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CRYOSOLS IN PERSPECTIVE: A VIEW FROM THE PERMAFROST HEARTLAND

GUIDEBOOK-MONOGRAPH FOR FIELD EXCURSIONS OF THE VII INTERNATIONAL CONFERENCE ON CRYOPEDOLOGY
Yakutsk-Tabaga August 23, 2017
Yakutsk-Churapcha-Tyungyulyu August 25-26, 2017
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МИР КРИОПОЧВ: ВЗГЛЯД ИЗ ЦЕНТРА МЕРЗЛОТНОЙ ОБЛАСТИ

Путеводитель полевых туров VII Международной конференции по криопедологии

Authors: R.V.Desyatkin, S.V.Goryachkin, D.E.Konyushkov, P.V.Krasilnikov, M.P.Lebedeva, M.A.Bronnikova, A.R.Desyatkin, A.N.Fedorov, S.F.Khokhlov, E.M.Lapteva, A.V.Lupachev, N.S.Mergelov, M.V.Okoneshnikova, V.A.Shishkov, I.V.Turova, E.P.Zazovskaya

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Different morphological, mineralogical, chemical and temperature characteristics of soils of Central Sakha (Yakutia) are elucidated in this book. Information on soil-forming factors – climate, topography, parent materials and vegetation is also explicated in the book. The main types of soil profiles are classified in WRB (2014), Soil Taxonomy (2014) and Russian classification system (2004, 2008).

The book is printed in accordance with the decision of the Scientific Council of the
P.I. Melnikov Permafrost Institute, Siberian Branch Russian Academy of Science

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Contents

demonstrated soil pits and soil sampling were performed by researchers from the IBPC SB RAS (Yakutsk), from the Institute of Geography of the Russian Academy of Sciences (IG RAS), the Dokuchaev Soil Science Institute (Moscow) and the This publication is a guidebook for field excursions of the VII International Conference on Cryopedology in Yakutsk (August 20-28, 2013). The organization of this conference in ultra-continental regions of Russia was envisioned long ago. During the I International Conference on Cryopedology in Pushchino in 1992, an outstanding researcher of the soils of cold regions Prof. I.A. Sokolov suggested that our foreign colleagues should get acquainted with the extreme diversity of permafrost-affected soils typical of Siberian territories. After 17 year this idea became a reality and in 2009 the V International Conference on Cryopedology was held in Trans-Baikal region in Ulan-Ude. However, the heartland of the permafrost – Central Sakha (Yakutia) was still unreachable for most of the cryopedologists because of financial and logistic reasons. In 2013 the WRB working group of the IUSS organized the field tour near Yakutsk for rather small group of specialists. This tour was successful and resulted in many changes in WRB system and in many suggestions for change of Soil Taxonomy. And now the main conference for cryopedologists all over the world meets its participants in Yakutsk. Unfortunately, temporal and logistic limitations that always accompany the organization of field excursions during large conferences do not make it possible to demonstrate the entire diversity of permafrost-affected soils in the ultra-continental region. The Organizing Committee tried to select areas with the maximum diversity of soils, on one hand, and with considerable amount of previously accumulated data on soil and permafrost conditions, on the other hand. Thus, four key sites in Central Sakha (Yakutia), on the both banks of Lena riverwere selected. Before the WRB tour there were described and analysed 7 profiles elucidated in this book, other 8 profiles were studied earlier by the team of specialists from the Institute of Biological Problems of the Cryolithozone of the Siberian Branch of the Russian Academy of Sciences (IBPC SB RAS) under the leadership of Prof. Dr. R.V.Desyatkin.

In 2012, to prepare the WRB field tour, a preliminary examination of Moscow State University. The soil samples were then analyzed in laboratories of the Institute of Geography and Institutes of Biology of Komi and Karelian Research Centers of RAS.

The main attention in the guide-book is given to information about the factors of soil formation and soil properties; the genetic interpretation of the facts is given in a brief form. As a supplement, information about the major site of attraction of the region—Lena Pillars—is presented. We saved the most of figures from the WRB tour guidebook (Desyatkin et al., 2013), that is why the additional information not relevant to our field excursions could be seen at some figures.

This guidebook is a result of a joint effort of the staff of the Institute of Biological Problems of the Cryolithozone (Yakutsk), the Institute of Geography (Moscow) of the Russian Academy of Sciences (RAS), Dokuchaev Soil Science Institute (Moscow),Institute of Physicochemical and Biological

Problems of Soil Science, RAS, Pushchino with an assistance and support of the Institutes of Biology of Komi and Karelian Research Centers of RAS, Melnikov Permafrost Institute (Yakutsk), and Moscow State University.

The authors are also thankful to staff members of the Chemical Laboratory (IG RAS) E.A. Agafonova, T.A. Vostokova, A.M. Chugunova and the staff of eco-analytical laboratory of the Komi Scientific Center Dr. B.M.Kondratenok, T.V.Zonova, A.N.Nizovtsev, the staff of the laboratories in Petrozavodsk T.V. Bogdanova, A.G. Kashtanova, L.I. Skorokhodova, I.S. Inina. Many thanks to P.P.Fedorov for help in the field work, and to M.N.Zheleznyak, M.N.Grigoriev, G.I.Chernousenko for scientific consultations in different fields. The soil studies, which were carried out for the preparation of this book were supported by Russian Foundation for Basic Research (projects 12-04-01457, 13-04-10181).

The publication of the guidebook was made possible owing to the financial support of the authorities from the Il Tumen (Parlament) of Sakha (Yakutia). The former Chair of the Division 1 of the IUSS Professor Karl Stahr receives a special gratitude for the financial support for conducting some complex chemical analysis.

We cordially welcome all the participants at thesefield excursions and hope that it will bring new concepts and ideas.

PART I
GENERAL CHARACTERIZATION OF ENVIRONMENTAL CONDITIONS

After a 6.5-h flight over 4883 km, the participants arrive to Yakutsk, the capital of the Sakha (Yakutia) Republic, the largest federal subject of the Russian Federation. The territory of Yakutia (3 103 200 km^2) extends from 105°E to 165°E (2500 km) from the west to the east. It is divided into the western (within the Siberian Platform) and eastern (the Verkhoyansk-Chukotka folded zone) parts by the boundary stretching along the western foothills of the Verkhoyansk Range, to the east of the Lena and Aldan rivers. Plain area with elevations of less than 200 m asl to the north and east of Yakutsk represents the vast Central Yakutian Lowland with its widest part in the lower Vilyui River basin. Thus, the tour takes place in Central Yakutia (Fig. 1), the area with the cold ultracontinental climate, deep permafrost, active thermokarst, and diverse soil and vegetation conditions against the background of a relatively flat macrotopography. The presence of steppe dark-colored soils, solonetzes, and even solonchaks amidst the taiga areas with boreal forest vegetation and boggy areas is the most striking feature of the soil cover of this region.

A vast body of literature is devoted to various aspects of the environmental and soil conditions in Central Yakutia. However, most of the works are in Russian and are low available to foreign researchers. Three important sources of comprehensive information in English are the paper by T.L. Pewe and A. Journaux devoted to the origin and properties of loesslike silt in Central Yakutia (1983), the recently published monograph on plant biodiversity and ecology of Yakutia by the team of authors from the Institute for Biological Problems of the Cryolithozone (ed. by E.I. Troeva et al., 2010), and a chapter devoted to the soil cover of Central Siberia in the Cryosols monograph (ed. by J.M. Kimble, 2004). In this guide, brief information about the environmental conditions of Central Yakutia is given below.

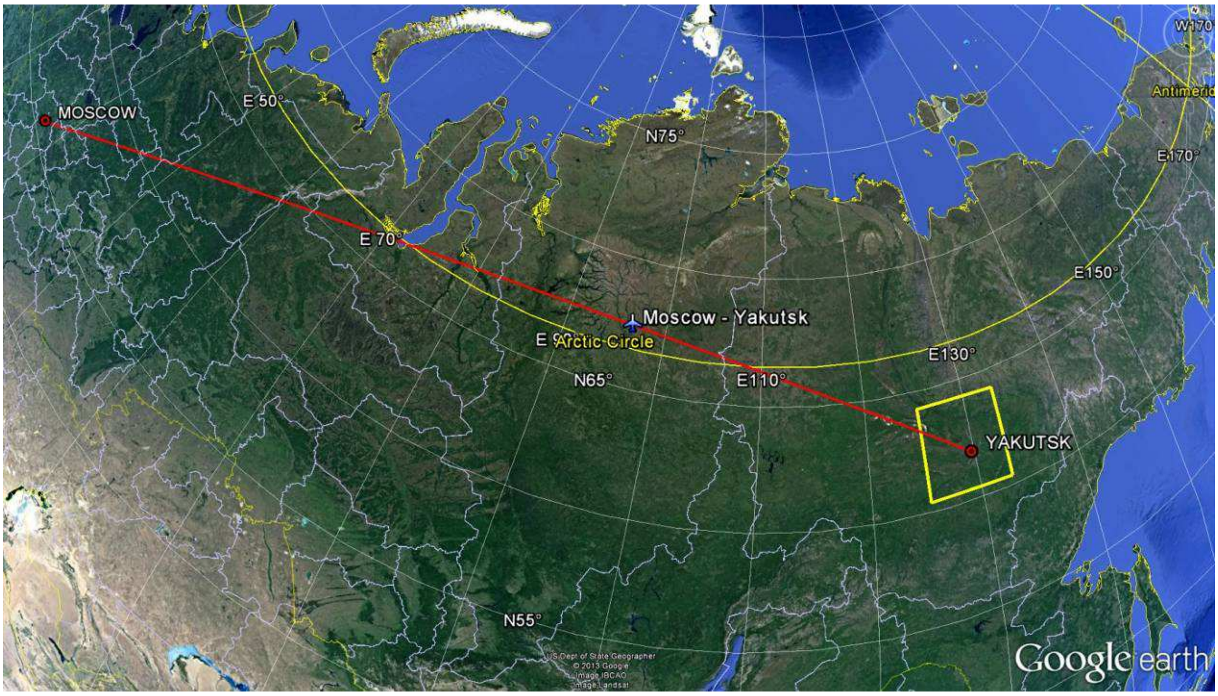


Fig. 1. Trip to Central Yakutia

GEOLOGICAL SETTINGS

Tectonics. Central Yakutia lies in the southeastern part of the Siberian Platform. The base of the platform is composed of the Archean schist and Early Proterozoic granitoid intrusive rocks. It outcrops to the surface within the Aldan Shield (to the south of the meridional section of the Aldan River) and the Anabar Shield to the northwest, beyond the Polar Circle. These two major uplifts of the base of the platform are separated by the vast Vilyuisk syneclise in the eastern part of the platform opened to the Verkhoyansk Foredeep to the east (Fig. 2). In the central part of the syneclise, the depth of the crystalline base of the platform is up to 10 km. The Vilyiusk syneclise is filled with Paleozoic and Mesozoic sediments. Mesozoic sediments predominate in the Verkhoyansk Foredeep. In the Cenozoic era, the center of descending movements shifted to the southeast of the axis zone of Vilyuisk syneclise, in the area of the Lower Aldan Depression, which is filled by a thick layer of Oligocene–Neogene and Quaternary deposits. The northern periphery of the Aldan anteclise (monoclize) is characterized by a gradual descent of the basement surface towards the north; this general pattern is complicated by the Yakutsk uplift of the platform base.

The character of neotectonic movements is shown on the schematic map by red "up" (uplift) and "down" (subsidence) arrows. Within the central part of the study area, these movements have been small (less than 0.1 km). This has resulted in a low dissection of the surface relief by the erosional network with a predominance of plain topography. Descending movements of high magnitude (1 km) have taken place in the northern part of the Aldan Depression. Ascending movements of moderate to high intensity have been observed on the northern slope of the Aldan anteclise in the south-southwest (including the Lena Pillars site) and within the Verkhoyansk Range to the north.

