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ИФХиБПП

SOIL CRYOLOGY LAB

International Conference

Earth's Cryosphere: Past, Present and Future

Pushchino, Russia, June 4-8, 2017

PRN Permafrost Researchers Young Network Russia

KrioLab

СЕВЕРНЫЕ ИЗЫСКАНИЯ

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PROGRAM

of the International Conference

Earth's Cryosphere: Past, Present and Future

Pushchino, Russia
June 4-8, 2017

June 4

(Sunday)

16:00 - 18:00	**ARRIVAL OF THE PARTICIPANTS** **CONFERENCE REGISTRATION OPEN** **At the hotel "Pushchino"**

June 5

(Monday)

08:30	**REGISTRATION OPEN**	
09:30 – 10:00	**OPENING&HOST REMARKS**	
	Chair, Director of IPCBPSS RAS	**Andrey Alekseev**
	Chair of the Local Organizing Committee	**Andrey Abramov**

Session 1:
Past, Present and Future state of cryosphere

Co-Chair Andrey Abramov		
10:00-10:20	Dmitry Streletskiy, Biskaborn B, Romanovsky V, Smith S, Shiklomanov N, Nötzli J, Vieira G, Philippe S, Schoeneich P , Maslakov A	Circumpolar Assessment of Spatial and Temporal Variability of Permafrost Temperature and Active Layer Thickness Based on Data from the Global Terrestrial Network for Permafrost (GTN-P)
10:20-10:40	Vladimir Romanovsky, Nicolsky D, Cable W, Kholodov A, Farquharson L, Panda S, Marchenko S, Muskett R	Measured and Modeled Changes in Permafrost along North American Arctic Transect
10:40-11:00	Guido Grosse, Heim B, Haas A, Schaefer-Neth C, Laboor S, Nitze I, Bartsch A, Seifert F	The Permafrost Information System PerSys – An Open Access geospatial data dissemination and visualization portal for products from ESA GlobPermafrost
11:00-11:30	**Coffee Break**	

Co-Chair Alexandr Kizyakov

11:30-11:50	Artem Khomutov, Bab kina E, Leibman M, Gubarkov A, Dvornikov Y, Kizyakov A, Babkin E	Paragenesis of thermal denudation with gas-emission crater and lake formation, Yamal Peninsula, Russia
11:50-12:10	Marina Leibman, Khomutov A, Dvornikov Y, Kizyakov A, Sonushkin A, Zimin M, Cauquil E, Dhont D, Stanilovskaya Y	Study of craters on the Yamal Peninsula using remote sensing data and ground-based observations
12:10-12:30	Alexandr Kizyakov, Sonyushkin A, Khomutov A, Dvornikov Y, Leibman M	Geomorphologic conditions of the Antipayuta gas-emission crater based on remote sensing
12:30-12:50	Alisa Baranskaya	The impact of tabular ground ice of the Gulf of Kruzenshtern coasts on exogenous processes
12:50-13:10	Anna Ivanova, Smulsky J	The Insolation Change and the Last Glacial Maximum in Western Siberia
13:10-15:00	**Lunch Break**	
Chair Alexey Galanin		
15:00-15:20	Alexey Galanin	Evidence of the catastrophic desertification of Eastern Siberia at the boundary of the late plestocene and holocene
15:20-15:40	Vladimir Sheinkman, Sedov S	New evidence demonstrating that in North-Western Siberia cryodiversity revealed itself during the Pleistocene cryochrones as interaction of permafrost and mountain glaciers but not as development of giant ice sheets
15:40-16:00	Mikhail Grigoriev, Maksimov G	Regularities of development and structure of subchannel permafrost in the Lena Delta

16:00-16:20	Olga Levochkina, Tumskoy V	Evolution of Thermokarst Depression in Coastal Zone of Sea
16:20-16:40	Yana Tikhonravova, Galeeva E, Kurchatov V, Butakov V., Slagoda E.	Structure and texture of ice wedge complex under the drained lakes (Gydan Peninsula, Russia)
16:40-17:10	**Coffee Break**	
Co-Chair Dmitry Streletskiy		
17:10-17:30	Oksana Zanina, Lopatina D	The reconstruction of vegetation communities during late pleistocene-holocene of the lower Kolyma Region on the basis of palynological and phytolith analyses
17:30-17:50	Anastasia Pikaleva, Nadyozhina E	Future changes in permafrost distribution based on CORDEX projections for XXI century
17:50-18:10	Vladimir Ostroumov, Fedorov-Davydov D, Koloskov A, Goncharov V, Davydov S, Davydova A, Volokitin M, Son B, Demidov V, Bykhovets S, Eryomin I, Kropachev D	The Heat Flux Data for Geocryological Monitoring
18:10-18:30	Alexey Maslakov, Ruzanov V, Fedorov-Davydov D, Kraev G, Davydov S, Zamolodchikov D, Streletskiy D, Shiklomanov N	Seasonal thawing of soils in Beringia region in changing climatic conditions
18:30-18:50	Stanislav Zabolotnik	Causes for widespread talik development in the Arctic Yenisey area
20:00-22:00	**PYRN-event**	

June 6
(Tuesday)
Session 1:
Past, Present and Future state of cryosphere

Co-Chair Alexey Maslakov		
09:00-09:20	Dmitry Drozdov, Ponomareva O, Korostelev Y, Ustinova E, Gravis A, Berdnikov N, Bochkarev Y	Assessment of changes in landscape and geocryological conditions in the central part of Western Siberia according to repeated survey and long-term monitoring
09:20-09:40	Elena Babkina, Leibman M, Khomutov A, Babkin E, Dvornikov Y	Active layer dynamics in Central Yamal of various landscapes
09:40-10:00	Valery Grebenets, Tolmanov V, Gubanov A, Kerimov A	Analysis of Active layer values and thaw ground subsidense in Taimyr (place R-32, CALM)
10:00-10:20	Eugeny Babkin, Dvornikov Y, Khomutov A, Babkina E, Khairullin R	Monitoring of peatland with degrading ice wedges, Gaz-Sale, Russia
10:20-10:40	Galina Malkova	The temperature regime and degradation of permafrost in the European North
10:40 – 11:10	**Coffee Break**	
11:10 – 11:30	Alexandr Zhirkov, Zheleznyak M, Permyakov P	Effect of convective flows of water and air on the formation of the temperature regime of soils
11:30 – 11:50	Alexandra Veremeeva, Günther F	Thermokarst lake and baydzherakh area changes on Yedoma uplands, Yakutian coastal lowlands: repeat inventory using high resolution imagery

Session 2:
Infrastructure management: engineering and processes
Chair Alexandra Popova, Co-Chair Felix Rivkin

11:50–12:10	Kanayim Teshebaeva, J. van Huissteden K	Estimation of surface soil moisture from SAR Sentinel-1 data
12:10–12:30	Alina Voytenko	Content and Dynamics of Maintenance Costs for the Railroad in Link with Geocryological Processes Dynamics
12:30-12:50	Elizabeth Makarycheva, Merzlyakov V, Besperstova N	Thermokarst Phenomena Distribution Regularities Investigated In Various Geographic And Geological Conditions Using Probabilistic-Statistical Method
13:00 – 15:00	**Lunch Break**	
15:00-15:20	Valentin Kondratyev, Bronnikov V, Valiev N	Additional cooling experiments for linear infrastructure on permafrost basement
15:20-15:40	Ivan Vakhrin	Effect of cryogenic structure on thaw settlement of sands and silts
15:40-16:00	Dmitriy Kaverin, Pastukhov A, Lapina L	Ttmperature regime of Tundra soils impacted by winter road (North East European Russia)
16:00-16:20	Sergei Primakov	Prospective directions for geotechnical monitoring development in permafrost
16:20-16:40	Gleb Gribovskii, Ramanouski Y	Computer Simulation of Thermal Regime of Soil Foundation of Power-Generation Building at Vorkutinskaya Compressor Station #4
16:40-17:10	**Coffee Break**	
17:10-17:30	Ramanouski Yury	Water Filtration Role in Thermal Design of Structures on Permafrost
17:30-17:50	Sergey Lukianov	Geocryological conditions of the upper Kolyma river

17:50-18:10	Timofey Orlov, Victorov A, Dobrynin D, Gonikov T, Arkhipova M ,Kapralova V	Stohastic time-space modeling and empirical verification of the lacustrine thermokarst dynamics
18:10-18:30	Leonid Tsibizov, Fage A, Rusalimova O, Fadeev D, Kabanov V	Magnetic Measurements in Permafrost, Lena Delta Case Study
18:30-18:50	Alexey Fage, Fadeev D, Kabanov V, Tsibizov L, Yeltsov I	3D GPU-based numerical modeling for interpretation of electrical resistivity tomography data, a Russian Arctic (Lena delta) permafrost case study
19:00-23:00	**Banquet**	

June 7 (Wednesday)
Session 3:
Life in permafrost

Chair Lada Petrovskaya, Co-Chair Elizaveta Rivkina		
09:00-09:20	Ronald Sletten, Lu Liu, Cuozzo N	Long-term stability of ground ice in McMurdo Dry Valleys, Antarctica and implications for microbial preservation
09:20-09:40	Viktoria Shcherbakova	Anaerobic bacteria and archaea in permafrost: life under extreme energy limitation
09:40-10:00	Chantal Abergel, Shmakova L, Rivkina E, Claverie J-M	Mining ancient permafrost in search for new (live) giant viruses
10:00-10:20	Lada Petrovskaya, Novototskaya-Vlasova K, Kryukova M, Rivkina E	Lipolytic enzymes from permafrost microorganisms
10:20-10:40	Dmitriy Nikitin, Baranova A., Sadykova V., Bochkov D., Gracheva T., Marfenina O.	Antibiotic activity of microscopic soil`s fungi of Antarctic
10:40-11:00	Alina Kudinova, Lysak L, Soina V, Mergelov N, Dolgikh A	Soil procariotic complexes of Eastern Antarctica
11:00-11:30	**Coffee Break**	

Session 4:
Physico-chemical problems of frozen ground

Chair Gleb Oblogov, Co-Chair Natalia Belova		
11:30-11:50	Alexander Vasiliev, Streletskaya I, Oblogov G	Permafrost aggradation and methane producing in low accumulative laidas of the Kara Sea
11:50-12:10	Irina Streletskaya, Vasiliev A, Oblogov G, Streletskiy D	Methane in frozen deposits of the western sector of the Russian Arctic as a risk factor of natural disasters
12:10-12:30	Nataliya Belova, Baranskaya A, Ogorodov S, Kuznetsov D, Novikova A, Kamalov A, Overduin P, Lantuit H	Permafrost coasts contribution to the carbon flux to Kara Sea, Kharasavey settlement, West Yamal
12:30-12:50	Nikolai Torgovkin	Geochemical Characteristic of Alluvial Sediments in Urban Area of Yakusk
12:50-13:10	Vladislav Butakov, Tikhonravova Ya, Slagoda E	Geochemistry of deposits and ice wedge of khasyrey on the north gydan peninsula
13:10-15:00	**Lunch Break**	

Session 5:
Fate of water in subzero areas

Chair Natalia Nesterova, Co-chair Anna Tarbeeva		
15:00-15:20	Natalia Nesterova, Makarieva O, Lebedeva L	Modelling hydrological processes at permafrost margin of Southern Siberia
15:20-15:40	Olga Makarieva, Nesterova N, Lebedeva L	Recent river flow changes at the Pole of Cold of Northern Hemisphere
15:40-16:00	Anna Tarbeeva, Krylenko I, Surkov V, Efremov V, Lebedeva L, Shamov V	Beaded River Channels in the Permafrost Zone: Past, Present and Future
16:00-16:20	Vladimir Ruzanov	Winter runoff and hydrochemestry of Chukotka rivers

16:20-16:40	Nikita Bobrov, Fedorova I	GPR and TEM investigations of hydrogenic taliks in the Lena River delta
16:40-17:10	**Coffee Break**	
17:10-19:00	**Poster session (PS.1, PS.2, PS.3, PS.4, PS.5, PS.6)**	
19:30-21:00	**„Music of a landscape - Kamchatka“ for prepared grand piano by Alexander Morawitz**	

June 7 (Wednesday), 17:10-19:00
POSTER SESSION

Poster Session 1: Past, Present and Future state of cryosphere		
PS.1-1	Galanin A, Pavlova M, Shaposhnikov G, Lytkin V	The structure, age and ground temperature of the late quaternary dune massifs in the low stream of Vilyui river (central Yakutia)
PS.1-2	Khomutov A, Leibman M, Dvornikov Y, Aref'ev S	Antipayuta gas-emission crater on Gydan Peninsula: first results of field study
PS.1-3	Pizhankova E, Popova A, Osadchaya G, Gavrilov A	The Pleistocene-Holocene relief-forming processes of the north part of the Pechora Lowland and their reflection on the remote sensing data
PS.1-4	Aleksyutina D, Shabanova N	Geocryological and hydrometeorological factors of coast dynamics at the Kara Sea
PS.1-5	Zadorozhnaya N, Oblogov G, Vasiliev A, Streletskaya I, Fedin V	The Holocene low surfaces of the Western Yamal coasts. Freezing and sedimentation
PS.1-6	Nekrasov D, Streletskaya I, Oblogov G	Methane in Ground Ice on Central Yamal (Bovanenkovo)
PS.1-7	Alexeev S, Alexeeva L, Kozyreva E, Vasil'chuk Y, Svetlakov A, Rybchenko A	Permafrost of the Okinskoe Plateau (Eastern Sayan Ridge)

PS.1-8	Günther F, Grosse G, Maksimov G, Veremeeva A, Fricke A, Haghshenas Haghighi M, Kizyakov A	Repeat terrestrial LiDAR and DEM-based change detection for quantification of extensive thaw subsidence on Yedoma uplands
PS.1-9	Orehov P, Popov K, Kostovska S, Kostovska S	Natural seasonal rhythms as a base for the investigations of arctic tundra island landscapes dynamics in western Siberia
Poster Session 2: Life in permafrost		
PS.2-1	Ryzhmanova Ya, Shcherbakova V	Desulfovibrio algoritolerans sp. nov., a psychrotolerant sulfate-reducing bacterium from a Yamal Peninsula cryopeg
PS.2-2	Cheptsov V, Vorobyova E, Bulat S	Radioresistance of Permafrost Microbial Communities by culturing and metabolic activity testing
PS.2-3	Mosendz I, Kremenetskaya I, Timofeeva M, Slukovskaya M, Fedoseeva V	Remediation of Highly Contaminated Technogenic Peat-Like Soil by Sungulite and Vermiculite
PS.2-4	Subbotin A, Petrov S, Kalenova L, Narushko M, Markevich T, Malchevskiy V	The prospects of biopotential of the microorganisms isolated from permafrost
PS.2-5	Kolyvanova S, Kalenova L	Influence of Representatives of the Genus Bacillus Isolated from the Permafrost Rocks of Siberia of Different Geological Ages on the Indices of the Immune System of Laboratory Animals
PS.2-6	Spirina E, Eddie A, Clack A, Grater E, Wilfong K, Sokolova (Durdenko) E, Komolova A, Rivkina E, Vishnivetskaya T	Viable Microorganisms from Permafrost and their Enzymatic Activity

Poster Session 3: Physico-chemical problems of frozen ground		
PS.3-1	Fedoseeva V, Fedoseev N, Burnasheva M	Physico-chemical nature of lyquid ice films influence for migration of chemicals in permafrost and glacial systems
PS.3-2	Drachuk A, Podenko L, Molokitina N, Kislitsyn A	Influence silica nanoparticles on formation kinetics and self-preservation effect in dry water methane hydrate
PS.3-3	Oblogov G, Vasiliev A, Streletskaya I, Zadorozhnaya N, Fedin V	Methane in ground ice and frozen Quaternary deposits of North of Western Siberia
PS.3-4	Romanenko K, Khaydapova D, Yudina A, Skvortsova E	Influence of freeze-thaw processes on soil rheological properties
PS.3-5	Pier Paul Overduin	Phase change interfaces in permafrost and subsurface redox potential
Poster Session 4: Fate of water in subzero areas		
PS.4-1	Pavlova M	Chemical composition of the groundwater of the cryogenic-aeolian formations (tukulans) in the Vilyui river basin (central Yakutia)
Poster Session 5: Infrastructure management: engineering and processes		
PS.5-1	Kalashnikova O, Kurchatova A	Microstructure of shelf sediments of the Kara Sea
PS.5-2	Khimenkov A, Sergeev D, Vlasov A, Volkov-Bogorodsky D	Transformation of Frozen Soils during the Dissociation of Gas Hydrates
PS.5-3	Iglovsky S, Kriauchiunas V	Frozen deposits of thermokarst relief (Bolshezemelskaya tundra, Russia), investigated by ground penetrating radar
PS.5-4	Ruzanov V	Geocryology of Anadyr district
PS.5-5	Grebenets V, Gubanov A, Tolmanov V, Streletskiy D	Forming of natural-technogenic geocryological complexes under intensive economic development of permafrost zone

PS.5-6	Isakov V, Kriauchiunas V	Forecast modeling the thermal behavior and cryogenic processes in road embankments constituted by fine grounds
PS.5-7	Bazhin K	Electrical resistivity tomography applications in hydrotechnical studies in permafrost areas
Poster Session 6: Permafrost affected soils: formation and function		
PS.6-1	Sheinkman V, Sedov S, Rusakov A, Terhost B	Gleyic Paleosols Are Tracers of Cryogenic Pedogenesis during the Late Pleistocene: Cases from Europe and Western Siberia
PS.6-2	Khodzhaeva A, Gubin S, Lupachev A	Distribution of potentially mineralizable organic matter in Cryosols

June 8 (Thursday)
Session 6:
"Makeev readings" - Permafrost affected soils: formation and function

Chair Elya Zazovskaya, Co-Chair Dmitry Fedorov-Davydov		
09:00-09:20	Alexander Makeev	Paleocryogenic stages of extreme pedogenesis in the geological history of the Earth
09:20-09:40	Nikita Mergelov, Dolgikh A, Shorkunov I, Zazovskaya E, Shishkov V, Pochikalov A	Hypolithic biocrust as a soil horizon and a hot spot for subsurface organic matter accumulation in the ice-free landscapes of the Larsemann Hills (East Antarctica)
09:40-10:00	Andrey Ivashchenko	Carbon Flux in Terrestrial Ecosystems of the East Antarctica (Oases: Schirmacher and Larsemann Hills)
10:00-10:20	Elya Zazovskaya, Mergelov N, Shishkov V, Dolgikh A, Goryachkin S, Cherkinskiy A	The age of organic matter in soils and soil-like systems of the oases of East Antarctica

10:20-10:40	Andrey Dolgikh, Mergelov N, Ivashenko A, Shorkunov I, Pochikalov A, Karelin D	Carbon stocks and carbon dioxide emission in natural and anthropogenically-changed soils of the Larsemann Hills oasis (East Antarctica)
10:40-11:00	Maria Dergacheva, Fedorov-Davydov D, Bazhina N, Zakharova E, Nekrasova O	Soil humic acids of different environmental conditions on Shirmaher oasis territory (East Antarctica)
11:00-11:10	**Coffee Break**	
11:10-11:30	Ivan Alekseev, Abakumov E	Cryogenic and Stagnic geochemical barriers in soils of the northern Western Siberia
11:30-11:50	Anna Kuznetsova, Afonin A, Tikhonravova Ya, Narushko M, Slagoda E	Reconstruction of the dynamics of the natural environment by the method of definition vegetations residues in peat and the deposits of the khasyrey on terraces of Gyda River
11:50-12:10	Matvey Tarkhov, Matyshak G, Ogneva O	Primary effect of warming on frozen peatland soils properties (North-Western Siberia, Russia, Nadym site)
12:10-12:30	Anastasia Shatilovich, Mylnikov A, Bykova S, Lupachev A, Gubin S	Diversity and Community Structure of Protists in the Arctic Cryosols and Permafrost
12:30-12:50	Vasily Shishkov, Zazovskaya E, Mergelov N, Dolgikh A	Soils forming on cryoconites material in the retreat zone of the glacier
12:50-13:10	Sergey Goryachkin	Role of O.V.Makeev in Classification of Cold Soils and Their Places in Different Taxonomic Systems
13:10-13:30	**Coffee Break**	
13:30-14:00	**Closing remarks**	

“Makeev readings” - Roundtable - Classification of cryogenic soils

Chair Alexey Lupachev, Co-Chair Maria Gerasimova

14:00-14:20	Dmitriy Fedorov-Davydov	Two views on soil cryogenesis and the concept of Cryozem in Russian soil science
14:20-14:40	Alexey Lupachev, Gerasimova M, Goryachkin S, Gubin S, Fedorov-Davydov D, Fominykh L, Matyshak G, Goncharova O, Bobrik A, Startsev V, Zhangurov E, Dymov A, Kaverin D, Mikhailov I, Khokhlov S, Abakumov E	Classification of cryogenic soils in the current russian soil classification system: results of online discussion
14:40-15:00	**Open discussion**	
17:00	**Finish of the conference activities**	

ABSTRACTS

of the International Conference

Earth's Cryosphere: Past, Present and Future

Pushchino, Russia
June 4-8, 2017

Session 1:
Past, Present and Future state of cryosphere

CIRCUMPOLAR ASSESSMENT OF SPATIAL AND TEMPORAL VARIABILITY OF PERMAFROST TEMPERATURE AND ACTIVE LAYER THICKNESS BASED ON DATA FROM THE GLOBAL TERRESTRIAL NETWORK FOR PERMAFROST (GTN-P)

Streletskiy D.[1,2], Biskaborn B.[3], Romanovsky V.[4,2], Smith S.[5], Shiklomanov N.[1], Nötzli J.[6], Vieira G.[7], Schoeneich P.[8], Maslakov A.[9]

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[4]University of Alaska Fairbanks, Geophysical Institute, Fairbanks, USA
[5]Geological Survey of Canada Natural Resources Canada, Ottawa, Canada
[6]WSL Institute for Snow and Avalanche Research SLF, Davos Dorf, Switzerland
[7]Instituto de Geografia e Ordenamento do TerritórioUniversidade de Lisboa, Lisboa, Portugal
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Permafrost is defined as soil, rock, and any other subsurface earth material that exists at or below 0°C continuously for two or more consecutive years. On top of permafrost is the active layer, which thaws during the summer and freezes again the following winter. The mean annual temperature of permafrost and the active layer thickness (ALT) are good indicators of changing climate and therefore designated as essential climate variables by the Global Climate Observing System Program of the World Meteorological Organization. Permafrost temperature and ALT are also essential variables in designing, building and maintaining infrastructure in the Arctic Regions, particularly in the context of Russia. Unlike majority of the Arctic, Russian permafrost regions have presence of substantial population and developed infrastructure. In such cases permafrost changes due to climate are exacerbated in areas of human activities and infrastructure development and may have severe socio-economic consequences as negative impacts of permafrost warming are expected to continue resulting in further deterioration of the infrastructure if adequate measures are not taken into account. That is why a reliable source of high quality data on permafrost

temperature and ALT under changing climatic conditions is critically important for the sustainable development of the Arctic Regions in general, and in Russia in particular.

The Global Terrestrial Network for Permafrost (GTN-P) provides systematic long-term measurements of permafrost temperature and active layer thickness (ALT), and is part of the Global Terrestrial Observing System of the Global Climate Observing System. Long-term monitoring of permafrost thermal state and active layer thickness generates essential baseline information for the assessment of climate change impacts in polar and high mountain regions and is particularly important in the context of Russia. The GTN-P data management system (DMS, gtnpdatabase.org) allows automatic data submission, standardization, quality control, processing, and data access and provides opportunity to evaluate spatial and temporal variability of permafrost temperature and ALT at various cold regions. Presently 1350 TSP boreholes and 250 active layer sites are registered in the DMS. While the majority of European and North American sites now feature multi-year borehole data, ground temperature data for the majority of the Russian sites are not available warranting further data integration from this region. Using DMS capabilities we selected sites with data available around the last International Polar Year and in the last five years (2010-2015) and estimated changes in thermal state of permafrost and active layer thickness between the two reference periods.

Permafrost temperature has generally increased across the entire permafrost domain, which is consistent with air temperature trends. The greatest increases in permafrost temperature are found in the High Arctic of Canada and western Siberia and are generally pronounced in regions with cold continuous permafrost such as Russia and North America. In the Subarctic, where permafrost temperatures are relatively high and within 2°C of the freezing point, there has been little change and permafrost temperature is similar to that of the IPY snapshot. In Alpine permafrost areas most measurement sites also show significant warming since 2009. In Antarctica, permafrost temperature showed various trends, depending on regional changes in atmospheric temperature and snow accumulation.

ALT exhibits large interannual variability, but has generally increased in the majority of regions, especially in European Arctic where several sites experienced permafrost degradation to the degree that does not allow to use mechanical probing to continue monitoring. In several locations thaw penetration into the ice-rich layer rather than ALT

thickening was observed under warming climatic conditions. This underscores the importance of thaw subsidence in understanding the response of permafrost system to climate change.

The results reveal further need for improved geographic coverage of the observational network, further refining of monitoring standards and integration of other ecosystem and climatic variables in order to better assess changes in permafrost system at global scales.

MEASURED AND MODELED CHANGES IN PERMAFROST ALONG NORTH AMERICAN ARCTIC TRANSECT

Romanovsky V., Nicolsky D., Cable W., Kholodov A., Farquharson L., Panda S., Marchenko S., and Muskett R.

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The impact of climate warming on permafrost and the potential of climate feedbacks resulting from permafrost thawing have recently received a great deal of attention. Ground temperatures are a primary indicator of permafrost stability. Most of the research sites in our permafrost network are located along a North American Arctic Permafrost-Ecological Transect. This transect spans all permafrost zones in Alaska from the southern limits of permafrost near Glennallen to the Arctic coast in the Prudhoe Bay region and further into the high Canadian Arctic. In this talk, the results of more than 30 years of the permafrost and active layer temperature observations along this transect will be presented. Most of the sites in Alaska show substantial warming of permafrost since the 1980s (Fig. 1). The magnitude of warming has varied with location, but was typically from 0.5 to 3°C. However, this warming was not linear in time and not spatially uniform. While permafrost warming was more or less continuous on the North Slope of Alaska with a rate between 0.2 to 0.5°C per decade, permafrost temperatures in the Alaskan Interior started to experience a slight cooling in the 2000s that has continued during the first half of the 2010s. There are some indications that the warming trend in the Alaskan Interior permafrost resumed during the last three years. The observed climate warming has triggered near-surface permafrost degradation. Several climate change scenarios were used to make projections of possible changes in permafrost during the 21st century. A high resolution (770x770 m) stand-

alone permafrost dynamics model was used to illustrate how changes in climate together with industrial development of the North Slope of Alaska will impact permafrost and ecosystems in this region. Results of these modeling will be presented and the possible consequences of the present and future permafrost degradation will be also discussed.

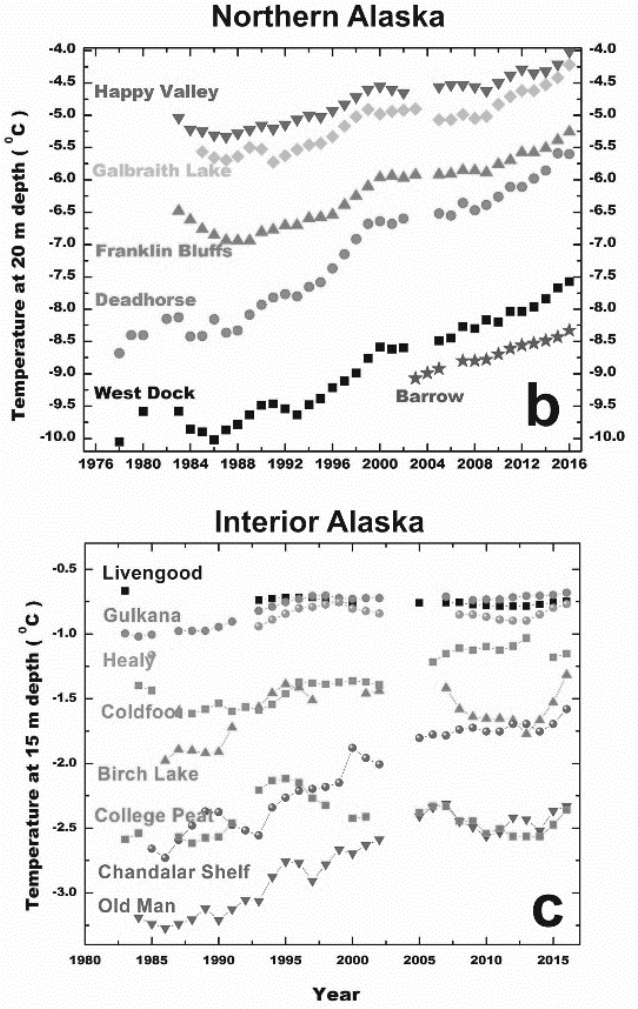

Fig. 1 Alaska North-South transect of permafrost temperature measurement sites: (b) and (c) time series of mean annual temperature at depths of 20 m and 15 m below the surface (updated from Romanovsky et al. 2016).

THE PERMAFROST INFORMATION SYSTEM PERSYS – AN OPEN ACCESS GEOSPATIAL DATA DISSEMINATION AND VISUALIZATION PORTAL FOR PRODUCTS FROM ESA GLOBPERMAFROST

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Permafrost is an important component of the Cryosphere, which is affected by rapid warming of the Arctic. The degradation and thaw of permafrost in vertical as well as lateral directions results in a reduction of permafrost in high latitudes and high altitudes. Since permafrost affects the ecosystem conditions of the about 23 million square kilometer large permafrost region, its loss has strong effects on hydrology, geomorphology, biogeochemistry, and biota. In addition, permafrost soils store about 1500 Gt of organic carbon, about twice the amount currently in the atmosphere and hence changes in permafrost will likely have impacts well beyond local scales. Remote sensing has become an essential tool for quantitatively detecting and monitoring changes in permafrost and associated landscapes.

The European Space Agency (ESA) has supported permafrost-focused remote sensing activities in two recent projects, ESA DUE Permafrost (2009-2012) and the ESA GlobPermafrost (2016-2019; http://www.globpermafrost.info). The first ESA DUE Permafrost project with spatial coverage of the Northern Hemisphere developed, validated and implemented Earth Observation to support research communities and international organizations in their work on better understanding permafrost characteristics and dynamics. Now, the GlobPermafrost project expands on this successful approach by including both polar hemispheres as well as mountain permafrost regions. Products in the new project will cover different aspects of permafrost by integrating in situ measurements of subsurface properties and surface properties, Earth Observation, and modelling. Currently, the GlobPermafrost team is creating prototype remote sensing derived datasets for defined product and user groups. Selected users will be able to access the usability and

validity of the products and provide feedback back to the GlobPermafrost team. The feedback from the Users Groups will be integrated into optimized remote sensing products until they have achieved a final state.

To bring the resulting data products closer to the permafrost user communities, the Permafrost Information System (PerSys) has been conceptualized as an Open Access geospatial data dissemination and visualization portal for Earth Observation, i.e. remote sensing derived datasets produced within the GlobPermafrost project. The prototype and final remote sensing products and their metadata will be visualized in the PerSys WebGIS, described and searchable via the PerSys Data Catalogue. The WebGIS visualization is managed via the AWI WebGIS infrastructure maps@awi (http://maps.awi.de) relying on OGC-standardized Web Mapping Service (WMS) and Web Feature Service (WFS) technologies for data display and visualization. The PerSys WebGIS projects allow visualisation of raster and vector products such as land cover classification, Landsat multispectral index trend datasets, lake and wetland extents, InSAR-based land surface deformation maps, rock glacier velocity fields, spatially distributed permafrost model outputs, and land surface temperature datasets. Each of these WebGIS projects is adapted to the spatial scale of the specific products, ranging from local to hemispherical coverage. The PerSys Data Catalogue will provide the metadata and the access to all mature-state and final-state GlobPermafrost products.

PerSys can be accessed through the GlobPermafrost project webpage. PerSys is also a core component of the Arctic Permafrost Geospatial Centre (APGC), a geodata portal for permafrost launched within the framework of the ERC PETA-CARB project at the Alfred-Wegener Institut Helmholtz Zentrum für Polar and Meeresforschung. The APGC framework features a range of permafrost-specific geospatial data projects, including PerSys, and will allow searching for project-specific geospatial data by tags, keywords, data type and format, licence type, or by location. PerSys will be launched within APGC in early 2017.

In addition, the Open Access data library PANGAEA as a certified ICSU member will serve as permanent archive for the GlobPermafrost final products, providing permanent Digital Object Identifiers (DOIs) for each dataset archived. The ESA DUE Permafrost final product data set is already published under DOI doi:10.1594/PANGAEA.780111. The final GlobPermafrost remote sensing products published in PANGAEA will remain visualised in the PerSys WebGIS and catalogued and made searchable and accessible via the PerSys Data Catalogue.

PARAGENESIS OF THERMAL DENUDATION WITH GAS-EMISSION CRATER AND LAKE FORMATION, YAMAL PENINSULA, RUSSIA

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Gas-emission craters (GECs) found in the North of West Siberia in 2014 occur in an area of wide tabular ground ice distribution. Tabular ground ice observed in the GEC walls also provokes thermal denudation: a complex of processes responsible for formation of thermocirques. These are semi-circle shaped depressions resulting from ground ice thaw and removal of detached material downslope. Shores of many lakes are terraced and have ancient to recent traces of thermal denudation activity. Termocirques are numerous in the GEC area giving reason to assume that GEC, tabular ground ice, thermocirques, and lakes are interrelated.

First found Yamal crater (GEC-1) expanded from initial 18 m wide deep hole in 2013 to an irregularly-shaped lake up to 85 meters wide in 2016. Expansion of the GEC is controlled by tabular ground ice thaw. Thus evolution of GEC can be considered in terms of thermal denudation and analyzed based on thermocirque study in the adjacent area. In summer 2014 and 2015 (the lifetime of the GEC-1) its wall retreat covered the area of 1730 square meters, which gives 865 square meters per year. In 2016, the warmest year for the period of observation at weather station Marre-Sale, retreat area increased by 2200 square meters.

Thermocirque, which exposed tabular ground ice similar to that in the walls of GEC-1, is observed on the nearest lakeshore. This thermocirque activation probably started in 2012 as elsewhere on Yamal. In 2015 its area according to GPS-survey reached 4400 square meters (a four-year average 1100 square meters per year). Since September 2015 and until October 2016 its area expanded by 2600 square meters, thus increased by 59%, more than twice compared to previous annual average.

Lake adjacent to GEC-1 in 2016 was separated from crater edge by only a 13 meter wide isthmus, most likely both GEC-1 lake and adjacent lake merge in few years. Therefore, single basis of erosion for thermal denudation appear. After lakes merge, it would become hard to determine

what the initial process for the lake formation was if not for the occasional discovery of the GEC-1.

