Permafrost researchs report of Russia 2020

The main results

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Earth Cryosphere Institute, Tyumen Scientific Centre, Siberian Branch, Russian Academy of Science (**ECI Tyumen Scientific Centre SB RAS**) **http://www.ikz.ru/**

The XVII Glaciological Symposium "The role of the cryosphere in the past, present and future of the Earth" was at 17-20 November 2020 in St.Petersburg, Russia. The Glaciological association, the Arctic and Antarctic Research Institute, the Institute of Geography of the Russian Academy of Sciences, the journal "Ice and Snow" are organizing the meeting.
Contacts (Organizing Committee): e-mail: glac2020@igras.ru

The results of the most fundamental and advanced investigations, important results on the programs of the Earth Cryosphere Institute (ECI SB RAS) and of the many others Institutes and organizations specializing on permafrost/cryosphere researches are presented in the journal "Earth's Cryosphere" ("Kriosfera Zemli"). Journal is translated into English since 2014, all the articles are available online for free at the website of the journal: http://izdatgeo.ru/index.php?action=journal&id=8**. The abstracts of the most interesting papers are submitted for the consideration of readers.**

(2020/No. 1)

1. STABLE ISOTOPES ^{18}O AND D IN CAVE ICE OF NATIONAL RESERVE LENA PILLARS (EASTERN SIBERIA)

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The structure, origin and temperature regime of caves, located within the National Natural Park Lena Pillars in the middle stream of the r. Lena (Yakutia, Eastern Siberia), have been considered.
The geometry features of "warm" and "cold" caves are discussed, which derive the character of the air circulation and the thermal regime in different seasons of the year. For the first time, data on the isotopic composition (□№^{8}□ and D) of various types of desublimation ice (hoar) are presented, which make it possible to reliably distinguish them from other types of surface and underground ices in the region. It has been established that the sources of moisture in cave ice derived from precipitation of the warm season. The horizontal zoning in the distribution of desublimation ice crystals and their isotopic composition was revealed. In the internal zones with a temperature of about -8°C, columnar crystals of extremely heavy composition are formed (□^{1} ^{8}O = -12.2 ± 0.7 ‰; □D = -99.2 ± 4.7; d_{exc} = -2.0 ± 0.8). In the transition zone, plates with a spiral structure of the following composition are formed: □^{1} ^{8}O = -14.9 ± 1.6; □D = -118.3 ± 12.0; d_{exc} = 1.0 ± 0.9. The lightest composition (□^{1} ^{8}O = -21.2 ± 0.8 ‰; □D = -178.0 ± 4.7 ‰; d_{exc}= -8.2 ± 1.5) has been established for desublimation ices forming a belt of fine-crystalline hoar near the cave entrance.

Desublimation ice, underground ice, caves, hoar-ice, stable isotopes of water, cryplitozone, permafrost, Lena Pillars, Central Yakutia, Eastern Siberia

(2020/No. 2)

2. INFLUENCE OF HYDRATE FORMATION ON THE GAS PERMEABILITY OF FROZEN SAND GROUND

E.M. Chuvilin[1], S.I. Grebenkin[1], D.A. Davletshina[1,2], M.V. Jmaev[2]
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To assess the change in gas permeability of frozen sand samples under hydrate formation conditions at negative temperatures, special experimental modeling was performed. The experiments were performed on the original installation, which allows to estimate the gas permeability of dispersed sediments in the conditions of freezing and hydrate saturation. During the experiments, experimental data were obtained on the change in the gas permeability of frozen sand samples saturated with methane or carbon dioxide under hydrate formation at a temperature of −5°□. It was established experimentally that during hydrate formation in frozen sand samples a decrease in gas permeability occurs, the value of which depends on the initial ice content. It also shows the dependence of gas permeability reduction on the degree of transition of pore ice to hydrate. It was revealed that the type of gas of the hydrate-forming agent influences the intensity of gas permeability reduction of frozen sand samples in time.

Frozen sand, hydrate formation. gas permeability, ice saturation, gas hydrates, methane, carbon dioxide

(2020/No. 2)

3. PERMAFROST DEGRADATION: RESULTS OF THE LONG-TERM GEOCRYOLOGICAL MONITORING IN THE WESTERN SECTOR OF RUSSIAN ARCTIC

A.A. Vasiliev[1,2], A.G. Gravis[1], A.A. Gubarkov[3], D.S. Drozdov[1,2,5], Yu.V. Korostelev[1], G.V. Malkova[1], G.E. Oblogov[1,2], O.E. Ponomareva[1,5], M.R. Sadurtdinov[1], I.D. Streletskaya[4], D.A. Streletskiy[1,6], E.V. Ustinova[1,2,3], R.S. Shirokov[1]

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The results of a long-term permafrost monitoring, which have been obtained at eight permafrost stations in the western sector of Russian Arctic, are presented. Increase in mean annual air temperatures in this area has reached approximately 2.8 °□ (1970-2018). The data on mean annual temperature dynamics have been obtained for the active layer and upper permafrost for dominant landscapes of various bioclimatic zones: typical tundra, southern tundra, forest tundra, and northern taiga. Three stages of permafrost stability under the warming climate were determined: stable permafrost, unstable permafrost, and actively degrading permafrost. It was shown that permafrost degradation leads to active development of vegetation and migration of the boundaries of bioclimatic zones 30 to 40 km towards the north (1975-2018).