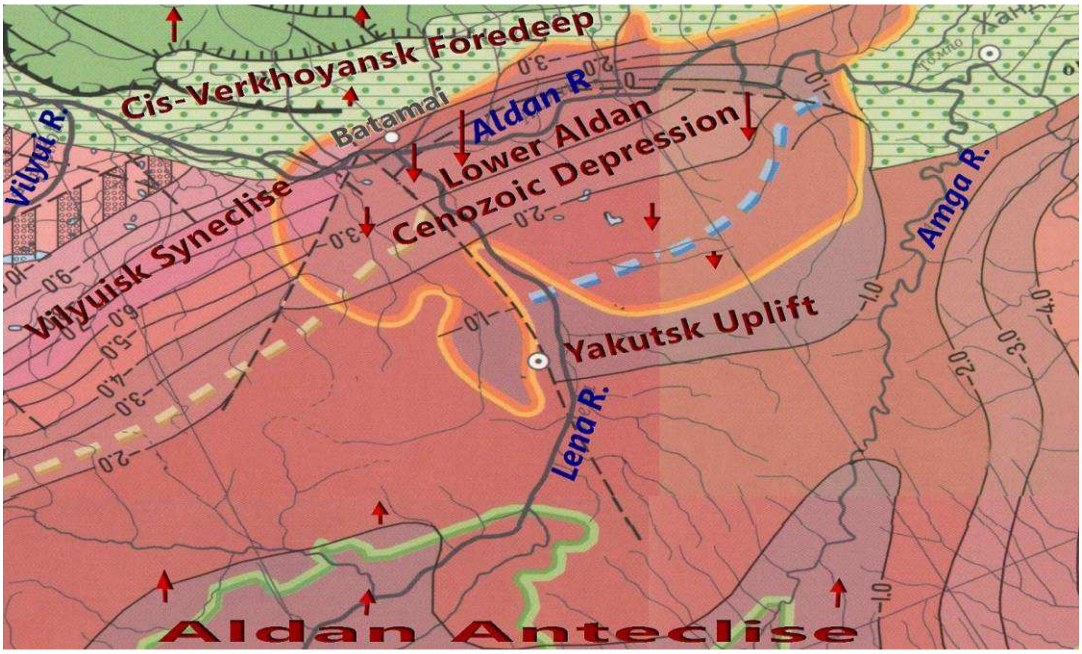


Fig. 2. Tectonic scheme of Central Yakutia (adapted from Milanovskii, 2006)

The tectonic structure of the region is seen in the stratigraphy of the rocks; it is also important in the context of the development of permafrost and its thickness controlled not only by the climatic conditions but also by the values of the geothermal heat flux ensuring degradation of permafrost from the bottom. In this part of Central Siberia, its maximum values (up to 50-60 mW/m^2) are in the central part of the Vilyuisk syneclise; they decrease to about 20 mW/m^2 on the northern slope of the Aldan anteclise (Balobaev, 1991).

Stratigraphy. A schematic geological map of Central Yakutia is shown in Fig. 3. The Late Proterozoic and Cambrian deposits on the northern slope of the Aldan anteclise are represented by the marine and lagoon dolomite and limestone with interlayers and lenses of gypsum, salt-bearing rocks, and red-earth deposits. Paleozoic marine and continental deposits are known in the western part of the Vilyuisk syneclise. Among them, kimberlite rocks of the Ordovician–Early Carboniferous periods—the source of Yakutian diamonds—should be noted; the western and northwestern parts of the syneclise were also characterized by the trappean basaltic volcanism in the Late Permian and Triassic periods. The Jurassic and Cretaceous terrigenous continental sandy-silty-clayey deposits filling the Vilyuisk syneclise contain coal layers.

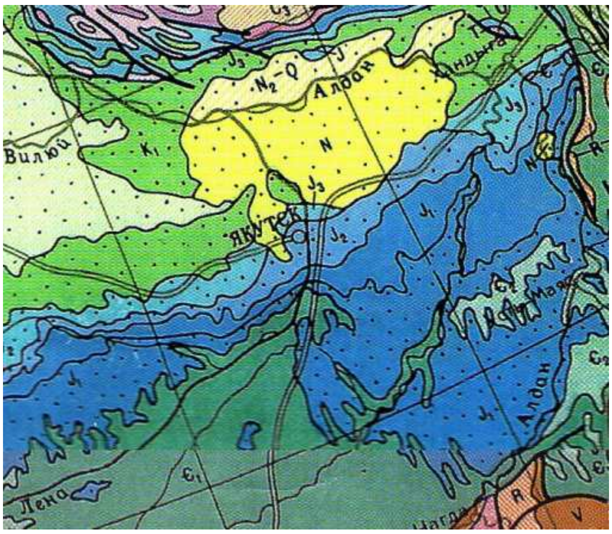


Fig. 3. Geological map of Central Yakutia.

The Oligocene deposits in the Lower Aldan Depression are represented by gray different-grained sands with gravels. In the axial part of the Lower Aldan Depression, alluvial and lacustrine-alluvial sands of the Miocene and Pliocene ages have the total thickness of more than 700 m. The Pliocene ferruginated sands of 4–15 m in thickness compose the upper layers of the Tabaga strath terrace (one of the oldest Lena terraces with absolute heights about 150 m a.s.l. on the left bank of the river).

The Late Pliocene deposits are represented by differently-grained sands with gravels; They cover Lena terraces at the heights of 110–120 m a.s.l. (the Cherendyai suite) and 80–90 m a.s.l. (the Tustakh suite). Wedge shaped sand pseudomorphs that substituted initial relatively thin epigenetic ice wedges are known in these deposits attesting to the stage of severe cooling in the Late Pliocene.

The Quaternary history of the region, including the genesis of parent materials, is a matter of numerous discussions (Solov'ev, 1959; Alekseev, 1961; Biske, 1964; Ivanov, 1984; Kolpakov, 1983; Pewe & Journaux, 1983; Popp, 2006). It is generally accepted that the Middle and Late Pleistocene glaciers covered the Verkhoyansk Range and left glacial, glaciofluvial, and glaciolacustrine deposits and typical landforms at the western foothills to the north-northeast of the Aldan and Lena rivers. About 100 km to the south of Yakutsk, within the denudation plain composed of the noncalcareous Jurassic and calcareous Cambrian rocks, the mantle of Quaternary deposits is very thin or absent, and the soils develop from the bedrock residuum.

The vast territory of the Central Yakutian Lowland is considered the ancient alluvial plain with a series of Lena terraces. As noted above, the most ancient terrace surfaces are composed of the Pliocene alluvial sands. In the middle reaches of the Lena River, three groups of terraces are distinguished: (a) low accumulative terraces, (2) middle accumulative-erosional terraces, and (3) high erosional terraces (Solov'ev, 1959; Alekseev, 1961). There is no commonly accepted stratigraphic scheme of the terrace deposits (Table 1).

Table 1. Stratigraphic division of the low and middle terraces in the middle reaches of the Lena River according to different researchers

Terrace	***Solov'ev, 1959***		***Alekseev, 1961***		Absolute age, ka (Composition..., 1979)
	H above the river, m	***Terrace name***	H above the river, m	***Terrace name***	
Low accumulative terraces					
-	8-10	***Floodplain***	-	***Floodplain***	-
I	14-18	***Yakutsk***	18-20	***1st terrace***	-
II	18-22	***Sergelyakh***	-	-	9-10 ka
Middle-high accumulative-erosional terraces					
III	25-36	***Kerdemsk***	25-30	***2nd terrace***	-
IV	56-78	***Bestyakh***	35-40	***3rd terrace***	-
V	66-98	***Tyungyulyu***	50-60	***4th terrace***	14-22 ka
VI	116-134	***Abalakh***	70-80	***5th terrace***	> 45-56 ka
VII	156-176	***Magan***	100-120	***6th terrace***	-

The Lena floodplain with relative heights of 3–9 m extends along the river channel; it widens from 2-3 km in the southwestern part to 6 km in the northern part; it is mainly composed of sands forming ridged topography.

The first terrace has a total width of up to 4-5 km; it is elevated by 10-12 m above the river and has a gently undulating topography with swampy hollows. It is composed of sands, loamy sands and loams and is actively used for agriculture.

The second terrace around Yakutsk (18–22 m above the river) is relatively narrow and is strongly dissected by oxbow depressions and thermokarst. It is composed of sands and is mostly covered by pine and larch forests.

The Bestyakh terrace on the right bank of the river is elevated by 56-78 m above the river and represent a wide (15–20 km) strip of predominantly sandy alluvial deposits of 60–115 m in thickness. Its surface is strongly affected by eolian processes with the formation of sand dunes, ridges, and other eolian landforms. On the map (Fig. 4), it is indicated by yellow color (vIIIsr – eolian sediments of the Late Pleistocene (Sartan) age). To the east, it is gradually replaced by the V (Tyngyulyu) terrace (66–98 m above the river; 25 to 40 km in width). The upper part of this terrace (about 30 m) is composed of the Ice Complex deposits – silty sands and silt loams with syncryogenic ice wedges. The radiocarbon age of the sediments was determined at 14–22 ka (Composition..., 1979). Their origin is open to argument. The four major hypotheses are the (a) fluvial, (b) fluvial-lacustrine with in situ cryogenic alteration, (c) in situ cryogenic alteration, and (d) eolian. In Fig. 4, this terrace is indicated as L,LIIImr-sr: Lacustrine and eolian cryogenic loamy sands of the Murukta-Sartan periods (Late Pleistocene glaciation). The terrace surface is complicated by relatively shallow (10 to 30 m) thermokarst depressions (alases); the largest of them, including the Tyungyulyu alas are confined to the transitional zone between the V and VI terraces. The area of alas depressions in the northern part of this terrace constitutes up to 30-50% (Geocryology of the USSR, 1989).

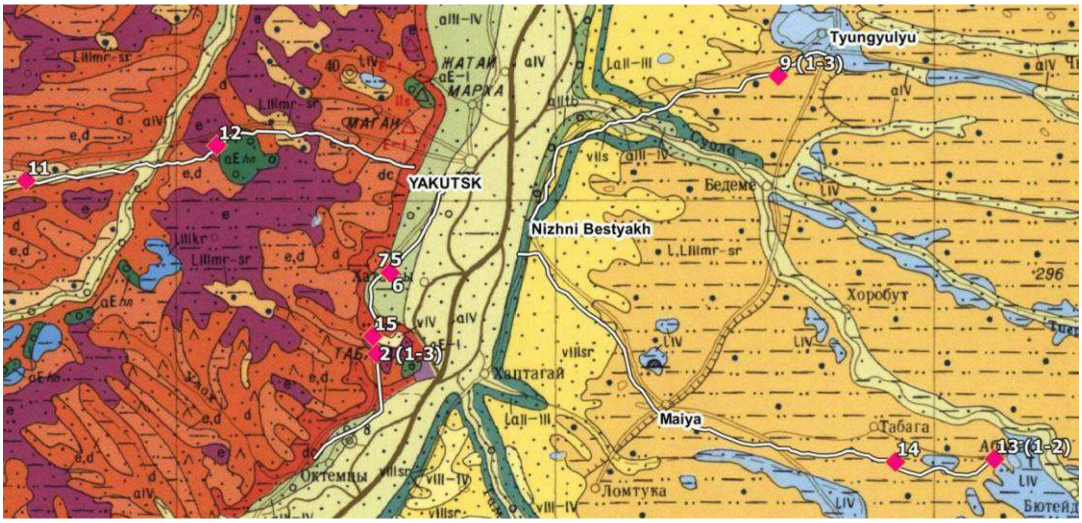


Fig. 4. Map of Quaternary deposits in the area of the WRB tour (from Kolpakov, 1992).

The VI (Abalakh) terrace is distinctly elevated relative to the V terrace; it is the largest of the accumulative Lena terraces in the area of Yakutsk; the thickness of the Ice Complex within this terrace is from 15 to 80 m; it is underlain by the ice rich sandy, gravelly, and loamy deposits. On the map (Fig. 4), the upper deposits on this terrace are shown by the same symbols (L,LIIImr-sr). The radiocarbon age of the deposits is estimated at 45–56 ka (Composition..., 1979). Thermokarst depressions within this terrace are generally deeper (30-60 m) (General Geocyology, 1989). Higher and more ancient river terraces belong to the surface of the erosional-accumulative plain; the mantle of Quaternary deposits on them is thin; the topography is complicated by erosional landforms, shallow thermokarst depressions, and various solifluction and frost heave microforms. On the map, these surfaces are shown in reddish colors with separation of eluvial (e) (divides) and deluvial (colluvial) (d) (slopes) deposits derived from the underlying Neogene and more ancient sediments.The lacustrine (swampy-lacustrine) sediments filling thermokarst depressions (blue color on the map) are of the Holocene age.