Thus, the rate of thermal denudation measured in terms of area expansion: 1) inside the GEC ranged from 865 square meters per year in 2014-2015 to 2200 square meters in 2016; 1) on the adjacent lakeshore thermal denudation expanded by 1100 square meters per year in 2012-2015 and was as high as 2600 square meters in 2016. In both landforms higher rates were observed in the warmest 2016 and were rather similar. Lower rate for the GEC-1 at its initial stage is due to its steep slopes and narrow hole with little sunshine reaching lower parts of the hole.

Adjacent lake providing basis of erosion for both features expands towards the GEC-1 lake and outside into tundra by thermal denudation activity and determines formation of a new feature: merged lake with components having different origin.

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STUDY OF CRATERS ON THE YAMAL PENINSULA USING REMOTE SENSING DATA AND GROUND-BASED OBSERVATIONS

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The objective of the study is to determine geomorphic, landscape and cryolithologic properties of the sites surrounding 3 known Yamal craters. Then, based on landscape-key method, we analyzed the probability of craters existence in a given area. The work uses processing of high resolution images. The objective was reached through the development of Digital Elevation Models (DEMs) for 5 key areas and known craters. Thematic maps (geomorphologic, landscape units and tabular ground ice extent) were compiled using image interpretation, DEMs analysis, and specific identification code (legends). Combined use of satellite imagery and DEMs resulted in improved accuracy and

reliability of interpretation of landscape components and terrain geometry.

The DEMs are developed using the following elevation systems: 1) standard spheroid reference surface WGS84, and 2) geoid elevations EGM2008. During compilation of geomorphologic maps, we have identified a number of terrace shaped surfaces consisting of marine and shallow marine Quaternary sediments. Slope gradient and curvature layer served as a temporary derivative technological product. The results obtained from this exercise were also included in the structure of legends developed for the thematic maps. These legends take into account environmental factors that affect in our opinion the possibility of crater formation.

The inland water system (hydrographic network) mapped on the basis of the available satellite images is an important feature for landscape mapping and study of its genesis. We created a single hydrographic network layer, which was used in all thematic maps. The major water features, including lakes, medium and large rivers, have initially been identified automatically during classification of the satellite images and afterwards they were processed and updated manually.

A morphodynamic legend is developed to capture the landscape morphology, genesis, landforms and distribution of modern geomorphologic processes for the Geomorphologic map. Geodynamic zones are subdivided as Denudation, Transit, Accumulation and Human impact. Each geodynamic type of relief is characterized by different landforms and elements, as well as morphological and morphometric features.

A Landscape units map contains 19 units. They differ by drainage, surface geometry, dominating vegetation, dominating soils and additional properties, such as windblown sands, landslides, small drainage hollows not visible at map scale.

Depth of tabular ground ice table is mapped on the basis of the indicators and conclusions derived from earlier ground ice analysis conducted for the site to the north of the study area having similar landscape features and permafrost conditions. Based on our long-term observation data, abundant small lakes on slopes are evidences of active thermokarst, which in its turn indicates shallow tabular ice table. A depth range for tabular ground ice table has been defined for each landscape unit as per earlier developed classification 1-5 m, 5-10 m, >10 m.

We conclude from analysis of the maps and field observations that known craters are located on relatively gentle slopes, in shrubby tundra,

in clayey deposits, with ground ice close to the surface. These locations are considered the most dangerous in terms of the possibility of the craters formation.

Field data used in this study was obtained through the RSF grant 16-17-16-17-10203

GEOMORPHOLOGIC CONDITIONS OF THE ANTIPAYUTA GAS-EMISSION CRATER BASED ON REMOTE SENSING

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As a continuation of Yamal gas-emission craters research we started the study of the Antipayuta crater located in the western part of the Gydan Peninsula in the upper reaches of the Yuribey River (Kizyakov et al, 2017). Remote sensing is used to assess the geomorphological effect of crater formation. Digital elevation models are created based on processing of very-high spatial resolution stereo pairs both before and after the formation of the Antipayuta crater to characterize relief evolution. Stereo pairs closest to the time of the crater formation and available for ordering are acquired on August 21, 2013 and October 11, 2014.

As a result of photogrammetric processing of satellite stereo pairs DEMs have been produced with a 1-m grid pattern. The automated measurement of the x-parallax within sub-pixel accuracy allowed us to increase DEM accuracy, which we estimated as 0.35m for 2013 and 0.55m for 2014. In this regard, relief changes less than 0.9 m have not been analyzed, because they are within the DEMs accuracy. Under the present environmental conditions it is possible to conventionally equate the notions of digital surface model (DSM) and digital elevation model (DEM), since tundra vegetation of the key-site does not exceed 0.5 m.

The remnants of the third terrace, widely distributed within the study area, are significantly dissected by erosion-thermokarst processes. The crater is located on the terrace edge, bordering with the small flat-

bottom valley. There are polygonal microrelief and small deflation hollows on the terrace surface.

The formation of the Antipayuta crater was preceded by the existence of a mound about 2 m in height, with a base diameter of about 20 m. The dimensions of the mound are smaller than that of the previously studied crater in Central Yamal with 5-6 м height, and a base diameter of about 45-58 м. Analysis of relief changes between 2013 and 2014 indicates the absence of accumulative bodies like those found around Yamal craters (Leibman et al., 2014), which have formed and survived in this time interval, taking into account the method accuracy. If the accumulative forms existed in October 2014, then their thickness was less than the DEM difference relative accuracy, up to 0.9 m. One can assume that since the event of the crater formation, part of the material ejected and deposited directly near the crater edge collapsed into the crater because of the icy walls retreat. Presence and relative stability of the Yamal crater parapet both related to the fact that loamy and clayey deposits, which were ejected to the surface, are more resistant to rainwater erosion.

After the crater formation several small ponds of 1.1-3 m in diameter were observed, probably associated with the impact effect of the fall down of large blocks of frozen rocks and ice that had been ejected from the crater.

Thus, position on the top of the terrace and domination of sandy deposits differs Gydan Antipayuta crater from Yamal craters. The absence of an accumulative parapet is another difference between the Antipayuta and the Yamal crater. One more specific feature is small area and height of the pre-crater mound compared to Yamal's crater. The data obtained shows that the search for the mounds-predecessors of the gas emission craters could not be based on the mound dimensions because of their considerable variations.

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THE IMPACT OF TABULAR GROUND ICE OF THE GULF OF KRUZENSHTERN COASTS ON EXOGENOUS PROCESSES

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The Gulf of Kruzenshtern in the western Yamal is a closed bay, protected from the waves of the Kara Sea by a chain of Sharapovy Koshki islands. However, in this area, well expressed thermoabrasional coastal segments are present. They have steep cliffs (up to 70-80^{o}), narrow beaches and sometimes overhanging niches.

The topography of the coastal land near the Gulf of Kruzenshtern is presented by a combination of several levels. The highest one consists of surfaces ranging from 20 to 30-35 m a.s.l.; they come to the coast to the south of Mordiyakha river and near cape Yasalia. The surfaces are cut by numerous thermoerosional ravines, complicated by thermokarst lakes and alases. In the coastal sections, two main units of Quaternary deposits outcrop: the upper one represented by interbedded brown silts and badly washed fine-grained dark grey sands of lacustrine-alluvial genesis; the lower one consists of dark grey bluish non-laminated clays outcropiing up to 2-3 m a.s.l.

The lower unit hosts massive ground ice. Its outcrops are wide-spread from the mouth of Niudia-Mongotayakha river to cape Yasalia. The ice is laminated with flowed upper contact, unconformly overlain by clays and silts. In the clays, numerous schlieres of ice up to 2 sm, both vertical and horizontal, appear. The outcrops of the ground ice are up to 20-30 m long; their visible thickness reaches 2 m, which allows to attribute them to tabular ground ice. Similar ice has been described in the outcrops and boreholes of the near-lying Bovanenkovo area.

The ice usually outcrops either in small thermoabrasional niches or in the basement of thermocirques up to 100-200 m wide. Suffusion processes are also connected with the ice: thawed water on the top of the ice body washes out the ground; as a result, mud springs appear on the beach under the cliff.

In this way, despite the fact that the Gulf of Kruzenshtern is a closed water area, and wave impact on the coasts is relatively small due to insignificant length of the wave fetch, thermoabrasional and thermodenudational processes here are intense due to thawing of the tabular ground ice outcropping in the lower part of the coastal cliffs.

THE INSOLATION CHANGE AND THE LAST GLACIAL MAXIMUM IN WESTERN SIBERIA

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The climate change on Earth depends on the amount of solar heat that enters the Earth. The amount of this heat or the Earth insolation depends on parameters of the Earth orbital and rotational motion. In the new Astronomical theory of climate change, large oscillations of the Earth's rotation axis were obtained: from 16.7° to 31°, whereas in the previous theory the oscillations of the Earth's axis varied from 22.26° to 24.32°. Such fluctuations of the Earth's axis lead to large fluctuations of insolation. The summer insolation at latitude 65° in the Northern hemisphere Q_s^{65N} is accepted for the characteristic of the climate. Over the last 50 thousand years its four extremes have been observed: 4.16, 15.88, 31.28, 46.44 thousand years ago (ka), which correspond to the middle of the Holocene period, the Sartan glaciation, the Kargin warming and the Yermakov ice age, respectively. As it is known, Ermakov and Sartan glacial periods correspond to two European glaciations of Late Weichselian and Early/Middle Weichselian, respectively.

The most consistent view of scientists has been formed about the last glacial maximum, the Sartan glacial period in Western Siberia. Geological information about it is still contained in the upper layers of the Earth. Therefore, it is possible to reconstruct the last glacial maximum. In the reconstruction of the paleoclimate, a number of criteria have been proposed for changing insolation I at equivalent latitudes to characterize the onset and end of the glaciation. Insolation I for certain latitude in the past shows the contemporary latitude with the same amount of heat in the summer.

Most researchers agree that at the time of the maximum cooling, the Barents and Kara ice sheets were united, and their center of glaciation was in the Kara Sea. The insolation period associated with the Sartan cooling began 22.08 ka This age is confirmed by geologists, for example, according to S.A. Arkhipov radiometric age of the Sartan glacial horizon is in the range of 23 - 10 ka

After two thousand years of continuous cooling, in epoch of 20.8 ka, insolation at equivalent latitudes reached the value $I = 80^{o}$ at latitude $\varphi = 70°$, and the glaciation of the territory extends to this latitude. Ice covered New Ground, partly Peninsulas of Yamal, Gydansky and Taimyr. Glaciation contributes to the reduction of heat in summer and increase

heat in the winter: the snow falling on the islands and the coast does not have time to melt over the summer, and warmer winters lead to later freezing on the seas, which increases snowfall in winter.

After 500 years at the time of 20.3 ka insolation in equivalent latitudes reached values I = 80º at latitude 67.5°, which indicates the promotion of the glacier on the land and blocking the flow of rivers such as the Ob, Poluy, Nadym, Pur, Taz and Yenisei. Lakes form in the mouths of rivers.

The minimum of summer insolation Q_s^{65N} = 5.36 GJ/m^2 is achieved at the time point of 15.88 ka. Insolation at equivalent latitudes reaches a value I = 80º at a latitude of 61.5°. This happened for a short time, so the latitude of 61.5° is the boundary, to which the glaciation could reach. During this period, the glacial relief of Western Siberia was formed, including marginal moraines in the 65.5º-67º on the southern foot of the Salekhard Hadtaken and the Khadateisky ridge of the Taz peninsula. Since the epoch of 15.88 ka and before the opening of the drain into the Arctic Ocean, forming the great West-Siberian Sea.

After a minimum of 15.88 ka, insolation at equivalent latitudes in the epoch 9.8 ka reached the value I = 80º at a latitude of 67.5º. From this moment, intensive melting of the glacier began. The drain of rivers into the Arctic Ocean opens, and the volume of the West Siberian Sea decreases. After a minimum of insolation, the glacier begins to recede from the mainland. It leaves after itself the Taman and Yamalo-Gydan moraine formations. The height of the Kara ice sheet exceeded 1 km, so the ice flow from it occurred both on the continent and the Arctic Ocean. The largest northern submarine trenches with U-shaped profiles: Medvezhinsky, Franz-Victoria, St. Anne and Voronin diverted ice streams from the Barents-Kara glacier to the Arctic Ocean.

The main events of the Sartan glacial period in Western Siberia: the beginning of glaciations, the overlap of river flow, the formation of the West Siberian Sea, moraines left by the glacier and underwater troughs are consistent with changes in insolation.

EVIDENCE OF THE CATASTROPHIC DESERTIFICATION OF EASTERN SIBERIA AT THE BOUNDARY OF THE LATE PLESTOCENE AND HOLOCENE

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For more than half a century, the hypothesis is discussed about the aquatic origin of the "edoma" - the thin-layered loam saturated with organic dust and polygonal ice veins (PIV), that spreading of from the Arctic coast up to the Aldan Highlands [1]. Its main task was to explain the origination of PIV by seepage of surface waters into seasonally opening permafrost cracks and their subsequent freezing.

In different variants of the "aqual" theories, an important role was played by the Verkhoyansk Range glaciations, which discharge was the reason for the expansion of fluvial morpholithogenesis on the adjacent "periglacial plains". The marginal variant ("superaquall") of the theory believes that glaciers repeatedly reached of the Lena valley and blocked its runoff, leading to catastrophic flooding of the vast territories of the Lena-Aldan interfluve.

The alternative (eolian) theory explains the formation of sediments by air deposition of loess in extra-arid conditions, and the origin of PIV is as result of condensation of water vapor in the form of drizzle on the walls of permafrost cracks with subsequent regelation.

Without going into the details of the dramatic discussions of the adherents of the "aqual" and "extra-arid" theories [1], it should be recognized that during the last cryochrones, from the point of view of the former, moderated and humid climates favorable for the expansion of the areas of the aquatic and sub-aquatic sedimentation environments are reconstructed. From the point of view of the latter, on the contrary, the extra-low temperatures during last cryochrones were accompanied by an extreme drying out of the climate, which led to a wide spread of extra-arid environments and a decrease of the role of fluvial processes.

In this report, we want to discuss the most vivid evidence of the grand Late Quaternary desertification of Central Yakutia and Eastern Siberia. In addition to the well-known ice-loess formation ("edoma") with PIV, the large Late Quaternary sand dune massifs occupy more than 1 billion km^2 in Lena basin and its tributaries. In some outcropes of river terraces the evidence of the distribution of facies of stony deserts is well recognized, that represented by horizons of venticrafts consisting with pebbles and boulders specifically polished by wind.

Numerous fossil forms of eolian relief of different hierarchy and good preservation testify to the grandiose desertification of the Region. These include deflationary-accumulative plains; ergs; yardangs; deflation basins with well-developed wind ripples at the bottoms; dunes of various orders, sizes and morphologies; biogenic-eolian hillocks, "mushrooms" and knolls.

The available geomorphological, stratigraphic and cryolithological data indicate the leading role of eolian environment in Central Yakutia and Eastern Siberia during the Late Quaternary. This requires a significant revision of key paleogeographic concepts and the origin of the permafrost in the region.

The study is continues by the support of RFBR-RS(Y) № 15-45-05129 and RFBR № 17-05- 00954.

NEW EVIDENCE DEMONSTRATING THAT IN NORTH-WESTERN SIBERIA CRYODIVERSITY REVEALED ITSELF DURING THE PLEISTOCENE CRYOCHRONES AS INTERACTION OF PERMAFROST AND MOUNTAIN GLACIERS BUT NOT AS DEVELOPMENT OF GIANT ICE SHEETS

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In North-Western Siberia, development of permafrost has been a fact that is beyond any doubt. The problem is its coexistence with glaciation that in various models has been represented by very different forms. Originating in the Early Pleistocene, the permafrost phenomena exist in the considered region so far; moreover, there are numerous evidences that for a long time such indicators of strong rock freezing as polygonal ice wedges formed here. The permafrost area fluctuated in size but during the Quaternary it always occupied the vast terrain of North-Western Siberia. Nevertheless, some researchers suppose a growth of giant ice sheets at this area during the Pleistocene cryochrones, though to explain the combined development of giant glaciers and well-expressed permafrost phenomena under conditions of that area is impossible. In any case, at the base of the ice sheets the frozen grounds and, all the more, underground ice bodies have to be transformed, whereas they occur in the considered region as unaffected in a state of fair preservation.

Analysis of literature on the subject shows that the problem is that for a long time study of glaciation in Siberia had been carried out on the base of the Alpine scientific concept defining high snow supply and ice turnover to form the glaciers. The glaciers have been then considered as so called warm ice bodies which lay on thawed bases, and for the most their part on the ground outside the permafrost area, and are a result of primary snow transformation. They must grow quickly under a cooling, since the snow supply is firstly enough against sharp ablation decrease yielded by the cooling. Such a process will go until the humid and cold (cryogygrotic) stage of the cooling will change by the dry and cold (cryoxerotic) stage. So, under initial high moistening the glaciation then can reach the sheet form over geologically short, relatively, Pleistocene cryochrones.

Such a model, thus, is suitable in the regions with climate similar to the Alpine, in order to explain forming the past ice sheets in Northern Europe moistened from the Atlantic. However that model is not suitable in Siberia where cold and enough dry environments prevailed over the Quaternary as an effect of cryoaridization (the phenomenon showing increase in climate continentality and permafrost promoting under enhancement in cold and arid conditions).

For this reason, the glaciation in Siberia had been denied for a long time whereas use of the Alpine rules yielded reconstructions of giant ice sheets alien to the Siberian terrain.

Study of different modern glaciers under continental climatic conditions in Siberia cleared up that there is not azonality in their development. In spite of low snow supply and active ablation (that is an attribute of continental climate) the glaciers exist due to big cold storage in their bodies: it keeps additional ice feeding, when thawed water repeatedly freezes on their surface. So, in Siberia, the glaciers, being under the initial developed cryoxerotic stage, had to react to the cooling during the Pleistocene cryochrones by slow growth. Their snow supply decreased as the cryoaridization was stronger, and during the cryochrones they, gradually absorbing scanty supply, could reach the valley form only.

Cold continental climate in Siberia has made conditional on the particular environments to form glaciers and to determine their dynamics. The glaciers, interacted with permafrost, become an element of cryodiversity (a set of objects and phenomena produced by cold) differed from the glaciers which have been considered from the position of the Alpine glaciation model. Being cooled till enough low temperature (significantly lower than 0ºC), the glaciers in Siberia obtain properties

which are more characteristic for Cryolithozone, than for the Alpine-type glaciers. The obtained quality requires reckoning the formed combination of the glaciers with Cryolithozone to the specific cryogenic-glacial geosystems.

REGULARITIES OF DEVELOPMENT AND STRUCTURE OF SUBCHANNEL PERMAFROST IN THE LENA DELTA

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In 2014-2016 the Permafrost Institute carried out field studies on formation and degradation of permafrost under the Lena Delta cannels. The river Lena near the delta divided into tens and hundreds channels which depth towards the sea essentially decreases. Their average depth on most part channels is less than 2-2,5 m, that is depth on which frost penetration goes to the river bed through the river ice during the long winter period. The area of channels in the delta makes about 7 500 км^2, that is almost a quarter of the whole Lena Delta.

Field studies were conducted in the apex of delta during the spring period from river ice, using drilling and geophysical sounding on a base of the new Arctic research station «Samoylov Island». The received results have shown that permafrost under channels is extended extremely widely, occupying the most part of their area. Channel bed sediments are characterized by very high content of organic material (up to 30 weight percent) presented mainly by wood detritus. Year-round under-channel taliks (unfrozen subaquatic deposits) are formed only within concerning narrow waterways.

On rather shallow part of a channel the temperature of bottom ground in April reaches a minus 10-12 °C. Studies of temperature regime of bottom ground, borehole and geophysical sounding show that permafrost near to deep-water zones of a delta channels degrades rather fast. It leads to accelerated erosion of bank slopes and to growth of scrolls which steadily freeze on considerable depth (more than 10 m). In this connection on the big area of shoals the bottom long-term frozen sediments thaw to the autumn only on some meters.

In the whole, the areas of new formation of underwater permafrost in the delta increase. During the summer the thawed layer a frozen ground on the channel shallows reaches only 3.5-7 and on the smallest channels

- only 1-3 meters. Such regularities of under channels frozen ground and taliks development probably can be extended to others Arctic mouth areas of the large rivers.

EVOLUTION OF THERMOKARST DEPRESSION IN COASTAL ZONE OF SEA

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East-Siberian shelf studied very poor from geological and geocryological points of view up to now. N.N. Romanovskii proposed the new conception of its development at the end of Late Pleistocene and Holocene. It take into account lake thermokarst appearance on the drained arctic shelf before it was submerged by seawater during the postglacial transgression. According to his idea, the upper horizon of frozen deposits were strongly modified up to 100-150 m depth within taliks under the numerous thermokarst lakes. The thermokarst depressions (TD) on the shelf surface were flooded by seawater during the transgression and turned into formations called by Romanovskii thermokarst lagoons (TL). It is suppose that TL were widespread in the Holocene on the shelf, but currently they spread is very limited. The lagoons of the Bykovsky Peninsula in the southern part of the Laptev Sea are the most accessible for study among them. The authors have studied them since 1999 and based on these materials the *evolution of thermokarst depression in the coastal conditions* has been developed.

Initial seawater ingression in the TD is possible by two ways: submergence of the depression, which partially destroyed by thermal erosion, during wind-induced surges, or along the channel, drained TD. Between TD and sea there is an episodic connection at first time, but as soon as the bottom of the basin becomes hypsometrically below sea level, the connection becomes permanent. TD gradually expand due to coastal thermal erosion, and when they are transformed into a depression with an open contour, separated from the sea by a spit, we say that it has become a thermokarst lagoon. After TL complete flooding, they transform to submarine (relic) form. At first, it can stand out in the bottom relief, but

sedimentation processes will quickly fill it. After this only the decrease of the top of relic permafrost, corresponding to the talik thickness, preserved after flooding, is remained.

The change of permafrost conditions within the TD is mainly dependent on the presence of a lake in them. A lake TL with a talik under them formed after submergence of the TD, in which there was a lake not freezing up to the bottom. If the TD before the flooding represent alas (drained lake depression) with a near surface frozen layer, we called them alas TL. In this case, within the TL, there is a relic talik under surface frozen layer, and pingo can be preserved at the bottom.

We distinguish the following evolutionary stages of thermokarst depressions in the coastal zone of sea now: 1) basin of an initial thermokarst lake or alas; 2) thermokarst depression, periodically flooded through the channel or during wind-induced surges; 3) flooded thermokarst depression, connected by channel with sea; 4) thermokarst lagoon, separated by spit from sea; 5) relic thermokarst depression, expressed in the sea bottom relief or in the relief of top of submarine permafrost.

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STRUCTURE AND TEXTURE OF ICE WEDGE COMPLEX UNDER THE DRAINED LAKES (GYDAN PENINSULA, RUSSIA)

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The structure of the upper part of the permafrost in “khasyrey” (“alas” or drained lake basin) on the second lacustrine-alluvial terrace at the North Gydan Peninsula was studied in 2016. The drained lake is 0.5 km in diameter, it is on lower level of the lacustrine-thermokarst depressions with numerous lakes and has blurred of the Gyda River. The drained lake is bounded on the east by a high terrace around 15 m height and it is adjoined by wetland with lakes on the west. The drained lake microrelief presented with flat polygons of pentagonal and trapezoidal shapes (15-16 m in length) and is complicated by smaller polygons (6 m) and low-centred polygons. The polygon troughs (1.5 m wide, 0.3-0.4 m

depth) deepened via thermal erosion near the shore. The round-shaped hill (50-60 m in diameter, 6 m height a.r.l.), probably frost mound, is located in the center of the drained lake. The frost mound is dissected by round-shaped high-centre polygons,15 m in diameter.

The cross section B4-2016 is located in bluff of drained lake (3 m height); under the polygon trough the lower part of the bluff is covered sandy sediments of the shore. Three layers of sediments are distinguished bottom-up in the section: layer 1 (0.6 m of exposed thickness) – loamy sands and sands with plant remains have ripples lamination; layer 2 (1.5 m thickness) – sands with interbeds of gray loamy sand and numerous ferruginous spots, cryoturbations, threadlike roots, massive cryostructure; layer 3 – peat (0.25 m thickness), soil wedge (0.8 m vertical) was filled with decomposed black peat.

The ice-wedge complex (by N.N. Romanovsky, 1977) was found in the upper and middle layers and covered by thawed ground. The sediments of 1 layer are curved-up along the ice wedge; the sediments of second layer are curved up and down indicating syngenetic formation of ice-wedge complex. The "head" of ice wedge is rounded by smooth depression indicating thawed top part of ice-wedge complex. The sands of the second layer have frequent subvertical micro-lenticular cryostructure (with cutting lamination) on a contact with head of ice-wedge complex indicating lateral melting of ice wedge. In the structure of ice-wedge complex 3 types of ice are distinguished: 1) transparent wedge ice, 2) ice of the composite wedge, 3) ice of the thermo-erosional gully. The borders of the ice wedge part and composite wedge part are poorly expressed.

The texture and structure of the wedge ice thin section from 1.9 m depth and the contact of wedge ice with ice of composite wedge thin section on 1.75 m depth was studied using the Polarizer . The vertical ice veins and air bubbles are expressed in the transparent wedge ice. The contact zone of the ice-wedge complex with enclosing sediments also include ice veins. The calculation of the quantitative parameters of ice crystals characteristics are the following: ice crystals are isometric, elongated, average diameter of the ice crystal ~0.2 cm, which coincides with an average ice crystal size in ice wedges. The ice crystals of composite wedge part have small average diameter ~0.1 cm and similar to ice vein size. The ice crystals on the contact with enclosing sediments have larger size (0.3 cm) than wedge ice crystal size indicating slow freezing at higher negative temperatures.

The ice-wedge complex structure shows changing conditions of accumulation and freezing of the sediments. The ice wedge of the first layer was formed in thermal contraction crack during the accumulation of syngenetically frozen sediments (flood plain, drained shoal). Accumulation and syngenetic freezing of bedded sand and loamy sand with ferruginous spots from second layer was accompanied by cryoturbations, which demonstrate changes of the thaw depth. At this stage there was a formation of composite-wedge parts of the ice-wedge complex. Probably, their formation is connected with partial thawing of the top part of the ice wedge and sand leaking into the cavities, and subsequent to relatively slow freezing. Later the growth of ice-wedge complex was frost cracking again which is confirmed by ice veins within the composite wedge part. After the ice thermo-erosional gully was formed due to the modern thawing and soil wedge formation.

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THE RECONSTRUCTION OF VEGETATION COMMUNITIES DURING LATE PLEISTOCENE-HOLOCENE OF LOWER KOLYMA REGION ON THE BASIS OF PALYNOLOGICAL AND PHYTOLITH ANALYSES

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In this study we examine the palaeoenvironmental record preserved in the frozen columns of sediment, cleared faces of Upper Pleistocene-Holocene sediment, modern soils and underlying layers (0-5m). The data about vegetation of Holocene and Upper Pleistocene of the Lower Kolyma River are obtained on the base of palynologycal and phytolith analyses. Presence and distribution of biomorphs in soil profiles on frozen ground is defined by a number of features of the pedogenesis. In the upper horizons, the specific is defined by input of litter with non-decomposed plant residues. In the central parts of profiles and deeply the biomorphs is penetrated whith a cryoturbation processes, a windbreak, and migrating whith waters.

Structure and profile distribution the microbiomorphs mostly has the character decreasing with a depth. Several accumulation zones of

biomorphs are revealed. The first of them is connected with surface of a mineral part of a modern soils profiles. Other accumulative zones are associated with cryoturbic material of the organogenic horizons, and his accumulation in the period of the maximum Holocene thawing (about 2-2,5m).

Microbiomorphic spectrums of investigated samples are contain different biomorphs (spore, pollen, phytolith, fungi, plant tissue, shell of diatom algae, testae, sponge spicule etc.). The part of pollen spores, phytolith, testae and sponge spicule is small, but the saturation a vegetable detritus and the remains of fungi is considerable at that. The number of morphological forms the diatom algae are detected. The various globular, elongate, lobate, lanceolate, cilindric and trapeziforms is dominate in phytolith spectrum. As a rule, the elongate smooth, lanceolate and trapeziforms prevail. Forms variety from the Upper Pleistocene layers not high.

Microbiomorphic spectrums of samples from depth 2.5-5m are monotonous and poor. The layer at a depth about 2 m especially stand out. This layer contain number of plant rests (moss tissue, grass epidermis and other detritus)

The microbiomorph analysis of modern soil profiles has shown that a quantity and a diversity of phytolith and palynological remains are characteristic of the Ah, Wao, T_2 horizons and top of the mineral horizon. The quantity of phytoliths decreases with a depth, whereas that for pollen doesn't change. The abundance of pollen of herbs and low shrubs with domination of cereals is established here. Cyperaceae, Caryophyllaceae and Asteraceae families are noticeable. At inclusions of peat-like organic material in Bgao horizon the quantity of phytoliths increases, but spores and pollen decreases. In Bg horizon (0.2-0.4 m) quantity of phytoliths sharply decreases. There are moss and shrubs remnants. Pollen of trees and bushes is single, except *Betula sect. nanae*.

These data give an important information on vegetation changes on Pleistocene-Holocene boundary and paleoclimatic reconstructions on this interval in Kolyma lowland.

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FUTURE CHANGES IN PERMAFROST DISTRIBUTION BASED ON CORDEX PROJECTIONS FOR XXI CENTURY

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The heat transfer and atmospheric boundary layer models are used to simulate the permafrost distribution over the Russian tundra zone. Monthly distribution of surface temperature, snow depth, radiation balance and the air mass parameters on the top of boundary layer are used to drive the models. Driving data is provided through the use of Coordinated Regional Climate Downscaling Experiment (CORDEX) output at 50 km horizontal resolution over the Russian Arctic (eight transient model simulations in total spanning.

It has been shown that the models reproduce the spatial permafrost distribution reasonably well. The simulations are compared with local observations derived from meteorological records and provided by the Circumpolar Active Layer Monitoring program (CALM). Changes in the temperature at different levels and active layer depth as well as major uncertainties of the ensemble projection for the Russian Arctic under the IPCC RCP8.5 scenario are presented.

THE HEAT FLUX DATA FOR GEOCRYOLOGICAL MONITORING

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The heat flux data can be useful to estimate the effective heat capacity, thermal conductivity, intensity of phase transitions and other processes in freezing soils. We measure the heat flux intensity at three monitoring sites.

The first site is located at the point of geocryological monitoring, Chersky village, North-Eastern Yakutia (the basin of the Kolyma River). Silty-loamy permafrost deposit here has an average annual temperature is -3°C. Measurements of the heat flow intensity were started in October 2014 at the first monitoring site.

Both second and third sites characterize the region of seasonally frozen soils.

The second one is located at the site of regular meteorological observations at the Moscow Region near Pushchino (the Oka river basin). The loamy soil has the average annual temperature +6°C here. Measurements of the heat flux intensity are conducted since November 2013 at the second site.

The third monitoring site is located at the Kirov Region near Kirivochepetsk (Vyatka river basin). The loamy soils of Vyatka river basin have an average annual temperature about +3°C. Measurements of heat flux intensity were conducted during 2 Years (2012-2013) at the third site.

The heat flux sensors 0924 (Etalon LTD) and data loggers 1/100 (Etalon LTD) are used to the measurements. The UGT DL-103 weather station and the Campbell Scientific Inc. equipment is used for the soil temperature monitoring.

Obtained data show the dynamics of intensity and direction of the heat flux in soils. They reflect daily, annual or long-term changes of the

thermal state of soil massif, depending of the depth of heat flux sensor and measure period.

Effective heat capacity and thermal conductivity of the soil was calculated using the temperature and heat flux intensity data. The equation of heat balance for soil layer was used to estimate the effective heat capacity of soil. The heat conduction equation was used to calculate the effective thermal conductivity of the soil.

The calculated average value of the effective thermal conductivity is 1.4 W/(m*K) at the first monitoring point. The effective thermal conductivity varies from 1.1 W/(m*K) to 1.9 W/(m*K) here. Effective heat capacity averages 2.2 kJ/(kg*K) and varies from 0.3 kJ/(kg*K) to 8.1 kJ/(kg*K). Similar amplitude fluctuations of effective thermo-physical coefficients were found at other monitoring Sites.

We explain the observed changes in the effective soil thermal conductivity and heat capacity by the heat effects of processes inside soil massif such as phase transitions during freezing and thawing, evaporation and condensation, convection of mobile phases, also by heat effects of chemical reactions, interfacial interactions, and biochemical transformations.

The obtained data allowed us to improve any design features the system for soil heat flux monitoring. The results show the feasibility of the using the heat flux data for the geocryological monitoring.

SEASONAL THAWING OF SOILS IN BERINGIA REGION IN CHANGING CLIMATIC CONDITIONS

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Active layer develops in warm period of the year in cryolithozone and occupies an intermediate position between the atmosphere and permafrost. Active layer thickness (ALT) is sensitive to changes in

weather and climate. Although active layer formation mechanism and natural factors affecting its spatial distribution are well studied in regional scale, high local variability of ALT brings uncertainty to modelled results and often forms multidirectional trends in interannual variations of ALT.

This study presents the results of long-term observations of the active layer dynamics in various parts of Beringia palaeo-region. The data are field measurements, conducted in framework of Circumpolar Active Layer Monitoring (CALM) program and study materials of Dionisiya field permafrost station (Anadyr area, Chukotka).

The sites, considered in this study, have mid- to long-term series of observations (16 to 28 years) for active layer thickness and provided with meteorological data. The key sites of the study are: 1) Kolyma lowland, having 5 CALM sites, situated both in zonal (tundra and northern taiga) and intrazonal (floodplain) landscapres; 2) Anadyr lowland (Dionisiya field permafrost station) with 2 CALM sites, reflecting tundra foothills and river lowland conditions; 3) Eastern Chukotka coastal plains (sedge tundra); 4) NW Alaska, representing high-latitude polygonal tundra (Barrow) and shrub tundra (Seward peninsula).

The analysis of interannual fluctuations of seasonal soil thawing depth and summer (June-September) air temperatures revealed common patterns and trends: the most of considered monitoring sites demonstrates increasing of active layer thickness, which was observed in 1980-1990, following increasing summer air temperature. This period was followed by relative stabilization in 2000-2010 and continuation of active layer thickening over the last several years. Several CALM sites in Kolyma lowland and in Eastern Chukotka demonstrates continuous ALT increasing during 2000-2010, even despite of summer temperatures stabilization. Obtained data shows ambiguity of cryosphere response to climate changes and requires necessity of further studies of interaction between active layer and natural conditions.