Permafrost, ground temperatures, long-term monitoring, permafrost stations, permafrost degradation, intermediate layer

(2020/No. 2)

4. THE STRUCTURE OF PERMAFROST WITHIN PARISENTO STATION (GYDAN PENINSULA) FROM GEOPHYSICAL DATA

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In this article the results of geoelectric survey investigations of permafrost in the area of Parisento station (Gydan peninsula) are presented. According to electromagnetic sounding data, the permafrost thickness is 210-300 m. Application of electrical resistivity tomography (ERT) has shown, that massive ice stratum is characterized by extremely high electrical resistivity, which is exceed million Om·m. It confines method sensitivity below depths of 50-75 m. Assignment of deep-seated conductive beds, which were determined by ERT sounding, has insignificant effect on error of ERT inversion. However, input of deep layers with fixed electrical resistivity lead to improvement of model for geological interpretation.

It was determined, that massive ice between lakes Krugloe and Parisento does not have continuous distribution, as it was appeared by the borehole data before. A linear area of low electrical resistivity was identified. It is probably connected with paleo channel connecting the lakes in the past.

Computational modeling of heat transfer revealed that the depth of open talik under lake Krugloe is 140 m and through talik is located under lake Parisento. The influence of 3-D conducting inhomogeneity, which is represented by taliks and lakes, on electrical resistivity distribution in 2-D and 3-D geoelectrical models was considered.

Parisento station, permafrost, electrical resistivity tomography, TEM sounding, electrical resistivity, massive ice, talik

(2020/No. 3)

5. DISCUSSION PROBLEMS OF GEOCRYOLOGY: REVIEW OF ACHIEVEMENTS

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The author has studied the most debatable theoretical and regional issues of geocryology since 1954 during his entire research work. This article presents the results of this work. The chronicle of changes in geocryological conditions for the last 3.1 million years was compiled for the first time to improve upon theoretical fundamentals of geocryology. The problem of the cryogenic metamorphism of deposits and ground waters within the geological structures was first considered from the position of thermal interaction between natural waters and permafrost section.

Regional studies of the author in southern Yakutia allowed explaining several phenomena. Those are ground temperature formation (from +2°C in the interfluves to -4°C in the valley bottoms), significant (on average up to 50%) permafrost discontinuity along with relatively small (from 0 to 150 m) permafrost thickness. The author also interpreted the abundance of large groundwater springs with an output up to 2-10 m^3/sec. The main controls for that phenomena are an air temperature inversion and infiltration of rainwater simultaneously with active tectonic movements. For the North of West Siberia, the author proved syncryogenic nature of the Holocene peatlands and revealed the reasons for formation of thick (up to 7 m) peatlands in Arctic regions. It is also demonstrated that forest's boundary did not advance essentially (for 400-500 m) onto the territory of the contemporary tundra in the early Holocene. The author explains this by the fact that at that time birchwood of high productivity grew only at the lake depression slopes.

Geocryological chronicle, cryogenic metamorphism, frozen ground, ground waters, air temperature inversion, infiltration, Arctic peatlands

(2020/No. 3)

6. THE ESTIMATION OF ROLE OF INSOLATION FACTOR IN VARIATION OF SEA ICE EXTENT IN RUSSIAN ARCTIC

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On basis of application of correlation and regression analysis the estimation of role of insolation factor in seasonal, interannual, long-term and general for Russian Arctic variations of sea ice extent for the period of satellite measurements (1979 – 2018) are obtained. It is reviled that for long-term variations of annual and monthly values of sea ice extent the correlation with long-

term variations of insolation contrast decreases at increase of spatial scale. For annual variation of sea ice extent it is marked out more stable and close correlation with annual variation of insolation (with phase shift for three months back). With annual variation of phase shifted insolation are also closely correlated annual amplitude of interannual variation of sea ice extent, the distribution of determination coefficient in regression models and annual variations of sea ice extent decrease.

Most conservative relatively insolation factor are seas of central part of Russian Arctic (Kara Sea, Laptev Sea and East Siberian Sea). Most noticeable response for variations of insolation and insolation contrast are marked at outskirt districts of Russian Arctic (Barents and Chukchi Sea). The character of response on insolation factor in these regions also considerably differs.

Russian Arctic seas, sea ice extent, annual, interannual and long-term variation, insolation, insolation contrast, correlation and regression analysis

(2020/No. 3)

7. METHANE AS AN INDICATOR OF PERMAFORST FORMATION CONDITIONS IN ANTARCTICA

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Research of permafrost in Antarctica revealed the methane in lacustrine (Larsemann, Schirmacher and Bunger Hills oasises), marine (King George Island) and temporary streams (Larsemann Hills) sediments. In moraine and deluvium deposits, we found no methane. The methanogenic activity has been proved by experiments with isotopically marked substrates. In permafrost there are number of viable methanogenic archaea, starting producing methane as ground temperature rises. The methane flux could be increased in the future due to deglaciation and active layer deepening due to activation of methanogenic bacteria and release of entrapped methane.

Antarctica, methane, permafrost, radioactive label

(2020/No. 3)

8. EXPERIMENTAL STUDIES OF TWO-PHASE CARBON DIOXIDE FLOW MODES IN TEMPERATURE STABILIZATION SYSTEMS OF SOILS WITH HORIZONTAL EVAPORATOR DEPENDING ON HEAT LOAD

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During experiments to study the regimes of two-phase flows of carbon dioxide in temperature stabilization systems of frozen soils, with thermal loads on the evaporator below 2 kW (6.58 W/m), flow pulsations from the condenser to the evaporator were recorded. According to the results of processing the ripple data, the boundary thermal load was determined at which the ripple of the refrigerant at the outlet of the condenser ceases.

