights for differential slowness in the range from 0 to 1.0 s/deg. On the sum SRF the signal with negative polarity is well distinguished - the Moho discontinuity at Tsp (Moho) = 5.19 s.

The joint inversion of PRF and SRF to the 1-D velocity models

To inverse modelling and determination of Vp and Vs velocities to a depth of 300 km, we use the summarpy PRF and SRF, as well as the residuals between the delay times from 410 km discontinuity. The values of the residuals are taken as 0.9 s for P-waves and 2.7 s for S-waves.

Inversion methods are based on the Monte Carlo method and are described in [4]. Optimal models are calculated using an iterative simulated annealing algorithm. The initial model consists of 9 layers lying on a half-space. Parameters in each layer are set as a wide range of values. In the inversion process are calculated of thousands of models. The features of the velocity models according to the PITK station data: the earth's crust is heterogeneous, has a layered structure. The crust discontinuities have a depth of 13 km, 21-22 km, Moho at a depth of 42-44 km. The Vp velocities in the crust are slightly increased, in the subcrustal lithosphere are without anomalies. At the Moho discontinuity the boundary velocity is Vp = 8.0 km/s. The Vs velocities in the middle and lower crust are increasing gradiently with Vs = 4.9 km/s in the Moho discontinuity.

Experimental velocity models in the PITK area are an important element of the of geological and geophysical data complex (gravimetric, magnetometric, petrophysical, etc.), which together with the seismic data of the White Sea and Barents-Kara region will allow to go to three-dimensional geophysical modeling. They will help to study possible connections between the deep structure and seismicity with surface structures, geological processes in the junction zone of the Baltic Shield, the Russian Plate and the south of the Barents Sea shelf plate.

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Literature

MÖSSBAUER SPECTROSCOPY OF GLAUCONITE AS A SOURCE OF INFORMATION ABOUT THE REDOX CONDITIONS OF SEDIMENTATION

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The glauconite belongs to the group of hydromica, has a non-permanent and complex composition, with the averaged formula (K, Na, Ca)(Fe³⁺, Mg, Fe²⁺, Al)₂[(Al, Si)₃SiO₁₀](OH)₂·H₂O. However, this name is often used in a wider sense - to refer to green grains and their aggregates, which include illite, glauconite-smectite, smectite and chlorite along with glauconite [1, 2]. Glauconite, an authigenic mineral of sedimentary rocks, is formed in the marine environment, in areas with slow sedimentation, at the boundary of contrasting redox conditions [3].

The wide distribution in sedimentary rocks and the potassium content in the mineral structure determined the possibility of using glauconite in geochronology to determine the absolute age of sedimentary rocks by the potassium-argon method [4]. The main difficulty in obtaining the absolute age of rocks was finding the criteria for the suitability of the material for isotopic dating. This is due to the fact that glauconite is formed in conditions where it is easily redeveloped and changed, and thus the ability to recognize authigenic and unchanged mineral species becomes an important factor. To identify the criteria for the suitability of glauconite for dating, including various physical methods of research, primarily X-ray analysis, infrared and Mössbauer spectroscopy were used.

According to crystal chemical data, iron ions are located in the center of oxygen octahedra, in which part of the oxygen ions are replaced by OH-groups [5]. According to the substitution method, two types of octahedra are distinguished: cis- (two hydroxyl ions are located on adjacent vertices of the octahedron) and trans- (on opposite). Thus, the Mössbauer spectrum of glauconite is a combination of 2–4 components represented by doublets associated with the presence of two and three valence iron in cis- and transpositions. The presence of additional components in the spectrum indicates the phase inhomogeneity of the sample.

Thus, as a result of a comprehensive study of glauconite, a considerable amount of literature data has been accumulated on various aspects of mineralogy and geochemistry of the mineral. But, as a rule, the results of Mössbauer spectroscopy are used mainly to clarify the chemical composition and formula coefficients. However, attention is drawn to the fact that, in addition to the slow accumulation of precipitation, an important factor for the formation of glauconite is the presence of organic matter [2], which affects the content of ferrous iron in the mineral. And thus, the amount of reduced iron indicates the richness of marine sediments with organic debris, which is of interest as evidence of the evolution of organic matter, including in the process of oil and gas formation.
Literature

CONDITIONS AND FEATURES OF THE METAMORPHIC COLLISIONAL ROCKS EXHUMATION IN THE PALEOPROTEROZOIC TIME

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The origin and evolution of ultrahigh-pressure metamorphic (UHPM) rocks are of the most enigmatic issues of studying collision processes in the Precambrian. UHPM are considered as a reliable indicator of collision and continental subduction.

This work presents the results of petrological-thermomechanical modelling, on the basis of which PTt-trends are built under various collision situations, and the features and conditions of exhumation of rocks of the continental margin in the post-collision stage are investigated.

Were applied models with different ratios of felsic and basic rocks in the composition of the continental crust. Continental subduction to significant depths and the following exhumation are rather rare and very short-term processes when the composition of the crust is dominated by felsic rocks (over 70%). The exhumation of these rocks occurs extremely quickly and exceeds the speed of 20 cm/year. In the continental crust with the main lower layer, the continental subduction is much more stable and extensive even in Paleoproterozoic conditions. On average, about 5-10% of the rocks of the continental margin during the collision reach the eclogite facies of metamorphism. Nevertheless, these indicators are incomparably small with the similar indicators of the Phanerozoic collision and are inferior to them by more than 4 times. The degree of exhumation in both cases is comparable and is approximately 83%. Also, there are significant differences in PT-conditions of subducted crustal rocks. Thus, rocks with an ancient collision reaches pressure up to 4.5 GPa, while with a modern one - 3.5 GPa. There are differences in temperature ranges: the temperature of the rocks of the continental margin during the Phanerozoic collision throughout their migration were under 600°C, while the Paleoproterozoic rocks at the final stages of collision reached 900°C.

The simulation results showed a significant influence of the lithosphere thickness on the degree of exhumation of the rocks of the continental margin. It was revealed that for the exhumation of rocks the thickness of the continental lithosphere should be at least 120 km. So, with a relatively low thickness (100 km) under conditions of temperature conditions corresponding to the Paleoproterozoic time, as well as its inherent thick oceanic crust (20 km), the slab breakoff happens before the crustal rocks subducts to considerable depth. With a further increase in the thickness of the lithosphere, an inverse relationship occurs: the thicker the continental lithosphere, the less rocks reach the subsurface depths.

Thus, we can conclude that the formation of Precambrian UHPM metamorphic rocks is most likely with a thin lithosphere, which, however, must be at least 120 km thick.
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