CAUSES FOR WIDESPREAD TALIK DEVELOPMENT IN THE ARCTIC YENISEY AREA

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The study area is located north of 68° latitude in the extreme north-west of the Central Siberian Plateau, 60 km from the mouth of the Khantayka River.

The geological structure of the region mainly consists of Ordovician carbonate rocks represented by a stratum of gray and dark-gray thick-platy and massive limestones interbedded with dolomitized limestones. The carbonate rocks are intruded by a sill of gabbro-diabases, which form the Bolshoy Ridge, Permian-Triassic in age. The bedrock in most of the region is overlain by Quaternary deposits.

Although the study area is located about 180 km north of the Arctic Circle, forest vegetation is still dominant here. It generally occurs on higher relief and is mainly represented by rare varieties of larch forests and, less often, birch woodland. Approximately 20-25% of the area is covered by various types of wetland.

Based on the analysis of detailed of the state of the permafrost observations, this study has determined the main regularities in the formation of the temperature regime of soils in the Khantaika River valley. Although the long-term mean annual air temperature in the region, estimated from the weather stations at Potapovo and Igarka, varies from -8.7 to -9.6 °C, permafrost is insular in distribution and occupies only about 60% of the area. Taliks have been found in all areas where increased snow accumulation is possible. They occur beneath the channels of rivers and creeks, in the floodplains, under the lakes and in the marshy depressions of all macro- and mesotopographic landforms.

The temperature of permafrost at the depth of zero annual amplitude varies from near 0 to -1.2°C. The permafrost thickness does not exceed 30-35 m, generally being 10-15 m in most of the area. The ice content of frozen sediments (as a fraction of weight of wet soil) varies over a wide range, from 5% in sands to 80-90% in peat. The sandy and clayey silts dominant in the region have ice contents of 15-30 and 50-60%, respectively. The cryostructure is layered in sandy silts and clayey silts and massive in sands and peat. Most widespread permafrost-related phenomena include solifluction, thermokarst and frost heaving. Cracking was only observed on wind-blown treeless surfaces of peat mounds.

The high temperatures and low thicknesses of permafrost, as well as the wide distribution of taliks are mainly due to the thick snow cover, reaching 100-150 cm or more in depth. The thick snow blanket strongly protects the soils from winter cooling, preventing permafrost development, since the mean annual temperature of the underlying ground is 6-10 or more degrees higher than the air temperature. Generally, permafrost is present on elevated, partially or completely vegetation-free areas, where snow is blown away by the wind. Permafrost also occurs in

tundra wetlands, where snow is heavily compacted due to the winds and significantly loses its insulating properties.

ASSESSMENT OF CHANGES IN LANDSCAPE AND GEOCRYOLOGICAL CONDITIONS IN THE CENTRAL PART OF WESTERN SIBERIA ACCORDING TO REPEATED SURVEY AND LONG-TERM MONITORING

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The behavior of permafrost is probabilistic as its structure and state have multiple controls: orbital, climatic, geological, geographic, etc. Therefore, geocryological monitoring makes it possible to identify those features of changes in permafrost properties that could not be precisely calculated due to unstable stochastic dependencies. This could be applies both to the influence of climate change and to technogenic impacts. The studies of ecological and geocryological regime are held in West Siberia to spatial and temporary description and forecast of change in the landscapes and geological environment. Several regime key-sites are placed in different natural zones and cryological conditions near Novyy-Urengoy and Nadym towns at the territory of previous repeated engineering geocryological survey held in 1970th and 1990th.

Changes of average annual ground temperature are mostly smoothed in comparison to external changes (e.g. air temperature) and they make it possible to observe general cryological trend not hidden by the random fluctuations and extrema. At Urengoy gas-field the temperature of permafrost increased approximately up to 1°C during the period 1975–1993 owing to the natural climate dynamics. Technogenic impact added extra 1…2.5°C, but this ground temperature rise is located close to human constructions. The continuous regime observations 1994–1999 testify retardation of the increase of the frozen ground temperature. The next 5 years displayed that it is. It seemed that the maximum on the

sinusoid of the ground temperatures was almost reached. The following step was to expect that the cycle of climate warming could be changed into temperature drop. But the rapid air and ground temperature rise, which started after 2010, terminate this assumption. Today, we can talk about an increase in soil temperature by 2-2.5°C compared to 1970th (and for some landscapes, even by 3°C).

So after the relatively cold period the 1970–1980's were characterized by the sharp warming up of air and ground which was evident at the north of Russia. But according to the data of geocryological observations the rise of ground temperature was slowed down and practically stopped since the middle 1990's. That allows to presume that the cycle of global warming can be changed decreasing of the temperature. Short period of 2005–2007 yr. appointed the insignificant temperature rise and after 2010 the rapid uneven air and ground temperature rise started. So the real trend of modern geocryological condition is not factually determined.

It occurs against the background of a shift to the north of the landscape boundaries, the northward advance of pre-tundra larch open forest. It can be assumed that the slowdown in soil temperature growth at the turn of the 20th and 21st centuries was due to the spread of the zone of seasonal phase transitions deep into the permafrost to the base of the layer of annual temperature variations and downward movement of the permafrost table.

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ACTIVE LAYER DYNAMICS IN CENTRAL YAMAL OF VARIOUS LANDSCAPES

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Monitoring of the active layer (AL) in Central Yamal is carried out at the key site "Vaskiny Dachi" CALM grid 100x100 m (121 points) since 1993. Different landscape units (LU) within the grid, as well as long-term

records allow analyzing both spatial distribution and temporal dynamics of the AL in the key area.

Dependence of the thaw on time is determined mainly by the dynamics of the summer air temperature. For the key area, the air temperature records of the weather station Marre-Sale (www.rp5.ru) are used for analysis. Changes in the AL for the area are controlled by the main components of the landscape: relief and microrelief, vegetation, composition and moisture of soils. The extreme heterogeneity of these indicators over the area determines the considerable spatial variability of the AL.

To assess the influence of climatic factors, the mean values of the thaw depth relative to the thaw index (sum of positive air temperatures) are considered for each year. The main pattern of AL dynamics is well understood in general, while specific features for the key area have been established earlier (Leibman, 2001). However, the extreme climatic events of recent years have led to significant deviations from both the mean thaw depths in the previous period towards their increase, and the AL response to climatic fluctuations. The period since 1999 is analyzed here. Warmer and colder years in terms of thaw index are distinguished, corresponding to larger and smaller AL depths. The coldest over the past 20 years are 1999 and 2014, with the mean values of AL depth in 1999 being predictably smaller than the values of warmer periods. A significant increase in AL depth occurred since the extremely warm 2012, after which the thaw depth in the cold 2014 decreased only slightly, and then continued to increase reaching its maximum in 2016 when the warm season was characterized by abnormally high thaw index.

The patterns of lateral AL changes are controlled by different landscape conditions varying within characteristic LU represented by highly vegetated clayey slopes and flat or concave hilltops versus sparsely vegetated convex sandy hilltops. For the entire observation period, the deeper AL is noted for drained convex sandy hilltops where the highest amplitude of AL depths between the cold and warm summers is also observed. Flat and concave tops and slopes, completely vegetated, show both the lower AL depths and the smaller range of AL changes in warmer and colder summers.

All LU show higher mean thaw depth for the period 2012 to 2016 compared to the previous period of observation (1999-2011). But the LU with deep AL are more responsive to warming as compared to LU with shallow AL, which is undoubtedly resulting from the presence in the second case of a heat-insulating ground vegetative layer.

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ANALYSIS OF ACTIVE LAYER VALUES AND THAW GROUND SUBSIDENSE IN TAIMYR (PLACE R-32, CALM)

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The permafrost soils are structurally unstable, and the seasonally thawed layer (STL) is characterized by its instability (in space and time) and dynamism.

The seasonally thawed layer undergoes frost heave during the freezing process, and while thawing goes processes of ground subsidence (during the thawing of large ice deposits and the development of thermokarst goes slump processes, which is a separate subject of research).The problem of the development of deformations of soil sediments in STS is relevant both for natural objects (impact on runoff, for changing the landscape and vegetation situation, etc.) and for economic objects: linear systems (pipelines, roads, etc.), buildings and structures.

Observations at the CALM program in Taimyr have been carried out since 2005 (site R-32, Talnakh) and observations of the surface geodetic level since 2007. The results of the measurements were processed, maps of thawing and changes in the geodetic level of the surface were constructed and differentiation of seasonally thawed layer and precipitation in different microlandscape conditions were studied. The depth of seasonal thawing and the change of surface movements are determined by three main systems: a) weather conditions and climatic trends; B) permafrost-lithological conditions, incl. Parameters of drainage and cryo-texture of the STL frozen during the previous winter; C) microlandscape characteristics.

It was established that for the Norilsk region (Taimyr) the trend of increasing STL was 0.3 cm / year (for the period of observations 2005-2016) with a certain slowdown in the last 3 to 4 years. A significant increase in the depth of the STL (following the increase of summer temperatures, winter warming , and a reduction of the cold period) is limited by icy transition layer in the upper part of the permafrost loam.

An exceptionally high impact of the summer precipitation conditions was revealed: for example, in the rather cold summer of 2012, with a large amount of precipitation, which dropped out mainly in the warmest month (July), the defrosting was the highest, and in a record-breaking number of positive degree days (for all 70 years of regular meteorological observations), but the anomalously dry year 2013 (in July - up to 10 mm atmospheric precipitation), the thawing was minimal during the research on the R-32 site.

The maximum thawing and the amount of precipitation are fixed in negative forms of relief, which have a water-resistant regime. Differences in the depth of the seasonally thawed layer and in the values of displacements within different landscapes can reach 50-70%.

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MONITORING OF PEATLAND WITH DEGRADING ICE WEDGES, GAZ-SALE, RUSSIA

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Permafrost areas have widespread polygonal relief formed by a system of frost fractures with the formation of ice wedges. Since 2012, climate of the north of West Siberia is characterized by abnormally air temperature, that affects the dynamics of active layer depth (ALD) and activation of cryogenic processes. Technogenic factors also have sufficient influence on changing the permafrost stability.

Polygonal peatlands with ice wedges, degrading under the influence of combined natural and technogenic factors, has been monitored near highway five kilometers west of the Gaz-Sale settlement in Tazovsky district of Yamalo-Nenets Autonomous Okrug.

The monitoring site is adjacent to road and, apparently, partly overlapped by its embankment and is a polygonal peat plateau with convex polygons and deeply settled water-filled inter-polygonal troughstroughs. Vegetation on one part of the peat is destroyed by fire.

To monitor dynamics of the peatland's surface it was surveyed with tachymeter in conditionalcoordinates and heights system with time benchmarks.

The survey has been carried out with the fixation of details like peat polygons' edges, trough thalwegs, flooded areas between the polygons, the polygons' topography, edges of roadway cover plates, the upper part of the culvert and the kilometer post “6 km from Gas-Sale”. Peat polygons' edges have been defined as pieces of sod and peat, “not torn” off the main polygon. If the piece was already torn off and lying in the water, it was not considered a part of the polygon.

The peatland surface is split by numerous intersecting frost fractures on rectangular, triangular and multangular polygons with perimeter of 17-65 m on the intact site and 30-94 m on the fire-affected. The central part of the most of the polygons is lowered by 0.2-0.3 m with respect to edges, the surface in some places is wet, supplemented by hummocks. Width of the inter-polygonal troughstroughs ranges from 0.4 to 3.0 m. In some places the troughs are filled with water. Depth of the troughs considerably varies from 0.1-0.5 m in dry areas to 1.0-3.0 m in flooded ones.

Within the peat we can distinguish: 1) rather drained flat tops and slopes of peat polygons; 2) lowered flat tops and slopes of peat polygons, poorly-drained; 3) peripheral parts of polygons; 4) inter-polygonal troughs, drained, flooded in some places. On each surface, the ALD was measured mechanically with a metal probe.

Vegetation cover of the polygons' flat surface is moss-lichen, in some places with sedge, ledum, cloudberry and cowberry; ALD is 53-63 cm; ALD on the polygons' convex surface overgrown with lichen, ledum and sedge is 44-52 cm while an average value for rather drained flat tops of peat polygons is 52 cm. Vegetation cover of the polygons' lowered central parts is lichen-moss with 5 cm thick sphagnum pillow, sometimes there are sedge and ledum. The ALD in such areas is 50-56 cm, the average value is 53 cm. Edges of the polygons are covered with lichens and ledum, in some places there are cloudberries, cowberries and sedge. The ALD varies within the range of 51-57 cm, in less than 0.5 m from the edge of polygons, 42-48 cm. For the peripheral part of the polygons the ALD average value is 56 cm.

The vegetation cover of the troughs in the intact part of the peatland is sedge-mossy, the sphagnum pillow's thickness is 8-15 cm, in some places the troughs are filled with water. The ALD in troughs is 52-59 cm, in 0.5-1.0 m away from water – 62-67 cm. Vegetation cover of the troughs of the fire-affected site is sedge-moss with 5-10 cm thick sphagnum pillow; sometimes there are dwarf birch, ledum and lichens. The ALD is

42-49 cm, along the sides of troughs overgrown with lichen, dwarf birches and cloudberries it is 61-79 cm.

Repeated topographic surveys will give an opportunity to reveal the decrease of the polygons' area in favour of troughs and to see the general dynamics of the surface. Repeated measurement of the ALD as well as establishment of such sites in peatlands at a distance from roads will help to completely analyze the combined influence of climate and technogenic factors on the dynamics of the ice wedges thawing in that area.

THE TEMPERATURE REGIME AND DEGRADATION OF PERMAFROST IN THE EUROPEAN NORTH

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Current climate changes have a very significant effect on the permafrost temperature and active layer thickness. Almost everywhere in the European North due to climate warming we observed the degradation of the cryogenic natural landscapes – increasing the temperature of the permafrost and the reaching the critical depth of thawing followed by the formation of closed taliks. As a result of years of observations the important patterns of transformation in the cryogenic landscapes were observed:

1. The trend of changes of mean annual air temperature (MAAT) for 32-year period is 0.09°C/year. The duration of the warm period increased by 2 weeks and annual precipitation increased (by 100 mm).

2. For Bolvansky and Shapkina sites the rate of permafrost warming in terms of natural landscapes in the south tundra falls behind the rate of climate warming by 2-8 times and change in a variety of landscapes from 0.04°C/year to 0.01°C/year.

3. In case of anthropogenic disturbance of the surface the major role in changing permafrost temperature regime play the lack of vegetation cover, changing the micro-relief of the territory, the character of wetting the surface and conditions of snow accumulation. Disturbed areas are experiencing an increase in the amplitude of fluctuations of soil temperature in the upper horizons, increase in thawing depth, formation of closed taliks up to 3-5 m depth. With the disruption of the natural surface of the landscape, the trends in increase of mean annual permafrost temperature (MAPT) increase dramatically and reach of 0.06°C/year.

4. The results of the monitoring of seasonal thawing of the layer indicate the increase of its capacity. In recent years, the thawing depth reached its critical value and in certain landscape conditions closed taliks and intrapermafrost area began to form. Thawing of the frozen ground from the surface starts in the tundra areas located on hilltops and formed by low icy clay loam or sand. Areas where the surface lies the icy peat stay in a frozen state and remain for now the most stable cryogenic landscapes.

5. In most cryogenic systems of the European North due to climate changes the average temperature of permafrost at the depth of 10 m has become equal to or higher than 1°C. Further increase in permafrost temperature has slowed down, because in the upper horizons started phase transitions in soils and permafrost thawing.

6. In all surveyed boreholes quasi-stationary temperature regime was observed in the thickness of the permafrost, which is typical for transient unstable state of frozen ground.

7. It was found out that during thawing of permafrost thermal economy is absorbed mainly in the active layer, there is the attenuation of seasonal fluctuations at depths below 3 m.

8. The climate change has initiated preparations for the permafrost degradation and thawing from the surface.

9. To assess the result of the joint impact of climatic and anthropogenic changes in cryogenic landscapes it is necessary to expand the monitoring network to involve automated methods of collecting information, extensive use of remote sensing, including geophysical methods to determine the parameters of permafrost.

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EFFECT OF CONVECTIVE FLOWS OF WATER AND AIR ON THE FORMATION OF THE TEMPERATURE REGIME OF SOILS

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The role of the influence of various natural factors on the formation of the geothermal field is very significant. In this paper, the authors

investigated the effect of infiltration of liquid atmospheric precipitation and condensation of water vapor in the aeration zone (underground condensation) on the temperature regime of soils and rocks.

When water moves in the soils of the active layer, the processes of heat transfer undergo significant changes that require careful study and analysis of the relationship between heat transfer of solid and liquid components. Water, filtered from the surface, is mainly directed downward under the influence of gravity. In the permafrost zone with the direction of water movement, the transfer of heat from the surface to the interface of thawed and frozen rocks coincides. Therefore, the usual conductive heat transfer in soils is accompanied by heat transferred to the soils by water.

In regions with the development of permafrost and deep seasonal freezing of rocks, warm and humid in summer, the relatively coarse composition of loose sediments, the condensation process proceeds quite intensively. Condensation of water vapor is an exothermic process, because of which it acts as a powerful heating factor. Taking this into account, its particularly important importance in the zone of development of intermittent and insular cryolithozone becomes understandable, where the slightest violation of the thermal balance causes a drastic change in the permafrost conditions.

In view of the foregoing, the authors of this article set the goal of obtaining a quantitative estimate of the effect of infiltration of summer atmospheric precipitation and underground condensation on the temperature regime of soils under the conditions of Central and Southern Yakutia.

To achieve the goal, natural and numerical experiments were carried out. The full-scale experiment was implemented from 2014-2016. On the scientific and experimental range "Tuymaada" of the Melnikov Permafrost Institute SB RAS with an artificial increase for precipitation three times on one of the two plots. The second plot was in natural conditions.

In formulating the problem, real features of the freezing-thawing process of various interbedded fine and coarse-dispersed media were taken into account. Typical conditions of Central and Southern Yakutia, taking into account the vegetation cover, were taken for the calculation environment (section).

The numerical experiment was implemented with reference to the natural and climatic conditions of Central and Southern Yakutia, covering only the warm period of the year (from May to September). It takes into

account the main processes taking place in nature (natural precipitation, evaporation from the surface and underground condensation). The options are compared with natural conditions (natural precipitation) and with additional irrigation, and taking into account the condensation in these two variants.

As a result of the full-scale experiment, we established that the lithological composition of the rocks is of great importance for their filtration properties, thereby contributing to the formation of the thermal regime of the soils. The conducted field experiment in the area of sandy soils of Central Yakutia (Tuymaada station) showed that the depth of penetration of the influence of infiltration of summer atmospheric precipitation can be traced to a depth of 5 m.

The 3-fold increase in the amount of precipitating summer precipitation leads to an increase in soil temperature at different depths from 0.2 to 2.3 °C.

As a result of a numerical experiment, we have established that underground condensation is of great importance in the formation of the temperature and humidity regime of soils. Especially in conditions with a lot of precipitation and a warm, long summer (in South Yakutia). In such conditions, the influence of condensation even exceeds the influence of atmospheric precipitation, because the process of condensation occurs almost constantly. In the conditions of Central Yakutia - this process plays a lesser role in the formation of the temperature regime of soils, although, due to underground condensation, the rock temperature rises to 1.5-2.0 °C. Especially where sandy soils are common.

This makes it necessary to take into account the processes of infiltration of liquid atmospheric precipitation and underground condensation in various calculations.

THERMOKARST LAKE AND BAYDZHERAKH AREA CHANGES ON YEDOMA UPLANDS, YAKUTIAN COASTAL LOWLANDS: REPEAT INVENTORY USING HIGH RESOLUTION IMAGERY

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Yedoma deposits are widespread on the lowlands of North-East Siberia. Besides the large fraction of polygonal ice wedges and intrasedimentary ground ice, these mostly silty Late Pleistocene sediments contain considerable amounts of buried and well-preserved organic matter. The very high total ground ice content of up to 90 % by volume renders Yedoma deposits extremely vulnerable to climate warming. Widespread ice wedge degradation throughout the Arctic (Liljedahl et al. 2016) resulted in relief changes on Yedoma uplands such as land subsidence, formation of baydzherakhs (thermokarst mounds) on slopes, and alterations of pond and thermokarst lake areas (Günther et al. 2016). In order to track dynamics of these processes in the tundra zone of the Kolyma lowland at Cape Maly Chukochy, located in the East Siberian Sea coast (N 72.08°, E 159.9°), we used a set of very high resolution remote sensing imagery (GeoEye, WordView-2, and historical air photos). The study site is located within the Chukochya Yedoma region and characterized by a high areal percentage of preserved Yedoma uplands of up to 60% (Veremeeva & Glushkova, 2016).

Analysis of climatological data from Chersky (about 150 km SE from the study site) shows not only an increase of 2 °C of mean annual but also of mean summer air temperature since the 1960s. Precipitation during summer has slightly increased, but in the last 5 years it has increased twofold when compared to the average trend. This precipitation increase has been also shown for the entire Kolyma Lowland by Sakai et al. (2016). Climate warming resulted in an increase of active layer thickness on Yedoma uplands that has been measured continuously at the study site since 1996.

Yedoma uplands at Cape Chukochy are surrounded by drained slopes and represent flat bogged areas featuring a high number of ponds with an average size of 5-10 and a maximum of 30 m in diameter. These poorly drained surfaces are considered as the only areas for potentially

strong thermokarst development in the future and still cover about 25% of the area. Our image dataset revealed a doubling in the number and areal coverage of ponds from 1972 to 2009 and a further twofold increase until 2013. We also found that the area of lakes that formed within Yedoma deposits increased by 7-10 % while the area of residual lakes in Alas thermokarst depressions decreased. Geomorphometric analysis of a detailed DEM created from WorldView stereo imagery shows that the bottom of thermokarst lakes that completely fill out their own depression, extends down to the lower base of Yedoma deposits. This suggests that their current growth is mainly of lateral nature and therefore a result of thermoabrasion and thermodenudation along the lake margins. Simultaneously, baydzherakh coverage estimates show increasing baydzherakh fields on Yedoma upland slopes of 20 % by 2013.

This increase of thermokarst ponds number and area, Yedoma lakes and baydzherakh fields highlights the activation and acceleration of ice wedge degradation on Yedoma uplands in response to increasing air temperatures and precipitation in the Kolyma Lowland.

Session 2:
Infrastructure management: engineering and processes

ESTIMATION OF SURFACE SOIL MOISTURE FROM SAR SENTINEL-1 DATA

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Soil moisture is a major factor in permafrost aggradation and degradation. Active microwave sensors such as Synthetic Aperture Radar (SAR) have been used for detecting surface soil moisture. The measurements using SAR polarization data is most accurate and sensitive measurements, because the backscattering properties of soils and vegetation are strongly altered when transitioning between frozen and thawed states. The backscattering strengths of soils and vegetation components increase with water content in thawed state and measured by the active sensors. While in frozen form soils and vegetation have very low backscattering strengths.

We analysed available Sentinel-1 SAR data between 2015-2017. The Sentinel-1 data is C-band SAR sensor. The available data is dual polarization data with repeat pass time of 11 days that indicate seasonal changes in freeze/thaw processes. Using time-series analysis of Sentinel-1 data it is possible to identify spatial distribution and estimation of surface soil moisture.

CONTENT AND DYNAMICS OF MAINTENANCE COSTS FOR THE RAILROAD IN LINK WITH GEOCRYOLOGICAL PROCESSES DYNAMICS

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Spatial distribution of geocryological phenomena and activity of geocryological processes aren't considered in practice of economic assessment and forecasts. Geocryological processes lead to economic losses, outlay and negative profit.They are belong in economical

classification to the cost in use and negative profit that is connected with planned and or force majeure remedial measures, or to capitalizable costs and negative profit, that is connected with actions for the organization of planned or unplanned engineering protection.It is difficult to outlay the size of these expenses and estamate the efficiency of protective and compensating measures in conditions of changing climate and proper dynamics of geocryological processes.

According to "The strategy of development of railway transport of the Russian Federation up to 2030" it is planned to construct over 20,7 thousands kilometers of new lines which essential part will be in the territory of thecryolithozone. Load to the existing lines will increase.Thelack of estimations of maintenancecostsfornew and existing infrastructure doesn't allow to provethe possibility of thesustainable development of Arctic regions of Russiain the conditions of the climate change.

The formation of a coherent assessment of economic costs and losses caused by the development of geocryological processes and a geocryological forecast taking into account changing climatic conditions is the main objective of the study.

On the basis of the field observations executed by the author as a part of works on geocryologic shooting for the first time it is shown that warming of climate leads to lateral reorganization of paragenesis of geocryologic processes without violation of a sploshnost of frozen thickness down on conditionally undisturbed landscapes. Approach to the linear division into districts of transport objects reflecting not only the leading process of violation of geometry of an embankment, but also dynamics of change of the leading processes in connection with climatic changes is for the first time developed, comparison spatially of the attached geoecological information on genesis of the geocryologic processes transforming natural and technogenic landscapes and economic information on repair of the sites of a railway embankment interfaced to them is for the first time carried out. It has allowed giving comparative estimation of cost of engineering protection and cost of annual repair, and the reception of preparation of recommendations about the choice of type and the period of application of engineering protection of an embankment considering the climatic forecast and history of development of geocryologic conditions is for the first time developed.

Economic estimation of cost of maintenance of the road in working order with regular operational negative profit makes 187 253 608 rubles of the Russian Federation. Economic estimation of cost of maintenance

of the road in working order with losses on engineering protective measures makes 512 468 216 rubles of the Russian Federation. The amounts were calculated for 73 years (till 2015). The received results show that application of operational negative profit is economically expedient, but in a due measure, they do not remove the cause of deformation sites, and only help to support iron expensively in working order for the short period of operation. Taking into account increase in volumes of transport transportations, operational negative profit will only grow therefore for further maintenance of the railroad application of engineering protective measures is economically expedient.

THERMOKARST PHENOMENA DISTRIBUTION REGULARITIES INVESTIGATED IN VARIOUS GEOGRAPHIC AND GEOLOGICAL CONDITIONS USING PROBABILISTIC-STATISTICAL METHOD

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The thermokarst phenomena along a 2500 km oil pipeline in the South of the Eastern Siberia and the Far East was analyzed. This both natural and technical system occupies different climatic, tectonic, landscape, and permafrost zones which require a variety of engineering-geological and geodynamic conditions.

Based on a remote sensing data and helicopter visual observation got using special equipment during a three-year monitoring survey (2010-1012), 2146 thermokarst phenomena were identified and mapped. The width of the survey area is three kilometers, therefore the phenomena were investigated not only in the pipeline affected zone but also under natural conditions.

Problems of permafrost process hazard assessment and selection of monitoring places location arises during oil pipeline exploitation in the permafrost zone. Now adays there are no invariable criteria for selection of sites location for thermokarst process monitoring. Due to large number of phenomena identified in the monitoring work it is impossible to equip a site for observations on each phenomenon. The task of representative sites choiceshould be solved usingzoning on the leading thermokarst formation conditions and factors. Probabilistic-statistical method of

thermokarst phenomena analysis on regularities distribution search in various geographic and geological conditions was carried out.

We used large-scale maps of the pipeline area created by IEG RAS as well as a series of small-scale maps of the territory. Average monthly changes in temperature and precipitation for the period from 2009 to 2012 were estimated according to 13 meteorological stations. We also analyzed geological profiles along the pipeline, as well as a map of termokarst process distribution.

Using of independent criteria for territory mapping make it possible to build a model on the basis of a probabilistic-statistical system and to carry out a computational experiment. Regional regularities of thermokarst phenomena distribution in the pipeline affected zone were revealed as a result of this experiment. The experiment was carried out both along the whole pipeline and on its separate parts.

It came possible to determine in which cases thermokarst phenomena can be considered as random event, and in which the interrelation between thermokarst in natural conditions and factors is significant. Numerical characteristic was adopted for the purposes of the investigation. It makes possible to find out correlations that are not random and to determine if the character of the interconnection is direct or reverse.

The analysis show large differences in phenomena distribution and morphological characteristics. All observed thermokarst phenomena were divided into 12 types based on their genetic and morphological characteristics. Phenomena distribution analyses by the types show the irregularity in their distribution. The numerical experiment was repeated for each type of thermokarst phenomena separately.

The dependencies obtained as result became the basis for the territory `zoning and prove effectiveness of the developed method. The developed method can be applied to other long line objects in permafrost zone.

ADDITIONAL COOLING EXPERIMENTS FOR LINEAR INFRASTRUCTURE ON PERMAFROST BASEMENT

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Since 2009 the Novochara railroad office started experimental work at Naledny-Hany (Central BAM) railway. The areas of ground deformation have occupied there 57 km (30% of all length) after inspection of 1.01.2016 г. For 11 years, the number of damaged areas increased 1.5 times, and its total length increased 2.9 times. The task was to stop the degradation of permafrost in the basement of railroad. Three shelters were installed (at 1841, 1835 and 1685 km marks), approved earlier at Tibetian railroad. Resulting cooling effect is enough to protect permafrost from the degradation.

Since November 2013 we start experimental work at underground oil pipeline VSTO-1 to decrease the incoming heat flux from the surface and increase outcoming one – resulting in cooling of permafrost around the pipeline. Two sites were selected - #1 at "Olekminsk" pump station, #2 at 1704 km mark. At site #1 (November 2013 – September 2014) we used snowpack removal during the winter and shielding the surface by polymeric rock sheet (light-gray color) at summer time. Resulting decreasing of active layer for one year was 1.66 m (40%), followed by decreasing of ground temperatures at 3.5 m depth for 0,7 – 4,5C^{o}.

At November 2014 polymeric rock sheet have been changed to shields (1.5 and 0.5 m height).The cooling was more effective, and ground temperatures (1-4 m depth) at mid-April 2016 was 4,3-2,6^{o}C lower compared with undisturbed site. At mid-September 2016 the temperature difference was 6,2-3,0^{o}C. The permafrost degradation was stopped, the upper permafrost boundary raised to 3 m, the active layer freezing time decreased for 20 days. On the undisturbed site the degradation continuing, the upper permafrost boundary is at 4.8 m depth, the talik is 2.5 m thick.

At site #2 for the period March 2014 – December 2015 the unfrozen areal under shelter decreased to 2-2.5 m, comparing with 5 m at unprotected area. The active layer under the shelter completely freezes for 10-15 days, while at unprotected site the 2 m deep talik is present.

The additional cooling of permafrost basement is effective to stabilase the underground pipelines.

EFFECT OF CRYOGENIC STRUCTURE ON THAW SETTLEMENT OF SANDS AND SILTS

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Experimental investigations on thaw settlement of frozen ground, without subdividing into settlement from thawing of ice inclusions and consolidation settlement, were begun in 1933. With this method, it was possible to estimate the total settlement of foundations upon thawing. These early studies on thaw settlement were important and necessary because of the acceleration of engineering activities in the permafrost regions and they remain to be so today.

This paper will discuss the methods and results of the laboratory experiments on thaw settlement of undisturbed sands and silts with a massive cryostructure. The total soil moisture contents in the tests varied from 0.144 to 0.371 (decimal). The sample preparation, testing procedures, and data analysis were performed according to the current standard.

The results of the investigation indicate that the thawing soils of different grain-size composition with massive cryostructures have thaw-strain parameters *(A_{th})* differing by more than one order of magnitude (Fig. 1).

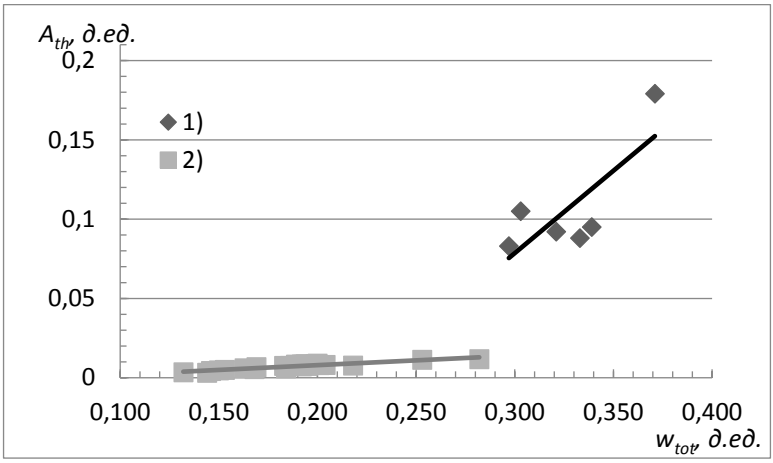

Fig. 1. Thaw-strain parameter A_{th} versus total moisture content w_{tot}: 1) massive cryostructure, clay silt; 2) massive cryostructure, sand.

In this case, it seems likely that thaw strains are dominantly affected by pore size, total porosity, and degree of pore saturation with ice and unfrozen water. The diffuse layer of the unfrozen water contributing to the total deformations of fine-grained, in contrast to sands, also appears worthy of investigation. It is evident from this study that a renewed look is required at the effect of the phase composition of thawing soils on thaw-strain parameters of soils with different grain-size compositions.

TEMPERATURE REGIME OF TUNDRA SOILS IMPACTED BY WINTER ROAD (NORTH EAST EUROPEAN RUSSIA)

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The features of temperature regime in tundra peat and mineral soils in the site crossed by a temporary winter road (North-Hoseda-Yu oil field, North-East of European Russia) have been studied. The effect of the winter road impact on soil thermal state in different landscape conditions of typical tundra subzone in continuous permafrost zone have assessed. The main differences in temperature regime of upper soil layer between anthropogenically disturbed soils (winter road tracks) and undisturbed sites under virgin tundra vegetation have been estimated. Winter, summer and mean annual soil thermal parameters have been studied. Thermophysical properties of soils (the amplitude of seasonal temperature fluctuations, phase shifts, averaged coefficients of thermal diffusivity) have been calculated.

It was found that non-intensive exploring of winter roads in the tundra landscapes with continuous permafrost, accompanied by disturbance of soil-vegetation cover, results in changes in the soil temperature regime. Road tracks are characterized by changes in thermophysical properties as well as winter and summer soil temperature parameters. Winter road making through the shrub tundra sites enhances the soil winter cooling resulted from the destruction of high shrub layer, which naturally contributes to snow accumulation. Whereas, in dwarf-shrub sites, winter road occurrence favors more intensive snow accumulation in road tracks. During the summer, a warming input is rather weak in the road soils.

Disturbed soils of winter roads are characterized by greater asynchrony and damping rate of temperature fluctuations, lower coefficients of averaged thermal conductivity in comparison to the virgin soils. Thus, the winter road impact on the temperature regime depends on the landscape type, that is reflected in the parameters of the mean annual soil temperatures. Mean annual soil temperatures, mainly reflecting the specific of the winter soil climate, are lower in anthropogenically disturbed soils of shrub tundra, and higher in the soils of winter road crossing dwarf-shrub sites.