Two-phase flow, carbon dioxide, horizontal evaporator system, simulation

(2020/No. 4)

9. OUTBURST FLOOD OF ICE-DAMMED LAKE SPARTAKOVSKOE ON THE BOLSHEVIK ISLAND (SEVERNAYA ZEMLYA)

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The changes in the level of the glacier-dammed lake Spartakovskoe in 2016–2019 were investigated. In the summer of 2016 the lake level reached maximum level and on August 16–26 a catastrophic flood occurred due to the emersion of an ice dam formed by the outlet glacier of ice cap Semenov-TienShansky. Estimation of the lake area was obtained as a result of

interpretation of satellite images. According to the processing of multitemporal DEMs, the volume of the lake and the height of the ice dam were determined. The maximum water level in lake Spartakovskoe is 122.9 m. It is defined by the point of overflow of water in the valley of the river Bazovaya. Upon reaching this level, the area and volume of the lake were 6.63 ± 0.42 km² and 404.3 ± 21.9 □m³. The minimum height of the ice divide of the dam before the descent of the lake was about 137 m, which ensured its ascent with an average ice density of 0.875 g/cm³. The calculations based on data from snow surveys and the amount of summer melting showed that the melting of seasonal snow cover, perennial snowpack and ice on the surface of glaciers in the catchment area of the lake gives a runoff value 37.1 to 48.2 mln. m³ of water annually, depending on average summer temperatures and precipitation.

Thus, the lake basin is completely charged over a period of about 10 years. The previous flood occurred in the summer of 2006 and until 2016 the level of the lake was continuously rising. At the end of August 2019, the level of the lake of the year reached 80 m, which is consistent with the calculations of runoff into the lake. While maintaining the pace of filling the lake next flood of lake Spartakovskoe may occur in 2024–2025.

Ice-dammed lake, outlet glacier, snow pack, melting, maximum level, floods, Northern Land

(2020/No. 6)

10. THE STUDY OF TALIK UNDER A SMALLWATERCOURSE BY THE CAPACITIVE RESISTIVITY SURVEY

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The results of applying the method of capacitive resistivity prospecting in complex of engineering-geocryological on the oil and gas industry area are shown. The presence of talik under a small watercourse was established. Talik formed as a result of filtration of underground water. A talik structure was mapped at a depth of 12 m under the stream. The effectiveness of applying the method of contactless electrical exploration in the conditions of the Arctic is shown.

Capacitive resistivity survey, oil and gas infrastructure, talik, electrical exploration, index depth of Investigation

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Melnikov Permafrost Institute, Siberian Branch, Russian Academy of Science (MPI SB RAS, Yakutsk) http://mpi.ysn.ru

Selected Research Results

The year 2020 has marked a very special triple anniversary for the Melnikov Permafrost Institute. Sixty years ago, in 1960, the Permafrost Institute was founded in Yakutsk as a successor to the Obruchev Institute of Permafrost Studies in Moscow. Its mission was set up by the USSR Academy of Sciences as to advance regional permafrost investigations in Siberia for benefits of the national economy. For three decades the Institute was led by Academician Pavel Melnikov whose name it bears now. Its oldest regional unit, the Igarka Geocryological Laboratory, was established ninety years ago, in August 1930, as a field station subordinate to the Northern Sea Route Committee and later to the Permafrost Institute. Many internationally recognized researchers worked at the station, including Academician Arsen Ananyan, Dr. Sergey Vyalov, Prof. Boris Dalmatov, and future MPI director Pavel Melnikov. The Vilyui Permafrost Research Station in Chernyshevsky, western Yakutia, was founded fifty-five years ago, in April 1965, to conduct geocryological investigations in the Yakutian diamond fields and in the Vilyui Hydro Project sites. To celebrate the anniversary, MPI held a national conference on 28–30 September 2020 titled “Environmental and Infrastructure Integrity in Permafrost Regions”. A total of 112 submissions were received from across the country (Yakutsk, Khabarovsk, Perm, Irkutsk, Moscow, Tyumen, Nizhny Novgorod, Novosibirsk, Chita, Vladivostok and St. Petersburg), as well as from Germany, Kazakhstan, China and Sweden. About 70 talks were presented in-person or virtually at a plenary and three oral sessions: (1) Permafrost science issues: climate-change and anthropogenic impacts on environmental integrity; (2) Surface and ground water interaction, hydrology and geochemistry of periglacial