Salinization of parent materials. A characteristic feature of surface deposits within the ancient alluvial plain and in the modern valley of the Lena River is the presence of soluble salts. Sediments of the Ice Complex contain about 0.27% of soluble salts with a maximum of up to 3.2%. Sandy alluvial sediments of the second terrace contain about 0.01-0.02% of salts (predominantly, sodium and calcium bicarbonates), whereas silty loamy sands of the floodplain facies contain 0.3–0.5% of salts with a predominance of sodium chlorides and sulfates. Maximum salinization (up to 5–8%) is typical of the areas, where highly saline solutions of cryopegs in permafrost are discharged to the surface. Thus, Central Yakutia is the area of considerable continental salinization. The origin of salts is related to the evaporative water regime established in the Late Pleistocene and to the presence of salt- and gypsum-containing layers in the Cambrian deposits eroded by the Lena River upstream. The evaporation of floodwater results in the concentration of salts in the river sediments with their further redistribution in the landscape by various processes. More detailed information about soil salinization patterns is given below in the section devoted to the soil cover of the region.

Geomorphologic conditions of Central Yakutia. Figure 5 illustrates the general scheme of geomorphologic conditions in the region. A generally plain of gently undulating topography of the ancient alluvial plain should be noted. The absolute heights of the territory range from about 83 m asl (Lena River) to 110-130 (Bestyakh terrace), 130-180 (Tyngyulyu terrace), 200-250 m asl (Abalakh terrace) on the right bank and 200--300 m asl (Magan and Tabaga terraces on the left bak). Mesotopographic features related to thermokarst and other processes are described in the section devoted to permafrost.

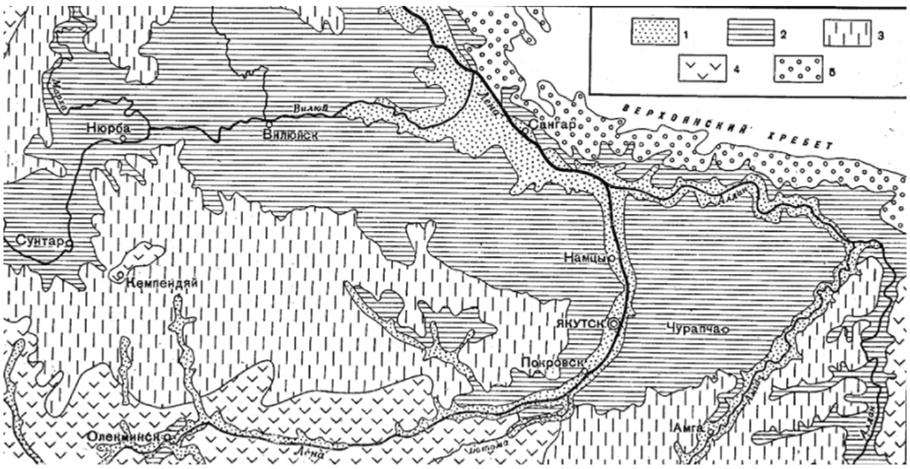


Fig. 5. Geomorphologic Map of Central Yakutia: (1) recent alluvial plains, (2) ancient alluvial plain, (3) denudation plateau composed of noncalcareous Mesozoic rocks (sands, clays, silts with gravelly interlayers), (4) denudation plateau composed of calcareous Paleozoic rocks, and (5) plain composed of glacial and glaciofluvial deposits (Elovskaya et al., 1966).

CLIMATE AND SOIL TEMPERATURE DYNAMICS

The climate of Central Yakutia is specified by its location in the center of the vast Eurasian landmass, where the influence of Atlantic wet air masses from the west is attenuated; it is also protected from the influence of summer monsoons from the Pacific coast. The Siberian anticyclone predominates in the winter with a small amount of snowfall. Sunny weather predominates in the summer. The “rainy” season is in the late summer and early fall.

According to the Koppen climate classification, Central Yakutia is the only world region with two two subtypes of cold climate (D) with winter temperatures <–38°C and with very dry (Dwd) or moderately dry (Dfd) winter conditions. This is the cold ultracontinental type of climate with the annual amplitude of temperatures up to 90–100°C.

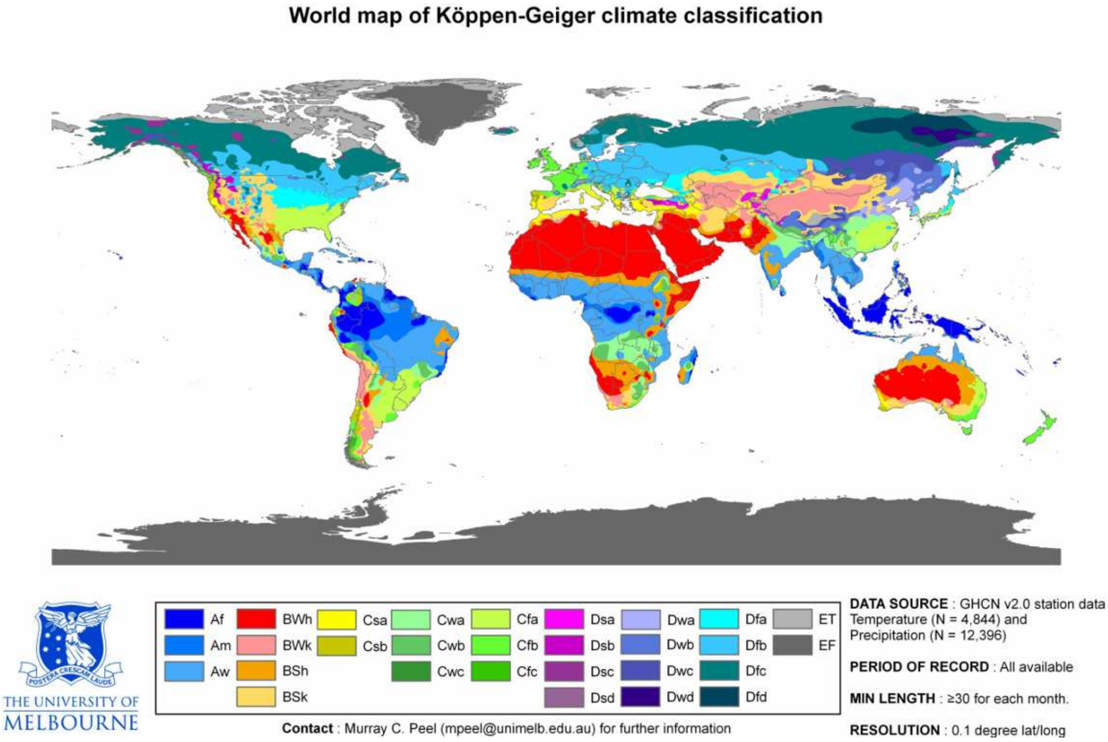


Fig. 6.Central Yakutia on the climatic map of the world (M. Peel et al., 2007).

According to weather records at Yakutsk station, the winter season with subzero temperatures lasts for 210 days (from the middle of October to the end of April), and the snow cover depth averages 30 cm. The summer period with above-zero temperatures lasts from the end of May to the beginning of September (128 days). Transitional spring and fall periods are relatively short. In summer, air warms up considerably: the mean July temperature is 18.5°C, and maximum temperatures may reach 38°C. The accumulated sum of daily temperatures above 10°C is up to 1800 degree-days in Yakutsk and decreases to 1200-1500 degree-days within elevated terraces. At the same time, frosts may occur in any summer month. The mean January temperature is –44.5°C, and the absolute minimum is –64°C.

The rainfall in June–August is 98 mm; during the warm season, 131 mm; precipitation of the cold period is 65 mm. The annual precipitation in different parts of the study area varies from 187 to 284 mm. The potential evaporation from the soil surface is estimated at 400 mm. Thus, this is the region with subarid to arid climate.

Central Yakutia is a region, where a tendency for global warming is distinctly pronounced. In the 19th century, the mean annual air temperature in Yakutsk was –11.2°C; at the beginning of the 21st century, it is about –8 to –9°. The rise in temperatures has been particularly distinct (by more than 2°C) in the recent 40 years (Fig. 7) (about 0.08°C/yr) (Skryabin & Varlamov, 2013).

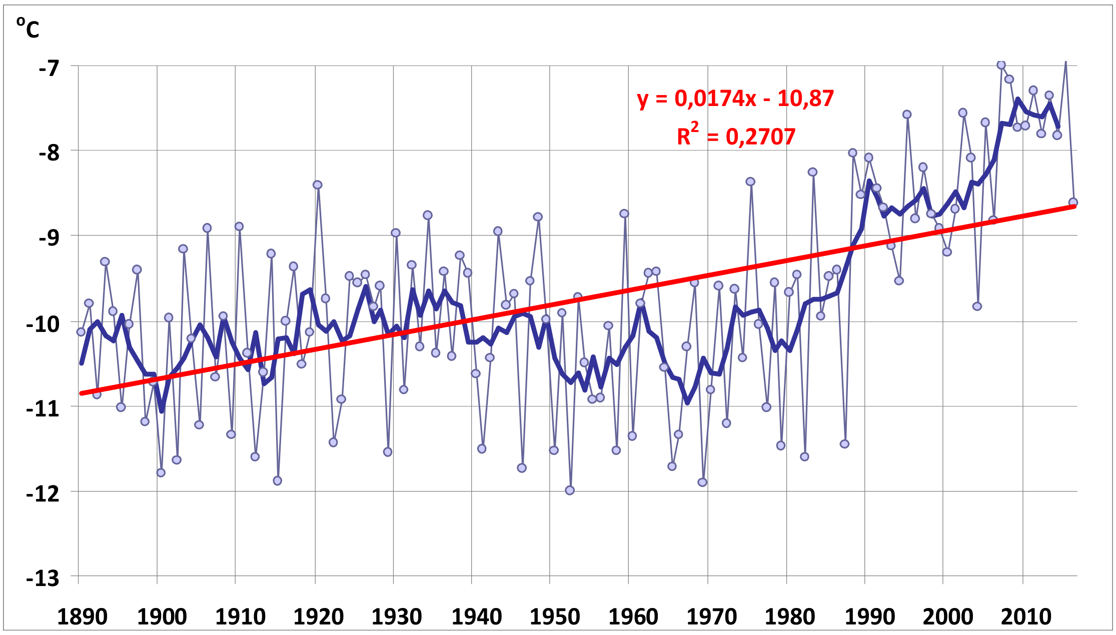


Fig. 7.Dynamics of annual air temperatures in Yakutsk.

During the period of instrumental weather observations in Yakutsk (1888–2013), annual precipitation has increased by 15–20%, mainly at the expense of summer rainfall (Fig. 8).