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PROSPECTIVE DIRECTIONS FOR GEOTECHNICAL MONITORING DEVELOPMENT IN PERMAFROST

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One of the most important strategic goal these days is arctic reclamation. Coastal territories that provide access to ports, roads, settlements, business enterprises, roads and other infrastructure elements are also part of the Arctic territories. Permafrost is one of the aspects of the Arctic territories. About ¾ of Russian territory is a permafrost zone.

As is known, the main risks for structures are associated with permafrost temperature dynamics and a relation of temperature and frozen soils strength. Usually the thaw settlement is considered the main risk factor. However, for example a loss of adfreeze strength with an increase of its temperature by a fraction of a degree can differ many fold. Such change can lead to a loss of foundation stability, structure deformations and accidents.

Geotechnical monitoring (GTM) is aimed to prevent risks associated with permafrost behavior at infrastructure facilities. GTM includes regular monitoring of soil temperature, position of foundation elements, etc. GTM has been mandatory in designing and maintaining objects on permafrost in the past few years. GTM results gave an opportunity to determine main directions of GTM development. GTM results gave an opportunity to determine main directions of GTM development.

One of such directions is undoubtedly an upgrade of equipment used for GTM. Systems of higher accuracy, automated, autonomous, using new measurement principles are needed today.

However, in addition to collecting quality information, current task is to use the data effectively. For example, using monitoring data for a quick prediction of negative geocryological processes development permits not only to reduce consequences of such changes but also to determine the cause of permafrost state deviations from the project and to develop strategy of risk elimination.

It is necessary to create modern geotechnical passports for objects, which would include a geocryological model for carrying out such forecasting. The model should include data on physical-mechanical and thermal properties of soils, data on heat exchange at the surface of a soil, and so on. Accumulated GTM data allows us to refine and correct the geocryological model. In turn, real-time analysis and forecasting of a geocryological situation become possible due to the use of an accumulated GTM database by simulating the processes on the geocryological model.

The introduction of such approaches to production can significantly increase the degree of facilities reliability, increase operational safety and reduce costs for accident elimination.

COMPUTER SIMULATION OF THERMAL REGIME OF SOIL FOUNDATION OF POWER-GENERATION BUILDING AT VORKUTINSKAYA COMPRESSOR STATION #4

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One of the biggest challenges in the comprehensive development of the Russian North, where soils are mostly permafrost, is the reasonable choice of the foundation design Principle for permafrost regions: it is permitted either to keep the ground frozen (the 1st Principle) or to use the base in a thawed condition (the 2nd Principle). The Principle must be selected upon the permafrost prediction. Such a prediction is a ground temperature forecast made with regard to multiple factors, such as geological structure, initial temperatures of geotechnical units, weather conditions, thermal effects of buildings and structures during operation.

Making a permafrost prediction causes a number of difficulties. In the absence of an analytical solution engineers are forced to use specialized software packages capable of solving the problem effectively by means of numerical simulation.

One such example of using specialized computer programs to design structures on permafrost is the large-scale construction of the Bovanenkovo–Ukhta gas pipeline system: most engineering companies use the Frost 3D Universal software package for thermal design of the system.

In the report we consider the thermal condition of soils under the power-generation building at the Vorkutinskaya compressor station #4 which is a part of the constructed Bovanenkovo–Ukhta gas pipeline system, given that 2 of the 12 vertical hybrid flat-loop termosiphons are out of order and the emergency horizontal flat-loop termosiphon has been started in order to keep soils frozen. We have performed 15-year permafrost predictions for the horizontal flat-loop termosiphon being on and off. Also we have compared the obtained numerical results with the 2.5-year temperature logs of the monitoring wells in the ground under the building.

We have obtained 3D distributions of the ground temperature for a period of 15 years. It has become clear that if the emergency horizontal flat-loop termosiphon is on, the soil thermal regime will be well-preserved after 15 years, despite of the 2 out-of-order vertical hybrid flat-loop termosiphons. Comparison of the 2.5-year temperature logs of the monitoring wells with our numerical results has confirmed a high accuracy of the simulation.

WATER FILTRATION ROLE IN THERMAL DESIGN OF STRUCTURES ON PERMAFROST

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Filtration of gravitational water through thawed soil is caused by hydraulic-head gradient, by water permeability of soil and by lack of waterproof partition walls.

Considering filtration of ground and surface water through soil is, in certain cases, necessary in computer simulation of ground temperature field.

First, filtration causes karst and suffusion that can be prevented, in particular, by artificial ground freezing. And to make a freezing system efficient, one has to design it taking the natural filtration velocity field into account.

Second, water is a heat transfer fluid and therefore ignoring filtration may reduce the accuracy of permafrost prediction. Depending on whether neglecting filtration knowingly leads to an optimistic forecast, it can be necessary to consider filtration.

A computer model of filtration is initialized with engineering research data. This data must include the filtration coefficients that represent water permeability of soils in thawed conditions and also the information about the water level regimes and desirably (especially in the case of surface water) the information about the water flow velocities. Besides, for surface water one needs the information about the natural thermal regime.

In thermal design of structures with sufficiently long operation period it is necessary to take into account global warming, degradation of soil and vegetation, salinization of ground and surface water. One should take the worst-case scenario for the operation period and treat the predicted trends as instant jumps at the initial time.

Global warming raises the level of surface water and causes permafrost loss that should be considered implicitly via increments of the following meteorological parameters: air temperature, radiation balance of the Earth's surface and wind speed in the warm time of year. Snow cover thinning, probable lowering of groundwater level as well as increase of wind speed in the cold time of year are all parts of the optimistic scenario, which, for reassurance, one is advisable to neglect.

Degradation of soil and vegetation contributes to permafrost loss: soil and vegetation provide heat insulation, during the warm time of year plants shade the ground surface and resist the wind and during the cold time of year they keep snow from blowing away and compaction, which enhances the warming effect of the snow cover. In addition, plants harden the soil by root interlock, the plant roots and the soil microfauna improve soil drainage, which reduces ground moisture and hardens the ground.

Salinization of the water filtered through soil is harmful for vegetation and keeps ground from freezing by lowering the freezing point.

The computer simulation of filtration is based on classical equations of mathematical physics. Filtration velocity can be expressed in terms of hydraulic head by the Darcy's law formula. For these

equations the Dirichlet (first-type) and the Neumann (second-type) boundary conditions are applied: the annual variations of the hydraulic head and of the inward flux are respectively specified.

The contribution of filtration to heat transfer is modeled by the convective term, added to the right-hand side of the classical heat equation. This term, being the volumetric heat capacity of the moving phase multiplied by the divergence of the temperature flux density, shows that the natural aeration of the soil can be neglected. Indeed, the volumetric heat capacity of air is more than 3 orders of magnitude less than of than the one of water.

Spatial interpolation of the water level in soil as well as computation of the corresponding filtration velocity field can be performed by solving the flow continuity equation.

A sample computer simulation of water filtration through the Vilyuy dam core, being frozen with deep seasonally-operating cooling units, will be considered in the report.

GEOCRYOLOGICAL CONDITIONS OF THE UPPER KOLYMA RIVER

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As a result of anthropogenic impact on cryolithozone, including land development at industrial sites, there are disturbances of permafrost, which causes the activation of exogenous processes – the main reason for the high accident rate of structures. Researches for foundation of the mining factory and its territory were held in Magadan region (Omchak river valley) in September 2013. Researches included drilling of wells and measuring the temperature of ground base.

Kolyma river headwaters are located within the midlands and can be characterized by continental climate with harsh snowy winter and short cool summer. The average annual long-term air temperature is –11,7 °C.

Research area is located in the region of continuous permafrost; its thickness varies from 60 m in the river valleys (Omchak river) and 300 - 400 m in the watersheds. Closed, open and through taliks are developed in river valleys. Stable taliks have a limited distribution: in the Omchakriver floodplain and in the mouth of its inflows: Geologicheskiy, Moroz, Pavlik and others.

The upper boundary of permafrost mainly repeats terrestrial landforms and depends on the exposure of the slopes, lithology, thickness and water permeability of unconsolidated sediments, the presence of vegetation and proximity of surface waters.

Temperature of sediments ranges from –0.1 to –5,4 ºC. Field investigations have shown that at a depth of 10.0 m, the temperature was –0.7 ÷–3,2 ºC, with an average of –2,4 ºC. In some drills lenses and interlayers of ice were found at depths of 0.2 - 14.5 m, the thickness of these layers is up to 0.1-4.9 m.

Ice content and the formation of cryogenic textures in sediments is determined, primarily, by their lithological composition, and within the same lithological group - with its genesis. In general, fine-grained soil is characterized by a decrease of ice content from fine sediments to macrofragmental and from the top to the bottom of the section.

Technogenic soil composed with rubble, gruss, gravel and pebbles with sand (rarely - loam filler), is characterized by the ice content in the range of 0.05 - 0.45 (this band is associated with poor sorting of a bulk material); cryostructures are mainly massive and crustal.

Bedrocks are presented with siltstones, sandstones, granodiorites, eruptive breccias, rhyolites with various fractures and strengths (from lower to very solid), with low ice content; within talik zones - thawed.

Investigated areas are characterized by widespread manifestation of exogenous processes. On slopes there are solifluction, frost fracturing and soil swelling, thermokarst processes associated with the melting of ground ice and frost erosion of bedrock. In the riverbeds of various creeks and Omchak river there are lateral erosion and icing, erosion of river banks and flooding of lower areas during snowmelt and prolonged rains, swamping of wetlands on floodplains and fluvial terraces.

STOHASTIC TIME-SPACE MODELING AND EMPIRICAL VERIFICATION OF THE LACUSTRINE THERMOKARST DYNAMICS

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Nowadays an expanding engineering activity takes place across the entire permafrost zone especially in Siberia. First of all these are linear structures such as pipelines and roads, which are being constructed. So it is very important to determine the thermokarst hazard using stochastic modelling.

Base stochastic model.

We have already developed a stochastic model of the thermokarst lakes appearance (Victorov et al. 2012, 2015). This model is based on following assumptions: appearance of initial thermokarst depressions is stochastic and happens independently at non-adjacent areas. The probability of every depression appearance within a study site depends exclusively on the site area; the depression size growth is independent due to the thermoabrasive action. The growth is proportional to local heat accumulation and is inversely related to the depression lateral surface area. Mathematical basis of the model is fully shown by Victorov et al. (2012, 2015). This model needs empirical verification and this is the aim of the research taking a certain site with significant thermokarst dynamics.

One of the main consequences of this model says that area (squares) of thermokarst depressions should fit the lognormal distribution at every moment we measure. Another main consequence is that the difference between natural logarithms of the measurements should fit normal distribution.

Data and methods

We selected a sample site in Central Yakutia region, 165 km south east from Yakutsk city. Central Yakut Site has MAAT -7 °C, ground temperature -2-4°C, mean annual precipitation 260 mm and permafrost thickness up to 300-400 m. The main site is located at terraces of the Amga river.

We have got two space images for different dates: 08.08.1969, Corona, 2.1 m/pix and 21.09.2009 GeoEye-1 image, 0.5m/pix. GeoEye images are provided by R&D Centre "SCANEX". The orthorectification and correlation of satellite images is performed by Scanex Image Processor v. 3.5.0.

Interpretation is done by hand-recognition method. The whole testing area is 253 square kilometers. 310 lakes with average area about 6000 square meters are found in 1969; 478 lakes with average area 7100 square meters are found in 2009.

We take into account lakes existed in 1969 and expanded to 2009. So only 215 lakes are chosen for testing at this site.

Main findings

We tested thermokarst lake areas both in 1969 and 2009. Lake areas of both dates separately fit lognormal distribution.

We tested also the difference between the natural logarithms for the both dates. This difference fits normal distribution.

So we can conclude that the first verification of the model is successful. We are planning to continue our research.

MAGNETIC MEASUREMENTS IN PERMAFROST, LENA DELTA CASE STUDY

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Magnetic survey could play an important role in integrated geophysical studies of permafrost. It is a rapid and efficient method of revealing such objects as ground ice, polygonal structures and other frozen ground inhomogeneities. Magnetic susceptibility of permafrost is closely related to its ice content and mineral composition. This allows mapping of upper layer structure with high-precision magnetic survey. Similar technique is widely used in archaeology and agriculture but poorly developed in permafrost research.

The work is dedicated to magnetometric studies experience in Lena Delta in 2016. Testing areas on Holocene deposits of Samoilov Island and

on Yedoma Ice Complex of Kurungnakh Island were studied with high-precision magnetic survey. Ice content distribution and mineral composition features were revealed in anomalous magnetic field. Negative magnetic anomalies of several nanoteslas distinctly mark polygonal-wedge pattern. Deposition zone on the slope of a thermokarst depression (named "alas") is observed as a band of positive magnetic anomaly with more than 15 nT magnitude. 18 sampling points up to 1 m deep were made within studied areas and in vicinity. Typical values of permafrost magnetic susceptibility in its frozen state are about $0.5\text{-}0.7 \cdot 10^{-3}$ SI units. Inverse relation between magnetic susceptibility and ice content was verified in permafrost samples. Magnetic data was combined with shallow ERT and GPR surveys. Spatial correlation was found between high resistivity, low permittivity and negative magnetic anomalies. Such zones were interpreted as ice wedges or zones with high ice content. High-resolution aerial photography was conducted with UAV and 3-dimensional digital elevation model was built. This allowed to locate observed anomalies spatially. Hidden ice wedges within the Ice Complex were observed neither in relief nor in vegetation, but they were easily revealed in anomalous magnetic field. Numerical method was used for magnetic anomalies interpreting. Forward magnetic modeling was made to fit anomalous magnetic field within studied areas. One-layered model was obtained for polygonal ice wedges in Holocene deposits on Samoilov Island and two-layered (with Holocene and Pleistocene generations of ice wedges) in Yedoma Ice Complex on Kurungnakh Island. This data falls in a good agreement with direct measurements of other researchers.

Obtained results show high efficiency of magnetic survey for engineering or scientific studies in permafrost. Shallow ground ice can be easily found by the method if needed. Ice content distribution can be mapped before sampling for its better representativity and for an upscaling of sample analysis. Besides that, quantitative estimation of ice content in upper layer can be done on the basis of magnetic data, modeling and sample properties. It is important in the light of permafrost degradation prognosis and, hence, climatic change.

3D GPU-BASED NUMERICAL MODELING FOR INTERPRETATION OF ELECTRICAL RESISTIVITY TOMOGRAPHY DATA, A RUSSIAN ARCTIC (LENA DELTA) PERMAFROST CASE STUDY

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A great importance of research in Arctic region is because these high latitude areas strongly contribute in global climate processes. Arctic tundra holds colossal deposits of unprocessed organic matter that is conserved in permafrost. When thawed this organic matter rapidly transforms to CO2, methane and a number of other gases, but generally speaking, only first two are under the climate scientist's spotlight. Permafrost in the Arctic thaws due to many reasons, but one phenomena is of great interest to us: a talik. Talik usually forms below large water bodies like thermokarst lakes and river channels. Its sophistication in terms of contribution to climate processes lies in talik's invisibility to a naked eye. It evolves, sometimes grows bigger, sometimes shrinks and all this happens below ground. Greenhouse gases are then emitted through the surface of a parent water body. In the past years there was a strong scientific effort directed to talik research: many models were created, on-site studies were conducted (drilling, geophysics) and certain understanding of talik formation process has been achieved. However there are still many questions out there and one of these questions is "what is the spatial configuration of a talik?". High-resolution geophysics is able to address this issue. In our case, electrical resistivity tomography is a weapon of choice.

Electrical resistivity tomography (ERT) is a cutting edge geophysical method that incorporates many useful traits such as high resolution in comparison to standard vertical electrical sounding, light weight, high informational value and relative easiness of data interpretation. Lightweight favors ERT intensive use in Polar studies, because heavy equipment is always a problem there. However, there are some not entirely obvious drawbacks attributed to this method and its usage: tendency to 2D interpretation of data (mainly people's mistake) and method's high sensitivity to surface and subsurface features. Latter being both method's strong and weak side. We can say that it is in part a

weak side because when an object with largely different physical properties is present aside of the survey line, there is a high chance that it will have its imprint on acquired data while field engineer or analyst will fail to take it into account. This is highly relevant to conductive large bodies that can produce unexpected low resistivity anomalies in electrical cross sections even at substantial distances.

The abovementioned problem is especially important for Polar Regions studies due to extremely high contrasts in resistivity values (You et al. 2017) that are usually observed there. Our group have noticed this phenomenon during year 2014 study of a thermokarst lake (Fish Lake) on the island of Samoylov at Bulunskiy ulus, Republic of Sakha (Yakutiya): inversion data showed large conductive anomalies under the lake, which seemed very much like talik. It was important in this study to clarify if the low resistivity zone in our cross section is indeed a subsurface feature or is it the influence of a large conductive water body. To resolve the issue we used our own high performance 3D numerical modeling software and calculated different models finally proving, that the observed effect is indeed mostly attributed to the water body and not the talik itself.

During 2016 expedition we have managed to do a survey on a very interesting object: a saddle-like structure that separates two thermokarst lakes from each other. The structure is a remnant of yedoma currently eroded by both lakes and their eventual merging is the most probable outcome. The most interesting feature of the ERT data that we have managed to acquire on this object is a low resistivity anomaly that is sitting inside of the yedoma sediments. This anomaly strongly resembles talik, however its presence (if proved true) means that talik can spread much sideways from the lake rim, which is currently a debatable question. To eliminate surface effects from large water bodies we once again used 3D numerical modeling and determined if there is indeed a talik or this anomaly has originated from lateral object.

Session 3:
Life in permafrost

LONG-TERM STABILITY OF GROUND ICE IN MCMURDO DRY VALLEYS, ANTARCTICA AND IMPLICATIONS FOR MICROBIAL PRESERVATION

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This study culminates a study of ground ice stability in Beacon Valley, Antarctica that involved David Gilichinsky and Viktor Sorikovikov during the field season of 1998 and we acknowledge their contribution and inspiration.

Periglacial processes are driven by the physical and chemical processes of ground ice. One area of ground ice that has gathered much interest is the long-term stability of ice in permafrost; this ice is a record of climate stability and the chemical composition of the ice serves as a paleoarchive of past environmental characteristics. Furthermore, ground ice is a reservoir of water and may be an extreme habitat.

Ancient ground ice has been of interest both in the Arctic and Antarctic primarily as a testimony to the long-term presence of permafrost conditions. A massive ice body buried under several decimeters of dry regolith in middle Beacon Valley was initially assumed to have present since the Miocene; however, this contention has always been controversial. We support an age of several Ma and this is significant since this remains as the oldest known ice on Earth. Our study combines the physical and chemical study that includes a long-term microclimate monitoring and analysis of several permafrost cores.

Vapor diffusion models suggest that ground ice in middle Beacon Valley is not stable under current climate conditions. To better understand the controls on sublimation rates and ice stability, this study employs an enhanced vapor diffusion model utilizing climate and soil temperature data from 1999 to 2011, as well as field measurements of episodic snow cover and snowmelt events that have not been represented in previous models. The model is then used to reconstruct the sublimation history over the last 200 ka using paleo-temperatures estimated from the Taylor

Dome ice-core data and a new empirical relationship between atmospheric temperature and humidity derived from our meteorological records. The model quantifies the impact of snow cover and snowmelt events accounting for a nearly 30% reduction in ground ice loss in Beacon Valley; the modeled rate averages 0.12 mm_{ice} a^{-1} between 1999 and 2011. This current rate is approximately 3 times faster than the long-term rate estimated from a vertical profile of cosmogenic nuclide concentration in an ice core from the study site in Beacon Valley (0.04 mm_{ice} a^{-1}), which in large part reflects the general warming over the last 20 ka. Parameterized with past environmental conditions, the modeled sublimation rate around 20 ka in Beacon Valley averages 0.05 mm_{ice} a^{-1}, which is remarkably consistent with the rate estimated independently from cosmogenic isotopes that have accumulated within quartz grains in the ice.

Another permafrost core collected in lower Beacon Valley reveals the same isotopic signature, as the middle Beacon ice suggesting the same origin as the ground ice in middle Beacon Valley. The ice show no fractionation below 7 m but significantly deviates from the global meteoric water line above 7 m, suggesting that substantial evaporation has occurred above this depth. This activity is further indicated by dolerite weathering occurring above 7 m only with little change below 7 m. Likely this is due to annual temperature fluctuations above -20 C about 7 m. This may also suggest that biological activity be activated annually as the temperatures warm and water is more available. These data may help explain the relatively high counts of microbes that Gilichinsky et al. reported for the Beacon Ice. The younger age would facilitate finding viable bacteria as well as the possibility of microbial activity during annual warming of the ground ice.

ANAEROBIC BACTERIA AND ARCHAEA IN PERMAFROST: LIFE UNDER EXTREME ENERGY LIMITATION

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When considering oligotrophic natural systems such as the permafrost grounds, it is important to bear in mind that our understanding of microbial energy metabolism stems primarily from studying

populations that are characterized by rapid growth, high metabolic rates and high cell densities — characteristics that do not apply to most microorganisms in nature.

Microbiological studies of the permafrost ecosystems showed the presence there of cultivated representatives of all three domains of life (*Eukarya*, *Bacteria* and *Archaea*). However, the question of the metabolic status of cultured and uncultured microorganisms under subzero temperatures and extra low amounts of nutrients remains unclear. The results of the anaerobic prokaryotes diversity research in permafrost are presented. The advantages of anaerobic life style under low-energy environments are discussed.

MINING ANCIENT PERMAFROST IN SEARCH FOR NEW (LIVE) GIANT VIRUSES

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Acanthamoeba species are infected by the largest known DNA viruses, both in terms of particle size (up to 1.5 μm in length) and gene content (up to 2500 protein-coding genes). The existence of such unusual viruses has reopened the historical debate about the living/non-living status of viruses, prompted new theories about their origin, their potential role in the emergence of eukaryotes, as well as the position they should occupy in the Tree of Life.

As of today, the known giant viruses infecting Acanthamoeba belong to five distinct families; in order of their discovery: the Mimiviridae, the Marseilleviridae, the Pandoraviridae, the Pithoviridae, and the Molliviridae. The prototypes of the last two families have been discovered in and revived from a 30,000-year old Siberian permafrost sample from the Kolyma lowland region. *Pithovirus sibericum* combines a giant amphora-shaped virion with a 600 kb AT-rich genome, a gene content more similar to Iridoviruses and Marseilleviruses, and a fully cytoplasmic replication cycle reminiscent of the Mimiviridae. Although isolated from the same sample, *Mollivirus sibericum* is very different with approximately spherical virion (0.6-μm diameter) enclosing a 651-kb

GC-rich genome, and a replication cycle that entirely rely on the transcription machinery of the host nucleus.

Following a presentation of the characteristic morphological and replication features of these two viruses, I will discuss how the use of Acanthamoeba as a bait to revive ancient viruses, combined to large-scale metagenomics analyses of the samples from which they derive, provides a safe way to estimate the possibility that other types of viruses could reemerge as ancient arctic permafrost layers melt as results of global warming or are disturbed by modern human activities.

LIPOLYTIC ENZYMES FROM PERMAFROST MICROORGANISMS

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Siberian permafrost contains the unique microbial community which is adapted to specific conditions including low temperatures, low content of organic matter, small amounts of liquid water and etc. Structural and functional characterization of the proteins from permafrost microorganisms provides a unique opportunity to reveal the mechanisms of their adaptations and to assess ability to cope with various environmental challenges. We have expressed and characterized several lipolytic enzymes from *Psychrobacter cryohalolentis* K5T and demonstrated that they possess unique properties including activity in a broad temperature range and, in some cases, enhanced stability. Furthermore, as a result of the construction and screening of metagenomic libraries from the oil-fed microcosm grown from permafrost soil sample, we have obtained and characterized new esterases belonging to the HSL family of lipolytic enzymes. We have demonstrated that PMGL2 is an esterase which is active in a broad temperature range, with an optimum at 45°C. Its amino acid sequence includes new GCSAG motif with a putative catalytic serine residue. PMGL3 displays temperature optimum at 30°C. Incubation at 50°C led to almost complete inactivation of

PMGL3, while PMGL2 preserved 65% of activity. The results of the study demonstrate that permafrost microorganisms contain lipolytic enzymes with various activity profiles and possess considerable biotechnological potential.

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ANTIBIOTIC ACTIVITY OF MICROSCOPIC SOIL`S FUNGI OF ANTARCTIC

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Many Antarctic microfungal strains, owing to the longtime geographical isolation and extremely severe climate of the continent, have developed peculiar genetic and physiological features. In particular, they are capable of producing secondary metabolites which account for their survival in extremely cold and dry conditions. Among these metabolites new cold-active antibiotics and enzyme may be found. The aim of this work was the screening for the antimicrobial activity of 31 microfungal strains isolated from Antarctic soils ("stone pavements", "ahumic soils", endoliths, soils from moss and lichen cover, gleezems). The objects for the research were strains of *Antarctomyces psychrotrophicus, Ascochyta pisi, Aspegillus fumigatus, Aspergillus sclerotiorum, Atradidymella muscivora, Botrytis cinerea, Hyphozyma variabilis, Cladophialophora minutissima, Cladosporium tenuissimum, Clonostachys rosea, Cylindrocarpon obtusisporum, Epicoccum nigrum, Eurotium niveoglaucum, Exophiala tremulae, Lecanicillium fungicola, Leptosphaeria coniothyrium, Leuconeurospora polypaeciloides, Microsphaeropsis olivacea, Microascus cinereus, Talaromyces flavus, Paecilomyces marquandii, Penicillium roseo-purpureum, P. simplicissimum, Periconia igniaria, Phialocephala lagerbergii, Phoma leveillei, P. violacea, Sarocladium kiliense, Thelebolus microsporus, T. ellipsoideus, T. globosus.* The strains were cultivated on Czapek's agar and glucose-peptone-yeast agar (GPY). The antimicrobial activity was tested against test cultures of *Bacillus subtilis* ATCC 6633, *Aspergillus niger* INA 00760, *Candida albicans* ATCC 2091, as well as Antarctic

bacterial strains: Gram-negative (*Bosea* sp., *Brevundimonas* sp., *Delftia acidovorans, Pseudomonas* sp., *Ralstonia* sp., *Sphingomonas* sp., *Sphingopyxis* sp., *Stenotrophomonas* sp., *Variovorax* sp.), Gram-positive (*Arthrobacter* sp., *Bacillus megaterium*) and actinomycetes (*Streptomyces tanashiensis, S. venezuelae*) at +25^{O}C using the agar block and the agar well diffusion methods.

Antibiotic activity of all strains, except *Hyphozyma variabilis*, was shown to be higher on the rich GPY medium, than on Czapek's medium. Most eurytopic microfungi exhibited only antifungal activity, while psychrotolerant strains (*Antarctomyces psychrotrophicus, Cladophialophora minutissima, Hyphozyma variabilis, Exophiala tremulae, Phoma leveillei, P. violacea, Thelebolus microsporus, T. ellipsoideus, T. globosus*) showed exclusively antibacterial activity. The highest activity (inhibitory zone of 20-25 mm) against *Bacillus subtilis* was exhibited by strains of *Antarctomyces psychrotrophicus* and *Hyphozyma variabilis*. All of the studied strains suppressed (inhibitory zone of 2-15 mm using the agar block method) growth only of Gram-positive bacteria and actinomycetes. Cultural broths of some microfungi (*A. sclerotiorum, E. niveoglaucum, L. fungicola, T. flavus*) slightly (1-2 mm) suppressed growth of several strains of Antarctic Gram-negative bacteria. None of the tested psychrotolerant microfungi inhibited growth *Aspergillus niger*. The antagonistic activity of the Antarctic microfungal strains was well-evident against a wide range of native Gram-positive bacteria, being less evident against the test culture of *Bacillus subtilis*.

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PROKARYOTIC COMMUNITIES IN SOILS OF EAST ANTARCTICA

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The study of bacterial communities from soils with cryptogamic hypolithic horizons in the ice-free landscapes of the Larsemann and Thala Hills in East Antarctica revealed specific distribution of prokaryotes biomass in the soil microprofiles, and potential viability of prokaryotes cells. It was shown that the number of prokaryotes in studied soils was significantly (by 1-2 orders of magnitude) lower, than in soils of the temperate zone and did not exceed 10^8 cells in 1 g: maximum values were registered in the upper organogenous horizons and lowest - in the subsoil mineral horizons. The maximum number of bacteria was detected in organogenous horizons (cyanobacteria-algae-moss biocrusts, peaty horizons), and soil horizons formed under the stone pavements. Considerable part of the prokaryotes was represented by filterable forms. The cells revealed different morphology as studied by TEM. It was estimated for the first time that the number and content of filterable forms of prokaryotes (nanobacteria) was rather high in Antarctic soils. The number of such cells ranged from tens to hundreds of millions of cells in 1 g of soil, and their proportion ranged from 5 to 90% of the total population, which is significantly higher than in soils of the temperate zone. FISH method (fluorescence in situ hybridization) revealed that both bacteria of normal size and filterable forms belonged to the same phylogenetic group. The data confirm the assumption of nanotransformation of bacteria in extreme environmental conditions. The study of taxonomic prokaryotic diversity at the level of phyla indicated on the predominance of *Bacteria* over the *Archaea* domain. Among the *Bacteria* domain the phylum Proteobacteria was dominant. The proportion of the phyla *Actinobacteria, Planctomycetes, Acidobacteri* was lower. Filterable forms belonged to the same phyla. The study of microbial succession, initiated by moistening, showed that the minimum index of the total number of prokaryotes was in the initial (zero) point, and maximum index reached on the 14th day and up to the 60th day, then the number of viable cells gradually declined. In contrast to normal bacterial forms, the maximum index of total number of filterable forms

was determined at the starting point of succession, and then declined. This process was accompanied by an increase in the content of larger cells in size, that indicate on appearance of usual bacterial forms. Estimation of the potential biological activity in studied horizons, using gas chromatography methods, showed that indexes of potential activity of nitrogen fixation, denitrification and production of carbon dioxide and methane were lower, than in soils of the temperate zone. The maximum values of those indexes reached in the upper horizons, with high number of viable prokaryotes and abundant growth of cyanobacterial/algal biocrusts. So, studied soils with cryptogamic hypolithic horizons contained niches, which harbored bacterial communities under the stone pavements, playing an important role in the formation of bio-abiotic profiles.

This study was funded by the Russian Science Foundation, Project No. 14-50-00029 in the part concerning microbiological study, and the Russian Science Foundation, Project No. 14-27-00133 in the part concerning the selection, description and analysis of the soils, and the Russian Foundation for Basic Research, Project No. 16-04-01776 in the part concerning studies of hypolithic organogenous horizons.

Session 4:

Physico-chemical problems of frozen ground

PERMAFROST AGGRADATION AND METHANE PRODUCING IN LOW ACCUMULATIVE LAIDAS OF THE KARA SEA

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During the last decades, a problem of impact of climatic changes on the state and properties of the permafrost region is widely discussed in the literature. Most of these publications were focused on study of the permafrost degradation processes. At the same time, along with the permafrost degradation under continental conditions, the processes of permafrost aggradation have been observed in the modern deposits of the Artic seas.

Modern low accumulative laidas (i.e. tidal flats) are relatively widespread along the Kara Sea coast.

Borehole (69°36`, N 66°49` E) was drilled in 2007 from the surface of tidal flats approximately 12 km south from the Marre-Sale weather station in the area of modern marine sedimentation. Measurements were performed for times per day by autonomy loggers HOBO Water Temp Pro v2 at depths 0.03, 0.6, 1.1, 1.6, 2.0, 2.5, and 3,0 m.

During the drilling at the tidal flats, soil samples were collected for moisture contents, grain size, salinity, chemical composition, and organic carbon content analyses. In 2013, 2014, 2015, and 2016, additional boreholes were drilled at the same point, and soil samples were collected to determine concentration and isotopic composition of methane using a "head space" method.

Detailed long-term temperature measurements in the upper permafrost of the tidal flats allowed us to determine main features of the thermal regime. Temperature distribution with depth measured at the beginning of every month indicates that the depth of zero annual amplitude of temperatures of freezing sediments was 3 to 4 m. Mean annual temperature of frozen soils at 3.5 m varied from -2.0 to -3.9 ^{o}C.

Low tidal flats are the area of active methane producing due to activity of anaerobic bacteria, which is confirmed by isotopic

composition of methane: $\delta^{13}C$ (CH_4) values vary from –64 to –79 ‰. Analysis of distribution of methane concentration with depth indicates increase in concentrations upwards from the base of the active layer (~1.8 m).

Based on distribution of methane concentration with depth, we can conclude that the soil temperature of -3.5 to -4.0 ^oC is a threshold for bacterial methane production in conditions of tidal flats of Western Yamal. Methane cannot be produced in frozen saline soils when the temperatures are below this threshold. Frozen soils contain only preserved methane which was produced before the permafrost aggradation.

The study was supported by the RSCF grant #16-17-102. The data on soil properties were obtained during the work on the RFFI project #16-05-00612.

METHANE IN FROZEN DEPOSITS OF THE WESTERN SECTOR OF THE RUSSIAN ARCTIC AS A RISK FACTOR OF NATURAL DISASTERS

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Methane in permafrost Pleistocene and Holocene sediments of the western sector of the Russian Arctic (the coasts and shelves of the Kara and Barents Seas) is a potential factor in forecasting of natural disasters. The identify areas with potentially high risks of natural disasters related to methane emissions is actual scientific task. The solution of this problem will help to decrease the risks associated with industrial development of the Arctic Regions. The effects associated with methane emission from permafrost on global climate system and as a factor potentially increasing the risk of natural disasters are of considerable importance in recent years and bringing attention of mass media, policy makers and scientific community.

A striking example is the formation of deep craters as a result of explosive methane emissions in Yamal, Gydan and Taz Peninsula. The nature of these catastrophic phenomena is under discussion in the scientific literature. The forecast of such catastrophic events should be

based on comprehensive investigations of methane occurrence and distribution in various types of Quaternary sediments, and on the analysis of changing climatic conditions and other environmental and anthropogenic disturbances that may trigger such catastrophic events.

The existing data on methane occurrence mostly available from the permafrost formed in the terrestrial sedimentation environment, however permafrost sediments of the western sector of the Russian Arctic are primarily of marine genesis. Our initial investigations show that methane concentrations in frozen marine sediments is an order or two magnitude higher than in terrestrial counterparts. Abnormally high concentrations of methane are found in ice-wedges and massive tabular ground ice. The key profiles established in Bolvansky Cape (Pechora River mouth), Yamal Peninsula and Western Taymyr. All key profile sections have full representation of the characteristic sedimentation types of sediments formed in the Pleistocene and Holocene.

Hazardous areas with potentially high risks of natural disasters related to methane emissions were defined based on the highest observed and projected rate of climate change or temperature of the seabed, and on high methane content in frozen sediments on coasts and shelves.

The study is supported by RFFI grant № 16-05-00612.