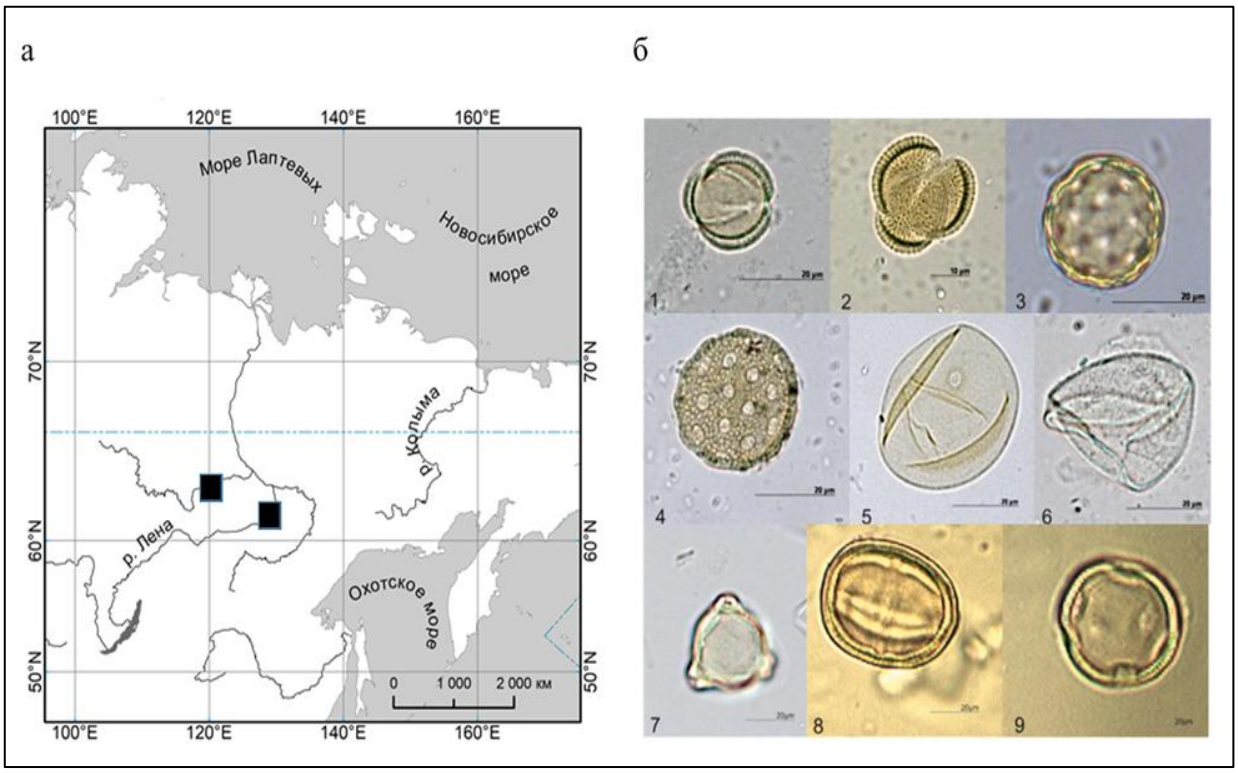
landscapes; and (3) Permafrost engineering issues: climate-change and anthropogenic impacts on infrastructure integrity. The conference concluded with a youth round-table discussion.

A group of conference participants, 30 September 2020, Yakutsk.

Despite the challenging circumstances brought about by the COVID-19 pandemic, MPI continued extensive field studies in Siberian permafrost regions. The final stage of a major three-year project to assess risk to the Power of Siberia Pipeline system from permafrost degradation and a changing climate was successfully completed. Several surveys were undertaken throughout the year for detailed permafrost and terrain characterization in problem areas along the pipeline corridor. A report was prepared and submitted to the pipeline design contractor, VNIPIgasdobycha, providing preventive and mitigative measures for changing permafrost conditions during the pipeline construction and operation.

Snow survey along the Power of Siberia Pipeline.

Investigations of cover sands in Central Yakutia (the D'olkuma Formation) continued in 2020 to reconstruct climate, vegetation and environments during the last 40,000 years. Pollen spectra from the sand deposits were found to be dominated by steppe and semi-desert herbaceous communities (Poaceae, Chenopodiaceae, *Artemisia*, Caryophyllaceae and Cyperaceae) and dry shrub tundra (*Betul*a sect. *Nanae*). Biostratigraphic evidence indicates the cyclic nature of arid and desert conditions. Periods of maximum aridity coincide with cooling peaks. Spores of specific fungi (*Glomus*, *Gelasinospora* and *Microthyrium microscopicum*) and charcoal were identified for the first time in the D'olkuma Formation, suggesting ultra-continental depositional environments, intense erosion and repeated fires during the periods of desert expansion. The data obtained from this study will improve our knowledge of the Late Neopleistocene and Holocene climates and landscapes in Central Yakutia.



Location of the D'olkuma Formation study sites (a) and key pollen taxa in dune deposits: 1 – Artemisia; 2 – Brassicaceae; 3 – Chenopodiaceae; 4 – Caryophyllaceae; 5 – Poaceae; 6 – Cyperaceae; 7 – Betula sect. Nanae; 8 – Polygonaceae; 9 – Thalictrum.

The geophysical group implemented a multi-technique approach to subsurface mapping and characterization of unfrozen aquifers in alluvial sands. Field surveys were conducted on the Bestyakh terrace of the Lena River, Central Yakutia, during 2018 to 2020 using electrical resistivity tomography (ERT), ground probing radar (GPR), seismic refraction (CR), capacitively-coupled resistivity (CCR) and radio magnetotellurics (RMT). A combination of ERT and GPR was found to be optimal, providing more reliable information on taliks occurring above and within permafrost and can be effectively used for three-dimensional mapping of unfrozen aquifers.