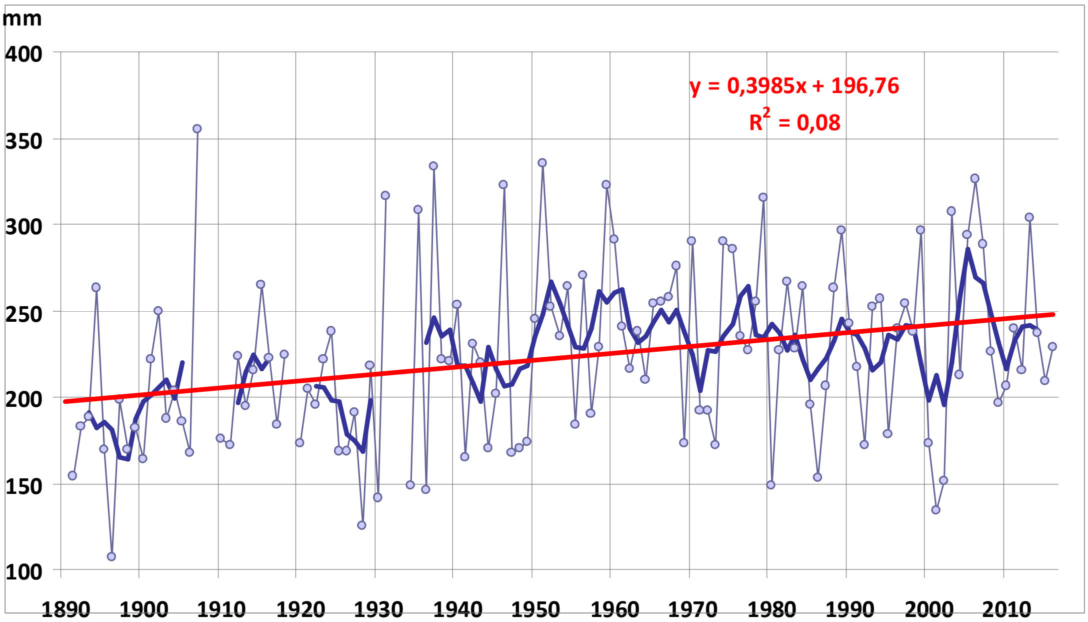
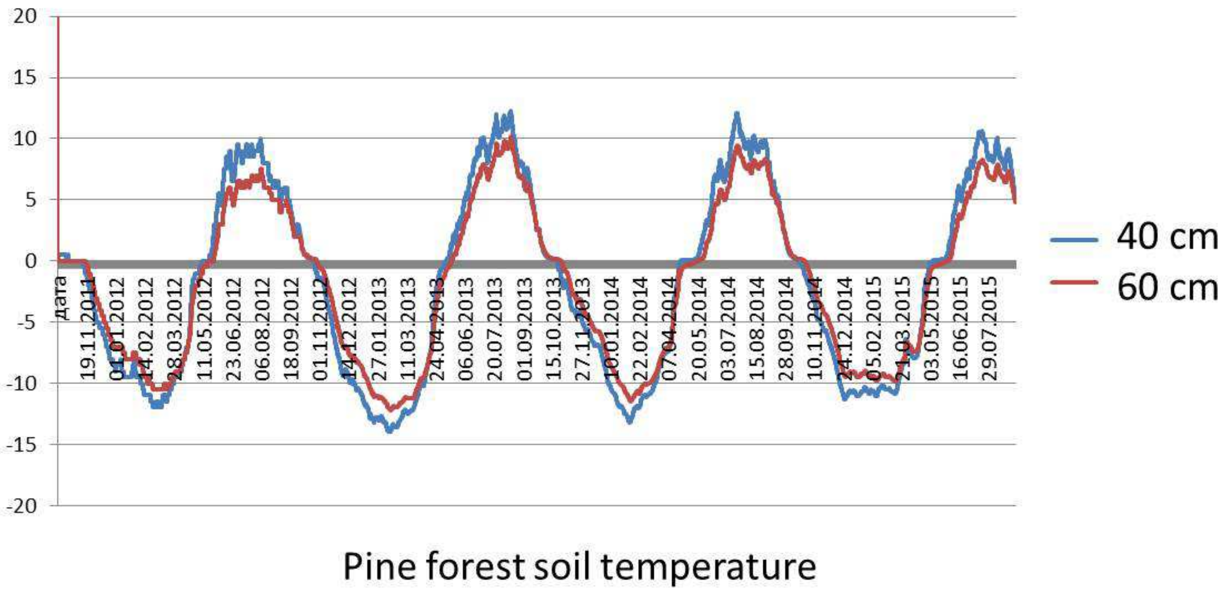


Fig. 8.Dynamics of annual precipitation in Yakutsk.

These changes have led to activation of thermokarst phenomena However, tendencies in changes of the surface ground (permafrost) temperatures are different. In general, the rise in permafrost temperatures is considerably smaller. According to Skryabin, Skachkov, and Varlamov (2003) this is mainly explained by a tendency for thinning of the snow cover.Measurements of ground temperatures were performed in 2002–2010 at several key sites with different soil conditions. The mean annual temperature in that period was –8.1°C (by 2.1°C higher than the climatic norm). In six years out of nine, winter seasons were also characterized by considerable precipitation (118–176% of the norm). The key sites characterized typical soiscapes of Central Yakutia with the (a) sandy podzolized permafrost-affected soil under pine forest (the warmest soil with deep thawing), (b) loamy permafrost-affected Pale (Palevaya) solodic soil under larch forest, and (c) xeromorphic permafrost-affected soil of alas depression (upper belt) under herbs. The results are presented in Figs. 9 and 9a.

T, °C



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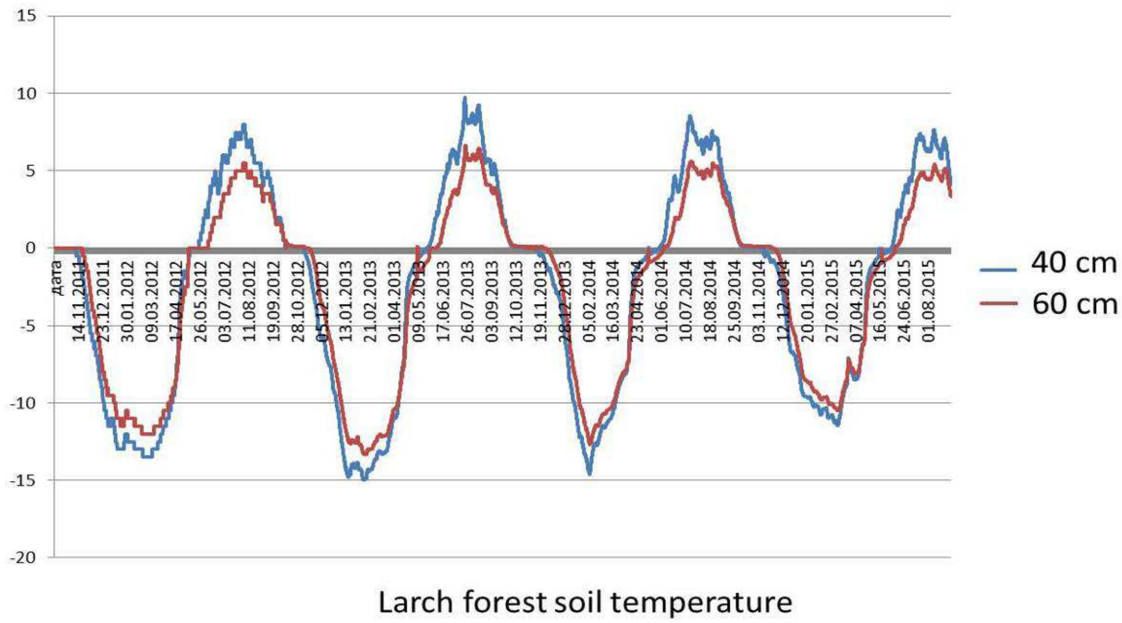

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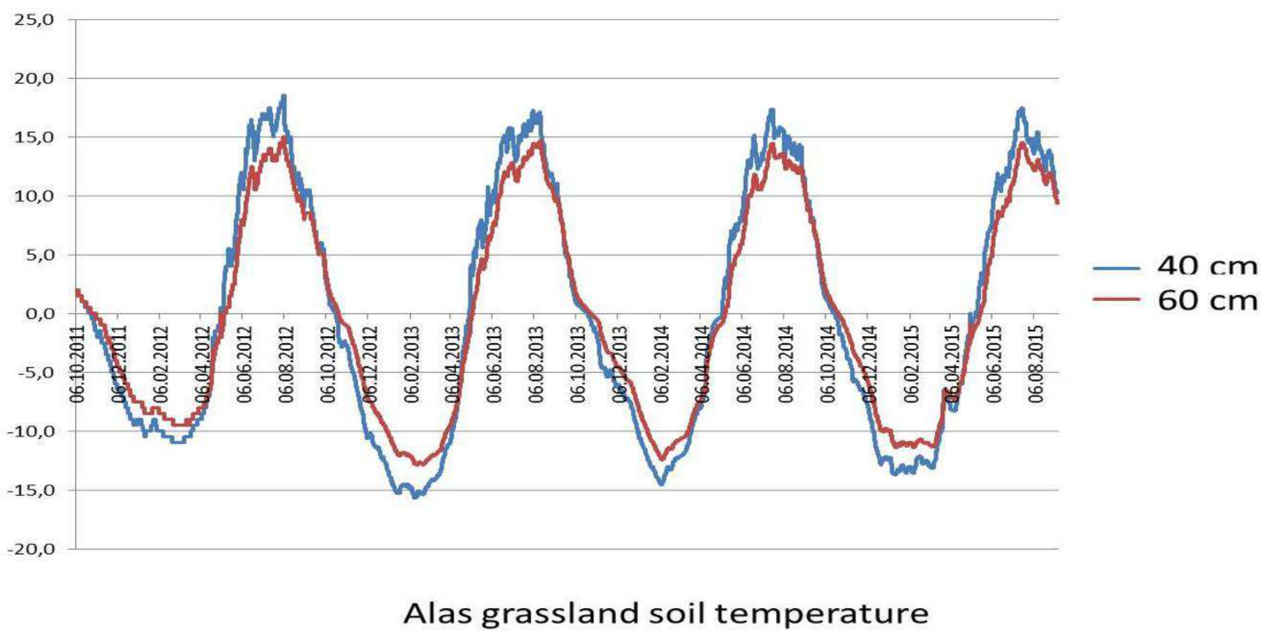


c

Fig. 9.Soil temperatures at the depths of 40 and 60 cm in soils under (a) pine and (b) larch forests and under (c) grassy meadow.

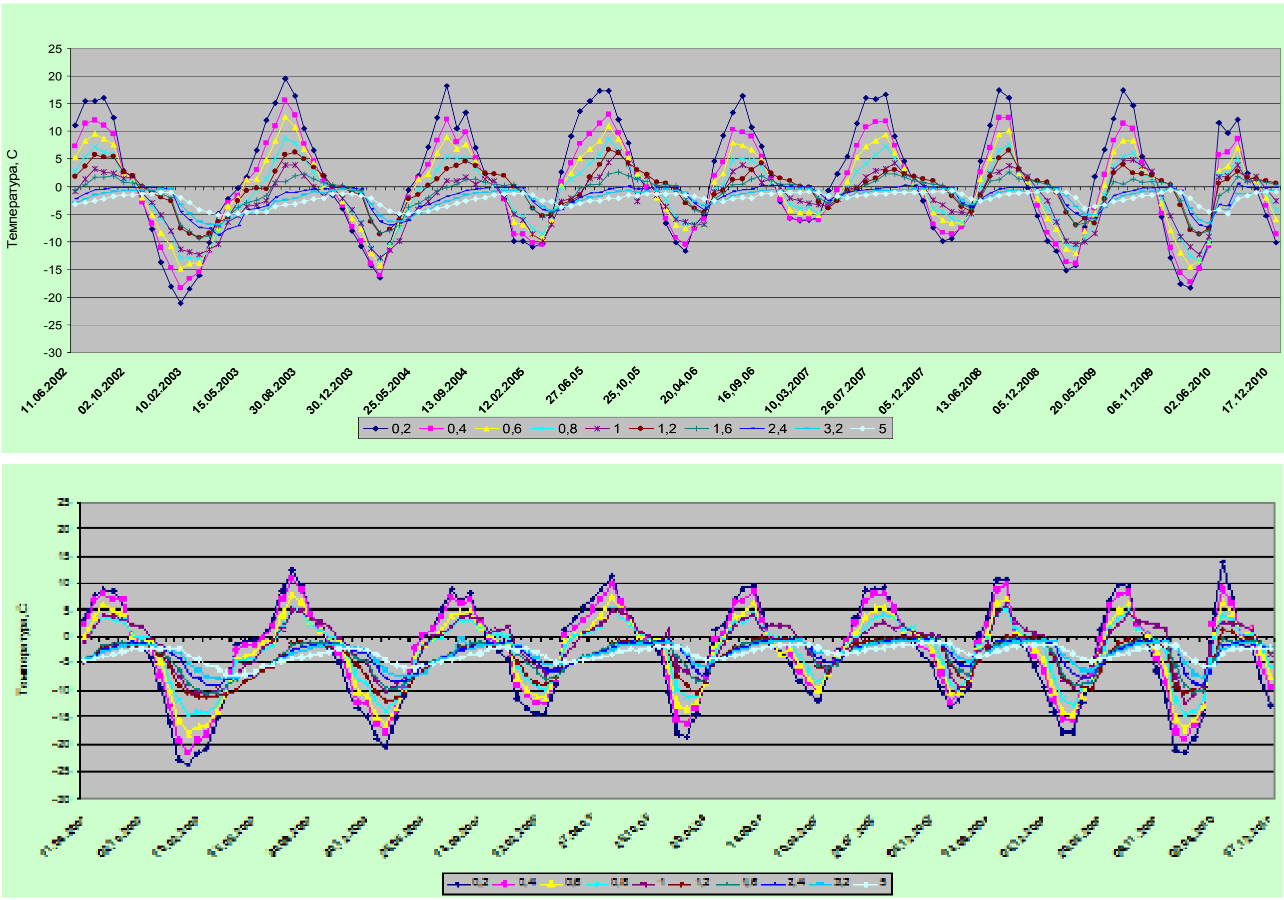


Fig. 9a.Soil temperatures at different depths in the (a) sandy soil under pine forest and (b) loamy soil under larch forest.