PERMAFROST COASTAL CONTRIBUTION TO THE CARBON FLUX TO KARA SEA, KHARASAVEY SETTLEMENT, WEST YAMAL

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Because of erosion along the Arctic coast, deposits of coastal bluffs previously preserved in the permafrost state erode into the shallow waters of the coastal zone. The organic carbon contained in these deposits can be degraded and converted to greenhouse gases, serve as a source of metabolic energy for primary production in marine ecosystems, be buried in marine sediments, or be transported out of the shallow water zone. Calculation of the volume of organic carbon entering the coastal zone during the erosion of the coasts is the basis for the quantitative and qualitative characterization of this part of the organic carbon cycle, which

is essential to determine pathways for further conversion of organic carbon.

Around the Kharasavey settlement on Western Yamal a monitoring network for coastal dynamics exists since the beginning of the 1980s. Abrasional coastal bluffs up to 12 m high between Kharasavey settlement in the north and Cape Kharasavey in the south (9.5 km) were studied to define the geocryological composition of the sediments exposed in cliffs. Various sediment strata were identified. Sediments of marine origin are predominant here. Total organic carbon (TOC) contents in sediments of various composition and origin were determined (34 samples). Based on a comparison of Corona (1961) and World View 2 (2016) remote sensing images, average coastal retreat rates over the past 55 years were obtained.

For the calculation of carbon flux, we used data on extent of various deposits, their ice content and density. Preliminary calculation of TOC input over the past half-century yielded values on the order of 50 t per year and km of coastline, which is lower than our previous estimates made for the period 1994-2008 (67 t / yr · km). The difference can be explained by the increase of Kara Sea coastline retreat rates in recent decades due to the increased influence of air temperature and wave energy. Over the last few years the rates of coastal retreat have remained high, as well as the mass of TOC transported to the sea.

The work was supported by Russian Foundation for Basic Research, projects 16-35-60099 mol_a_dk. The study was conducted in accordance with a theme AAAA-A16-116032810055-0 "Geoecological analysis and forecast of the dynamics of the permafrost zone of the Russian Arctic". World View image have been provided by Digital Globe Foundation©. TOC analysis was conducted in the laboratory of Alfred Wegener Institute, Potsdam, Germany.

GEOCHEMICAL CHARACTERISTIC OF ALLUVIAL SEDIMENTS IN URBAN AREA OF YAKUSK

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Yakutsk is the most populous city of the world, situated in the permafrost zone. The thickness of the active layer in Yakutsk is 1.6-2.0 m (and up to 2.5 m in places) for sandy-loam, and 1.5-1.7 m (up to 2.0 m in places) for loam.

The Holocene alluvial deposits, from which hypergenic weathering products are derived, are slightly acidic, mixed-cation sulfate-bicarbonate type with approximately equal concentrations of ammonium and chlorides and low salinity, 0.025%/100g. The Quaternary alluvial deposits within Yakutsk are geochemically specialized for lithophile and chalcophile elements - B, W, Pb, Ti, Sn, Mo and Ag, whose concentrations are 1.2-2 times the natural abundance values. The alluvial sands and silts are poor in V, Co, Ni, Cu and Hg.

Geochemical modification of the technogenic deposits is greatest near the surface where the contrast of the chalcophile (Hg, Zn, Pb, Ag, Tl) and lithophile (B, Ti, Mn, Y) groups has significantly increased under the influence of anthropogenic impacts.

The technogenic deposits have elevated pH, increased salinity with higher levels of bicarbonates, sulfates and nitrates, as well as anomalous concentrations of heavy metals (Zn, Pb and Hg) exceeding 2-3 times those in the underlying alluvium.

The seasonally thawing and perennially frozen technogenic sediments are virtually homogeneous in geochemistry, but nearly all chemical elements have higher concentrations in the active layer. The nitrate concentration, however, is significantly, almost an order of magnitude, higher in the permafrost compared to the active layer.

An acidic geochemical barrier develops at the base of the technogenic deposits which may exist under alkaline conditions when strongly alkaline conditions change to weakly alkaline. These barriers concentrate anionic elements, including silica, B, V, Mo, As, S, and Cr, whose mobility are reduced in an acidic environment. The ability of these elements to form soluble anion and complex compounds in the alkaline environment significantly expands the range of their migration in technogenic deposits.

In vertical extent, the chemical anomalies extend throughout the entire thickness of technogenic deposits down to the alluvial deposits. The thickness of technogenic anomalies depends on duration of technogenic impact, concentration and temperature gradient, and depth to geochemical barriers, reaching 7-9 m for Hg, Na, N, S, Cl; and 5-6 m for Ca, Mg, C, V, Mn, Co and Zn.

Geochemical characteristics of perennially frozen alluvial deposits in the area of city of Yakutsk were revealed for the first time. Groups of lithophilic and chalcophilic elements - B, W, Pb, Ti, Sn, Mo and Ag, content that higher than Clark meanings 1.2-2 times, and dominate their chemical composition.

The Russian Foundation of Basic Research (project № 15-45-05050 r_vostok_a) supported the work.

GEOCHEMISTRY OF DEPOSITS AND ICE WEDGE OF KHASYREY ON THE NORTH GYDAN PENINSULA

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The fieldwork was conducted on the second lacustrine-alluvial terrace in the north of the Gydan Peninsula in 2016. Khasyrey (thermokarst lake, drainage, and drained basin) has a diameter up to 0.5 km. It is a lower level of the lacustrine-thermokarst depressions with the numerous lakes. It has been washed out by the Gyda River. The hasyrey has the flat polygons. They have the pentagonal and trapezoidal shapes (15-16 m).

Three layers of sediments are distinguished bottom-up in the section: layer 1 (0.6 m of exposed thickness) – loamy sands and sands with plant remains have ripples lamination; layer 2 (1.5 m thickness) – sands with gray loamy sand interbeds and numerous ferruginous spots, cryoturbations, threadlike roots, massive cryostructure; layer 3 – peat (0.25 m thickness), soil wedge (0.8 m vertical) was filled decomposed black peat.

There were methods of conductometry, ionometry, titrimetry and photometry in the "TyumenPromIzyskaniya" laboratory. Into the B4 section, the composition of the aqueous extract and the granulometric composition of the deposits (6 samples) were determined. Also the hydrochemical composition of the fresh melt of ice wedge was determined from a depth of 1.9 m. The deposits can be referred to the fine-grained sands and sandy loams.

According to the composition of salts, the sediments are ultra-fresh, chloride-hydrocarbonate calcium-sodium. In comparison with sands, the content of organic, sodium, and chlorine is increased in the loams. Iron and ion nitrate content is increased in the sand interlayers over sandy loam bands.

The increase in the concentration with depth was revealed. The analysis of the water-soluble compounds revealed a tendency to concentration increase with stratification depth deeping of the sample. At

depth, the hydrogen bicarbonate content of the ions is 0.45 m ~ 0.004%, at a depth of 1.8 m ~ 0.012%. Calcium and magnesium are increased with depth from ~ 0.001% to ~ 0.004%. The concentration of iron ions, sulfate and nitrate ions are also increased with depth.

Soils are classified according to salinity as non-saline. However, the increase in mineralization with respect to the electrical conductivity and the sum of the cations and anions of aqueous extract in depth, from ~ 0.002% (in terms of NaCl) to ~ 0.013-0.015% has been traced.

The melting of ice wedge is ultra-fresh, chloride-sulfate-hydrocarbonate, calcium-magnesium, with a high content of total iron. The mineralization of ice wedge (31.3 mg/l) is comparable with the mineralization of sandy loam (27.1 mg/l) in terms of the sum of cations and anions. The melting of ice wedge in composition is comparable with the deposits of mineralization, the content of nitrate ions and organic matter.

The water-soluble salt composition of deposits of khasyrey`s section B4 section and ice wedge melt confirms the continental conditions of sedimentation. The content fluctuations of total iron and nitrate ions presumably are due to section structure. The interstratified layers of more clay-bearing soils are waterproof.

Presumably, the increase of mineralization with the depth is associated with the concentration of water-soluble compounds on a geochemical barrier known as a relict melting border.

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Session 5:

Fate of water in subzero areas

MODELLING HYDROLOGICAL PROCESSES AT PERMAFROST MARGIN OF SOUTHERN SIBERIA

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The changes of river runoff, especially low flows are being detected at discontinuous permafrost zone of Eastern Siberia. The reasons of those changes are still unclear because the hydrological regime of rivers at the area of the Baikal-Amur Mainline (BAM) is poorly studied. The aim of the research is to adapt a hydrological model and develop its parametrization based on collected experimental hydrological data for modelling poorly-gauged river basins on larger scales near the southern margin of the permafrost zone in Eastern Siberia.

We used the data of the experimental watershed Mogot located in the upstreams of the Amur River basin. The studies were carried out there in 1976-1983 and later in 2000s. The watersheds of different scale were selected as the objects of our studies from 2 to 4060 km^2.

The process-based hydrological Hydrograph model was used in the study. It explicitly describes hydrological processes in different permafrost environments. The model uses basic meteorological data as the input. The level of model complexity is suitable for a remote, sparsely gauged region such as Southern Siberia as it allows for *a priori* assessment of the model parameters based on field data. The model parameterization was developed according to available quantitative and qualitative data in the Mogot station.

The territory can be divided ito 4 main landscapes: watershed divides, shaded and exposed slope and valley bottoms. Watershed divides with sparse vegetation have well drained soils that prevent any water accumulation. Larch forest on the shaded slopes has thick organic layer. It determines shallow active layer and relatively small subsurface water storage. The soil at the exposed slopes has thinner organic layer and thaws

up to 1.6 m depth. Flood plains are the wettest landscape with highest water storage capacity.

Model parameterization verified at small Mogot watersheds was employed to simulate runoff generation at four river basins with the area from 150 to 4060 km^2 in the surrounded region. The model simulation of river runoff, snow depth, soil temperature and moisture in the Mogot study site and larger basins are satisfactory.

The study shows that the estimation of a model parameters based on the use of field observations instead of calibration is possible even for such remote and data-sparse regions if adequate model algorithms are used. Process based model parameterizations that are confirmed and refined in this basins can be applied for practical tasks and in the studies of climate change impacts.

The study was supported by Russian Foundation for Basic Research (project 15-35-21146).

RECENT RIVER FLOW CHANGES AT THE POLE OF COLD OF NORTHERN HEMISPHERE

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Analysis of daily runoff data for 19 hydrological gauges in the basins of the Yana and Indigirka Rivers has shown the presence of statistically significant ($p < 0.05$) positive trends in monthly runoff in the autumn-winter period. In October, runoff increases at 11 of 19 rivers, in November and December – at 7 and 5 of 11 non-freezing rivers. The trend values in these months are 62% /1.9 mm, 64% /0.4 mm and 84%/0.1 mm, respectively. At 10 watersheds with an area of more than 7,600 km^2, spring flood increases in May with a median trend value of 93% or 7.8 mm. The annual air temperature has risen by an average of 2.0 °C in 1966-2012. The analysis of monthly precipitation revealed the absence of systematic statistically significant trends, however, at some stations in the basin of the river Indigirka a decrease in precipitation in January and February is observed. 5-7 days earlier shift of spring flood dates has been revealed.

The increase of runoff in spring and autumn-winter period may be due to the redistribution of underground water between rivers and aufeises in different seasons of the year. In spring, due to the increase in air temperature, aufeises melting intensifies and increases flood runoff. The changes of ground freezing conditions improve the interaction of underground and surface waters reducing the volume of aufeises.

BEADED RIVER CHANNELS IN THE PERMAFROST ZONE: PAST, PRESENT AND FUTURE

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One of the typical results of the interactions of hydrological and cryogenic processes is the formation of specific small river channel planforms represented by prominent alternations of widened and deepened lake-like pools and connecting narrow runs best termed in the literature as «beaded channels». Beaded channels are widespread throughout the northern hemisphere in permafrost zone and occupy up to 50% of the length of all small watercourses (1-3 orders) of the tundra landscapes.

Our study conducted in Yamal Peninsula (arctic part of Western Siberia) and Central Yakutia (continental part of Eastern Siberia) aims at the revealing of modern processes of beaded channels formation and also reconstruction of its Holocene history. We used pressure and temperature data loggers, automatic photo camera, bathymetry and tacheometry, ground and ice drilling, geophysical measurements, paleochannel analyze to determine morphological characteristics of beaded channels, their hydrological, thermal and ice regime, geological structure, history and causal relationships between meteorological parameters, ice thickness, water, ground and ice temperatures.

We revealed that specifics of the planform and longitudinal profile shapes of beaded channels determine characteristics of their thermal, chemical and water regimes. Deepened lake-like pools («beads») are sufficiently (up to 20°C) warmed during summers and don't freeze over entirely during winters, even under harsh climatic conditions of the Central Yakutia. As a result there is usually a lens of pressurized water

(up to 2-3 m depth) under surface ice underlain by lens (up to 1.5-2 m thickness) of the perennially thawed sediment (taliks). Shallows (runs) freeze up to the bottom and there is no thawed sediment under the channel. Freezing of the pool leads to pressure increasing under the ice cover and ice cracking several times during winter. Biogenic gases release due to ice cracking and, thus, the water enriches by oxygen. It has an important impact on the hydrobionts (minnows, frogs, insects, leeches) overwintering in these pools. Such regime distinguishes beaded river channels from other rivers of permafrost zone. It has important implications for flow discharge regulations and permafrost ecosystems, providing overwintering habitats, biodiversity dispersal, leading to generation and release of biogenic gases into the atmosphere.

Planform of beaded channels also is a good sign of permafrost condition and drainage network development in the past and present. Majority of scientists considers that a significant role in the formation of lake-like pools belongs to thermokarst and thermal erosion processes. However alternative opinions also exist, arguing that beaded channels were formed by freezing over of bedload accumulation forms in channels and «beads» are inherent from the former pools preserved since warmer and more humid period. Preliminary analysis carried out by the authors allows suggesting that beaded channel pattern formation is likely a result of complex processes interaction triggered by decrease in flow discharges caused by natural climate changes in the past. This assumption is based on the fact that small 2-3 order stream channels in Arctic often have a specific transitional meandering-to-beaded form resembling the shape of unconfined meandering rivers, but consisting of «beads» and runs. However, such channels exhibit no evidences of present-day erosion of concave banks and sediment accumulation at the convex banks as typically being observed in normally meandering rivers. The meandering shape of some beaded channels and presence of sickle-shaped oxbow lakes on the floodplain in the absence of modern development of bends indicate that it was formed under different conditions. It can be suggested that their formation occurred under unconfined meandering conditions governed by the greater channel-forming flow discharges. Transition to the beaded channel planform took place only later, presumably as a result of climate changes – reduction of water runoff and increase of the seasonal freeze-thaw depth.

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WATER RESOURCES AND HYDROCHEMISTRY OF THE RIVERS OF CHUKOTKA DURING THE CRITICAL (WINTER) PERIOD

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With a significant amount of data on water resources in the territory of the Chukotka autonomous okrug, there is a lack of new information, especially in the context of warming, winter runoff and hydrochemistry of the rivers in the region. Field hydrological works were carried out in April 2013 in the basin of the Anadyr river, chosen as a reference site. Ice drills were drilled in 6 sections in the middle and lower parts of the rivers Anadyr and Belaya. In each section - from 3 to 6 holes (wells). Measurements of ice thickness, a layer of water under ice were made, samples of water from rivers and water wells were taken for chemical analysis. The mineralization and pH were determined on site. In the polynyas river flows were measured. Data collected from previous years on the freezing of rivers, on winter runoff and hydrochemistry are collected.

The region is characterized by a subpolar and polar climate and is located in the area of continuous permafrost. In the area of the village of Markovo there is a stable through talikal zone with a width of up to 20 km. The water layer under the ice in the upper alignment reached 4.08 m, in the lower - 5.96 m (in April 2013). The width of the bed was 130-140 m. The thickness of the ice was only 0.18-0.92 m. In the polynia 35 m wide and 0.6 m deep, located 7 km below the village, the discharge of the river was 18.7 m^3 / s.

Near the village of Ust-Belaya, the permafrost capacity reaches 170 m. The end-to-end talisman is installed under the riverbed of the Anadyr river. The water layer under the ice reached 3.63 m in the upper alignment (above the village) and 1.29 m at the bottom. The flow rate of the river is 26 m^3 / s.

The Belaya river is the left tributary of the Anadyr river. In winter, the flow of the river does not exceed 2-10 m^3 / s. At the end of winter 2013 the river at 0.7 km above the mouth partially froze, in some parts of the drain there is practically no flow. Measured in April 2013, the flow of the river in the year-round polynyas is very small - 0.033 m^3 / s.

The mineral content of the rivers Anadyr (39.5-82.9 mg / dm^3) and Belaya (57.6 mg / dm^3) during the survey was very insipid. The chemical

composition of surface waters in the area of Markovo and Ust-Belaya sharply differ: in "Markov" water the anionic composition is dominated by hydrocarbonates, in Ust-Belskaya - by chlorides, but also by the presence of a hydrocarbonate ion. "Markovskaya" river water, from the Anadyr river, judging by its composition and mineralization, is closely connected with underground, shallow water. Conclusions. As a result of the works of 2013 it was established that the expenditure of the Anadyr river during the period of the works carried out - the end of the winter critical period, is comparable to the costs measured a few dozen years ago. For the first time, a complete freezing of the Belaya river in the estuary has been established. For many years the mineralization and chemical composition of the surface waters of the Anadyr river are relatively stable. On the Belaya river, the data are sketchy, but the new and identified literature data of previous years suggest the freezing of this watercourse in certain areas.

The obtained material allows us to state that at the end of the critical (winter) period, all the Chukotka rivers with a length of up to 400 km completely freeze or in some areas. The hydrological and hydrochemical parameters of the investigated rivers were used to calculate the standards for the permissible impact on the water ecosystems of Chukotka.

GPR AND TEM INVESTIGATIONS OF HYDROGENIC TALIKS IN THE LENA RIVER DELTA

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Taliks in cryolithozone are subjects of increased interest in hydrological and hydrogeological investigations as they are extremely sensitive to permafrost thermal regime. Electrical properties vary greatly for sediments being in frozen and unfrozen state, so, electromagnetic geophysical methods can be useful tool to recognize taliks. In April 2016 a set of geophysical works has been carried out in the Lena River delta at Samoylov Island and surroundings. Main aims of investigations were: i) evaluation the thickness of underbed talik in the Lena River branches (Olenekskaya and Bolshaya Tumatskaya) and ii) determination of bottom relief and talik thickness at thermokarst lakes of Samoylov Island.

Measurements have been performed by two geophysical methods – Ground Penetrating Radar (GPR) and Transient Electromagnetic method (TEM) with vertical magnetic dipole (square loop) as a source.

GPR works have been carried out with SIR 3000 radar, the main instrument was 200 MHz antenna, being portable and easy to operate. Besides, low-frequency 40 MHz *Subecho* antenna was used, which allowed in some cases to substantially enhance the depth of investigations.

The survey with 200 MHz antenna carried out at Bolshaya Tumatskaya. Branch has revealed the probable talik zone, flanking the channel, and geological interfaces in the onshore part of the section. The thickness of underbed talik could not be detected by GPR operated from the ice surface. Water mineralization is relatively high in winter season in Lena River branches, electrical conductivity of water amounts the value 500 mkSm/cm. This leads to extra damping of radar signal and does not permit to penetrate below 9 meters even with low-frequency 40 MHz antenna.

The survey on Samoylov Island with 200 MHz antenna has allowed to determine the bottom relief of the lakes down to depth of approximately 10 meters, due to low conductivity of water in the lakes as compared with river water conductivity. The use of 40 Mhz *Subecho* antenna has helped to reveal geological interfaces under the bottom of the lakes and to follow boundaries related to talik zones and lithology of the section down to depth more than 30 meters. The thickness of taliks under the lakes can be evaluated as equal to several meters.

TEM soundings have been carried out with TEM-FAST equipment using one-loop array with square loops 50*50 and 25*25 meters. TEM sounding curves obtained in the Lena River delta are everywhere complicated by fast decaying induced polarization (IP) processes, leading to sign reversals of transient voltage responses. This effect was multiply observed in permafrost regions and can be explained only by specific cryogenic structure of frozen ground. The quantitative interpretation of TEM soundings distorted by IP is ambigous without parametric holes.

At sounding curves measured in the onshore part of the profiles crossing Lena River branches ***two*** polarization processes with different characteristic times can be identified. The first one appears in the time range 10-100 mks, the second one – in the time range 100-1000 mks. When sounding array is approaching to the river bank from the land side, the first polarization process becomes less pronounced and completely disappears when measuring on the ice. The second process remains

visible at the curves obtained on the ice in the middle of the stream. This means that permafrost is obviously presented below sub-river talik. Estimates based on the results of numerical modeling give the thickness of talik not exceeding first tens of meters.

At the profile crossing the main Lena River bed IP processes were recorded at the land (flood plain) sites only. The IP influence was completely lacking when measuring above the main stream that points out to the relatively large (more than 50 meters) thickness of sub-river talik there.

Poster session:

THE STRUCTURE, AGE AND GROUND TEMPERATURE OF THE LATE QUATERNARY DUNE MASSIFS IN THE LOW STREAM OF VILUY RIVER (CENTRAL YAKUTIA)

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Completely organized massifs of parabolic sandy dunes (*tukulans*) occupy large areas in the middle basin of Lena river and its left tributaries - Viluy, Linde, Tyung, Blue and others. There are divided on actively moving unvegetated dunes of different hierarchy and more ancient sand massifs, vegetated with pine and birch forests. First one area reaches up to 3200 km^2, the second exceeds of 60000 km^2 in the Region The depth of sediments reaches 20-30 m and more. Dune massifs are modeling the surfaces of different age river terraces, overlap or block of low-ordinal river network of previous cutting stage. Modern drainage system practically undeveloped within the dune massifs.

Dune deposits are composed of fine-grained sands and sandy loams, quartz (74,9-86,5%) and minerals of the light fraction are dominated. There are some secondary minerals (ferromanganese tubes and quartz fulgurites). The average particle size (301±41 microns) in vegetated dunes is almost identical to modern unvegetated dunes (295±29 microns). Both modern and Late Pleistocene aeolian deposits are characterized by similar sorting coefficient (1,6±0,09 and 1,56±0,08), positive asymmetry towards fine fractions, reflecting the predominance of deflation of silt fraction during sedimentation.

Most important features of aeolian origin are specific cross-bedding of the sediments, low humidity and ice content (<5%), high porosity (up to 25%), presence of rhythms of different order (the alternation of deflation and accumulation), vertically buried trunks of trees, soil and peat horizons, syn- and epigenetic sandy wedges ect. An important genetic feature is the predominance of sublimation cryostructures.

Collected C^{14} and OSL dating recognize at least 2 phases of aeolian processes activations in the Late Pleistocene. The maximum development they reached in the range of 20-12 kyr. During the Boreal Optimum (10-5 kyr) main part of dune massifs were vegetated. In the Late Holocene

(<4 thousand years ago) aeolian processes resumed again, dune massifs began to expand in south-east direction, reaching their maximum sizes during the Maunder minimum.

The permafrost of Central Yakutia relates to a continuous type and it is characterized by temperatures -4-5 ° C at the base of zone of annual fluctuations of ground temperature (AFGT). Against this background the tukulans are geothermal anomalies, their temperatures at the base of AFGT are close to zero. Very extensive network of highly watered interpermafrost taliks penetrates the dune massifs, inheriting the buried ancient thalweg net. There are specific lakes, perennial underground water sources, frazils, thermoerosion cirques and cayons are widespread inside of dune massifs and its surroundings. The permafrost and hydrogeological conditions of dune massifs are unique and they are the most favorable in the region for the construction of all types of engineering structures.

The location of dune massifs coincides with the center of the Yakutian (Siberian) Maxima (anticyclone) - the area with the coldest ultra-continental climate of Northern Hemisphere. The annual temperature amplitude at the dune surface reaches 100 °C, and the moisture ratio (0.8) is comparable to the deserts of Central Asia and Northern Africa. The landscapes of contemporary tukulans are characterized by the presence of endemic species and vegetation communities. They are an integrated natural system - a relic of the ancient cryodeserts and the contemporaries of Pleistocene mammoth biome.

The study is continues by the support of RFBR-RS(Y) № 15-45-05129 and RFBR № 17-05- 00954.

ANTIPAYUTA GAS-EMISSION CRATER ON GYDAN PENINSULA: FIRST RESULTS OF FIELD STUDY

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Deep craters in the North of West Siberia are specific objects in permafrost zone first observed in 2014 and later detected on satellite images to form in 2013. Their origin is under discussion yet. Authors hypothesize their formation from gas accumulation and later sudden emission.

Scientific community was informed of Antipayuta gas-emission crater (AntGEC) soon after first Yamal crater was found in 2014. Despite this knowledge, a real opportunity to visit AntGEC with true coordinates and logistic support appeared only in 2016 field campaign.

Our field study of AntGEC included a description of the surrounding area and visible geological section, GPS-survey of crater settings and related surface disturbances, measuring the depth of seasonal thaw, the internal lake bathymetry and water sampling from internal lake and other "knocked out" ponds. We also looked for traces of the initial mound preceding the GEC formation. We collected the willow branches for tree-ring dating of the events preceding the "eruption" using a specially developed technique, tested on willows, collected from Yamal gas-emission crater (GEC-1).

Based on measurements of the depth, bathymetric map of AntGEC was compiled. The maximum measured depth at the crater center was 3.6 meters. Depth distribution was uniform in plan. The estimated volume of lake water was 1642.6 m^3. Water samples were taken at different depths. The water temperature at the time of measurement was 8.8^{o}C near the surface and 7.8^{o}C at a depth of 3 meters.

Preliminary dendrochronological analysis of AntGEC willow from the ejected block with turf showed the age of about 90 years. Annual growth rate of willow on AntGEC location was low (~0.1 mm) in 1918-1947. An elevated growth rate (0.45 mm) is registered in 1948. This increase is chronologically correlated with previously defined increase of willow growth rate on GEC-1 location.

A significant difference between Gydan AntGEC and 3 known Yamal GEC is observed. While Yamal GECs are located on gentle concave slopes, overgrown with a more or less dense willow thickets, predominantly in loamy soils, the AntGEC is located almost on the watershed, although near the drainage hollow, in mostly sandy deposits, one of the walls exposes a hilltop with windblown sandy depressions and sandy section. Shrubs even in the bottom of the hollow form separate sparse groups. Only tabular ground ice close to the surface unites Yamal and Gydan GECs. With these new data we need to adjust our understanding of landscape indicators of terrains potentially dangerous in relation to the GEC formation so far based on Yamal GEC study.

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THE PLEISTOCENE-HOLOCENE RELIEF-FORMING PROCESSES OF THE NORTH PART OF THE PECHORA LOWLAND AND THEIR REFLECTION ON THE REMOTE SENSING DATA

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Remote sensing data application is becoming more widely available in the present-day methods of geocryological investigations and mapping. The Russian European North is the region which causes continued discussions about the Quaternary sediments origin during the last several decades. They are, as the lithogenous basis for landscapes, the major objects of thematic interpretation and geocryological mapping. The chosen concept of the interpreter influences data interpretation and resulting cartographic models vitally.

The co-existence of Late Pleistocene glaciation and sea activity in the region proves the glacial concept. It explains the possibility of marine terraces formation at the drawdown of the sea level up to 100-140 m against the contemporary one. In that case the marine terraces are formed under the influence the glacioisostatic motions. At the same time, the last glacial period was Valdai in European Russia) [Svendsen et al., 2004]. That is, in the absence of glaciations, cryogenesis can be named as the key factor in formation and transformation of composition of rocks, their cryogenic structure, their spreading, the constitution and the thickness of frozen grounds during the last 50, 000 years. This situation is shown on the last geocryological maps [Oberman, 2003, Popova, 2012, Osadchaya, 2016].

However, the remote sensing data application at the decryption scheme creation carried out under the project on compilation of the governmental hydrogeological map at a scale 1:1 000 000 of Pechora artesian basin [2016] suggests that the processes might be more difficult. The unique exogenous geological phenomenon were discovered which still remain unexplained. This applies first and foremost to the middle levels of the right and left banks of the Pechora River, which are flat sandy hills up to 5-10m high and up to 1,0-1,5 km in diameter – so-called "limnokames" [Lavrov, 2005]. They are covered with the lichen pine forests in the subzones of the forest-tundra and northern taiga. The pine-forests are gradually replaced by sparse larch forests, elfin woodlands,

and deflation sands towards Naryan-Mar. The grass-moss wetlands, often swamp, lie between them – in the inter-hillside depressions. The permafrost areas occur here more and more to the north. As seen plan view, the areas are characterized by polygonization which reminds the polygonal figure of block tundra. However, the plan size of the hills contradicts this opinion. Besides, the hills often group together and form the belts 0,5-1,5 km wide and up to 10 km long, separated by wetlands and watercourses. The space image analysis shows two types of the area: the plains with "limnokames" and "limnokame terraces" – the zones characterized by parallel-ridge relief with the sublatitudinal and the North-Western spread direction.

The typical relief shape proves glacial and lacustrine-glacial origin. These are Laya-Adzva and Kozhva end moraine ranges, melt-waters hollows; kames and eskers in some particular cases. The size of fluvial forms of the level I-II terrace to the south of the latitudinal part of the Pechora River is bigger than the size of the present-day forms. They were formed under the conditions of the subaerial outwash plain. The wetlands with typical meander outlines are deciphered on the right bank of the Pechora River on the site from the mouth of Laya River up to the M. Mutnaya River and the middle stream of Laya River within lacustrine-glacial plain. These are the abandoned river-beds of the tributaries of the PraPechora River and the PraLaya River.

The paper presents decryption scheme of remote sensing data and landscape indication table, where landscapes indicators such as nature zones, relief, hydrography, soils, vegetation cover are characterized; it shows also their space images (including Digital Elevation Models (DEMs)), the indicated hydro-geological and permafrost conditions, as well as dated exogenous geological processes related to the Late Pleistocene, the Holocene climatic optimum and to the recent situation.

GEOCRYOLOGICAL AND HYDROMETEOROLOGICAL FACTORS OF COAST DYNAMICS AT THE KARA SEA

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The Arctic coast is a complex and actively changing system. Every year the Arctic coastline composed by frozen dispersed deposits retreats into the continent by a value of several centimeters to several meters. The

coastal erosion rate varies in time and space. The combination of hydrometeorological factors determines the conditions for soil thawing and removal of thawed material in the sea. Year by year these conditions change. Hydrometeorological factors of the Arctic coastal retreat include first of all the thermal regime of the territory (air temperature, sea water temperature, surface temperature) which determines the thermodenudation intensity, and the energy (wind-wave) regime that determines the thermal abrasion intensity and removal of thawed material from the beach. The wind-wave regime depends on the frequency and intensity of storms directing to the coast from the sea side and on the duration of the ice-free period.

This article considers the dynamics for the Western (Ural) coast of Baydatskaya Bay which is characterized by high variability of geocryological conditions.

The studied area is the part of the accumulative alluvial-proluvial plain, within several altitude levels from 3 to 20 m. The soils have various lithological composition: sandy loam and sands with ice content near 20-50%; and sandy loam and loam with peat where the total ice content reaches 50-70% and there are ice wedges and massive ice.

Hydrometeorological data analysis for this period in the MarreSalya weather station and ERA Interim reanalysis data showed an increase in the annual sum of positive daily air temperatures by 25% and an increase in the duration of the ice-free period by 40-50% compared to 1979-1989. In addition, the period from 2005 to 2012 is characterized by increase in wind-wave energy by 80%.

Coastal dynamics monitoring and different satellite imagery analysis for the period 2005- 2015 in comparison with the previous period of observations showed that the coastal erosion rate was significantly differentiat for coast with various geocryological conditions. The average rate of the retreat for medium-silt sediments coast increased in 1.5 times and reached 2-4 m / year, while in the coastal segments composed by ice-reach loams increased in 2 times and reached 3-6 m / year.

Thus, due to global warming and thermal and wind-wave effects there is a tendency of increase in coastal erosion rate. In that connection, the mechanism and the erosion intensity are determined by geocryological features, such as the presence of ice (massive ice and ice wedges), soil's ice content, soil composition and thermal properties.

THE HOLOCENE LOW SURFACES OF THE WESTERN YAMAL COASTS. FREEZING AND SEDIMENTATION

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Recently, due to climate change in scientific literature great attend to the degradation of permafrost in the Arctic zone. But the process of new formation of frozen ground, which is important for understanding evolution of the permafrost zone, has not been researched. In 2015 and 2016 author observed the young accumulative low surfaces, called in Russian laida, at the Marre-Sale station on the Western Yamal.

Two types of low surfaces were studied in the Marre-Sale region: The first type – estuaries flowing into the sea where river and partly marine sediments freeze (estuaries of the Marre-Yakha River); the second type – sea laida where marine deposits are accumulated (the site called Mayak in 11 km to the south of the Marre-Sale meteorological station). In the cold climate sediments accumulates and immediately freeze here i.e. syngenetically. Different conditions of sedimentation affect to the amount of organic matter and salts in the sediment that influences on their thermophysical properties during freezing.

In 2015-2016 the boreholes were drilled to a depth of 3.20 m, 19 samples of sediments were taken to determine the granulometric composition, moisture, salinity and organic matter content on laida Mayak. In 2016 5 samples of the sediments were taken for determine the organic carbon and ice content from the Marre-Yakha River estuary sediments. Some samples were studied on the floodplain of the river in 2010-2011. Sediments on the low surfaces are represented by interbedding of sand, sandy loam and loam layers.

In wells on the laida sites were used long-term data loggers LPC to characterize the temperature of grounds. The wells temperatures of rocks on low accumulative surface of Marre-Yakha river showed that estuaries outside zone of influence the sea waters has depth of zero annual ground temperature is 7-8 m. The same depth on the sea laidas is no more than 4-5 m. The established average annual temperature of rocks in the river mouths is about mines 5.7 below zero, which is lower than on the marine laides, where the temperature is about mines 4 below zero.

The examinations of temperature regime show correlation between the temperature of permafrost and air. Low surfaces are more susceptible

to changes of external conditions than watersheds. This is explained by the features of the composition of the sediments because the sand composition of sediments and high salinity increase the thermal conductivity of the sediments.

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METHANE IN GROUND ICE ON CENTRAL YAMAL

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Methane in underground ice has been already studied on Western Yamal; it was detected in permafrost sediments on Central Yamal (Bovanenkovo gas field) during parametric wells drilling, but it has never been studied in the outcrops of underground ice on the banks of lakes and rivers. New data of methane gaseous inclusions in underground ice and frozen Quaternary sediments and methane concentrations in the air on Central Yamal (Bovanenkovo) is discussed.

Total of 26 samples of ice were obtained from five underground ice outcrops in Se-Yakha river basin, 2 samples were taken from air and two from icy permafrost sediments. The concentration of methane in the samples was determined by the "Headspace" method.