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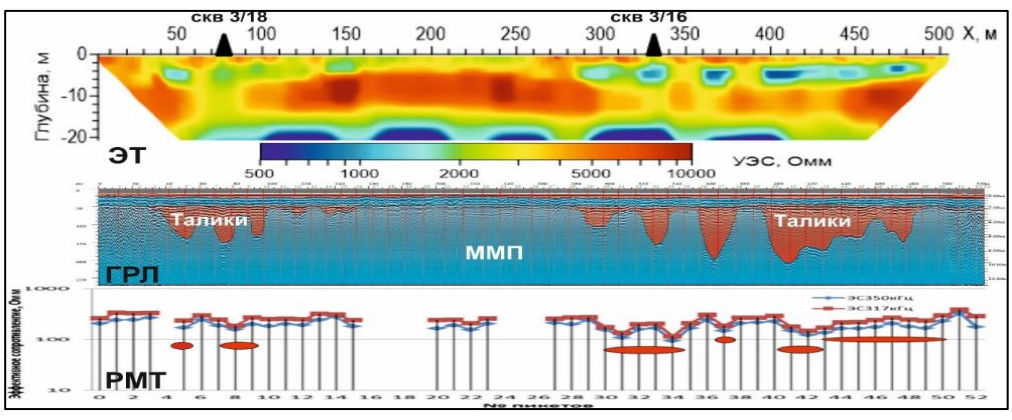

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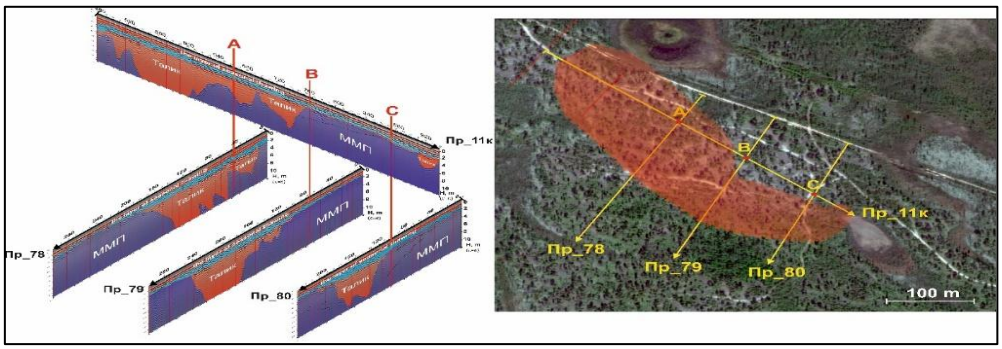


Comparison of ERT, GPR and RMT in identifying suprapermafrost taliks (a); and talik mapping by integrating ERT and GPR (b).

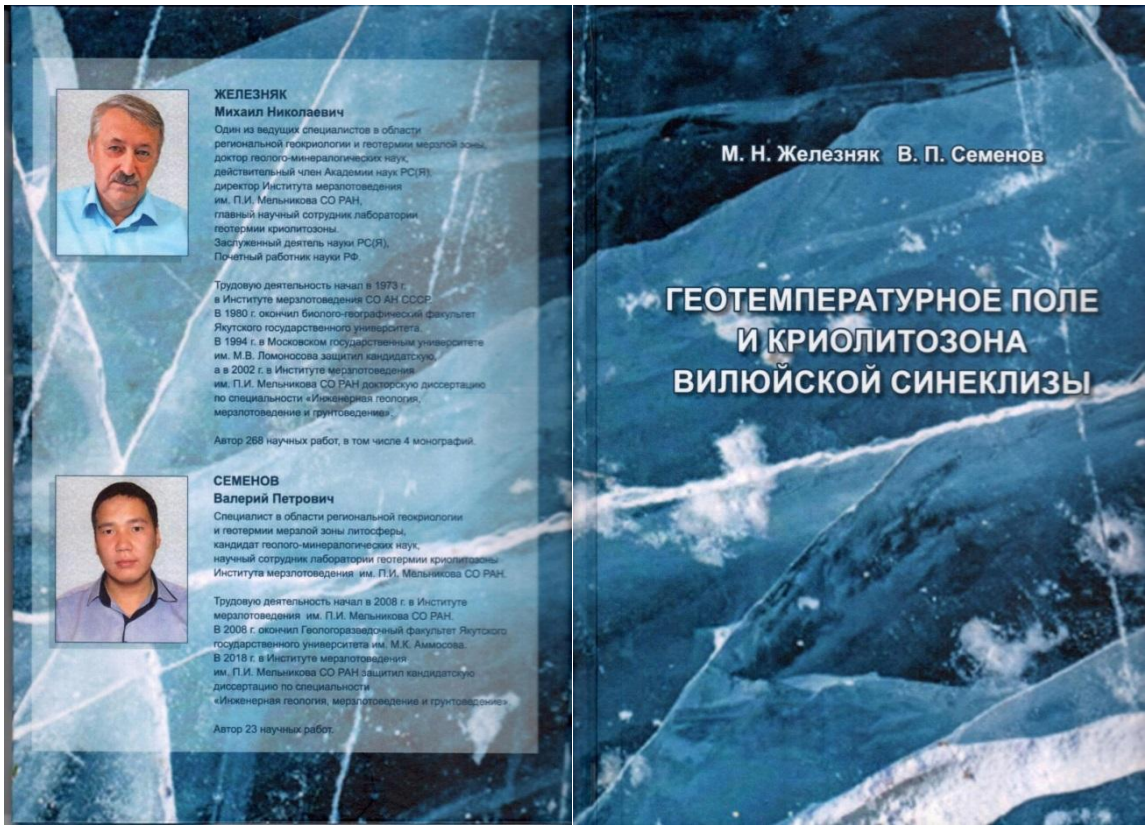
During 2020, cave ice was studied for the first time in the Lena Pillars National Park. Cave geometry was found to be the primary factor controlling the air circulation and thermal regime in caves, as well as the type of ice formation. Isotopic analysis has shown that desublimation ice, the most common type in the caves, has a heavier isotopic composition ($\delta^{18}O$ = -12.2±0.7‰; δD = -99.2±4.7‰; d_{exc}=-2.0±0.8) and differs significantly from all the recent and fossil ice known in the region. Study results provide a new insight into the mechanisms and environments of permafrost formation in East Siberia.