The major conclusions can be formulated as follows. The sandy soil under pine stand is well provided with heat. Temperatures in the upper 20 cm reachedh 20°C in the warmest years. Temperatures above 10°C penetrated to 40–60 cm. The thawing depth varied from 2 to 2.7 m. The pattern of soil freezing depended on the soil moistening in the summer. In wet years, the soil freezing proceeded slower. The soil freezing proceeded both from the top and from the bottom; upper and lower frozen layers merged at a depth of 1.2–1.6 m in December in dry years and at the beginning of February in wet years. The mean annual temperature at a depth of 0.5 m was about –0.5°C.

Soil freezing-thawing processes under larch forest proceeded slower. Temperatures above 10°C penetrated to the depth of 20 cm (in 2003, down to 40 cm). The soil thawing depth varied from 1.2 to 1.5 m. Complete soil freezing took place in the middle of November in dry years and at the end of December in wet years; the merging of the upper and lower frozen layers took place at a depth about 1 m. The mean annual temperature at a depth of 0.5 m was about –3°C. The mean annual temperature of the soil under grassy meadow at this depth was –0.35°C.Thus, virtually all the soils in this area fit the definition of gelic regime. Anthropogenic disturbances lead to a general rise in the soil temperatures and deepening of seasonal thawing to 2-2.5 m (in loamy soils) and down to 3-4 m in dry sandy soils. However, permafrost is present in most of them, and the lower boundary of seasonal freezing reaches the permafrost table. More detailed information about permafrost conditions is given below.

GEOCRYOLOGICAL CONDITIONS

Initial data on the presence of frozen ground and on the low suitability of Siberian territories for digging wells for water supply in the winter appeared after the settling of Russians. First measurements of air and ground temperatures were performed in the 19th century. On their basis, Heinrich von Wild (1882), developed the first map with indication of the tentative southern boundary of permafrost (Fig. 10).

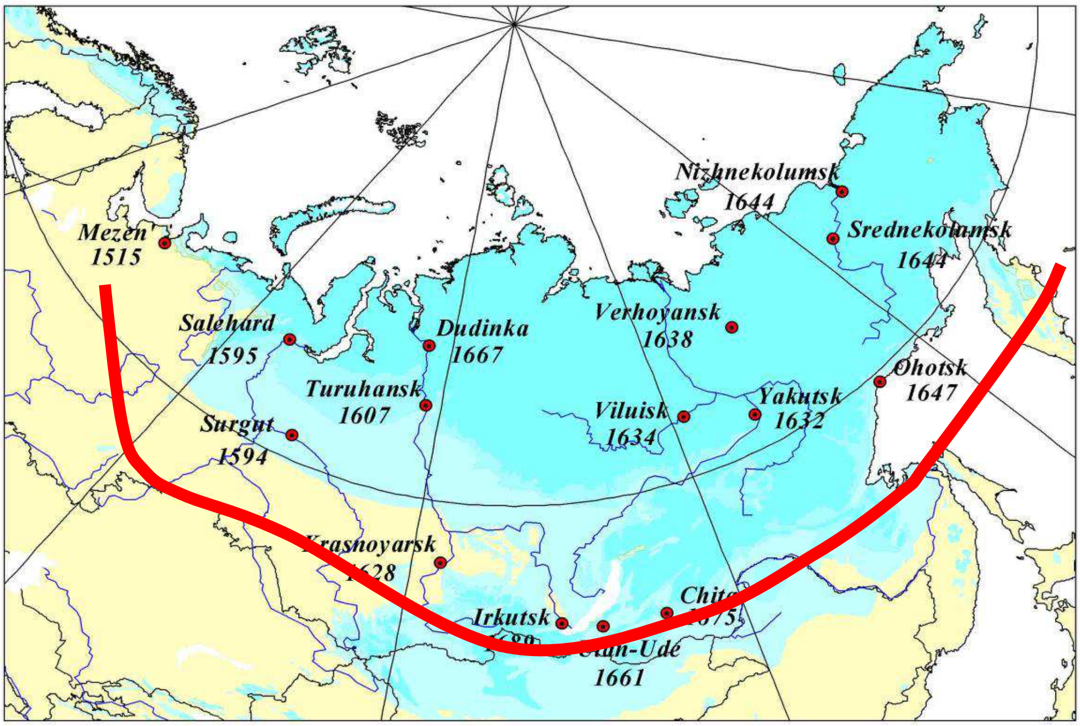


Fig. 10.Distribution of continuous, discontinuous, and sporadic permafrost in Russia and the southern boundary of permafrost determined by Wild. Years of foundation of the most ancient Russian settlements are indicated (from Anisimov et al., 2007).

Since that time, permafrost in central Yakutia has comprehensively been studied, and the famous Permafrost Institute was organized in Yakutsk. In Central Yakutia, a network of deep boreholes that penetrated through the permafrost was established (Fig. 11).

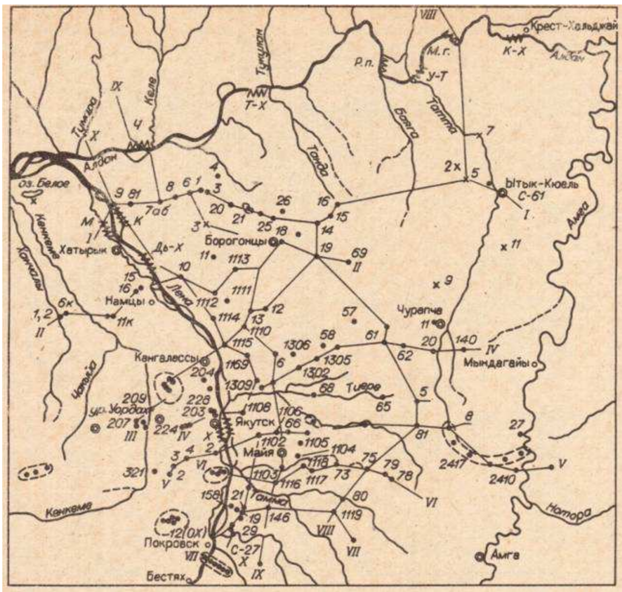


Fig. 11. Location of boreholes andgeocryological profiles (Ivanov, 1984).

These data were used to develop the map of ground ice conditions in the area (Fig. 12).

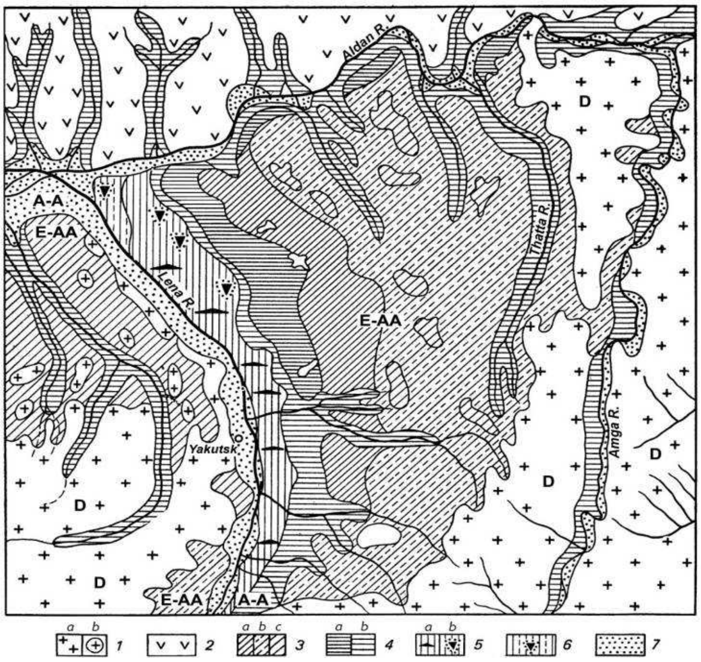


Fig. 12. Ground ice conditions in Central Yakutia (after Ivanov, 1984):(1) denudation plain; ground ice in the form of texture-forming ice and ice wedges (a) and without ice wedges (b); (2) accumulative glacial-glaciofluvial plain; (3) erosional-accumulative Abalakh plain; (a) tectonic escarpment of the plain, (b) widespread occurrence of ice wedges (Ice Complex), (c) sporadic occurrence of ice wedges; (4) Tyungyulyu terrace and its analogues with (a) deep (15 to 60 m) syngenetic ice wedges and (b) relatively small (10–20 m) syngenetic ice wedges; (5) Bestyakh terrace with (a) local ice beds and (b) local syngenetic ice wedges; (6) Kerdemsk terrace with degraded and locally developed ice wedges; (7) river sands with a low ice content.

The permafrost thickness, as well as the permafrost temperature at the depth of zero annual amplitudes (about 15-20 m) are highly variable. Under Yakutsk, permafrost temperatures vary from –2 to –7.1°C. The thickness of permafrost changes from about 200 to 300–500 m. Talik zones are established under large river valleys and, partly, under large lakes in alas depressions.

Annual thawing depths change in dependence on the particular landscape positions and soil and vegetation conditions. A schematic profile of maximum thaw (September 15, 1967) on different elements of the Tyungyulyu terrace is shown in Fig. 13.

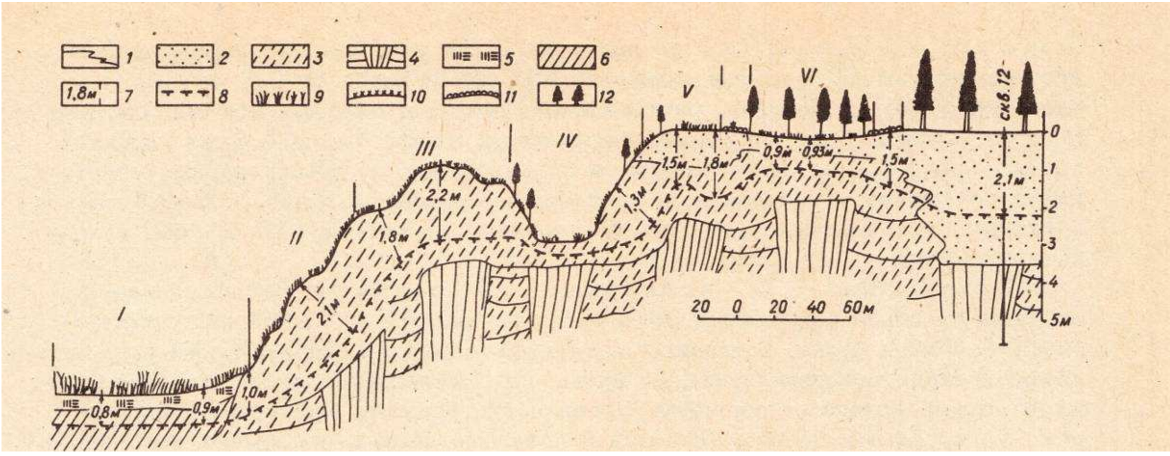


Fig. 13. Maximum depth of seasonal thawing on different elements of the Tyungyulyu terrace (from Ivanov, 1984): (1) lithological boundaries, (2) sand, (3) loamy sand, (4) upper part of the Ice Complex, (5) mineralized peat, (6) silt loam, (7) maximum seasonal thawing, (8) lower boundary of the active layer, (9) herbs, (10) mosses, (11) lichens, (12) larch. I—bottom of the alas; herbs 0.5-0.7 m, peat 0.3-0.4 m; II—slope of southwestern aspect; III—degrading slope of the alas under steppe vegetation; IV—erosional-thermokarst ravine with mosses 15-20 cm; V—forest border; VI—dense larch stand with mosses 10-15 cm.

VEGETATION

Central Yakutia is traditionally attributed to the middle taiga zone of low-productive larch and pine forests and with meadow-steppe and steppe vegetation on warmer and well-drained sites. The climatic aridity increases at the low levels of the Lena River. Forest vegetation is also absent in thermokarst depressions (alases). It is supposed that the lack of forest vegetation on the first (above the floodplain) Lena terrace is due to the long-term anthropogenic impact on this territory.