High concentrations of methane in underground ice – 32283 ppmv and 18330 ppmv was found in 2 samples from northern part of "Outcrop №1" [70.380537°, 68.413028°] located in thermoerosional gully on the right bank of Se-Yakha river. Width of underground ice outcrop is 15-17 m with average height of 1.9 m. Other values of methane concentration in this outcrop vary from 12 to 681 ppmv. Our hypothesis is that these sediments have complex genesis – southern part is an ice wedge (there is also a local depression in relief above outcrop with 20 m width and 300-350 m length towards watershed) and northern part is a part of massive ground ice structure (which has been studied before by Dofofeev, Parmuzin, Sukhodolskiy etc).

Similar concentrations of methane in underground ice – 30505 ppmv and 30899 ppmv were detected in 2 samples from northeastern part of "Outcrop №2" [70.387129°, 68.347017°] located on thermoterrace on the right bank of Se-Yakha river. Width of underground ice outcrop is 130-150 m and height varies from 3.5 m in southwestern part to 7-8 m in

northeastern part. Other values of methane concentration in this outcrop vary from 13 to 56 ppmv, but in this case there is no geomorphologic reason to divide this outcrop. For "Outcrop №2" and neighboring "Outcrop №3" [70.386255°, 68.353583°] (with 95-1000 ppmv) we assume that increased methane concentrations were detected randomly and generally methane in air bubbles inside underground massive ice are distributed unevenly and for further understanding, more methodical studies are needed.

In "Outcrop №4" [70.434060°, 68.439014°] low methane concentrations (24-50 ppmv), the linearity of ravine development, the small width of outcrop (6.7-7.0 m) allows us to assume that detected underground ice is an ice wedge structure.

Air samples with 1205 ppmv on a watershed in tundra landscape and 426 ppmv on the anthropogenic embankment in Se-Yakha floodplain indicate increased methane emission from natural landscapes, which also correlates well with sample from permafrost with 1000 ppmv (lake terrace, sampling depth – 0.85 m).

We suppose that lowest concentrations 9 ppmv in "Outcrop №5" [70.480923°, 68.738484°] and 12 ppmv in "Outcrop №4" [70.434060°, 68.439014°] from bubble saturated ice identify firn samples, which shows that methane emission from surface stops during winter season.

The high content of methane in the massive ground ice we explain by migration of methane from freezing deposits into ice body during its formation; ice wedges have low content of methane because gaseous inclusions are forming during spring season from atmospheric air, which comes inside with thawing snow.

PERMAFROST OF THE OKINSKOE PLATEAU (EASTERN SAYAN RIDGE)

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Research has been conducted on the permafrost in the Sentsa River valley, Okinskoe Plateau, Eastern Sayan Ridge for the first time. The features of the permafrost that have been investigated are cryogenic structures of unconsolidated deposits and active layer temperature, the

morphology and structure of large frost mounds and the chemical composition of the core ice.

The Okinskoe Plateau is located at an altitude of 1800-2400 m asl. The Sentsa River cuts the Okinskoe Plateau to a depth of 800 m. The river valley is a classic trough with Late Pleistocene side-moraine and end-moraine complexes. The alluvial and lacustrine sediments are gravels, sands, silts and clayey silts.

The climate is acutely continental; the average annual air temperature varies from -5.6°C to -6.6°C. Permafrost is continuous in distribution; its thickness is about 150-200 m. The depth of seasonal thawing does not exceed 2 m.

On one of the large frost mounds in the Sentsa River valley the borehole was drilled (52°39,795′ N, 99°29,877′ E) to a depth of 4.8 m. From the surface the frost mound consists of interlayering silts, ice-rich clayey silts and pure ice lenses. Cryostructures are layered, cross-laminated, lenticular, reticulate and basal.

At the depth 2.5-3.0 m ice lenses reach a thickness of up to 12 cm. The interval of 3.1 to 3.6 m consists of inclined lenticular and irregular reticulate sediments with 0.5 to 2.0 cm thick ice veins and lenses from and 0.3 to 2.0 cm soil bands. The visual volumetric ice content is 50–60 %. In the lower part of the section, cross-laminated silt enclosing pure transparent ice lens with a thickness of 1.5 cm was found.

The chemical composition of ground ice is HCO3 and SO4-HCO3 Ca with a salinity of 6.5-153 mg/L, pH=5.6-6.7. The ground ice salinity changes unevenly with depth. From the surface down to 4 m, ground ice salinity and NH4+-content are 10-20 times lower than in the underlying sediments, and SO42- is practically absent. Content of SO42-, NH4+, NO2- and NO3- in the ice lenses increases in intervals of 3.2-3.3 m and 4.6-4.9 m. Water in the thermokarst lake near the frost mound base and in Sentsa River has HCO3 Ca chemical composition with a salinity of 99-160 mg/L.

The vertical isotope variations are from –157.9 to –142.7 ‰ δD, from –20.27 to –18.61 ‰ δ18O, and from 11.78 to 2.58 ‰ d*exc*. Based on the slight variation of δ18O and δD an intensive influx of new water portions during the rock freezing and the formation of the frost mound can be assumed. However, a significant isotope fractionation during rock freezing and ice formation did not occur.

The geothermal regime observations during 2014-2016 have shown that significant temperature variations occur in the layer of 0-2 m. Deeper the rock temperature is negative in the two-year cycle. It varies

from -1.6 °C (in winter) to -0.8 °C (in summer) at a depth of 4.4 m. The rock temperature is constant (-2.1°C) at a depth of 10 m.

Thus, the permafrost in the Sentsa River Valley is presented by ice-rich lacustrine-alluvial deposits. The mean annual rock temperature is -2.1°C at a depth of 10 m. Frost mounds were formed during sediment freezing. The studied frost mound has a cryogenic formation, a combined segregation-injection genesis as probable. It is evidenced by its structure (interbedded ice lenses and ice-rich silts and clayey silts) as well as the chemical and isotopic composition of ice.

In the recent decade due to increasing average annual air temperatures, an active destruction of frost mounds in the Sentsa River Valley is accompanied by the formation of small and large thermokarst lakes, and by a significant annual retreat of floodplain terraces as a result of thermal erosion.

The researches have been carried out with financial support from the Russian Foundation for Basic Research (project 16-05-00115).

REPEAT TERRESTRIAL LIDAR AND DEM-BASED CHANGE DETECTION FOR QUANTIFICATION OF EXTENSIVE THAW SUBSIDENCE ON YEDOMA UPLANDS

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Permanently frozen ground in the Arctic is being destabilized by continuing permafrost degradation, an indicator of climate change in the northern high latitudes. Accelerated coastal erosion due to sea ice reduction and an increased intensity of ground settlement through ground ice melt caused by rising summer air temperatures result in widespread geomorpho-logical activity. However, particularly in the light of the

enormous area underlain by ice-rich continuous permafrost, still only few observations of permafrost-thaw related landscape dynamics exist. Because these phenomena are hard to detect, they have received not much attention, despite their potentially global significance through the permafrost carbon feedback. The objective of our study is to analyze time series of repeat terrestrial laser scanning (rLiDAR) for quantification of extensive land surface lowering through thaw subsidence, which is the main unknown in terms of recent landscape development in the vast but neglected East Siberian Arctic. These *in-situ* data provide the basis for calibration and validation of large scale surface change assessments using very high resolution space-borne elevation data with high precision.

Local field measurements (active layer thickness, meteorology, ground temperature, geodetic surveys) during several recent Russian-German Arctic expeditions on Sobo-Sise Island in the eastern Lena Delta and on the Bykovsky Peninsula close to Tiksi complement our remote sensing studies and help differentiating factors causing relief and land cover changes. Our work aims at finding commonalities and differences of change or no change on yedoma uplands and surrounding slopes, where we expect recent changes to take place first. The established subsidence survey grids are equipped with glassfiber benchmarks anchored deep in the permafrost. These benchmarks serve as long-term height reference markers for terrestrial laser scanning. The set-up is generally geared towards a comparison of several measurement campaigns for quantifying modern thermokarst rates not only with high spatial but also high temporal resolution of interannual intervals.

First repeat measurements have been made during the Lena Delta expedition in August 2016. We operated the Leica MultiStation MS50, a hybrid instrument combining high-accuracy surveying with fast laser scanning capabilities, from many different positions inside the survey grids. The radius of laser scans was usually in the range of 80-100m in order to ensure overlap between neighboring scans and to capture micro-topographical features resulting from permafrost thaw. Accurate positioning of the MS50 is realized using our fixed benchmarks that have been surveyed with precise GNSS instruments. Depending on specific measurement tasks, we operated the MS50 in various scanning modes, optimized either for longer distances, higher precision, or fast scanning. Resulting point clouds have been interpolated to DEM rasters, portraying the land surface in unprecedented detail.

Complementing our surveys, we conducted botanical mapping within the extent of our survey grids. This allows us to relate elevation

differences to specific surface conditions and enhances our capabilities to extrapolate our local observations to larger areas through land-cover classifications of multispectral remote sensing data such as RapidEye, WorldView-2, and WorldView-3.

Additionally, highly detailed digital elevation models (DEMs) with sub-metre accuracy have been stereophotogrammetrically derived from WorldView-1, WorldView-2 and GeoEye satellite data for all study sites. These DEMs are not only an essential prerequisite for the conversion of oblique imagery into ortho-images with the geometry of a map, allowing distance and area measurements, but also contain valuable terrain height information for 3D change detection, in case of DEMs representing the state of a study area at different points in time.

A novel approach we are currently evaluating is the comparison of our detailed DEMs with ICESat (Ice, Cloud, and Land Elevation Satellite) space borne laser altimetry data. ICESat provided multi-year elevation data from 2003 to 2009. Dense along-track point spacing of 170 m with high precision and a time lag of more than a decade compared to our modern elevation opens up the possibility to quantify thermokarst rates over large regions and across climatic and topographic gradients. The time span bracketed on the one side by ICESat data beginning from 2003 on the one side and DEMs representing the current 2015/2016 topography captures not only several all-time sea ice minima of the 21st century, but also the warmest summers since records began. The results show that for all study regions elevation differences are almost always negative. When calculated as rates over time, land surface lowering in the ice-rich permafrost regions of northern Siberia amounts to 3-10 cm per year. We are currently in the stage of expanding these analyses on all key study sites where high resolution DEM data has been made available through the European Research Council funded project PETA-CARB.

DEMs were also used to extrapolate thickness measurements of the protective layer, which covers pure ground ice bodies on an empiric basis. Relating active layer and protective layer thicknesses to our observations of elevation change revealed interesting of patterns thaw subsidence and highlights the vulnerability of ice-rich permafrost to recent environmental changes in the Arctic. This local understanding of processes will help to identify and quantify permafrost degradation over large remote polar regions with future earth observation missions.

NATURAL SEASONAL RHYTHM AS BASIC FOR INVESTIGATION DINAMICS OF ARCTIC TUNDRA ISLAND LANDSCAPES IN WESTERN SIBERIA

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The climate change has increasingly attracted attention of specialists in recent decades. Most scientists agree that the climate change at that territory, especially warming, has occurred faster and bigger than at the rest territory the globe due to significant fluctuations. At the same time, at the local level over a long period of potential climate change it is possible to talk after a careful and detailed analysis of databases, i.e., with allocation of the seasons and phases in the annual cycle. In 2009, Earth Cryosphere Institute on the White island (the Kara sea) was developed the station of complex geocryological monitoring. As information basis for the station work were developed and drew out a database with the main components of the natural environment based on the analysis and stock published literature on the scientific studies conducted in different years on the island from 1904 to the present. One of the main components of the databases was data of climate observations conducted at the hydrometeorological station M. V. Popov from 1933 to the present. The main arguments in favor of need to analysis of arrays of information daily and compiling their own databases become Data for the monthly and annual average air temperature became the main arguments to analyze the arrays of daily information and compiling their own databases. Climate support literature showed different air temperature in different years. This fact led to some difficulties to use these data practically. For example, the average annual temperature for the period from 1933 to 1960 in one of the edition of the climatic Informationbook (1965) is -10,4°C, in Informationbook on climate of the Soviet Arctic (1973) average annual air temperature on the island is White -10,4°C, but for the period 1933-1965 years. For the climate normal period 1961-1990 the "reference" values of average annual air temperature was (according to the] WDC) -11,1°C. At the same time, the average annual temperature for the period 1933-2015 years, calculated from the array of average daily air temperature is -10,1°C. The average annual Amplitude of air temperatures over 82 years of observation was 8.5°C. The minimam was -14°C, which was close to the mean annual air temperature value for the zone of polar deserts (Hayes island, Franz Josef land archipelago, -13,3°C) and maximum of -5,5°C, a value close to the mean annual air

temperature in the subzone of Northern taiga (Nadym, -5,6°C). Thus, the Arctic tundra island landscapes in Western Siberia operating in very changeable conditions and fair view of the long-term dynamics of landscapes of the Arctic tundra is only possible on the basis of the study of natural rhythms, resulting from daily variations of the main climatic parameters of the functioning of the landscape and defined its borders with natural seasons of the year, and they define the rhythms of the biota and other natural processes.

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DESULFOVIBRIO ALGORITOLERANS SP. NOV., A PSYCHROTOLERANT SULFATE-REDUCING BACTERIUM FROM A YAMAL PENINSULA CRYOPEG

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Cryopeg is a layer of unfrozen ground that is perennially cryotic (forming part of the permafrost) in which freezing is prevented by freezing-point depression due to the dissolved-solids content of the pore water. Cryopegs remain liquid at the in situ temperature of −2°C to −11°C and make up the only habitat on the Earth that is characterized by permanent subzero temperatures, high salinity, and the absence of external influence during geological time. They are located within permafrost marine sediments of the High Arctic at different depths and harbored by diverse psychrophilic and halophilic microorganisms. Despite on the sulfates contains in the cryopeg water, only sulfate-reducing bacterium (SRB) *Desulfovibrio arcticus* from Varandey Peninsula cryopeg has been isolated.

The psychrotolerant sulfate-reducing bacterium, strain K3S^T, was isolated from Yamal Peninsula cryopeg within permafrost. The cells of isolate were Gram-negative motile vibrions (0.5×2.0 μm) with monopolar bitrichous flagella. Strain K3S^T grew at the ranges of the temperature from –2 to 36ºC (optimum 26˚C), salinity from 5 to 40 g·l^{-1} (optimum 20 g l^{-1}) and pH value from 6.8 to 7.4 (optimum pH 7.0-7.2). Growth was dependent upon Na^+-ions. The strain K3S^T was able to use lactate, formate, pyruvate, fumarate, alanine, ethanol and molecular hydrogen as electron donors and carbon sources in the presence of sulfate.

The utilized electron acceptors were sulfate, sulfite, thiosulfate, elemental sulfur in the presence of lactate. Fe(III) citrate and Fe(III) EDTA were reduced without growth. Major polar lipids were phosphatidylserine, phosphatidylethanolamine, phospholipids, cardiolipin, and aminolipid; major fatty acids were $C_{16:1\omega7c}$, $C_{16:0}$ and $C_{18:1\omega7}$; predominant isoprenoid quinone was MK-6 (H_2). The isolate was positive for desulfoviridin as a bisulfite reductase. The DNA G+C content of the type strain was 42.3 mol. %. Phylogenetic analysis showed that the closest relative for strain $K3S^T$ was psychrotolerant sulfate-reducing bacterium isolated from permanently cold Arctic fjord sediments *Desulfovibrio ferrireducens* (97.4% similarity). Polyphase taxonomy data suggest that strain $K3S^T$ (=VKM $B\text{-}2877^T$= DSM 100341^T) is type strain of the novel species *Desulfovibrio algoritolerans*.

Our previous investigation of the anaerobic bacteria abundance in the Arctic cryopeg samples has shown insignificant amount (10-100 cells/ml) of acetogens and methanogens are presented. And most likely SRB play a major role in the mineralization of the organic matter in the cryopeg ecosystems.

RADIORESISTANCE OF PERMAFROST MICROBIAL COMMUNITIES BY CULTURING AND METABOLIC ACTIVITY TESTING

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The knowledge about limits of resistance of microbial communities to impact of ionizing radiation is still scarce. According to different authors, sterilizing doses vary from 15 to more than 50 kGy. However, in recent years, it has been shown that *Cryomyces antarcticus* fungi remain viable after exposure to gamma radiation at doses up to 117 kGy, and microbial communities of extreme habitats withstand exposure to the doses up to 1 MGy (if irradiated under low pressure and low temperatures). It confirms necessity of further investigation of the limits of microorganisms' radioresistance.

We irradiated ancient Arctic permafrost by gamma rays (^{60}Co source) with dose gradient 159, 343, 463, 743, 1000, 1350 kGy in conditions close to normal (+ 16°C, 1 atm.) in order to estimate the limit of resistance of its microbial community to gamma radiation.

Culturable bacteria were found in samples irradiated by doses of up to 463 kGy. Amongst them, representatives of the genera *Microbacterium*, *Kocuria*, *Micrococcus*, *Tsukamurella*, *Dietzia* (all related to *Actinomycetales*) and *Sporosarcina* (related to *Bacillales*) were identified. With increasing of doses, the number of CFUs decreased more rapidly than the total number of cells determined by epifluorescence microscopy. It allows to assume that part of the cells have entered to the viable but nonculturable state.

Even at the minimal dose (159 kGy) the potential metabolic activity of the microbial community as shown by multisubstrate testing (MST) was drastically reduced and as was noted the only one substrate (peptone) was utilized. After irradiation with higher doses, metabolic activity by the MST method was not detected at all.

In general, studied microbial community showed high resistance to gamma radiation, which is beyond the scope of existing knowledge. The obtained data confirm that the radioresistance of microorganisms being entrapped into the complex natural substrates is significantly underestimated.

This work was supported by the Russian Foundation for Basic Research (grant № 16-34-01275).

REMEDIATION OF HIGHLY CONTAMINATED TECHNOGENIC PEAT-LIKE SOIL BY SUNGULITE AND VERMICULITE

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In the Russian Arctic zone, the degradation of soil and vegetation in the impact zones of copper-nickel enterprises led to the formation of man-made wastelands, i.e. the areas with a protective covering of

vegetation of 10-15%. Under these conditions, the natural restoration of the ecosystems proceeds extremely slowly because of e.g. the extremely high concentrations of heavy metals, the degradation of the soil organic matter, the low content of macroelements, and the limited seed bank.

To overcome these negative factors, the experiments on the phytoremediation have been conducted since 2011 on the plot located at 0.7 km from the copper-nickel enterprise near the town of Monchegorsk (Murmansk region). Here the vegetation cover was created with the use of mineral mining waste and a hydroponic substratum of thermovermiculite.

The average content of the components in the peat-like soil (Corg conc. 38%, pHH2O 4.3, pH_{KCl} 3.9) was 1.6, 6.5, 1.8, 1.1 and 0.2 g/kg for Ni, Cu, Ca, Mg and K, respectively. The proposed technology has shown high efficiency. The height of grass exceeds 60 cm, the projective cover amounts to 100%, and the extensive formation of seeds is observed.

The vermiculite-sungulite wastes are suitable for a large-scale use of this technology, as they are stored in large amounts in the Murmansk region. The aim of this work is to investigate the effect of thermovermiculite and sungulite on the migration status of heavy metals.

It was determined that the thermovermiculite, which is the basis for the formation of the grass cover in phytoremediation technology, reduces the content of the most toxic water-soluble and plant-available forms of Cu and Ni compounds of technogenic soil.

The degree of purification of the soil solution from Cu and Ni with thermovermiculite is about 75-90% for water-soluble forms and 15-30% for the forms available to plants, and the sorption of Ni by vermiculite is 2-3 times higher than that of Cu. The amount of metal sorption by vermiculite decreases with decreasing temperature, which is characteristic for the ion exchange.

Sungulite is a source of Ca and Mg and has the ameliorative effect on technogenic soil. Additionally, sungulite can reduce the mobility of metals due to the sorption processes.

The sorption of the water-soluble forms of Cu and Ni differs insignificantly and increases with decreasing temperature, which indicates the physical adsorption on the surface of sungulite.

The obtained data justified the use of vermiculite and sungulite for the rehabilitation of technologically contaminated landscapes in the Arctic zone by reducing the geochemical mobility of ecotoxicants.

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THE PROSPECTS OF BIOPOTENTIAL OF THE MICROORGANISMS ISOLATED FROM PERMAFROST

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The working collection is created on the basis strains of viable bacteria isolated from samples of permafrost selected in Western and Eastern Siberia. The 70 of bacterial strains were identified by sequencing on 16S RNA, part of them deposited at the RCIM FGUPGosNIIGenetika.

The results of research. The strains of bacteria of the genus Bacillus, selected us from permafrost, used in the study. Bacterial suspensions and the metabolites derived from them were investigated for effects on morphological and physiological parameters of plants, for reparation of skin wounds of mice; for reparation of experimental mechanical erosion of the eye corneal epithelium of rabbit's and on the outcome of closed brain neurotrauma of experimental rats. The requirements of the Helsinki Declaration of the World Medical Association, the European Convention for the Protection of Vertebrate Animals used for Experimental and other Scientific Purposes (number 123, 1986), as well as the order of the Ministry of Health of the Russian Federation № 267 from 19.06.03 "Rules of good laboratory practice in the Russian Federation" of humane treatment of laboratory animals were observed in all experiments.

When studying the effect of pre-treatment the seeds of wheat of sorts Irgina by bacteria strains were demonstrated that the treatment of seeds improves plant productivity, their growth and development. There is marked the increase of germination energy and germinability. The growth of the root system and the work of the photosynthetic apparatus, increasing crop yield are stimulates. Is perspective the development of bacterial preparations on the basis of selected strains, which improve the plant productivity.

When studying the skin wound repair rate in mice under the influence of the metabolites derived from bacteria, wound healing of the mice was 18.2% faster than that under the influence of placebo and of 9.1% faster than under the action of the drug "Solkoseril".

The study of the efficacy of treatment of experimental erosion cornea of an eye of rabbits with a preparation containing metabolites of the bacteria strain Bacillus sp. showed that a full recovery after

experimental injury of the cornea occurs in 2,5 times faster than in the treatment of drug "Solkoseril".

In experimental closed brain neurotrauma of rats, was found, that the mortality of animals in the experimental group was 10 times lower than in the control and reference groups by intraperitoneal injection of the suspension of the strain Bacillus sp. cells. It was shown that the preparation on the basis of strain Bacillus sp has a marked protective effect.

The findings suggest that the development of pharmaceuticals based on metabolites of bacteria strains isolated from permafrost may be perspective.

INFLUENCE OF REPRESENTATIVES OF THE GENUS *BACILLUS* ISOLATED FROM THE PERMAFROST ROCKS OF SIBERIA OF DIFFERENT GEOLOGICAL AGES ON THE INDICES OF THE IMMUNE SYSTEM OF LABORATORY ANIMALS

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The area of permafrost in Russia occupies almost 65% of the country's territory. In the rocks of permafrost of different geological ages and genesis living microbial communities including bacteria of the genus *Bacillus* have been discovered, which are the most ancient saprophytic microorganisms with which man has faced throughout his history. It is evidence of the natural "cryopreservation" of ancient genes in the form of "living fossils" (Zavarzin, 1984, Gilichinsky et al., 2007; Stewen et al., 2007; Brushkov et al., 2009; Bulat et al., 2009; Wilhelm et al., 2011, etc.). In relation to microorganisms permafrost is probably a cryomembrane capable of selecting descendants of "ancient" bacteria with a high adaptive potential (Kalenova et al., 2014). The reciprocity of microorganisms with modern representatives of mammals occurs mainly through the immune system. Reactions of the immune system to descendants of bacteria that have undergone a long evolution in isolated conditions of permafrost and outside of contact with modern ecosystems are of undoubted interest.

In this regard the purpose of our research is to study the influence of microorganisms of the genus *Bacillus*, isolated from permafrost of different geological ages on the immune system of modern mammals.

Two strains of bacteria of the genus Bacillus were studied in the experiment: 1 - strain 8/75 (*B. megaterium*) from the permafrost of the Pleistocene-Holocene period (rocks age 35-40 thousand years); 2 - strain M3 (*Bacillus sp.*) from the permafrost of the late Neogene (rocks age 3,5-2 million years). The study was conducted on 60 mice F1 CBA/Black-6. In a dose $50 \bullet 10^3$ microbial cells/mouse, microorganisms were injected intraperitoneally. The cellular composition of peripheral blood, phagocytic (PA,%) and metabolic (NBT test, %) activity of macrophages, functional activity of cellular (DTH test) and humoral (Cunningham's technique) immunity were assessed on the 14^{th} day after the injection by microorganisms. Data analysis was carried out with the latest version (R.2.15.2) of R.

In the peripheral blood content of erythrocytes and hemoglobin didn't change under the influence of both strains of microorganisms relative to the control level. Strain 8/75 contributed to a decrease in the number of neutrophils ($p < 0.01$) and monocytes ($p < 0.01$) in the peripheral blood and an increase the phagocytic ($p < 0.05$) and metabolic ($p < 0.01$) activity of macrophages. The strain M3 had no significant effect on the cellular composition of peripheral blood, but significantly increased the metabolic activity of macrophages ($p < 0.05$). None of the strains tested had a significant effect on the functional activity of cellular immunity (according to the level of the delayed-type reaction, %). Under the influence of strain 8/75, isolated from more "young" rocks, the level of humoral immunity (antibody-producing cells in spleen) increased progressively 4-fold, and under the action of strain M3 isolated from more "ancient" rocks it increased only by 29%.

Based on the obtained data, it can be concluded that different strains of *Bacillus* bacteria isolated from permafrost can have both moderate (strain M3 *Bacillus sp.*) and pronounced (strain 8/75 *B. megaterium*) stimulating effect on the immune system of laboratory animals.

VIABLE MICROORGANISMS FROM PERMAFROST AND THEIR ENZYMATIC ACTIVITY

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Permafrost is unique permanently frozen environment where life could be preserved and survived for geologically long time. Microbiological research of permafrost sediments could open doors in to microbial life of the past epochs, and consequently studying ancient sediments could be used to predict future changes of permafrost microbial communities. During this research we studied permafrost samples of the freshwater lake-alluvial origin and different freezing ages (3 thousand to 3 million years old), which were collected on the Kolyma-Indigirka lowland in Northeastern Siberia. Cores were collected with a slow rotary drill that prevented down-hole contamination using quality assurance and quality control procedures. Collected cores were subsampled with sterile knife into sterile Whirl-Pak bags in the mobile field laboratory for later analyses. The permafrost samples were stored and transported in frozen state to the Institute of Physicochemical and Biological Problems in Soil Science and farther to the University of Tennessee. Serial dilutions of permafrost were prepared in pre-chilled PBS-buffer and plated on ½ TSA, ½ TSA + 10% NaCl, and R2A. Plates were incubated during 1 to 4 weeks at 20°C and 4°C, respectively. Viable cell count was in range from 1.1 x 10^2 to 1.0 x 10^4 cfu g^{-1} of sediment and decreased with increasing of borehole depth. The cfu numbers were higher on reach but diluted medium in comparison to diluted mineral medium. Most of the colonies grown on agar media were colored yellow, orange, or pink, which support opinion that cell pigments may have a positive effect on survival, and increase resistance to environmental stresses. A total of 232 bacterial strains grown on nutrient media were isolated. Among isolates, the phyla Actinobacteria 54%, Bacteroidetes 17%, alpha-Proteobacteria 25% and beta-Proteobacteria 4% were identified. A total 15 bacterial strains were characterized for peroxide, cytochrome oxidase, cellulose, lipase, indol, lecithinase activity and for resistance to 12 antibiotics. Bacteria of the genera *Arthrobacter, Micrococcus Aeromicrobium, Ancylobacter,*

Brevundimonas and *Pedobacter* were detected. The genus *Arthrobacter* was the most abundant among isolates.

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PHYSICO-CHEMICAL NATURE OF LYQUID ICE FILMS INFLUENCE FOR MIGRATION OF CHEMICALS IN PERMAFROST AND GLACIAL SYSTEMS

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Ice is a major component of permafrost and glacial systems and acts in the accordance with its physico-chemical nature. At temperatures close to the melting point, the liquid film is present on the surface of solid bodys. This state is unique to ice, as it happened under the «normal» temperatures. This liquid films can influence the migration of soluble chemicals in frozen ground. To estimate the role of ice surface for soluble chemicals the experiments have been done. First experiments back to 1980-1981 observed soluble properties of liquid films. The presense of liquid and solid state for ice is only possible at high concentration of electrolyte. To study this liquid films we add microcomponent (ions of MoO_4^{2-}), with constant composition in a wide range of conditions. Sorbtion of molybdate ions are higher at higher pH values, as the liquid film is thiker in this case due to structurisation of water molecules by OH^- ions. Mg ions acts the same way. The adding of ethanole decreases the sorbtion of molybdate ions due to hydrofobisation of the liquid film and aggregation of the ice particles.

INFLUENCE SILICA NANOPARTICLES ON FORMATION KINETICS AND SELF-PRESERVATION EFFECT IN DRY WATER METHANE HYDRATE

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"Dry water" is a free-flowing powder contained up to 98 wt% of water prepared by mixing water and hydrophobic fumed silica nanoparticles in air with a high speed. "Dry water" is a high-potential material for gas hydrate formation with purpose to use them in the technologies of natural gases transportation, storage and utilization due to the fact that dry water methane hydrate (DWMH) formation rate is high and DWMH may stay stable for a long time at 0.1 MPa and a temperature below 273 K (self-preservation effect).

Recently, it is shown the formation rate of CO_2 gas hydrate in "dry water" is significantly (by several times) increasing with the decrease in the silica particle concentration in "dry water" from 6 to 2 wt%. This fact points at the capability of speed control by changing the silica nanoparticle concentration. Though, nature of influence silica nanoparticles on the DWMH formation rate at a concentration lower than 5 wt% remains unclear.

Abnormal-low gas hydrate dissociation rate 0.1 MPa known as self-preservation effect tends to be the same for DWMH. Moreover, preservation effectiveness of the DWMH may significantly hinge on the silica nanoparticle concentration. However, the dependence is not investigated for "dry water" contained silica nanoparticles less than 5 wt%.

In this work, methane hydrate formation and self-preservation effect in "dry water" contained silica nanoparticles from 2 to 15 wt% was studied for the first time using the complex approach. For "dry water" preparation the hydrophobic fumed silica with different BET surface area was used.

The research showed that if "dry water" contained no more than 7 wt% of silica nanoparticles the dispersity of water phase and the water to hydrate transformation half-time significantly decreased (by 2 times and 10 times accordingly) and a fraction of undissociation hydrate D_{nd} varied not much (no more than 40%) with silica nanoparticle concentration increase from 2 to 7 wt%. The silica nanoparticle concentration increase from 7 to 15 wt% led to a sharp decrease in the fraction of undissociation

hydrate D_{nd} (approximately by 5 times) while water phase dispersity and the water to hydrate transformation half-time in "dry water" varied not much (no more than 40%).

It was shown the hydrophobic fumed silica BET surface area that was used to prepare "dry water" might significantly influence on sizes of the water droplets and the gas hydrate formation rate and effectiveness their preservation. Then, with increase in the hydrophobic fumed silica BET surface area by 2 times the water droplet size in "dry water" decreased approximately by 4 times while the water to hydrate transformation half-time decreased approximately by 10 times, the fraction of undissociation hydrate D_{nd} decreased by 3 times.

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METHANE IN GROUND ICE AND FROZEN QUATERNARY DEPOSITS OF NORTH OF WESTERN SIBERIA

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Due to the natural processes and technogenic influences gases from the upper horizons of rocks including conserved in the permafrost released into the atmosphere. Particular attention of researchers is attracted to methane (CH4) as one of the main greenhouse gases. When analyzing the relationship between climate change and greenhouse gas flows, the main problem is the lack or insufficient amount of empirical data on methane content in natural sources, including permafrost and underground ice. In this regard, it is not possible to adequately assess the contribution of a specific region to the overall global methane budget of the atmosphere.

We carried out studies of the methane content in the permafrost, underground ice and in the seasonal thawing layer for the area of the geocryological station Marre-Sale (Western Yamal). A total of about 420 samples were collected. The CH4 concentration was measured by headspace-equilibration, using KhPM-4 (Russia) gas chromatograph with

flame ionization detector and hydrogen used as a carrier gas (Pushchino, Russia).

Initial data indicate that methane concentrations in frozen marine clay sediments (more than 5000 ppm) are an order of magnitude or more higher than in sandy terrestrial sediments (about 100 ppm). The highest concentrations of methane are noted for the massive ice (an average of about 6000 ppm). In the ice wedges concentration of methane are greatly varies from the air concentrations to more than 4000 ppm, an average of about 500-600 ppm.

Based on the average values of methane content in frozen sediments and underground ice, an attempt was made to estimate the annual emission of methane during the retreat of a 100-meter specific section of the sea shore with a known geological section. The amount of retreat for this section of the coast is known and is 1.7 m per year. From the calculations follows that about 14 m3 (or about 10 kg) of methane per year emitted for the selected 100 m shore.

For the first time of the study area, the methane content by the depth in the seasonal thawing layer for different types of landscapes was analyzed. The data obtained show that the greatest amount of methane is realized from the landscapes of highly waterlogged lowland areas and flood plains, in contrast to the watershed landscapes with well drained deposits. Based on the map of landscape zoning for the area of the geocryological station Marre-Sale, a preliminary map of the methane content in the seasonal thawing layer for different types of landscapes was constructed.

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INFLUENCE OF FREEZE-THAW PROCESSES ON SOIL RHEOLOGICAL PROPERTIES

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The mechanism of cryogenic structure formation of soils, as the processes of swelling and shrinkage, is very interesting. The study of the processes of freezing and thawing, as well as swelling and shrinkage, will provide a deeper understanding of the nature of the formation of soil structures. The results of the research can find application in predicting the behavior of soils in conditions of changing climate.

The aim of the study was to elucidate the effect of freeze-thaw processes on the rheological properties of Albiluvisol soil in the Moscow region under the conditions of a model experiment.

The investigations were carried out on forest Albiluvisol heavy loam soil of the Moscow Region.

Samples of soil were capillary moistened and frozen in the freezer for 30 minutes, then thawed at room temperature for 30 minutes. The temperature was detected by temperature sensors. Samples of the soil were subjected to 5 cycles of freezing-thawing. Further were determined granulometric and microaggregate composition and the rheological properties: the linear viscoelasticity range (the point of transition of the body condition from the elastic to the viscoelastic) and the point of intersection of the elasticity and viscosity moduli (the point of transition of the body condition from viscous-elastic to viscous)

Changes of rheological properties as a result of multiple freezing-thawing were monitored: the range of linear viscoelasticity or the area of elastic behavior increases, but on the whole the range of elastic-ductile behavior decreases, it means that the soil behavior becomes more fragile and the structure breaks down and passes into a viscous flow condition . This can be explained by the destruction of soil aggregates as a result of crystallization of ice in the soil material, which is confirmed by the data of the microaggregate composition of the initial and after freeze-thaw cycles samples, which showed a decrease of the amount of large aggregated particles and an increase in the finely dispersed fraction in the samples after freezing. But the value of elasticity moduli and viscosity at the crossover point increases in the samples after freezing-thawing, which may indicate that small particles form bonds with each other and deform as a single system, and no slip boundaries are formed inside the deformed body. This indicates that multiple freezing-thawing without application of external pressure does not lead to the formation of a cryogenic structure typical of freezing soils, but contributes to the formation of a massive fusion structure.