Arctic permafrost programs are continuing in the Lena Delta and the Laptev Sea coastal region, including the Russian-German Expedition Lena. During 2020, new data were collected on coastal dynamics at key monitoring sites, as well as on degradational processes in the Lena Delta and in the Pleistocene Ice Complex along the Laptev Sea. Studies were undertaken to locate permafrost beneath the Lena River distributary channels using a bottom probe.

Eroding ice-rich coastline, Bykovsky Peninsula, Laptev Sea.

In 2020, a 123-paged monograph “The Subsurface Temperature Field and Permafrost in the Vilyui Basin” by M.N. Zhelezniak and V.P. Semenov was published in Novosibirsk by the RAS Siberian Branch Press (in Russian). It presents an overall summary of geothermal research conducted in the region by MPI since the 1950s. The book describes the environmental setting and ground temperature controls, as well as the history, methods and major findings of previous

work. The thermal regime of disequilibrium permafrost is characterized. Permafrost thicknesses are estimated for mineral deposits, hydrocarbon fields and structural units within the Vilyui Basin. Bulk determinations of rock thermal and physical properties are presented. Using the thermophysical properties and thermal measurements, geothermal heat flow distribution in the Vilyui Basin is estimated.



Cover of the book "The Subsurface Temperature Field and Permafrost in the Vilyui Basin" by M.N. Zhelezniak and V.P. Semenov, 2020, Novosibirsk: RAS Siberian Branch Press, 123 pp.

Four **dissertations** were successfully defended at MPI in 2020. Andrey Zhang and Anatoly Kirillin defended their Kandidat Nauk (equivalent to Ph.D.) dissertations titled respectively "Thermal Stabilization of the Railway Embankment and Foundation by Sideslope Insulation" and "The Subsurface Temperature Field and Permafrost in the Elkon Horst". Alexander Fedorov, MPI Vice-Director, was awarded the Doktor Nauk (a higher tier of doctorate) degree in geography for his study on "Evolution and Dynamics of Permafrost Landscapes in Yakutia". The Doktor Nauk in engineering was awarded to Sergey Velikin, Head of the MPI's station in Chernyshevsky, who presented a dissertation summarizing his many years of research on "Integration of Geophysical Methods for Assessing the Condition of Permafrost Foundations of Water-Retaining Structures and Mine Facilities in the Yakutian Diamond Province".

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Sergeev Institute of Environmental Geoscience RAS (IGE RAS, Moscow)

http://geoenv.ru/index.php/ru/

The field studies were carried out by the Institute of the Earth's Crust SB RAS in conjunction with the Institute of Environmental Geoscience of the Russian Academy of Sciences. The current position and internal structure of the southern geocryological zone's borders near the Lake Baikal were estimated. It helped to identify the coastal segments with marks of active, passive and relict geocryological phenomena that linked with permafrost southern border dynamics. It is including the polygonal structures, solifluction steps and terraces, nivation niches and rock glaciers. The long-focus photographing of the shores from the "Geolog" research

vessel, and the perspective and orthogonal aerial photographing from a radio-controlled quadcopter were used (Fig. 1, 2).

The regular geocryological GTN-P observations were carried out in Chara (Trans-Baikal Territory). The thermometric data series reaches 15 years long in this region. It was found that regional climatic trends are synchronous in different parts of the territory and in different altitudinal zones of the mountains of Northern Transbaikalia. The mountainous part of the Udokan Ridge demonstrates the current permafrost warming tendency, which is corresponding the regional climate warming. The intermountain depressions show the relative permafrost cooling, which is not coincide with the dynamics of the average annual air temperature.

Figure 1. Inspection of proluvial fan on the western coast of Lake Baikal (picture from a quadcopter)

Figure 2. Fresh movements of clastic material of the relict rock glacier on the eastern coast of Lake Baikal (picture from the ship)

List of papers published by the IGE RAS staff in 2020:

1. Khimenkov A. N., Koshurnikov A. V., Sobolev P. A. Gas Filtration in Frozen Soils // Moscow University Geology Bulletin. 2020. Vol. 75, No. 4. p. 404-412.
2. Nicolsky D.J., Tipenko G.S. Application of the Non-Hermitian Singular Spectrum Analysis to the Exponential Retrieval Problem // Izvestia Vishikh uchebnikh Zavedeniy Rossiyi. Radioelectronika. 2020;23(3):6-24. https://doi.org/10.32603/1993-8985-2020-23-3-6-24.

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Institute of Physicochemical and Biological Problems in Soil Science, RAS (Soil Cryology Laboratory)(Pushchino, Russia) http://www.issp.psn.ru/