Pyrogenesis is also an important factor of vegetation dynamics in central Yakutia.Chevychelov, Perk, and Skrybykina (2005) determined differences in the climatic parameters within taiga, forest-steppe, and meadow-steppe communities as follows:

Zone	Height, m a.s.l	P, mm	Khum	T>10^0C	Kcont.
Taiga	270-450	255-304	0,40-0,51	1365-1518	245-272
Forest-steppe	120-270	215-255	0,31-0,40	1518-1645	272-295
Meadow-steppe	90-120	209-215	0,30-0,31	1645-1663	295-298

Khum- humidity factor: precipitation-to-potential evaporation ratio; Kcont - continentality factor (according to N. Ivanov).

A detailed description of vegetation and its history is given in a monograph by Troeva et al. (2010). The major types of vegetation along the routes of the field trip can be judged from a small-scale vegetation map of Central Yakutia. included in the Atlas of Yakutia (Fig. 14).

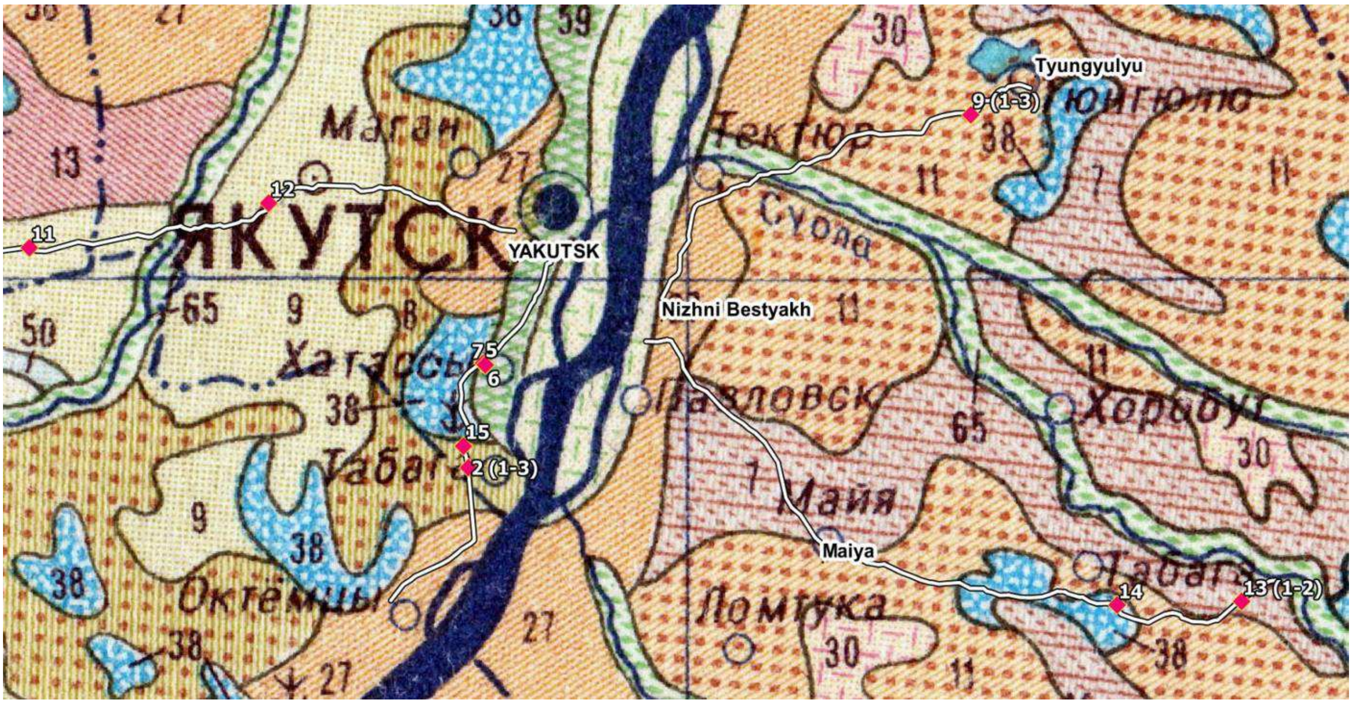


Fig. 14.Major types of vegetation in the study area.

Middle taiga Larch (*Larix gmelinii, L. Cajanderi*) forests with (7) cowberry and herbs (*Pyrola incrnata, Thalictrum minus*) in combination with grassy (*Alopecurus arudinaceus, Calamagrostis langsdorffii*) alas meadows; (9) cowberry and herbs (*Pyrola incrnata, Thalictrum minus*) in combination with birch–larch herbaceous (*Poa pratensis, Calamagrostis langsdordfii*) forests; (11) limnas (*Limnas stelleri*) and coweberry in combination with alder–larch cowberry forests and grassy (*Calamagrostis langsdorffii*) and sedge (*Carex juncella*) alas meadows; (13) cowberry-green moss (*Aulaconium turgidum, Ptilidium cillare*) with sedge (*Carex juncella*) and moss (*Sphagnum, Tomenthypnum nitens, Polytrichum commune*) bogs.

Pine (*Pinus sylvestris*) forests with (27) bearberry and lichens (*Cladina stellaris, Cetraria cucullata*) in combination with sparse pine woodland on sands.

Birch (*Betula pedula, B. pubescens*) cowberry forests (38) in combination with larch cowberry forests.

Valley meadows (65) with Calamagrostis and sedges and valley larch forests (59) with grassy and sedge meadows.

SOILS AND SOIL COVER PATTERNS– GENERAL SCOPE

First studies of Yakutian soils were performed in 1912–1916 under the aegis of the Expedition of the Department for Peoples' Migration. R. Abolin investigated the Lena-Vilyui interfluve, G. Dolenko and K. Nikiforov surveyed the Lena valley and the Lena-Amga interfluve. In the 1920s, soil surveys in the area were performed by A. Krasyuk (1927) and A. Grigoriev (1926). The results of these early studies were summarized by K. Glinka (1927) and by R. Abolin (1929). They were rather controversial. On one hand, the specificity of the region was noted; it was displayed on the first soil map of the Russian Empire compiled by Glinka in 1914, where Central Yakutia was shown as an area of paradoxical combination of podzolic soils typical of taiga and solonetzes and solonchaks typical of southern regions. The great role of permafrost in differentiation of soil cover patterns and in water conservation in the soil profiles was emphasized. On the other hand, this period was marked by the transfer of traditional concepts of soil zonality developed in European Russia onto vast Siberian regions. Podzolic soils typical of European taiga were shown on the maps of Siberia, though field descriptions stressed that the soils are "weakly podzolized," or even "nonpodzolized." Also, bleached eluvial horizons typical of acid Podzolic soils were sometimes confused with bleached eluvial horizons typical of Solod soils and some solonetzes with alkaline reaction under the bleached horizon or even within it. This situation continued until the 1950s.

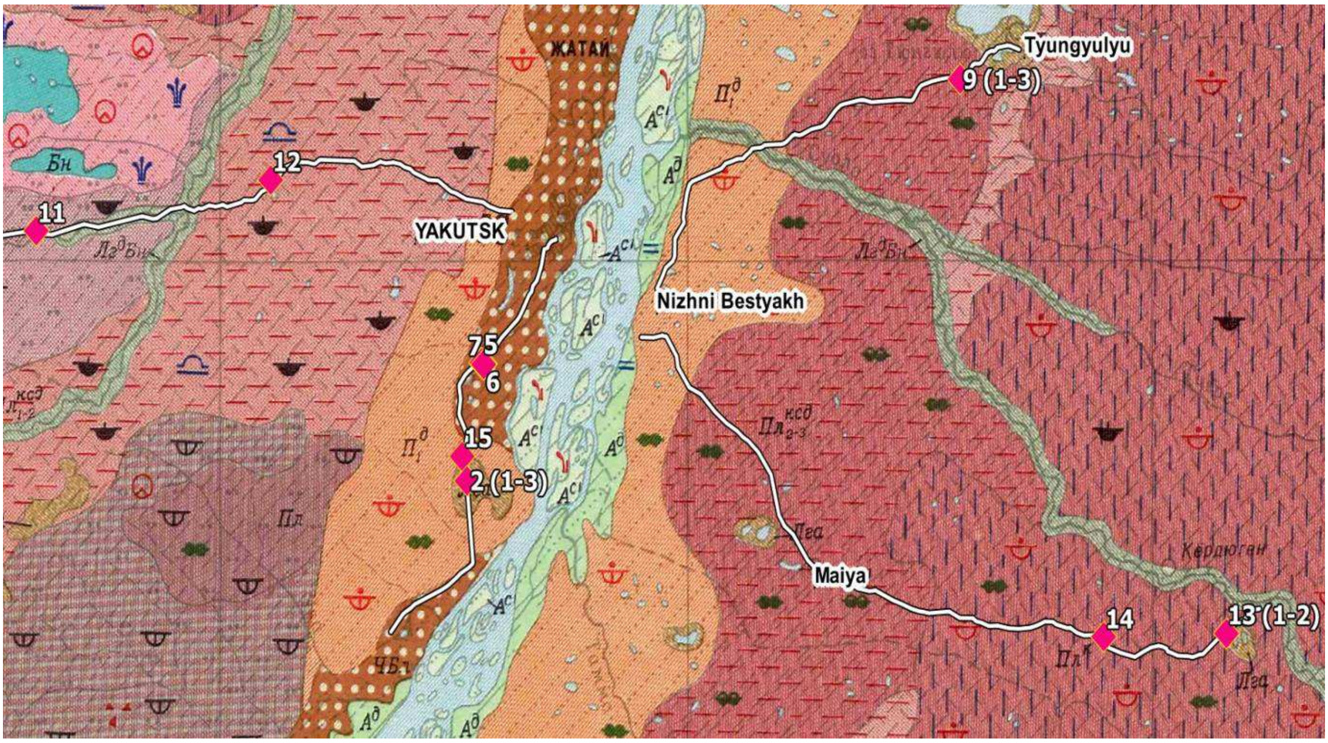
In 1952, I.P. Gerasimov clearly stated for the first time that the soils under Yakutian larch taiga are highly specific and should not be "mixed up" with podzolic soils. Instead, he suggested the terms Palevye (Pale) soils and Solodic Palevye soils. This was in line with findings of V.G. Zol'nikov, a long-term leader in the study of soils of Western Yakutia, whose works in the 1940s–1960s shaped the carcass of our knowledge about this region.

In the 1950s–1980s, active soil surveys were performed in Central Yakutia. Salt-affected soils were studied in detail by L.G. Elovskaya and A.K. Konorovskii; soil temperature regimes were investigated by D.D. Savvinov. On the maps compiled in the 1960s, podzolic (slightly podzolic) soils remained only on terrace sands. The entire territory was separated as a specific cold continental region of "taiga frozen" (taiga permafrost-affected) soils. Actually, under this name, quite different soils could be described. Under taiga vegetation in permafrost regions, both well-drained mesomorphic and poorly drained hydromorphic soils can develop in dependence on the soil texture and general drainage pattern. The name Palevye soils was applied mostly to mesomorphic soils. On the maps compiled in the 1970s and later, Palevye soils represent the major group of soils types under taiga vegetation in Central Yakutia.

However, their classification position and their diagnostic features remain uncertain up to now. In fact, in Russian soil science, there are two concepts of Palevye soils. Initially, these soils were described by V.G. Zol'nikov on calcareous loamy substrates and called "Soddy Forest Palevye soils." The presence of some amount of calcium carbonates in Palevye soils is considered their characteristic feature by L.G.Elovskaya; this is also a diagnostic feature of Palevye soils as distinguished in the new Russian soil classification system (2004). A somewhat different and more general concept of Palevye soils was suggested V.G.Zol'nikov, E.N. Ivanova, and E.M. Naumov (1974) and developed by Sokolov (1986). According to it, the presence of carbonates is not a diagnostic feature of Palevye soils. It is taken into account at a lower taxonomic level in the division of Palevye soils into noncalcareous (typical), calcareous, podzolized, solodic, and other subtypes (or types). This approach was partly realized on the Soil Map of the Russian Federation (1:2.5 M, 1988) and on separate sheets of the State Soil Map (1:1 M).