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PHASE CHANGE INTERFACES IN PERMAFROST AND SUBSURFACE REDOX POTENTIAL

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Permafrost thaw is a positive global-scale climate feedback mechanism and a potential climate tipping point. This feedback mechanism works through the release of greenhouse gases from thawing permafrost, which can lead to further thaw. Microbes facilitate transformation of organic carbon in permafrost to greenhouse gas. To understand the rate and sensitivity of the permafrost feedback to future change, it is imperative that we understand how the microbial environment changes when the subsurface environment freeze and thaws. Microbially important environmental parameters are temperature, water chemistry, inhabitable space and redox potential. The latter determines which metabolic pathways are energetically available to microorganisms

Redox potential has been shown to change with freezing and thawing. There is ample evidence that subsurface redox potential changes in response to flooding, wetting and drying, and separation from atmospheric oxygen. Drying and freezing both reduce the activity of water in the pore water solution. Freezing often creates a gas-impermeable barrier between the subsurface and the atmosphere, and thawing can greatly intensify the diffusion of electron donors and receptors. Both freezing and thawing concentrate and dilute dissolved species in the remaining liquid pore water. It is therefore likely that permafrost thaw is accompanied by change to redox potential. We examine pore water chemistry at freeze-thaw boundaries in the active layer, at the permafrost table and within warming submarine permafrost. Concentrations of dissolved ions important in redox couples varies greatly near these boundaries, suggesting changing redox potential as a consequence of freezing and thawing. The goals of this presentation are to describe some possible subsurface thawing and freezing interfaces, to present observations of redox species concentrations above and below such interfaces, and to speculate on consequences for microbial activity.

CHEMICAL COMPOSITION OF THE GROUNDWATER OF THE CRYOGENIC-AEOLIAN FORMATIONS (TUKULANS) IN THE VILYUI RIVER BASIN (CENTRAL YAKUTIA)

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The nine sources of intrapermafrost groundwater are studied within the dune massive – Kysyl-Syr and Mahatta tukulans (low part of the Vilyui river basin, Central Yakutia) in 2014 and 2016. The aim of research is identifying characteristics of groundwater chemical composition.

Water samples taken from places of discharge of rills to a surface in pre-prepared containers in accordance to GOST 31861-2012.

The macro-componential composition, electrical conductivity and pH of water were analyzed in laboratory of permafrost groundwater and geochemistry of the Melnikov Permafrost Institute Siberian Branch of the Russian Academy of Science (Yakutsk) according by standard techniques.

The micro-componential composition of water were analyzed by inductively coupled plasma atomic-emission spectrometry method (ICP-AES Thermo Scientific 6000 Series) in laboratory of analytic of the Institute of Inorganic Chemistry Siberian Branch of the Russian Academy of Science (Novosibirsk).

The temperature of the groundwater rills of Kysyl-Syr and Maxatta tukulans were measured on the field. The temperature of their had been fixed between 0.1 to 3.0 C.

The Mahatta tukulan groundwater is characterized to predominance of neutral reaction of the geochemical environment (pH 6.3-6.7), and Kysyl-Syr tukulan groundwater has been weakly acidic reaction (pH 5.6-6.4).

The intrapermafrost groundwater had a hydrocarbonate magnesium-calcium composition.

The index of groundwater hardness is defined as a soft (0.25-0.82 mq- eq/l). Mineralization of the intrapermafrost groundwater between 19.1 - 48.1 mg/l. The geochemical environment of the studied waters is characterized by the values of Eh from 498 to 553 mV.

The complex of microcomponents of groundwater are contained which varies over a wide range (mkg/l): Al from 9 to 280, Ba from 5.7 to 30, F from 13 to 78, Fe from 17.6 to 6600, Mn from 4.7 to 1200, Sr from

25 to 100, Cu from 0.16 to 22, Zn from 1.1 to 26, Li from 0.3 to1.9. In addition, in the Kysyl-Syr tukulan groundwater are contained also of Co (1.1-14), Ti (2-5), V (0.47-2), Cr (3).

Comparative analysis indicates that main part of the chemical elements of tukulans groundwater are lower than Clark values for river waters (Al, Ba, F, Sr, Li, Ti, V).

Fe, Mn and Cu are present in the tukulans groundwater more than Clark values for river waters. Zn and Co are present in the intrapermafrost groundwater at the Clark level values for river waters.

Generally, intrapermafrost groundwater (7 of 9) had increased content of iron and manganese. In comparison with standards of maximum allowable concentration content in groundwater of Fe exceeds by from 2 to 22 times, Mn exceeds by from 5 to 12 times that does waters less suitable for the use in the economic and drinking purposes.

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MICROSTRUCTURE OF SHELF SEDIMENTS OF THE KARA SEA

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Strategic interests of Russia in the Arctic is one of the most important topics today. The study of shelf sediments is one of the most rapidly developing direction of the Arctic research.

The study of sediments microstructure allows to obtain data on the size and shape of minerals and their aggregates. Also it allows you to assess the nature of the surface of the mineral grains, uniformity of deposits. In addition each of these parameters can be investigated with different detail. These indicators contain information about the conditions of the genesis of sediments. It allows to determine some of their properties, including engineering-geological characteristics.

The samples were selected directly from the shelf zone of the Kara sea during field work performed in 2007 by the expedition of VNIIOkeangeologia on the research vessel "Ivan Petrov". Samples were examined using scanning electron microscope (SEM) Hitachi TM3000 in

combination with an energy dispersive spectrometer Swift3000 (Oxford) in the laboratory of Institute of the Earth cryosphere SB RAS.

The samples were studied under different magnification. Small-scale survey allows you to assess texture, layering, the location of the single grains in space and their relationship with clay matrix. Also it allows to estimate the density and porosity of the sediments. Medium-scale survey allows a detailed examination of the structure of the sample, the surface of the individual grains, to assess the degree of roundness and leaching, to detect the chips and cracks, to note the signs of the genetic origin of the sediments. Large-scale survey, as a rule, necessary for the detection and detailed study of neoplasms, as well as other inclusions.

The small-scale survey revealed that the aleurite clay samples are characterized by high density and uniformity, low porosity. Individual sand grains in these samples are present in small amounts, as a rule, they are well rounded and completely covered with clay "fur coat". At larger magnifications clearly visible the presence of clay aggregates with a size up to 30 microns. Sediments are characterised by a mosaic orientation of clay particles.

Samples of sandy silt are characterized by a less dense structure, high porosity sediments and characterized by a honeycomb texture. The large increases allows to observed in arenaceous siltstone a large number of angular grains of quartz with features of cryogenic soils such as a conchoidal fracture, cracks, cavity of leaching.

Neoplasms in the form of iron sulphides and ferromanganese nodules established in samples. The presence of a large number of clay particles in all types of aleurites was found, which is typical for marine sediments, also marine genesis is confirmed by numerous finds of shells of gastropod and presence of marine diatoms.

According to the results of work performed we can draw the following conclusions:

1. Microstructure shallow sediments of the Kara sea varies depending on the lithological type of sediments: clayey siltstone have a dense homogeneous structure and low porosity, while sandy sediments, on the contrary, contain a large number of pores and are characterized by a honeycomb texture.

2. Neoplasms of iron (sulphides and ferromanganese concretion), sea shells and diatoms, characteristic of shelf sediments are present in the sediments.

3. Signs cryogenes were installed in some samples: quartz grains with conchoidal fracture, cavity of leaching and fresh chips. This may

indicate redeposition of eroded late Pleistocene terraces, largely transformed by the processes of cryogenesis under subaerial conditions.

TRANSFORMATION OF FROZEN SOILS DURING THE DISSOCIATION OF GAS HYDRATES

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The main reason for the appearance of gas emission craters, found in the territory of the North of Western Siberia, is the dissociation of gas hydrates in the frozen soils. The authors' position is that the onset of dissociation is associated with a local increase in temperature under the surface water body. There are four stages of gas emission craters development.

I stage. Formation of the lake above frozen soils. A zone of high temperature, compared with the surrounding soils, is formed under the lake.

II stage. Zone of temperature increase in permafrost, reaches a layer of gas hydrates. The process of gas hydrates dissociation begins with the gas and supercooled water release. The decomposition of a metastable gas hydrate causes an increase in the pore pressure, which is much higher than the hydrostatic pressure. Gas-water fluids under the influence of pressure begin to migrate to the least solid area, which is the zone of high temperature under the lake and to saturate the primary ice-soil substrate with gas.

III stage. Due to saturation with gas-water fluids, a rod consisting of gas-saturated ice with numerous traces of ice and soil flow, plastic and explosive deformations is formed under the frozen screen. The increase in pressure in the fluid migration zone leads to the mound development on the thermokarst lake site. As the lake is draining and passing from the subaquatic state to the subaerial, the temperature of the upper layer of the soil decreases. This forms a frozen screen, which is an obstacle to the movement of fluids coming from below.

IV stage. As plastic deformations in the frozen table reach their limit, fragile deformation fractures occur in it. The gas, which is under pressure and penetrates the rod of deformed ice all the way from the gas hydrate layer to the table, bursts out together with the ground and ice. As a result, a dry crater of the gas emission is formed.

Depending on the ratio of various factors, scenarios for the development of the gas emission craters and, accordingly, their morphology, may differ. With a slight and short-term rise in temperature, the gas hydrates dissociation can quickly end as a result of self-preservation. With sufficient depth and width of the lake, the gas released during dissociation may not accumulate under the frozen screen, but be released directly into the lake. Depending on the rate of pressure growth, gas emissions can occur both: without and with the formation of the mounds of various sizes and morphologies. In those cases when the pressure release occurs gradually, the formed gas-saturated ice-ground stock remains in the permafrost.

The proposed hypothesis is based on observations of the geological structure of the Yamal crater and other gas emission craters.

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FROZEN DEPOSITS OF THERMOKARST RELIEF (BOLSHEZEMELSKAYA TUNDRA, RUSSIA), INVESTIGATED BY GROUND PENETRATING RADAR

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Seven plots (50 × 50 m) in 2015 and nine - in 2016 were established in Bolshezemelskaya tundra (up to 100 km in the vicinity of Naryan-Mar) in the vicinity of the village of Khorey-Ver (Nenets Autonomous District), Kolva, Sandyvey, Shapkina rivers. The study of frozen deposits was conducted by ground-penetrating radar GPR SIR-3000, equipped by a low-frequency (70 MHz to 25 m) and high-frequency antennas (400 MHz, up to 4 m). Each profile was measured by dragging the GPR equipment at constant walking speed. Ground-penetrating radar (GPR) is well suited to imaging the near-surface thermal structure and stratigraphy of permafrost. GPR applications for the study of the permafrost zone, as a multi-phase system (ice, water, soil, air), is reduced to constructions with the release of its permafrost table, and sometimes permafrost base. This is due to the difference in dielectric permittivity of rocks. The basic principle of GPR is the transmission of a short electromagnetic pulse, with a specified frequency, down into the ground and the recording of

reflected energy as a function of time, amplitude and phase. The specified central frequency is controlled by the transmitter and receiver antennae length.

According to geocryological conditions, the territory belongs to the area of development of relict permafrost that lies deeper than 200 m. The studied areas were located in the zone of development of continuous permafrost (vicinity of the village of Khorey-Ver, Kolva, Sandyvey, Shapkina rivers) with a temperature -3 to -4º C, massif-island and discontinuous permafrost (East of Naryan-Mar to Shapkina river) with a temperature 0 to -1.5º C and massif-island permafrost (vicinity of Naryan-Mar, Pechora river) with a temperature 0 to -0.5º C. High ice content is characteristic for lake and lake-marsh sediments. The depths of the seasonally thawed layer varied from 0.5 to 2 m. Thermal-contraction crack and wedge ice, hillocks and area of frost heaving, thermokarstic and thermo erosion forms of relief are noted. Wetlands, blowing spots on sandy grounds, erosional forms of relief in combination with thermo-erosion forms are widespread. There are modern wedge ices in peat bogs. The study area occupies the subzone of the southern tundra. These are Middle Quaternary elevated accumulative platform plains and hollow-hilly glacial-marine plains with fragments of lake-glacial and lacustrine-alluvial accumulation. Absolute elevations reach from 100 to 160 m. According to lithology, the rocks under study are boulder loams, loamy deposits, clays, sands underlain by clays.

The landscapes and soils within the explored areas in 2015 can be divided into five different groups by the results of georadiolocation: 1 (first plot, «Shapkina-1»), 2 (second plot, «44 km»), 3 (third «14 km», fourth and sixth «2 roads» plots), 4 (fifth plot, «Red village») and 5 (seventh plot, «Larch»). Sixteen GPR profiles were laid on each plot. Geocryological, landscape, soil conditions within the studied areas of 2016 can be grouped into four different groups, based on the results of georadiolocation: 1 – «Khoreyver» (six plots, 60 GPR profiles), 2 – «Kolva» (1 plot, 8 GPR profiles), 3 – «Sandivay» (1 plot, 8 GPR profiles), 4 – «Shapkina-2» (1 plot, 11 GPR profiles). A deeper seasonally thawed layer can be found in areas with high shrubs and in hollow. Thinner seasonally thawed layers were encountered at zones with grass and moss or low shrubs. Studies with a low-frequency antenna (400 Mhz) show that the thickness of the seasonally thawed layer varies. It increases to 3.7 m. when approaching the shores of the thermokarst lake and to the hollow.

Peat plateau complexes offer an interesting challenge to the Cryosphere community as they are clear mosaics combining local-scale differences manifested as permafrost variations. As such variation occurs both horizontally and vertically in the landscape, GPR offer a good possibility to record current permafrost conditions across scales.

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GEOCRYOLOGY OF THE ANADYR MUNICIPAL DISTRICT

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The municipal district includes the territory of the Anadyr city and the Tavayvaam village, as well as the adjacent neighborhoods within a radius of 12 km, where there is a reservoir, helicopteral ground, quarryes, cemetery, dumps, fishing areas etc. The total area of the district is 40 km^2, while the residential area part (the actual construction of the city and village itself) does not exceed 5 km^2. Most of the territory of the municipal district is located on the pleistocene sea and glacial-sea plain, complicated by valleys of rivers, streams and basins of lakes. This is a typical tundra with marks of 10-50 m. In the north and west, the terrain is hilly, the mark of the peaks is 115-250 m. From the north and east, the territory of the district is limited by steep shores of the Anadyr estuary. The city of Anadyr is located mostly on the slopes of low hills with elevations of 116-131 m; the eastern part of the city and the village of Tavayvaam are located on the sea spit, the floodplain of the Kazachka river and the upper quaternary sea terrace.

The geocryological conditions of the Anadyr area are unique, due to the joint manifestation of natural and man-made factors: a harsh climate (the average annual air temperature is -7.4°C); neotectonics; dismemberment of the relief; a wide complex of rocks - from rocky paleogene and neogene to quarternary of various genesis; a thick layer of permafrost; the presence of closed and through taliks; dissemination of cryogypergene geological processes; fission of frozen soils etc.

In tectonic terms, the area is confined to the ledge of the Zolotogorsky uplift of the cenozoic Koryak-Kamchatka region. In the

paleocene the coal-bearing Kazachka depression was laid here. In the neogene there was an uplift of the territory, accompanied by magmatism and disjunctive tectonics. In the pleistocene, the transformation of the depression is associated with a sharp cooling of the climate, glaciations and transgressions, the formation of a powerful cryogenic stratum.

The current permafrost-hydrogeological conditions are determined by the continuous distribution of the permafrost thickness from 50-80 m in the valleys of watercourses and near the estuary to 190 m away from them. The temperature of permafrost soils at a depth of 10 m is -3 ... -6°C in natural conditions and -0.9 ... -4.6°C in the territory of the building. The through taliks are installed under the estuary, in the lower reaches of the Kazachka river, and also in the upper reaches of the streams, where elevation marks exceed 100 m. The subpermafrost waters in the elevated areas are fresh, off the coast salty and brine.

In the territory of the Anadyr city, within the slopes of the hills, the thickness of the frozen quaternary slope and eluvium varies drastically, from the first meters to 10-35 m; in some areas rock volcanic rocks come to the surface. A wide development of re-veined ice has been established. In the areas of water leaks from utility networks, thawing of underground ice, the formation of closed technogenic taliks, and ice formation have been revealed. On the shores of the estuary, thermo erosion ravines are intensively developing, during periods of summer-autumn storms, thermal abrasion of the ledge of terraces and cliff occurs. In recent decades due to adverse natural and man-caused impacts in the city had to demolish several emergency 4-5 storey buildings. A municipal special permafrost monitoring service for urban areas in Anadyr is absent.

FORMING OF NATURAL-TECHNOGENIC GEOCRYOLOGICAL COMPLEXES UNDER INTENSIVE ECONOMIC DEVELOPMENT OF PERMAFROST ZONE

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Instability of engineering permafrost conditions leads to unstable of deformations and deterioration of local population life. This is related to climate changes, with various anthropogenic impacts and with appearance of "new reality" - special conditions of heat exchange through the surface in system "permafrost - atmosphere."

During the last decades exacerbated the problem of permafrost-ecological situation stability and reliability of buildings and infrastructure under the economic development of the permafrost zone. There is a significant, sometimes an irreversible changes in landscape-permafrost conditions, which reduces geotechnical stability, increases the risks and losses.

Economic development of the cryolithozone creates a new pattern of geocryological conditions, different from natural parameters. This pattern is characterized, firstly, by drastic landscape transformation, promoting changes in the conditions of heat and mass turnover within the permafrost/atmosphere system, and, secondly, by engineering and technical influence upon the frozen ground, leading to alteration of its physical, thermal and mechanical properties. In the northern cities this causes ground temperature rising and intensification of hazardous cryogenic processes in areas under engineering development, reducing hereby stability of geotechnical environment.

Research goal - to estimate the change of frozen-ecological and engineering-geocryological permafrost conditions in the lifetime of the major cities.

In-work methods – permafrost engineering surveys, observation nature investigations (boring, soil pits, description of landscapes and cryogenic processes and events), numerical modeling, graphic and cartographic mapping.

Field studies were carried out in some large settlements in permafrost zone of Russia: Norilsk, Dudinka, Yamburg, Igarka, etc. It was found that the combination of certain natural and technogenic permafrost complexes are connected not only with the industrial orientation of region, but also with regional factors: climate, landscapes, hydrology and permafrost conditions.

As a result of anthropogenic-technogenic influence today is possible to allocate different complexes in terms of heat exchange on surface, a set of cryogenic and exogenous processes, changes in the temperature conditions at depth. For instance, field reconnaissance of permafrost and geological conditions resulted (and mapped) 13 complexes in Norilsk industrial area, 7 types in Yamburg gas condensate field, Taz Peninsula, and 12 complexes in Igarka city, lower Enisey. Modern complexes dynamics, depending on the scale of urban system, on the set of its elements and on duration of impact upon nature as well as on degree of stability of natural permafrost, attracts the particular interest.

These changes have triggered thermokarst processes causing increases surface waterlogging, have resulted in increased of deformation of the remaining buildings, etc. Succession of non-tundra vegetation does not promote the conservation and restoration of permafrost. The remaining buildings have significant geotechnical problems.

Under the changes in natural conditions, in view of observed in the last decade climate warming in the region and taking into account that the anthropogenic influence will increase, trends to degradation will continue.

FORECAST MODELING THE THERMAL BEHAVIOR AND CRYOGENIC PROCESSES IN ROAD EMBANKMENTS CONSTITUTED BY FINE GROUNDS

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Fine grounds are frequently used for constructing road embankments in the cryolithozone. This practice is associated with increased difficulties since fine grounds are prone to hazardous cryogenic processes and are typical of highly differentiated properties. Significant differentiation of physical and mechanical properties of the fine grounds happens during the freezing and thawing cycles. This poses an importance of a forecast model for seasonal and annual dynamics of the temperature in the road embankment body. Thermal changes in the embankment grounds trigger cryogenic processes, which may disrupt the transportation reliability.

We committed the forecast modeling in the WARM software environment for four study sites with different types of quasistationary thermal conditions (on roads in Anadyr, Norislk, Yakutsk, and Chita). The modeling embankment parameters were 6 m of height, comprised by sandy clay up to 5 m (ice content 0.15) topped with 1 m of ballast. We treated the natural surface grounds as typic to each of the study area.

Thermal state forecast revealed that the sandy clays in the embankments are more thermally contrasting and with shallower active layer than these for the embankments constituted by coarse grounds. This situation involves the volume of grounds within a permanent state of being frozen or thawed. We also observed steeper thermal gradients within the seasonally frozen layer.

Monthly analysis of the trends showed the segregational ice formation in fine grounds may result in various cryogenic textures. Moisture redistribution within the active layer along with the diversity of cryotextures differentiate structural behavior of the easonally frozen grounds, hence, producing uneven deformation of the embankment.

Favorable conditions for the frost heave appear first of all underneath the embankment top (for all of the study sites), on the margins of taliks (for Norilsk and Yakutia) and at the bottom of the active layer (for Chita). Frost cracking appears in all the study sites with the crack depth of 2-3 m for Anadyr and Chita, 3-4m for Yakutsk and 4-5 m for Norilsk. This process is forecasted for Chita and Yakutsk to be found within the seasonally frozen layer only, while for Anadyr and Norilsk the ice wedge can penetrate into the frozen core of the embankment.

The presented modeling outcomes can be employed for deformation modeling of the embankments as well as for elaborating more efficient embankment stability design solutions.

ELECTRICAL RESISTIVITY TOMOGRAPHY APPLICATIONS IN HYDROTECHNICAL STUDIES IN PERMAFROST AREAS

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Observation and control of the condition of a dam and coastal junctions, is an important criterion for its safe use. Geophysical methods are non-destructive inspection methods, a fact which is important for investigation of the technical state of water works facilities. Depending on the method, their use could allow its integrated assessment. Moreover, geophysical methods can be used during different seasons, and as a result allow observation of the construction all year around. Drilling, by contrast, can negatively affect the condition of these facilities. Piezometric and temperature boreholes cannot secure the dam stability.

In continuous permafrost, dam coastal junctions and spillway sections are the most failure-prone areas. Technical assessment of these, and other, dam sections is frequently performed using various electrical exploratory methods. Electrical resistivity tomography (ERT) is used in areas with complex geology, typical for landslides, infill and artificial soils, permafrost, inclined bedding and in karstic terrain.

Two stations were used in the frame of this study, ‘Syscal Pro Switch 72’ (Iris Instr., France) and ‘SibER-64’ (SibER-instruments,

Russia). Both stations have similar characteristics and operation modes. ERT method employs the same electrodes sequentially as transmitting and receiving, according to a template sequence, described as a measurements protocol.

In the scope of the study, the ERT technique was employed at a right-bank junction of the Sytykan River dam, Western Yakutia, and at the tail race of the Matta River dam, Central Yakutia.

ERT and drilling were used to revise the technical state of the Matta River dam at Berdigestyakh, at the tail race of the dam. Geoelectrical profiling revealed the non-frozen ground state at the dam base, neighboured by frozen ground. Control boreholes confirmed the presence of non-frozen water-saturated grounds at the dam base.

Observations on the Sytykan River dam are conducted for several decades. Long-term impact of the reservoir on the adjacent carbonate rocks with high ice content resulted in thawing of these rocks and a talik formation at a right-bank junction. Seepage flow has been developing at this section of thawed rocks, presenting itself through rill flows and gryphon cratering at the tail race of the dam. Talik area and its temporal development were observed using ERT technique. Geoelectrical profiles confirmed a thawed state of rocks at the coastal section, penetrating 400m deep into the coast. The talik limits were not detected because of the presence of power transport lines in the vicinity. Five consecutive years of ERT profiling are shown to be useful in tracing the changes in the internal features of talik zones.

ERT method is effective in showing geocryologic structure of each studied water facility (dam). The results of the ERT research can be used for developing protocols for supporting efficient and safe functioning of the dams. Geophysical monitoring is to be performed routinely in order to discover, in a timely fashion, to outline the geocryological changes at the base and junctions of the dams.

GLEYIC PALEOSOLS ARE TRACERS OF CRYOGENIC PEDOGENESIS DURING THE LATE PLEISTOCENE: CASES FROM EUROPE AND WESTERN SIBERIA

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Over last decades weak paleosols formed during the last cryochrone attracted major attention. They are interpreted as indicators of the climatic fluctuations within cryochrones as well as the markers of occupation surfaces of Pleistocene megafauna and Palaeolithic cultures. Correct pedogenetic interpretation of these paleosols is a key to decipher this archive.

It is accepted that during the major cold period extension of permafrost was much more than during the Holocene and previous thermochrones leaving behind numerous direct indicators of those events as pseudomorphs after polygonal ice wedges, sedimentary cryoturbations, solifluction features, segregation ice lenses etc. Pedogenetic processes are strongly influenced or modified in presence of permafrost. In particular icy permafrost layers could cause water saturation and thus switch on the hydromorphic soil forming processes: accumulation of peat and gleyzation in the mineral horizons, in the geomorphic positions and substrates which should limit redoximorphic processes and where otherwise well-drained non-gleyic soils are formed. We have interpreted some of the Late Pleistocene gleyic soils as a product of cryogenic paleopedogenesis and indirect tracers of ancient permafrost. The following cases were studied in detail:

1. Recently well-developed paleosols formed during the MIS3 – Bryansk Thermocrone were discovered to the north from the Eurasian Loess Belt, in the Center-North area of European Russia, Upper Volga basin (Rusakov, Sedov, 2012) and North-Western Siberia, Middle Ob' basin (Sheinkman et al. 2016). The paleosols are developed within the Late Pleistocene alluvial and lacustrine sequences and produced radiocarbon dates from its organics within the time interval of 50–25 Ka BP. They represent hydromorphic profiles with Histic horizons or

materials and gleyic colour pattern; in thin sections numerous specific ferruginous pedofeatures (concentric nodules, mottles, strypes). These paleosols demonstrate contrasting difference from synchronous Cambisols and Chernozems formed within loess sequences to the south. Conspicuously they are developed in the well-drained geomorphic positions, where modern soils (Podzols and Luvisols) have only weak surficial redoximorphic (stagnic) features.

2. In the Late Pleistocene loessic sequences of Germany and Austria strongly gleyed soils (known as Tundragley) correspond to the strata, developed during MIS2 including MIS3/MIS2 transition (Terhorst et al. 2015). Again, they are formed in the elevated landsurfaces providing good drainage on porous calcareous loess which hampers gleyzation. Indeed earlier (MIS3) and later (Holocene) soils of the same sequences are non-gleyic Cambisols and Luvisols. Additional evidences of permafrost in these soils are provided by morphological features of horizon fragmentation and mixing by cryoturbation and solifluction. Also in thin sections signs of cryogenic structuring, grainsize sorting, mixing of organic and mineral materials and deformation of plant debris and pedofeatures by frost processes are observed.

As far as in both cases we attribute gleyzation to water-logging by permafrost, we classify these paleosols as Reductaquic Cryosols. From the described spatial/temporal occurrence of the cryogenic gleyic paleosols we deduce the following: 1) Our data on gleyic MIS3 paleosols in the Upper Volga and Middle Ob' basins together with the observations of rather similar MIS3 gleyic paleosols in Kolyma lowlands (Zanina et al. 2011) point to a continuous zone of Histic and Reductaquic Cryosols in the Northern Eurasia during the Middle Valday/Karga cryochrone. This zone shifted several hundreds of km to the southwest during the MIS3-MIS2 transition, conditioned by the southward extension of permafrost.

In general, we propose to use the indirect pedological indicators of past and former permafrost in order to complete the information about its spatial distribution and chronostratigraphic occurrence.

DISTRIBUTION OF POTENTIALLY MINERALIZABLE ORGANIC MATTER IN CRYOSOLS

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The content and distribution of the potentially mineralizable organic matter in Cryosol profiles were detected. Soil samples were collected from surface organomineral (Oao 0-5 cm) and mineral (CR 5-23 and 35-60 cm) horizons and patches of cryoturbated (@ 56-60 и 60-66 cm, @ao 51-62, 64-71 и 65-70 cm) and layers buried by solifluction ([Oao] 28-48 cm) organic material (Kolyma Lowland).

The content of the potentially mineralizable organic carbon (C_0) were determined by biokinetic method (from data on the C–CO_2 emission from the soil incubated at constant temperature (22°C) and moisture conditions (25 wt. %) during 150 days). The incubation experiment was performed in triplicate. The biokinetic parameters were calculated by the method of nonlinear evaluation included in Statistica 6.0 software. The equation coefficients with the significance level $P > 0.05$ were discarded. The indices of carbon mineralizing activity ($CA = C_0 \cdot k$, mg/100 g per day) and stability of the soil organic matter ($SI = (TOC - C_0)/C_0$) were calculated. TOC content in the soil was determined by wet oxidation.

Approximating cumulative curves of the C–CO_2 production with single component exponential regression equations for the long incubation period, we calculated the initial concentrations of C_0 contents in different layers of the studied soils. The content of C_0 in Cryosol profiles was 86±7 mg/100 g in surface organomineral horizon (Oao), from 34±5 to 48±1 mg/100 g in mineral horizon (CR), 42±2 mg/100 g in layers buried by solifluction [Oao] and from 34±0.4 to 49±2 mg/100 g in patches of cryoturbated organic material (@) on different depths. The C_0 distribution in the Cryosols had a positive correlation with TOC ($r = 0.86$, $P < 0.05$), loss on ignition ($r = 0.86$, $P < 0.05$), K_2O ($r = 0.68$, $P < 0.05$) and opposite correlation with pH_{H2O} ($r = -0.73$, $P < 0.05$). The ratio of the C_0 to the TOC reached 1-3 %.

The index of CA takes into account the content of the potentially mineralizable soil organic matter and the rate of its mineralization. It gives us additional information on the formation and renewal of the organic matter available for microorganisms. Its values, was low in every layers of Cryosols (except for the surface organomineral horizons). The index of SI reached from 37 to 101. Such high rates of SI can be caused

of initial durability or nutritious inferiority of the components of organic matter and discomfortable conditions for microorganims especially in lower layers of Cryosols. That shows low size of the microbial biomass (38-121 mcg C/g) in every layer of soil profiles.

Thus, the highest content of potentially mineralizable organic matter in Cryosols is typical of the surface organomineral horizon. The main part of the organic matter of Cryosols in mineral horizon and patches of cryoturbated organic material and buried layers has low mineralization ability even under optimum temperature and moisture conditions.

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Session 6:
"Makeev readings" - Permafrost affected soils: formation and function

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PALEOCRYOGENIC STAGES OF EXTREME PEDOGENESIS IN THE GEOLOGICAL HISTORY OF THE EARTH

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Cryogenic soils (Cryosols and long season frozen soils) are formed in extreme environments, when pedogenesis is limited to a very short period with positive temperatures, and soil horizonation is influenced by cryogenic processes. The study of paleosols leads to the development of a new research area – paleocryogenic studies. Cold biospheres in duration do not exceed 4% of the geologic history of the Earth. Nevertheless plate tectonics and shifting of the poles result in expansion of paleocryogenic soils in the geological record of all thermal belts of the Earth, including tropical ones. During cold biospheres the glaciers could occupy up to one third of the Earth terrain with periglacial zones even wider. Frost features in paleosols could be correlated with similar features in soils of modern cryolithozone and for this reason paleocryogenic soils are one of the most reliable indicators of cold environments. Frost features in soils helps to reconstruct the former land surface (especially when paleosol profile is truncated), position of permafrost table and the depth of seasonal freezing. So paleocryogenic soils are important for stratigraphy and paleoenvironmental reconstructions.

Like in modern soils, frost features in paleosols appear at all morphological levels - soilscape, macro-, meso-, micro- and sub-micro levels. Frost impact also influences chemical features of paleosols. Frost features may be syngenetic to pedogenesis. However quite often features of temperate pedogenic and cryogenic features in paleosols are in a complex relationships, preceding each other. So that frost features could affect temperate soils and temperate pedogenesis could be superimposed on frost features appeared in the preceding cold period.

The evolution of the pedosphere in the geologic record is a succession of extreme cryogenic and non-cryogenic stages. Paleocryogenic soils are currently recorded starting from Paleo-

proterozoic, they are described in Neo-proterozoic, Upper Ordovician and at the time of Permo-Carboniferous glaciations. Paleocryogenic features are widely spread in soils formed in the Quaternary glacial and periglacial sediments and could often influence surface soils of the Upper Pleistocene glacial and periglacial areas.

Research is supported by the Russian Science Foundation, Grant #14-27-00133.

HYPOLITHIC BIOCRUST AS A SOIL HORIZON AND A HOT SPOT FOR SUBSURFACE ORGANIC MATTER ACCUMULATION IN THE ICE-FREE LANDSCAPES OF THE LARSEMANN HILLS (EAST ANTARCTICA)

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Hypolithic biocrust (occurs beneath rock debris, stone pavements) is often not perceived as a soil horizon and an integral part of the whole bio-abiotic profile. However, the profiles with cryptogamic hypolithic horizons could act as precursors to the more advanced soil formations or even the steady state soil bodies if occur in regions with climatic extremes. Hypolithic horizons dominated by cyanobacteria are the substantial spots for primary production and nitrogen source in oligotrophic landscapes of East Antarctica giving the rise to the more advanced biotic components (if conditions are favorable). Organo-mineral interactions that take place in hypolithic layers significantly alter the mineral matrix with some byproducts being vertically and laterally redistributed in soil. Understanding soils with cryptogamic hypolithic horizons is of fundamental importance, since they are possibly among the closest modern analogues of protosoils that existed before the higher vascular plants with root systems established.

As in many other parts of Antarctica a significant portion of organic matter in the Larsemann Hills oasis (69°24'S, 76°14'E) is produced by hypoliths in cryptic niches underneath the stone pavements on loose sediments and by endoliths inside the fissure network of hard rocks. The survey conducted in Larsemann Hills revealed that hypolithic bio-abiotic systems (soils) together with the endolithic ones (soloids) occupy from 20 to 60% of the wet valleys floors and slopes area.