1. The presence of photosynthetic microorganisms in permafrost is a well-known phenomenon. For the first time, this issue has been studied by metagenomic approach. Recent paper in Vishnivetskaya T.A., Almatari A.L., Wu X., Spirina E.V., Williams D.E., Pfiffner S.M., Rivkina E.M. Insights into Community of Photosynthetic Microorganisms from Permafrost // FEMS Microbiology Ecology. 2020. DOI 10.1093/femsec/fiaa229 uncover cyanobacterium fraction as 0.25 to 3%, Streptophyta (algae and plants) as 0.01-0.45% and Chlorophyta (green algae) as 0.01-0.1% from the total count.
2. The paper Rivkina E.M, Abramov A.A. Antarctica, methane, permafrost, radioactive label. Earth. 2020; 24(3):46-51, DOI: 10.21782/EC2541-9994-20203(4651) summarizes data about methane concentration in the permafrost sediments from the Antarctic boreholes. The maximum (up to 330 moll/kg) was obtained for marine sediments from the KGI area. The methanogenic activity has been proved by ex- periments with isotopically marked substrates.
3. The viable Protista from permafrost were studied with genetic approach in mind. The papers Malavin S., Shmakova L., Claverie JM, Rivkina E. Frozen Zoo: a collection of permafrost samples containing viable protists and their viruses // Biodiversity Data Journal. 2020; 8. doi: 10.3897/BDJ.8.e51586 and Malavin S., & Shmakova, L. Isolates from ancient permafrost help to elucidate species boundaries in Acanthamoeba castellanii complex (Amoebozoa: Discosea). // European Journal of Protistology, 2020, 73, 125671. https://doi.org/10.1016/j.ejop.2020.125671. Covers intriguing details about this “frozen Zoo”.

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The studies of 2020 were conducted in a number of directions, traditionally distinguished in the scientific research of the Department of Cryolitology and Glaciology.

Cryolithological research

V.V. Rogov and I.D. Streletskaya continued study of the cryogenesis role in the formation of loess sedimentss in the Lower Volga River region. The papers (Rogov et al., 2020; Taratunina et al., 2020) presents the new results of studying the evidences of cryogenesis in alluvial and loess-soil deposits of the Lower Volga River region. Four stages of the development of permafrost processes during the Late Pleistocene were newly recognized for the region through the example of the Srednyaya Akhtuba reference section.

I.D. Streletskaya obtained new data in the course of studying the organic matter and the gas component in permafrost in the north of Western Siberia. Based on our studies in the Marre-Sale area, it was obtained new reliable data on the methane content in the active layer, underlying frozen soils of the transition zone of the upper permafrost, and data on the methane emission into the atmosphere for the dominant landscapes of the typical tundra region of Western Yamal (Oblogov et al.,). The dissolved organic matter in the analyzed ground ice samples is mainly formed (>88%) by biochemically refractory allochtonous humic acids. Using the protein-like DOM fluorophores as indicators of the labile autochtonous OM, we observed the features of preferential involvement of the associated carbon pool in microbial mineralization. This trend is expressed to various degrees for both: TGI samples, preserving the oxygen-depleted soil environments, and ice-wedge ice, subjected to oxygenated conditions during formation (Semenov et al., 2020).

I.D. Streletskaya and colleagues from VNIIOkeangeologiya have developed a geochemical model of changes in geosystems of the coastal shelf zone under the conditions of current climate warming in the Arctic (Vanshtein et al., 2020). Together with terrigenous material, organic matter, gases, occluded in ice and sediments, and low-valent metal ions (mainly Fe (II)) enter the water, thus causing a change in physicochemical parameters of the coastal zone environment. The researches performed geochemical studies of ground ice and host sediments on three sections of the Kara Sea coast (Spindler area; Marre-Sale subsoil; Sopochnaya Karga subsoil). The results allowed developing a geochemical model of changes in the geosystems of the coastal-shelf zone under current climate warming conditions in the Arctic. The oxidation of Fe (II) during thawing of the permafrost requires the amount of oxygen contained in about 1 km3 of water. In the absence or limitation of the rapid exchange of water masses inside the basin, the oxygen contained in seawater will be completely exhausted for iron oxidation, which will lead to both complete stagnation of the coastal biota and development of anaerobic processes. Significant variations in the CH4 concentrations in sediments and ice indicate possible accumulations of these gases in “traps” inside frozen rocks. Their destruction can be dangerous for coastal geosystems (Vanshtein et al., 2020).

Yu.B. Badu published the results of the analysis of the spread of frost-heaving mounds (pingos) in the north of West Siberia (Badu, Nikitin, 2020). The density of the spread of pingos on the Yamal, Gydan and Tazovsky peninsulas is naturally concentrated above the neotectonically heterogeneous part of the sedimentary cover incision, which concentrates gas deposits of gas-bearing structures at depths of no more than 700-900 m from the daily surface; the highs of the area distribution of pingos are timed to the coastal areas of the sea and lagoon-sea terraces of the western and eastern Yamal, the north and south of the Gydan Peninsula, the north and central part of the Taz Peninsula.

Detailed analysis of five gas emission craters (GEC) found in the north of West Siberia was undertaken by A.I. Kizyakov with co-authors (Kizyakov et al., 2020). GECs are found in various environmental (shrublands or moss-grass tundra) and geomorphic (river valley, terrace, slopes) conditions. The objective is to identify common and differing geomorphologic and environmental characteristics of all the five GEC, and their mound-predecessors. The study was based on a compilation of DSMs before and after the GEC formation using very high-resolution satellite imagery stereo pairs compared to ArcticDEM project data. Diversity of terrain and settings along with rather a narrow range of GEC and mound-predecessor morphometric parameters allows concluding that the mechanism of GEC formation is most likely similar for all

the GEC and is controlled rather by internal geologic and cryolithologic structure than by any surface properties.

V.I. Grebenets, F.D. Yurov, V.A. Tolmanov and V.A. Fedin continued to analyze the regional aspects of the interaction of cryogenic processes and economic infrastructure in the Arctic settlements.