According to Sokolov et al (1982, 2004), Palevye soils are the soils shaped by the processes of in situ alteration of parent material with the formation of autochthonous thin iron films of iron-bearing minerals (rubification) in the B horizon and specific structuring. The amount of precipitation is insufficient for the development of leaching of bases and eluvial-illuvial redistribution of substances in the soil profiles. The character of vegetation (taiga or tundra) does not favor the development of deep humus horizons of the chernozemic type (though the development of gray-humus horizons is possible). The soil texture and the soil water content before freezing do not favor the activity of cryoturbation (except for sorting of coarse rock fragments) and frost heave. The soil is characterized by a monotonous pale yellow-brown color of the central Bm (Bw) Cambic horizon with cryogenic ooidal structuring, if developed from fine-earth sediments, or by the Bm horizon without illuvial coatings on rock fragments and gravels, if developed from the hardrock residuum. Such soils are developed under subarid to arid cold continental conditions in the permafrost zone. Their taxonomic position in the Russian system is above the type level. The division at the type level is based on superimposed processes specified by the local factors: cryoturbation (heavy-textured soils with shallow permafrost; very cold climate); gleyzation (increased hydromorphism); podzolization (quartz-rich materials, more humid climate conditions); ferrugination (abundance of weatherable minerals); solodization (presence of sodium); carbonate accumulation (presence of calcium carbonates with their migration and precipitation in dispersed forms); humus accumulation (rich herbaceous vegetation at the taiga-steppe interface); etc.

In the study area (Fig. 15), Palevye soils (except for Podzolized Palevye soils) are developed from sediments that contain some amounts of calcium carbonates and soluble salts. Effervescence is usually observed in the middle-profile horizons. Combinations of typical and solodic (with a bleached and clay-depleted) Palevye soils are common (Profiles 2, 14). Soils on terrace sands are only slightly podzolized and may contain stagnic features because of their slow thawing, when the frost table retains moisture in the soil profile and allows the development of redoximorphic processes (Profile 15). Soils of alas depression (profile 9 (1-3)) are an example of concentric soil cover patterns and illustrate evolution of alas sediments and soils upon lake drying. Soils at the bottom of a vast alas (Profile 13) illustrate initial stages of pedogenesis on saline and alkaline substrates. Increased hydromorphism and cryoturbation canbe seen in Profiles 11 and 12.



Symbol	Soil	Symbol	Soil
	Mucky gley taiga permafrost-affected		Salt-affected Alluvial
$П_{1-2}$	Slightly and moderately podzolized (shallow-podzolized)		**Small-area soil combinations**
$П_1^д$	Soddy slightly podzolized (shallow-podzolized)	ЧБл	Chernozems, meadow chernozems (incl. saline), solonetzes, meadow-bog
Пл	Palevye (typical taiga permafrost-affected)	Лга	Meadow chernozems (incl. saline), solonetzes, solonchaks, sapropel (alas)
$Пл^{оп}$	Podzolized Palevye (podzolized taiga permafrost-affected)		Meadow chernozems solodic, solonetzes, solods, palevye calcareous
$Пл^{кс}$	Calcareous gray Palevye (residual-meadow Palevye)	$Лг^дБн$	Soddy meadow, soddy meadow gleyed, peat swampy (lowmoors)
$Пл_1^{ксд}$	Slightly solodic calcareous Palevye (Palevye slightly solodic)		**Soil texture and parent materials**
$Пл_{1-2}^{ксд}$	Slightly and moderately solodic Palevye		Sandy loamy and silty loamy on ancient lacustrine-alluvial deposits
$Пл_{2-3}^{ксд}$	Moderately and strongly solodic Palevye		Sandy loamy and loamy sandy on ancient lacustrine-alluvial deposits
$Пл^к$	Calcareous strongly solodic Palevye		Sandy on ancient alluvial deposits
Бн	Peat and Peat Gley of lowmoors		Silt loamy and, rarely loamy sandy on colluvium of sandstone and slates
$А^{сl}$	Alluvial stratified weakly developed		Sandy loamy and loamy sandy on colluvium of sandstone
$А^д$	Soddy Alluvial		Frequent alteration of texture (sands, loams, clays)

Fig. 15.Soils of Central Yakutia (State Soil Map, 1:1 M scale; map sheet P-52 (Yakutsk), 1988).

Highly complicated soil patterns related to the development of thermokarst can be seen in Profile 2 (1-3). Combinations of dark-colored (chernozem-like) and solonetzic pedogeneses on the first terrace of the Lena River are shown in Profiles 5-7. The complexity of soil cover patterns in such areas is illustrated by the folllowing schematic soil map.

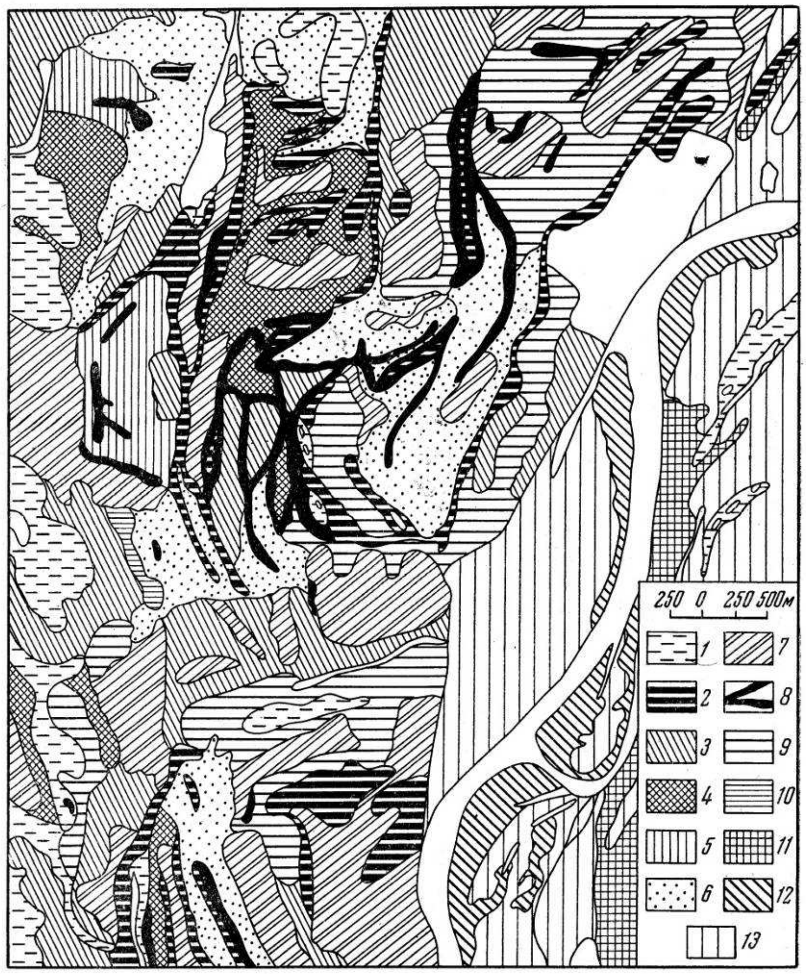


Fig. 16. Detailed soil map of a key site on the floodplain and low terrace (area of profiles 5, 6, 7). Soils and vegetation: (1) meadow-swampy (sedge-reed and sedge meadows); (2) soddy meadow, often solonchakous (forb-grassy and iris meadows); (3) meadow-chernozemic solonchakous and solonetzic (grassy–sedge steppe); (4) meadow-chernozemic solonchakous and moderately to strongly solonetzic with spots of true solonetzes (wormwood-sedge and bluegrass-sedge steppe); (5) meadow-chernozemic solonetzic and solonchakous solonetzes (20%); (6) meadow-chernozemic solonetzic and solonchaks (10%); (7) meadow-chernozemic slightly solonetzic (grass-forb meadows with sedges and feather grass); (8) solonchaks and solonchakous solonetzes (halophytes); (9) meadow-chernozemic solonetzic, solonchaks and solonetzic and solonchakous soils (10-15%); (10) sandy nonpodzolized permafrost-affected (herbaceous pine stands); (11) soddy floodplain soils, often solonchakous, with solonchak spots (forb-grassy steppe meadows); (12) floodplain layered alluvial soils (willow thickets, horsetail meadows); and (13) soddy floodplain soils, partly solonchakous (forb-grassy meadows) (Elovskaya et al., 1966).

ALAS PHENOMENON: SPECIFIC FEATURES, GENESIS, AND DYNAMICS

Thermokarst depressions are the main form of mesotopography complicating plain terrace surfaces. The evolution of alases and their soils is discussed in detail in the recent monograph by Desyatkin (2008). They appeared in the Early Holocene, and their active development took place in the Holocene climatic optimum. The modern period of climate warming coupled with anthropogenic disturbances of vegetation favors the development of new alases (Fig. 17).

Fig. 17.Recent dynamics of alases at the Yukachi key site near the settlement of Maiya, 50 km to the southeast of Yakutsk.

In 1980–2012, the area of recent thermokarst lakes at this site increased by more than four times.

The development of alases proceeds in several stages (Fig. 18).

Alases appear due to penetration of seasonal thawing to the upper layers of the Ice Complex with massive syngenetic ice wedges (normally, at a depth of 3-5 m). Ice melting initiates small surface subsidence with the formation of rounded mounds of up to 1 m in height and several meters in diameter (the Bylar stage). Progressive melting of the ground ice results in the development of small lakes and the death of tree vegetation around their banks (the Dyuedya stage). Then, when the major part of ground ice is molten, typical thermokarst lake of rounded shape appear (the Tyympy stage). Under arid conditions, these lakes are partly dried, and meadow vegetation appears on their banks. This is a mature alas.

Fig. 18.Stages of alas development: (a) Bylar, (b) Dyedya, (c) Tympy, (d) mature alas, (e) drying of alas lake and freezing of talik zone under the lake, the beginning of bulgunnyakh (pingo) formation and (f) bulgunnyakh.

The development of alases is accompanied by considerable transformation of parent materials and soils. At the first stages, fallen trees from the banks enrich the sediments with coarse organic material; bank erosion leads to the accumulation of the eroded fine earth. Then, under mature alas, bottom sediments enriched in the organic matter (lacustrine deposits, LD) accumulate in the alas. After partial drying of the lake, the upper horizons grow upward owing to peat (T) accumulation (T/LD) (Fig. 19). The deposits formed in thermokarst depressions drastically differ from the main surface.

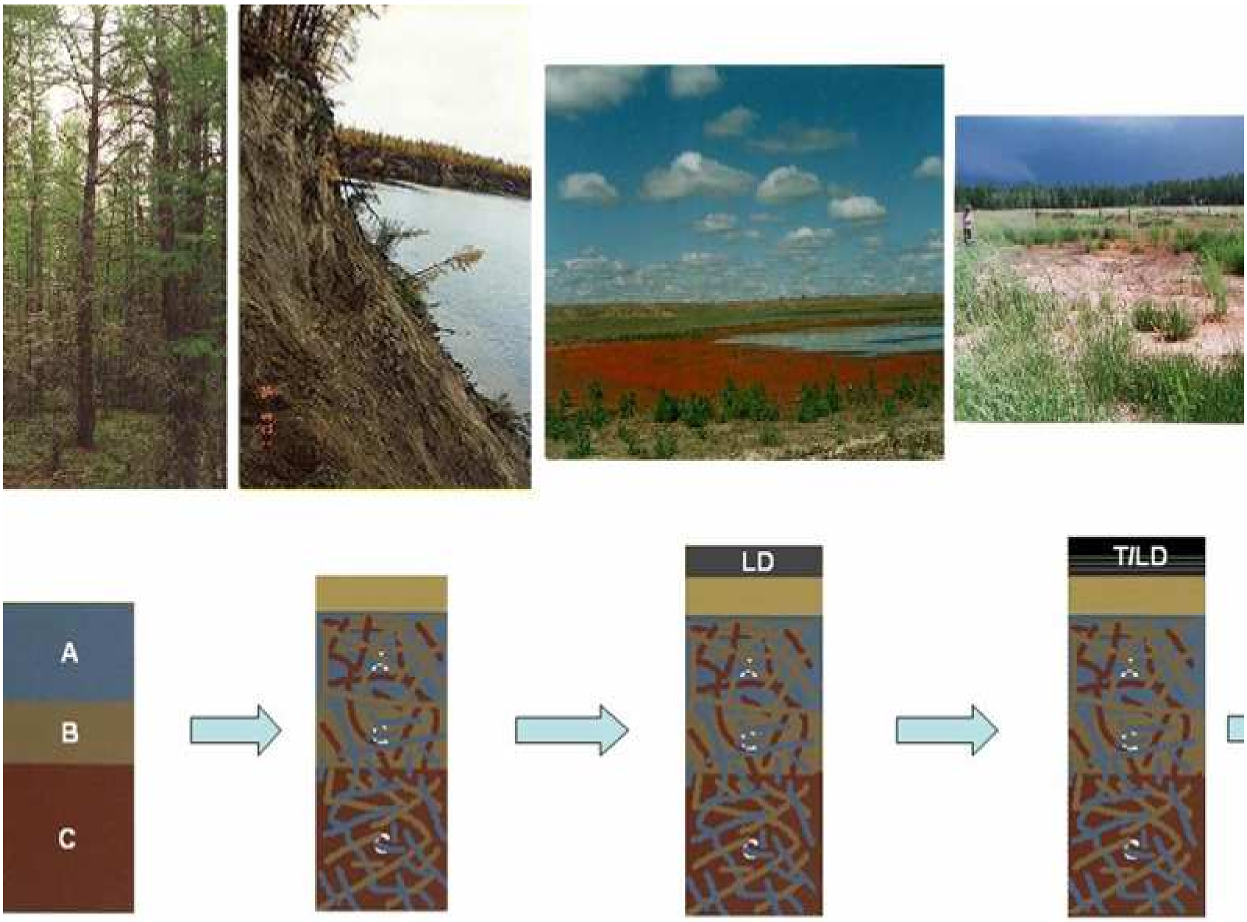


Fig. 19. Scheme of transformation of the parent material upon the alas formation.