The spatial distribution of various types of hypolithic biocrusts (cyanobacteria, green algae, fungi and bryophyte dominated series), its thickness, moisture content, carbon and nitrogen content/stocks, as well as C/N ratios were studied at a detailed scale at several key sites along the grid of 10x10 m with a step of 1 m (121 sampling points each). The data received are evident that microbial and cryptogamic photoautotrophs activity in hidden habitats under the stone pavements could lead to the substantial organic matter accumulation in extreme environment of East Antarctica - up to 5% of C and 0.4% of N. C/N ratios in modern hypolithic biocrust varied between 7 to 30 and δ13C between -24 to -30‰, both indicating differences in microbial and cryptogamic photoautotrophs contribution. Carbon dioxide emission (g C-CO2/m2 per hour) altered between 0.008 from the surface of cyanobacteria dominated hypolithic biocrust to 0.023 from the bryophyte dominated one.

The long-term preservation of organic matter in hypolithic environment is questionable in a number of locations in the Larsemann Hills since the values of fraction modern (F14C) according to the radiocarbon data surpass "1" in some cases. This contrasts with 14C "ages" for endolithic systems on surrounding slopes of the valley exceeding 500 and sometimes 1000 yr BP. However, once organogenous material of hypolithic origin is buried under sand and gravel only 2-5 cm deeper than its common location it could persist for long periods with 14C estimates up to 1100 yr BP. As evidenced by optical and scanning electron microscopy this old organogenous material of hypolithic origin still retains clear filamentous structure of cyanobacteria biofilm as well as remnants of EPS stabilized mainly by amorphous Al-Si compounds. Both "fresh" hypolithic organic carbon pool utilized by biogenic and abiogenic processes (e.g. erosion) and the older one, which is more stabilized through burial, are superimposed on the really old carbon pool with 14C "ages" exceeding 6000 yr BP. The latter starts from the depth of 8-10 cm and has a complex origin comprising relocated endolithic microfossils, lacustrine organic matter and carbon from other sources. It resembles the dual carbon pool model of a common soil with faster pool in topsoil and slower one in subsoil.

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CARBON FLUX IN TERRESTRIAL ECOSYSTEMS OF THE EAST ANTARCTICA (OASIES SCHIRMACHER AND LARSEMANN HILLS)

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Carbon balance is an important integral parameter illustrating ecosystems' functioning. It is a quantitative characteristic of the response to external influences and an indicator of the internal state of the system. The values of carbon fluxes in terrestrial ecosystems of the East Antarctica oases were calculated on the basis of field data.

Field investigations were carried out within the frameworkof the Russian Antarctic Expedition (RAE) seasonal work at the Novolazarevskaya station (70.45°S, 11.35°E) – Schirmacher oasis (RAE-58, 2013), and Progress station (69.30°S, 76.20°E) – Larsemann hills oasis (RAE-61, 2016).

The most typical forms of the Antarctic biota, such as algobacterial pellicles, moss associations and lichen clusters have been selected for research. Plant species were similar in both oases.

Studies of carbon dioxide fluxes from terrestrial ecosystems were carried out *in situ* according to the closed chambers method using a portable gas analyzer upgraded by the author to stand the Antarctic field conditions.

In the sites of a sufficient moss-lichen aggregations and algobacterial pellicles coverage, as well as in the vegetation-free-soil areas chamber basements were installed for 24 hours prior to measurements. The equipment included 10 opaque (diameter 10 cm, height 25 cm) and 3 transparent chambers (diameter 9 cm, height 20 cm).

To assess a daily respiration flux, three opaque-chamber measurement sessions were carried out. Each session consisted of a preliminary measurement for 2-3 minutes, followed by a one-hour exposure with closed valves. A post-exposure measurement, so called "accumulation", took 1-3 minutes (up to a maximum concentration of CO_2). The "instantaneous" value of the daily respiration flux was calculated as a difference between the last value of the "accumulation" and the last value of the preliminary measurement. Similar measurements were carried out in transparent photosynthesis chambers, which were first exposed to light and then covered. After each measurement session, the chambers were opened to restore the natural conditions.

The respiration flux data below was expressed in [$mgCm^{-2}hr^{-1}$]. The value for the Schirmacher oasis moss associations (28.25) is almost 3 times higher than the value for the Larsemann hills oasis (6.42), the average soil moisture was 3 times higher, respectively, and resulted in 21.5% and 8.7%. The soil moisture under moss-lichen aggregations was identical in both sites and valued 12%, while the values of respiration differed in the selected oases and resulted in 9.79 and 6.39 respectively. The average surface air temperature in the Schirmacher oasis was 1 ^{O}C higher then in Larsemann hills (6.0 ^{O}C and 5.1 ^{O}C). Algobacterial pellicles emitted much less carbon dioxide than moss aggregations, and the Larsemann hills oasis emissions were more intense (4.33) than those in the Schirmacher Oasis (2.76), with the respective average air temperature of 5.9 ^{O}C and 4.7 ^{O}C and soil moisture of 32.5 and 36.6%. A low carbon dioxide flux was registered in vegetation-free soil (0.66-0.76 and 0.68-0.74 respectively). It is remarkable that similar fluxes were registered in soil of different oases. Integral darkness period flux for the season in the Schirmacher oasis resulted in 42 $mgCm^{-2}$ hr^{-1}, while similar biotopes of Larsemann hills oasis emitted 19 mg of carbon per hour.

THE AGE OF ORGANIC MATTER IN SOILS AND SOIL-LIKE SYSTEMS OF THE OASES OF EAST ANTARCTICA

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What are the possibilities for the formation of temporally stable organic matter (OM) under the extreme conditions of the oases of Antarctica and for the continuous development of soil organoprofile from the date of the latest retreat of glaciers? It is assumed that the modern phase of pedogenesis within the coastal zone of Antarctica has the age of the Last Glacial Maximum or younger (Bockheim 2015). Our research objects included main types of soils and soil-like systems within three oases of East Antarctica. From existing palaeogeographical data on the oases studied follows the assumption that, from the start of second half of the Holocene, these oases have been free from ice and that their size and features have barely changed up until the present time. The age of OM was determined by radiocarbon dating with the use of accelerated mass spectrometry (AMS). The treatment of the samples was influenced by

both the small size of dated materials (e.g., endolithic soil-like systems) and by the low organic carbon content in most samples. The total amount of data obtained (around 40 radiocarbon dates) demonstrated that a temporally stable pool of OM can be formed under the extreme conditions of Antarctica, where the OM is originated not from vascular plants, but from some cryptogamic organisms and photoautotrophic microbes. Endolithic soil-like systems that develop upon stable horizontal rock surfaces within the East Antarctic oases are at least 500 years old and, in some cases, more than 1000 years old. The characteristic timescale for the formation of wind-sheltered soils is about 500 years and for that of soils with macroprofiles under moss communities – just up to 300 years. The hypolithic soil-like systems that develop under contrasting conditions of desiccation and wetness are characterized by rapid organic matter renewal without the accumulation of organic compounds. Soils (with micro- and macroprofiles) sheltered from winds that occupy an epidaphic niche are characterized by a gradual increase in radiocarbon age with depth, which also confirms the possibility for the formation of stable organic and organo-mineral substances, despite the original sources of organic matter being poor in polycyclic compounds and the biological cycle being slow. Among the radiocarbon dates obtained, only very few were significantly older than the aforementioned typical ages of the OM. The older dates included 1100 BP for buried soil horizons, around 6000 BP for the lower horizons (20-25 cm) of hypolithic complexes and 1800 BP for the OM of endolithic soil-like systems. It should be highlighted that the most ancient dates were those obtained from the horizons that had the lowest (less than 0.5%) organic carbon contents. Therefore, the oases have an ancient carbon pool, the stabilization of which is likely to be associated with the following processes: the OM burial, the encapsulation of an ancient microbial OM (similar to the OM stabilization within aggregates/peds), the adsorption of OM by clay minerals and/or the formation of stable organomineral complexes. However, the continuous formation of an organoprofile of Antarctic soils is limited by climatic and physiographic factors: strong winds, intensive water erosion and local catastrophic events that disrupt the soil cover.

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CARBON DIOXIDE EMISSION AND CARBON STOCKS IN NATURAL AND ANTHROPOGENICALLY-CHANGED SOILS OF THE LARSEMANN HILLS OASIS, EAST ANTARCTICA

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The investigations of greenhouse gas fluxes and carbon stocks are relevant for polar latitudes. There are numerous examples where global warming has led to the mobilization of this carbon and increased greenhouse gas emissions. Most studies are concentrated in the Arctic. In southern polar regions the most studied areas are Maritime and West Antarctica. Only a few articles were published based on the results of research in East Antarctica (Zhu et al., 2007, 2008; Ding et al., 2013)

Field measurements (closed chambers method with gas analyzer) were conducted in the Larsemann Hills oasis (69°30′ S, 76°20′ E; Princess Elizabeth Land, East Antarctica) in January 2016. This oasis is occupying 50 km^2 of ice-free territory. In contrast to the Dry Valleys—large continental oases of Western Antarctica—the studied territory is characterized by the presence of temporarily waterlogged sites in the valleys. It is argued that the deficit of water rather than the low temperature is the major limiting factor for the development of living organisms and the pedogenesis on loose substrates. The soils of the wet valleys in the Larsemann Hills oasis do not contain carbonates. The larger part of the biomass is concentrated inside the mineral soil matrix rather than on the soil surface. The stresses caused by surface drying, strong winds, and ultraviolet radiation prevent the development of organisms on the surface of the soil and necessitate the search for shelter within the soil fine earth material or under the gravel pavement (hypolithic niche) (Mergelov, 2014). The dominant soil taxa are Aquiturbels, Haploturbels, ornithogenic and limnogenic soils, and endo- and epilithic soil-like bodies (Mergelov et al., 2014).

Organic carbon stocks in different soils of the Larsemann Hills varied from 0.1 to 37.2 Mg C ha-1. Maximum was registered in lacustrine and ornithogenic varieties, minimum - in epilithic, hypolithic and ahumic bodies. This is several times less than for the Antarctic Peninsula (King George Island).

In the Larsemann Hills oasis CO_2 emission in soils under subaquatic green algae is 7.3±1.5 mg C m-2 hour-1, soils with hypolihitic biocrust 8.0±0.8; «ahumic» soils (no phototrophs) 6.2±1.4; soils under moss 21.2±5.4; soils in wind shelters under moss communities with ornithogenic impact 16.0±2.6 mg C m-2 hour-1. The most common anthropogenically-changed soils in the oasis are the soils of the tracks of the crawler vehicles (ATV, tractor, etc.). The vegetation cover in these areas is disturbed, and sometimes is completely absent. In these anthropogenically-changed soils under disturbed moss cover carbon dioxide emission is reduced by one and a half to three times.

Surface CO_2 fluxes in the McMurdo Dry Valleys generally range from -4.3 to 6.5 mg C m-2 hour-1, although at sites with higher C and moisture contents rates can be as high as 33.7 mg C m-2 hour-1 (Parsons et al., 2004; Gregorich et al., 2006). Average CO_2 soil emission in Maritime Antarctica (King George island) is from 3.5 mg C m-2 hour-1in ahumic soil to 52.0 mg C m-2 hour-1 in soil under moss cover and 97.5 mg C m-2 hour-1 in soil under *Colobanthus quitensis* and *Deschampsia antarctic* (Thomazini et al., 2015, 2016).

Thus, average carbon dioxide emissions in the Larsemann Hills oasis (East Antarctica, Mid Antarctic snowpatch barrens) is higher than in the Dry Valleys (West Antarctica, cold deserts), but lower than in Subantarctic tundra and barrens (Maritime Antarctica). In the cases of strong anthropogenic disturbances soil carbon dioxide emission significantly decreases.

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SOIL HUMIC ACIDS OF DIFFERENT ENVIRONMENTAL CONDITIONS ON SHIRMAHER OASIS TERRITORY (EAST ANTARCTICA)

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The Shirmaher oasis is positioned in the Central part of Queen Maud Land in 90 km from the Lazarev Sea (East Antarctica). It is one of the coldest flat Antarctic oases. This territory is characterized by the presence of different combinations of environmental conditions for the formation of soils: hills of different heights (an average from 10 to 100 m) with different orientation in space and location in relation to the wind rose. Soil-forming rocks have different texture and stoniness. The moss and algal communities and presence the areas without vegetation cover are predominated. Detailed characteristics of the Shirmaher oasis environment conditions formation in the territory of the, their morphological and other properties of soils wrer given earlier (The Soils of Antarctica, 2015).

More than 130 humic acids are extracted from soils by 0,1 n NaOH after freeing their from calcium. Then humic acids are precipitated with 2n HCl. Treatment of humic acids either by 6n HCl or the mix HCl and HF for removal of ash elements was not carried out because additional hydrolysis can reduce the amount of carboxyl and other functional groups.

The composition and spectral features of humic acids were investigated. IR, UV, VIS-spectrum and spectrum of fluorescence and NMR ^{13}C were analyzed. All quantitative parameters of humic acids were recalculated for ashless matter.

A complex study of soil humic acids in different forming conditions made it possible to establish that:

– the hydrogen and carbon ratio in elemental composition of humic acids does not depend on vegetation type and fluctuates within 1,4–1,6; the saturation of humic acids with nitrogen is high; the ratio of carbon to nitrogen does not exceed 10–11 in most cases.

.– the quantity fluorescence characteristics of humic acids (λ_{max}, M_1, α) fluctuate within narrow limits; the maximum emission and magnitude of the first moment (M_1) lie in limit from 460 to 465 nm and 460–468 nm respectively. These characteristics do not correlate with vegetation communities.

– the IR spectra of the humic acids of the soils under different forming conditions have a high degree of similarity; the typical maximums of humic acid absorption are found in all samples; this indicates the proximity of their chemical structure and confirms that we are dealing with typical humic acids that characteristics are similar to the Antarctic and the Arctic other regions: quantitative estimation of the functional group content based on IR spectroscopy data was carried out; it is based on the ratios of the optical densities of the absorption bands of oxygen-containing groups to optical densities corresponding to aromatic polyconjugated systems at 1610 cm^{-1} and aliphatic markers at 2920 cm^{-1}

– the determination of the quantitative indices of the intensity ratio of the light absorption bands shows that all humic acids have a high share of aliphatic fragments with the high contents of active sour groups (carboxylic and hydroxyl). The results of the of the ^{13}C NMR spectrum analysis confirmed the high share of aliphatic macromolecules in humic acids. A definite link of its share with the forming conditions within the territory of the Schirmacher oasis has not been established.

CRYOGENIC AND STAGNIC GEOCHEMICAL BARRIERS IN SOILS OF THE NORTHERN WESTERN SIBERIA

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Polar ecosystems are crucial in sense of polar biomes functioning. Soils are the part of polar ecosystems and play a key role in accumulation, transformation, redistribution and migration of various chemical compounds and elements. As a whole, soil is as a linkage between small and large geological cycle of matter and energy. Besides, studying of polar soils has a practical value due to intensive development of polar regions infrastructure on the one hand and high vulnerability of polar ecosystems on the other. Chemical pollution of polar regions landscapes

leads to the risk statement of region's flora and fauna and to decline in human live quality in settlements. Studying of cryogenic landscape geochemistry (in particular, geochemical barriers) let to determine trends in accumulation of chemical pollutants in soil-permafrost layer and develop adapted environmental legislation.

The area of study is located within Yamal autonomous district and cover southern part of Yamal peninsula, the Polar Urals and its foothills, Gydan peninsula and Beliy island. Soil diagnostics were performed according to "Russian Soil Classification system" and WRB.

Depths of cryogenic and stagnic geochemical barriers have been determined using vertical electrical resistivity sounding with portable device Landmapper (to a depth of 300 - 500 cm) according to Schlumberger methodology. The distance between the A and B electrodes ranged from 10 cm to 3 m while the distance between the M and N electrodes was constant – 10 cm. Depths of active layer in each key plot have been determined using the same approach as well.

Most hydromorphic soils – Stagnic Cryosols and Histosols – are confined to over-saturated sites of valleys, lides and floodplains. Gleyic and cryogenic processes determine formation of these soils. Automorphic soils are represented by Spodic Cryosols and Podsolised Cryosols.

Functional relationships between soil type and profile distribution of electrical resistivity values have been distinguished. Specifically, it has been obtained quantitative data on characteristic ranges of this indicator for different soil horizons. It was shown that the depth of cryogenic geochemical barrier varies from 20-30 cm (in northern Yamal and Gydan) to 150-200 cm (in southern Yamal). Besides, role of gleyic processes in geochemical organization of soil profiles has been determined. Gleyic and superficial gleyic horizons are stood out in studied soils as well as Cryic horizons. In general, studied region is characterized by predominance of gleyic soils of over-saturated valleys and plains, lides and floodplains. Cryic horizons in such conditions are normally in subordinate positions with supra-permafrost gleyic and superficial-gleyic horizons below and above. Cryoturbation processes play a significant role in redistribution of trace elements from topsoil to lower horizons and their immobilization in gleyic horizons. This determines the necessity of harmonization existing standarts on chemical pollutants limits in soils in context of their cryogenic redistribution and suprapermafrost accumulation. Al-Fe humic process is activating in studied area only on aeolian sediments and alluvial shafts (where gleyic process is not

developing). It is revealed regional feature of hydromorphic cryogenic soil-forming in northern Western Siberia.

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RECONSTRUCTION OF THE DYNAMICS OF THE NATURAL ENVIRONMENT BY THE METHOD OF DEFINITION VEGETATIONS RESIDUES IN PEAT AND THE DEPOSITS OF THE KHASYREY ON TERRACES OF GYDA RIVER

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In 2016 vegetations residues in peat and frozen sediments from a drained lake trough within the II lacustrine-alluvial terrace in the north of Gydan were studied. This khasyrey is located on the left bank and is washed out by the Gyda River. The polygonal relief is expressed on the surface of the hasyrey, and their polygons and depressions are covered with a layer of peat.

A section (clearing B4-2016) with a height of 3 meters with polygonal vein ice and a peat horizon from a coastal ledge of khasyrey was studied. Vegetation residues are defined in micropreparations from sediments and peat.

In a soil with a layered wave ripple on the 197-197 cm depth, lenses and layers (1-5 cm thick) out of vegetations residues are located. Carex sp., Equisetum sp., Eriophorum sp. and dominant Drepanocladus polygamus are represented in this peat sample. This community of plants is typical for places with high humidity, and this type of moss - for an environment with a high content of mineral salts and calcium carbonate in the soil. These features of the lamination of deposits and botanical composition of plants, indicates on their accumulation, probably, during the flooding of khasyrey by flood waters.

The monolith of autochthonous peat a thick of 23 cm was selected from top of khasyrey. The peat has inclined lamination and parallel to the surface with hummocks, it the bottom disturbed by cryoturbation. In the dry state, it is divided into 6 layers along visible boundaries.

The bottom layer of decomposed peat from the 23-20 cm depth is contain the remains of roots of Eriophorum sp., Carex sp., Equisetum sp., Calamagrostis sp. and Vaccinium vitis-idaea, there are leaves of moss Drepanocladus polygamus. In yellowish brown decomposed peat on the 20-12 cm depth, in addition to the listed plants, an insignificant amount of birch appears and the amount of moss Drepanocladus polygamus decreases. These layers correspond to the beginning of the accumulation of peat and the completion of the floodplain regime of precipitation accumulation.

Peat with lenses of light gray fine sand from the 12-8 cm depth is less decomposed. This is shown by the remaining hairs on the roots of the sedges. In this community of plants - the largest content of birch leaves, Empetrum sp. detected; completely moss of Drepanocladus disappears. In addition to the listed plants Petasites sp. detected in yellowish-brown with impurities of sand of sample of peat from the 8 - 5 cm depth. This set of plants is prefers for comfortable conditions (as for the Betula nana and Petasites sp.) - without excess moisture on peat and sedge bogs of typical tundra and without flooding with floodwater. Friable dark brown peat (from the 5-3 cm and 0-3 cm depths) includes impurities, layers of sand and roots of modern plants. Peat-forming plants include Vaccinium uliginosum, Betula nana, Carex sp., Equisetum sp., Eriophorum sp., Petasites sp., Rubus arcticus and moss Sphagnum sp. In the botanical composition, the quantitative of birches decreases and moss of characteristic of acidic substrates appears. The upper layers of peat were accumulated in the subaerial conditions of the khasyrea, without flooded with the waters of the Gyda River.

The botanical composition of peat and plant residues in sediments differs from modern vegetation in the hasyrey, it's connected to changes the climatic conditions and the furnishings of their accumulation.

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PRIMARY EFFECT OF WARMING ON FROZEN PEATLAND SOILS PROPERTIES (NORTH-WESTERN SIBERIA, RUSSIA, NADYM SITE)

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Peatlands located in Russia contribute up to 35% of the global carbon stock in peatlands and it should be focused on when accessing permafrost-affected soils feedback to climate changes. Considering this fact we performed our study to comprehend the initial frozen peatland soils response to temperature increase.

In the field (aug 2016) the soil transplant experiment was performed in a frozen bog ecosystem in forest-tundra (65°18′55″N, 72°52′34″E). We established two experimental sites with contrasting soils daily average temperatures (0-5 cm): "cold site", 5.5 °C, and "warm site", 11.8 °C. Undisturbed soil samples in PVC tubes were cored from cold site: one part was transported to the warm site and the second part was placed back as a control. After one week of CO_2 efflux measurements we've found the transported soils CO_2 efflux rate to be 4 times higher comparatively to control (320 and 76 mg/m^2*per h. correspondingly).

In the laboratory (autumn 2016) Carbon (C) mineralization rate, basal respiration (BR), dissolved soil organic carbon content (C_{DOC}) were analyzed to estimate the soils first response to warming. We found almost positive soils feedback that was shown as 90% growth in C mineralization rate on the last 30th day of sequential temperature increase from 5 to 30 °C. BR rate was in line with C mineralization rate and at 25 °C after 5 days of equal-time incubation was 2,5 times higher as compared to incubation at 5 °C for upper soil layers. Instead of these results the C_{DOC} content haven't dramatically changed from 5 to 25 °C for similar upper soil layers.

In summary our first results indicate a possible frozen peatland soils adaptation to substantial increase in temperature of their functioning and this item should be considered if discussing soils respiration contribution in various climate prediction models.

DIVERSITY AND COMMUNITY STRUCTURE OF PROTISTS IN THE ARCTIC CRYOSOLS AND PERMAFROST

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Previous investigations have shown that resting cysts of soil protists can survive in permafrost for thousands of years at negative temperatures. The species diversity of ancient viable protists is assumed to be a result of constant selection going not only in permafrost sediments, but also in the modern permafrost soils during long-time transition of cysts into the frozen deposits. Cryosols are subjected to the different processes of cryogenic mass-exchange that redistribute the fragments of the uppermost soil horizons with microorganisms inhabiting this material. The transition of protist cysts from the uppermost to the lower parts of the Cryosols profiles and then into the upper layers of permafrost is considered as the period of pre-adaptation of organisms and formation of communities capable to prolonged cryobiosis and forming a natural cryobank of soil biota in the permafrost.

The main goal of the study was to investigate the patterns of diversity and abundance of viable protists' community in the permafrost sediments and in the profiles of Cryosols and to determine species that have developed adaptations to survive in consistently adverse environments.

Forty three analyzed samples of organic and organo-mineral material from fourteen pits of Turbic Cryosols were collected during 2013-2016 field seasons in the region of Kolyma Lowland and arranged into five groups according to the leading cryogenic mass-exchange processes: modern uppermost organogenic horizons undisturbed by cryoturbations; their fragments that were buried by solifluction; cryoturbated fragments; cryoturbated fragments that were accumulated in the transient layer of permafrost; mineral horizon of Cryosol profile with no signs of cryoturbation. Radiocarbon age of plant remnants that were brought into the mineral part of Cryosol profiles by cryoturbation processes varies within 2,1-4,5 Kyr.

The taxonomical analysis of cultivable protists communities isolated from Turbic Cryosol revealed 56 species and forms of

heterotrophic flagellates from 11 taxonomical groups and flagellates *incertae sedis* and 38 species of ciliates from 7 taxonomical groups. Protists vertical distribution in soil profiles allows to select three groups of species:

1. Species occur only in the modern uppermost soil horizons (23% and 32% of the total number of isolated ciliates and flagellates species, respectively).

2. Part of the protists' community (71% and 36% of ciliates and flagellates species) that occurs in material of organic and organo-mineral soil horizons both a modern and buried into the Cryosol profiles by different processes of cryogenic mass-exchange.

3. Species found only in the organic material buried in the processes of solifluction and cryoturbation (5% and 32% of the isolated ciliates and flagellates species).

Communities of ancient viable protists isolated from permafrost sediments contain 13 species of ciliates and 26 species of flagellates that is 32% and 56% respectively from the diversity that was observed in protists community of modern Cryosol.

According to our results significant part of protists communities in Cryosols have adaptive and protective mechanisms enabling long-term cryobiosis in the inhospitable conditions of the arctic soils and permafrost.

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SOILS FORMING ON CRYOCONITES MATERIAL IN THE RETREAT ZONE OF THE GLACIER

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Cryoconites are the finely dispersed sediments on the surface of a glacier containing mineral and biological components. The cryoconitematerial serves as a unique soil-formingand plant-supporting substrate because of its properties, particularly, a high content of biogenic elements and a fine particle size, as compared to other deposits within the modern periglacial zone.

The study was conducted on soils formed on moraines of different ages (exposed for 18 and 70 years as a result of the glacier retreat) and

also fine earth and moss fragments from cryoconite holes in the Aldegonda Glacier located in the Nordenscheld Land, western Svalbard (N 77.98, E 14.11). This glacier is retreating very rapidly (2 km in the last 100 years). Soil profiles are 15-20 cm thick with a carbon content of 2.5-1% were found on young moraines. Thus, we see the soil on the cryonicite material of the glacier in the first decades of formation, the same in thickness as the soils that formed hundreds of years around. The organic matter being inherited from cryoconites. The morphological features of cryoconite material are preserved for several decades with in the soils studied, with cryogenic differentiation being the main process of reorganization of mineral mass. On the basis chemical and morphological analyses, isotope analyses it was revealed that the cryoconite material is the primary source of SOM on the moraines studied. Judging from the radiocarbon dates, the cryoconite material is supplied as a result of rapid melting of deep layers of the glacier. The radiocarbon age of soil organic matter (SOM) varied from 6600 to 11000 14C years BP on moraines exposed from under ice18 and 70 years ago, with the most ancient SOM found on 70-year old surfaces in the central part of the glacier bed. The age of organic matter in cryoconite holes was about 7000 14C years BP. The age of moss fragments in cryoconite holes was 30-70 years BP (CaliBomb).

These radiocarbon dates show the inheritance of the organic matter of the Holocene from the glacier. It is important that carbon accumulated in the glacier body is incorporated into the carbon cycle.In the zones of accumulation of cryoconite, the process of soil formation is faster.

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ROLE OF O.V.MAKEEV IN CLASSIFICATION OF COLD SOILS AND THEIR PLACES IN DIFFERENT TAXONOMIC SYSTEMS

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O.V.Makeev was a forerunner of the contemporary place of cryogenic soils in the most of soil classification systems of the world. Makeev and Dugarov (1972) proposed the separation of cryogenic and cold soils at the highest taxonomic level. In his paper (Makeev & Kerzhentsev, 1974) he wrote: “The cryogenic processes result in specific

soil properties and the development of unique soil types, subtypes and taxa at lower levels. Two major groups are involved: frostgenic soils and coldgenic soils. In frostgenic soils, the seasonally frozen and thawed layers contact permafrost tables. In coldgenic soils, either the permafrost tables occur below the maximum depths of seasonal freezing and thawing or there is no permafrost. The term "cryogenic soils" should be used to cover both frostgenic and coldgenic soils".

Since 1978, when Cryosolic order has been established in the Canadian soil classification system the permafrost-affected soils are recognized as very important ones in several classification systems of the world. In the Canadian system and in the US Soil Taxonomy soils of the world are divided into those with permafrost and other soils. In WRB system permafrost-affected soils are also very high. In Chinese and Russian classification systems the permafrost are recognized only on the 3rd-4th taxonomical levels. However since that time when all these classification systems came into being community of soil scientists got new challenges for the classification of cold soils in a wider sense than just permafrost-affected ones. 1. The problem of shallow soils of cold climates, whether we can accept them as Gelisols, as they theoretically have permafrost within 1 or 2 m of solid rock, or they should be classified as Gelorthents as nobody can see permafrost in the profile because of shallow lithic contact. 2. The contrary problem on the classification of soils in loose materials which have permafrost below 2 m, but this permafrost results in cryoturbations and salinity of soil horizons because of impermeability of the deep permafrost. 3. The problem of soils with well-pronounced cryoturbations but without permafrost. 4. The problem of soils of highly continental climates – they may be very productive but with low MAST. 5. The problem of Antarctic soils – they may have same names as tundra soils but they are microsoils.

The new draft list of cold soils on the middle level of classification is proposed for wide discussion to be used in the different soil classification systems. It includes all the soil features that Gelisols/Cryosols have in Soil Taxonomy and WRB soil classification systems. Several amendments are proposed – AHUMI- (for soils with <0,02% organic carbon content), CAMBI- (with cambic horizon), CRUSTY- (for soils with crusts on the surface that is typical for arid landscapes), HOMOGENI- (for soils where cryoturbations result in soil mass homogenization), MUCKY- (for soils with mucky organic horizon), ORNITHI- (for soils enriched by bird guano), PAVI- (for soils with stony pavement), PROTI- (for soil profiles without macro-horizons).

Several amendments to the Russian system are also recommended. 1.Expand the understanding of the subtype "frozen", bending it to the international standards (cryosols/gelisols), - soils with permafrost within the limits of 1 meter, and also soils with permafrost within 2 m under the presence of cryoturbations. 2. Check all soil units on the presence of "frozen subtype" - do not forget peat soils. 3. Enter the sub-type of "deep-permafrost" for soils with the appearance of cryogenic processes and the presence of permafrost >2 meters. 4. Enter the diagnostic features and subtypes "supra-permafrost-organo-accumulative", "supra-permafrost-retinized", "supra-permafrost-gleyic", "supra-permafrost-salinized", "supra-permafrost-calcified".

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TWO VIEWS ON SOIL CRYOGENESIS AND THE CONCEPT OF CRYOZEM IN RUSSIAN SOIL SCIENCE

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At the 1965 Conference on Forest Soil Science held in Krasnoyarsk, prof. O.V. Makeev posed the following question: “Is cryogenesis one of the main ways of soil formation (“type of pedogenesis”, according to Kossovich) or permafrost features only form a peculiar natural background causing specific facial manifestations of the main ways of soil formation revealed beyond the permafrost zone?” This denoted two radically different points of view on soil cryogenesis, its place in the system of soil-forming processes, and the classification of soils subjected to perennial or seasonal frost conditions. The differences between these positions translated into a lively and fruitful discussion, the culmination of which fell on the turn of the 1970s and 1980s.

Around the same time, prof. I.A. Sokolov, leader of one of the disputing parties, formulated the concept of hydromorphic nongley soil formation: a principally new type of pedogenesis. The soils resulting from hydromorphic nongley soil-forming processes were referred to as Cryozems. I.A. Sokolov was first to identify this taxon in the northern taiga; however, analogous soils were soon described for the tundra zone, as well as for more southern taiga landscapes of Trans-Yenisei Siberia. All Cryozems develop on shallow permafrost; their range corresponds to

areas with the most severe and continental climate, where the effect of the cryogenic factor is most manifested.

The concept of Cryozem, in a sense, conciliated the contradictory views on soil cryogenesis. The synthetic point of view can be formulated as follows: cryogenesis creates an original natural background and participates, along with other processes, in the profile formation of most soils in the cryolithozone, its extreme form acts as a self-contained type of pedogenesis and creates various Cryozems. In the case of Cryozems, cryogenesis suppresses other profile-forming processes: humus accumulation, gleization, eluvial–illuvial redistribution of substances, soil weathering and other metamorphism manifestations. The suppression of most soil processes in the profiles of Cryozems results in the dominance of cryoturbation signs, which are also common in many other (both permafrost-affected and cold) soils of the cryolithozone. The slight manifestation of other pedogenic processes makes it possible to distinguish, along with Typical Cryozems, other Cryozem subtypes: Gleyic, Pale-metamorphosed, Humus-impregnated, and other subtypes, which are transitional taxons to other sections of the postlithogenic order of soil classification.

CLASSIFICATION OF CRYOGENIC SOILS IN THE CURRENT RUSSIAN SOIL CLASSIFICATION SYSTEM: RESULTS OF ONLINE DISCUSSION

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Cryogenic soils in the recent Russian soil classification system (RSCS) were discussed by a group of experts in terms of revising their taxonomic position; improving the definitions of diagnostic horizons and diagnostic properties, probably, introducing new ones; accounting for the

depth of permafrost for qualifying soils as “cryogenic”, or as “permafrost-affected”.

Since the criteria for specifying *orders* in RSCS comprise processes inherent to all order’s members and manifested as a common diagnostic horizon, in case of cryogenic soils order, these are: cryogenic mass-exchange processes - cryoturbations: mixing, heaving, cryohomogeneization, frost boiling, cryogenic sorting, solifluction, as well as formation of specific pedocryogenic structures (“cryocambic” or cryometamorphic phenomena), fragmentation of organic material. Hence, the following diagnostic horizons are identified: cryogenic CR, cryometamorphic CRM, cryogenic organo-mineral CRO, the latter was recently proposed. The common diagnostic element for the order is permafrost within 2 m depth indicated as $_{T}$C. According to the rules of RSCS, soil *types* are identified by combinations of horizons. In cryogenic soils order, CR and CRO horizons may be combined with gley and/or organic horizons providing several types *of* cryozems. As for the cryometamorphic soils, where permafrost may be absent, the question of including them into cryogenic order remains open for further discussion.

At the *subtype level,* minor manifestations of the processes enumerated are recorded in cryozems, similarly to WRB supplementary qualifiers for Cryosols, such as humus impregnation, cryogenic abrasion or stratification in patterned grounds, particularities of sorting, etc.

Many obvious cryogenic features in soils of other orders should be also qualified at the subtype level, such as cryoturbations in podzols and other soils without permafrost at least within 2m. In frost-affected soils on unconsolidated materials, deep permafrost may be also responsible of redoximorphic features and salinity owing to its impermeability, hence, the subtype level in any soil type is also appropriate. An opposite situation is common in shallow soils of cold climates: they may be recognized as cryogenic ones, since they theoretically have permafrost within 1 or 2 m of solid rock because of shallow lithic contact; two alternative solutions may be discussed: lithic cryozems or cryogenic lithozems, in terms of taxonomy, each one may be either type, or subtype.

Thus, problems related to the depth of the permafrost table may be solved by means of preserving “cryogenic soils” as soils with shallow active layer and introducing cryogenic subtypes (cryoturbated, cryometamorphic, cryosorted etc.) in frost-affected soils of other RSCS orders.

We hope that together with colleagues from Siberia this discussion will be as efficient, as that on urban soils performed in 2013-2014, and will result in several proposals for RSCS.

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