L.I. Zotova summarized the experience of estimated permafrost maps on a landscape basis for environmental purposes. The assessment procedure includes a selection of main permafrost and biotic factors(such as ground temperature and ice content, depth of seasonal thawing, vegetation heat-insulation properties, self-recovery rate and etc), methods of their comparison, ranking anthropogenic pressure, calculating the integral coefficients for clustering landscapes, evaluation mapping. The principles of drawing up multi-scale maps are considered: potential resistance of cryogenic landscapes to mechanical impacts, permafrost-biotic state, maps of geoecological situations, maps of cryogenic processes activation and geoecological zoning. All legends for these maps are proposed to be compiled in matrix form, which facilitates its GIS interpretation. To create these maps, methods of landscape indication, interpretation of satellite images, expert assessments, statistical calculations, and GIS analysis are used. (Zotova L.,2020).

A.A. Maslakov has conducted landscape and permafrost studies within key area of Eastern Chukotka coastal plains. The monitoring of the active layer parameters has been conducted, the cryolithological structure of the transient layer has been characterized, and the massive ice beds been described and sampled. The influence of climate variations and human activity to thermal regime of communal ice cellars of Eastern Chukotka settlements has been assessed (Maslakov et al., 2020). Coastal erosion within Lorino settlement was studied.

V.I. Grebenets and A.A. Maslakov carried out annual active layer monitoring fieldwork to as part of the CALM (Circumpolar Active Layer Monitoring program) program at sites in the Talnakh region (in the north of Krasnoyarsk Territory) and in Eastern Chukotka.

Glaciological research

Under the leadership of V.V. Popovnina, in the summer of 2020, a set of field work was carried out in the basin of the representative mountain glacier Dzhankuat in the Central Caucasus. The long-term series of mass-balance observations is continued.

M.N. Ivanov studied modern changes in the glaciers of the Polar Urals and the climate. A numerical estimate of the reduction in their area was given (Nosenko et al., 2020). The complete disappearance of 44 glaciers has been established. More than half of all glaciers that were last inventoried as of 2009 have completely melted, which is an unprecedented event (Cherkasova, Ivanov, 2020).

In the Polar Urals, field glaciological, geophysical and geodetic works were carried out, on the IGAN, Anuchin glaciers again and MGU glacier for the first time since 2010. The IGAN glacier surface height survey was carried out using a DGPS. The study of terminal moraines was carried out using electrotomography to identify ice cores and assess the outburst hazard of moraine dammed lakes.

M.A. Vikulina continued collecting and data analyzing on the most significant avalanches in the Khibiny mountains. Winter 2019-2020 characterized by maximum snow cover thickness of 168 cm. An increase in avalanche activity in the territory of the Khibiny mountains range was established, associated with an increase in the amount of solid precipitation and the duration of the avalanche active period (Vikulina, Marchenko, 2020). The indicators of social avalanche risk are growing every year due to the expansion of the mining industry in Kirovsk and an increase in the tourist load to the region (Vikulina, 2020).

D.A. Petrakov continued glaciological research in Central Asia. Jointly with research group from Switzerland they assessed current state and future projections of the cryosphere in the region. An important role of the cryosphere in water security has been emphasized (Barandun et al., 2020). We analyzed reasons of the most catastrophic glacial debris flow in Central Asia during recent decades, claimed about 100 people. Before this, there were no detailed research of the Shakhimardan debris flow happened in 1998. A role of periglacial change in debris flow initiation has been identified. It has been argued that stony debris flows can entrain solid material at lower path angles than previously supposed. Recommendations on regional risk mitigation were provided (Petrakov et al., 2020). During research in the Central Caucasus jointly with scientists from IG RAS a technology how to assess growth potential of glacier lakes has been developed.

Important conclusions about possibility of lakes formation at sites of receding glacier snouts at Mt.Elbrus were done. Actual national standards do not consider probability of this situation, thus, some infrastructure will require additional debris flow protection in future (Lavrentiev et al., 2020).

N.A. Volodicheva and A.D. Oleinikov continued snow-avalanche studies to detect changes in snowfall and avalanche activity at the Elbrus educational and scientific base of Moscow State University. A decrease in the degree of avalanche activity has been established due to predominance of snowy, warm winters in the last decade with a peak in snow accumulation and avalanches in the spring (Oleinikov and Volodicheva, 2020). The past winter season has been identified as mid-snowy and abnormally warm.

A catalogue of catastrophic avalanches in the Elbrus region (upper reaches of the Baksan river valley) was compiled based on the results of generalizing a 50-year series of stationary observations (1968-2018). On the basis of the carried out research, the most informative avalanche indicators of extreme situations of avalanche formation have been identified. A new indicator is proposed for long-term forecasting of especially large avalanches based on data from climate models. An analysis of the previously obtained data on the evolution of the Elbrus glaciers was undertaken, which made it possible to generalize information about fluctuations of the southern slope glacier Big Azau and to make additions to the dating of moraines of the last stages of glaciation, from the Little Ice Age to the end of the 20th century.

The scientists of our department took a part in the European Geosciences Union General Assembly 2020, American Geophysical Union (AGU) 2020 Fall Meeting, XVII Glaciological Symposium (St. Petersburg, AARI, November 17-20, 2020) and made many presentations.

During XVII Glaciological Symposium (Saint-Petersburg, AARII, November 17-20, 2020) D.A. Petrakov was elected as one of Vice-Presidents for Glaciological Assosiation.

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Russian scientific-practical conference «GEORADAR-2020» was held **19-22 of oktober 2020** in online mode. The conference It is a continuation of the conferences on georadio-radiation held in the 2000s at the Moscow State University. It is the new way of the previously held GPR-oriented conferences. https://georadarconf.ru/conf2020/english/