Thus, the subaqual stage of sedimentation is replaced by the superaqual stage under swamps, then wet meadows, and then dry meadows. Alases represent valuable agricultural areas used for hay production. It is interesting that, once appeared, alas depression devoid of forest vegetation are preserved for indefinitely long time being subjected to cyclic rejuvenation related to the dynamics of the lakes; normally alases are completely filled with lakes once or twice a century, and they are completely dried with the same periodicity. The formation of new ice bodies under alases takes place under the impact of water migration to the freezing front that appears after drying of the lake and changes in the surface heat exchange. Cryostatic pressures cause the development of bulgunnyakhs.

Alas depressions are also “concentrators” of salts; the formation of solonchaks is common in them, though these soils usually occupy relatively narrow belts around the lakes.

AGRICULTURE AND OTHER ANTHROPOGENIC ACTIVITY IN CENTRAL YAKUTIA

According to official data on January 1, 2012, the total area of agricultural land in Yakutia comprised 21802.8 thousand ha. Of this area, the land really used in agriculture was 885.6 thousand ha (4.16%), including 93.9 thousand ha of cropland, 482.5 thousand ha of hayfields, and 295.5 thousand ha of pastures (State Report..., 2012). A larger part of this land is in central and southwestern regions of the republic, the major producers of agricultural foodstuff. This are the regions with the major rural population; 89% of hayfields, 99% of cropland, 90% of cattle, and 80% of horses are concentrated in this region (Basharin, 1990).

A significant role in farming and cattle breeding e under the severe climatic conditions belongs to thermokarst ecosystems in the taiga zone. The anthropogenic loads on these "pseudoequilibrium" ecosystems has been increasing fro several centuries. First cattle breeders settled in the Lena valley at the end of the 13th century AD. The newcomers significantly modified the economy of the region, organized haymaking and pasturing systems, and created a unique center of cattle and horse breeding in the severe climate of northeastern Eurasia (Gogolev, 1993). From the 14th to the 17 centuries, the extensive anthropogenic influence of alas-taiga ecosystems predominated.

In the 17th century, with the advent of Russians, the anthropogenic loads on the local ecosystems increased considerably, and the structure of the agricultural economy changed. Farming practices were introduced (Safronov, 1961). Two-field rotation systems predominated. The major areas subjected to plowing were relatively warm floodplains and alases with fertile soils. Three-field rotation systems were introduced at the end of the 18th century with the aim to adapt local farming systems to spring and fall frosts. Agriculture based on cattle and horse breeding in combination with arable forming exerted more significant impact on alas-taiga ecosystems. At the beginning of the 20th century, changes in the botanic composition of meadow vegetation in alases with disappearance of some flora and fauna species became evident; many initially virgin meadow and forest plots were transformed into pastures and cropland (Desyatkin, 2004).

The new stage began in the 1920s with the mechanization of agriculture and creation of large agricultural enterprises (kolkhozes). The agricultural production in Yakutia significantly increased.

In the 1950s, the density of rural population in many parts of the region exceeded optimum values for these fragile ecosystems, which meant a significant increase in agricultural loads on them and a considerable reduction of forested areas with extensive land plowing. The whole structure of land use changed. The destruction of forest vegetation changed the water balance of alas-taiga ecosystems (Desyatkin, 2008). The input of water into alases and local rivers from the adjacent forested areas decreased. In many areas, croplands suffered from severe water deficit. The productivity of alas meadows and hayfields also decreased.

It should be noted that arable farming is much more harmful to alas ecosystems than cattle breeding; it is accompanied by their radical transformation with the development of diverse degradation processes.

Statistical data indicate that up to 30% of arable fields in Yakutia are subjected to salinization. Overgrazing resulted in degradation of vegetation on about 40% of meadows (230 thousand ha). Incompetent application of mineral fertilizers under conditions of the cold climate with a short period of biological activity and their improper storage cause the environmental pollution and the contamination of agricultural produce.

In the recent years, the problem of considerable recreation loads on ecosystems around Yakutsk has aggravated.

PART II
SOILS OF CENTRAL SAKHA (YAKUTIA)

METHODS OF STUDY

The routine macromorphological procedure was used for soil description. The profiles were described by S.Goryachkin, E.Zazovskaya with consultations of R.Desyatkin, D.Konyushkov, P.Krasilnikov and also with a help of N.Mergelov, who tuned Russian description to standards of Guidelines for soil description (2006). Besides symbols of master horizons (FAO system), the more informative Russian system was also used for symbols of soil horizons. We included also symbols that were not used in the Russian classification system – **“LD”** for the horizons formed on lacustrine sediments (suggested by R.Desyatkin) and **“pyr”-** for horizons with a lot of pyrogenic charcoals. All the profiles were correlated with WRB (2006 with improvements of 2007), Russian Classification system (Shishov et al., 2004; Field guide, 2008) and Soil Taxonomy (Keys to Soil Taxonomy, 2010).

Methods of Chemical Analyses

The chemical analyses were carried out in laboratories of Institute of Geography, Russian Academy of Sciences, Moscow, Karelian Scientific Centre, Petrozavodsk (carbon and clay mineralogy), ecoanalytical laboratory of Komi Scietific Centre, Syktyvkar (CEC and exchangeable bases). Bulk chemical analyses were done in Dokuchaev Soil Science Institute, Moscow. The analyses were mainly conducted in accordance with FAO procedures (van Reeuwijk, 2002).

pH values were measured in the suspension with soil to H_2O (or 1 M KCl) ratio 1:2,5 with shaking for 2 hours oronce mixing by hand and standing for 30 min (pH_{H2O}) or standing for 18-20 hours with mixing occasionally (pH_{KCl}). pHvalues were measured potentiometrically.

Total organic carbon.

Dry combustion. C was determined with an Elemental Analyser (Vario Max) on dried and ground samples. Samples are burned to CO2 and CO2 are quantified by a TCD.

Wet combustion. The Turin’s procedure of organic carbon determining is similar to the Walkley-Black procedure. This involves a wet combustion of the organic matter with a 1:1 mixture of 0,14 M $K_2Cr_2O_7$ and concentrated H_2SO_4 at 150^0 C for 20 min and titration with ferrous sulphate solution or measurement on spectrometry SPECOL 211 at 590 nm

Carbonates

Carbonates were determined by method after Kozlovsky. The procedure includes a treatment with 2M solution of hydrochloric acid. The evolved CO_2 is trapped in 0,4 M NaOH. Then in a test-tube with NaOH add saturated $BaCl_2$ solution and residual alkali is titrated with 0,2 MHCl.

Dithionite extractable iron (Mehra& Jackson procedure).

The samples were heated in a complexing buffer of sodium citrate/bicarbonate with 1:100 soil to solution ratio to which solid sodium dithionite were added as a reducing agent. The aliquots of extracts were coloured with sulphosalicylic acid at pH about 9. Measurements were conducted with spectrometer SPECOL 211 at 420 nm.

Acid oxalate extractable iron and aluminium.

The samples were shaken with a complexing acid ammonium oxalate solution for 2 hours with soil to solution ratio 1:100. Fe in the extract was determined colorimetrically with sulphosalycylic acid. Al was coloured with aluminon at pH about 4.4.

Soluble salts.

Soluble salts in soils were determined by measuring the cations and anions in water extracts with 1:5 soil to H_2O ratio. *The salinityof the soil* is assessed by the electrical conductivity (EC) of the extract. For the samples with high EC there was measured the EC in 1:2.5 soil to H2O ratio ($EC_{2.5}$) and the EC of saturated extract (EC_{SE}) was calculated by the formula

$\mathbf{EC_{SE} = 250*EC_{2.5}/WC_{SE}}$ (FAO, 2006).

The values for the water content of saturated extract WC_{SE}were taken from the table (FAO, 2006). It takes into account the texture and organic carbon content.

Concentrations of easily soluble cations were determined with the use of AAS (Ca, Mg) and FES (Na, K). *Carbonate and bicarbonate* (alkalinity) are determined by potentiometric titration of the extract with HCl at pH 8.4 and 4.4 respectively. *Chloride* is titrated with 0,02 M $AgNO_3$ at the presence of K_2CrO_4. As the water extracts were the darkly coloured, the aliquots of water extracts were dried by boiling, burnt and then dissolved in hot water. *Sulphate* is titrated by $BaCl_2$ solution.

Particle size analysis.

The procedure is applied to the fine earth (<2 mm). After oxidation of organic matter by H_2O_2, removal of carbonates by HCl and shaking with dispersing agent ($NaPO_3$+ Na_2CO_3) the sand is separated from other fractions with a 63 µm sieve. The clay (<2 µm) and silt fractions (2-63 µm) are determined by pipette method (Reeuwijk, 2002).

Cation exchange capacity and exchangeable bases.

The determination of the cation exchange capacity and exchangeable bases content was conducted in accordance with the methodological guidance of «Procedures for Soil Analyses»(van Reeuwijk, 2002) - ammonium acetate method, using a programmable mechanical vacuum extractor (Model 24VE).

In the non-carbonate, non-saline soil samples the exchangeable bases were displaced by 1M NH4OAc solution (pH 7.0), sample weight of mineral specimens - 2.5 g, and that of organic one - 1 g.In saline carbonate and calcareous soils the procedure of the previous washing of samples with 80% ethanol wasperformed. Then exchange baseswere displaced by a solution of 1M NH4OAc (pH 8.2), the cation exchange capacity (CEC) was determined using a solution of 0.9 M NaOAc (pH 8.2). The concentration of Ca^{2+}, Mg^{2+}, K^{+}, Na^{+} in solution was measured using atomic emission spectrometer with inductively coupled plasma Spectro CirosCCD (Germany, Spectro Analytical Instruments GmbH).

In calcareous and saline soilsthe determination of cation exchange capacity and exchangeable bases was also conducted using silver thiourea method (pH of the soil, without buffering) (van Reeuwijk, 2002). The measurement of the bases concentration was performed using atomic emission spectrometry as it was mentioned above.

To determine the standard cation exchange capacity in carbonate and saline soils there was also used the Bobko-Askinazi method The method is based on the displacement of exchangeable cations in buffer solution BaCl2-Ba $(SH3COO)_2$, pH 6.5 after prior removal of soil carbonates, and soluble salts by treating of the soil samplesby 0.05 n. solution of HCl. CEC is valued by the number of barium ions, which is determined by the difference between the number of mmols of equivalents added to the soil saturated with barium, 0.05 n. H_2SO_4 and equivalents of mmols of the acid remaining after the interaction with the soil.

Yakutsk-Tabaga August 23, 2017.

Pokrovsk road. Cambic Turbic Cryosol. Profile 11a.

This is the “zonal” Typic Pale soil for the Central Sakha (Yakutia). A lot of such kind of profiles can be found in the region including the close vicinities of Yakutsk. The participants of the field workshop can observe vast territories of high old Lena terraces with lower ice-content substrates covered by larch taiga and bogs.

<table>
<tr><td colspan="5">Site 11a N61°48’27.02 E129°31’49.03 H~211 m 30,5 km of the Pokrovsk road. Larch forest affected by ground fires, undergrowth represented by 10-15 years-old birch, cranberry, mosses, 100% projective cover..Hummocky-clumpy microtopography.</td></tr>
<tr><td>O</td><td>O</td><td>+1-0</td><td>yellowish brown, low degree of decomposition, moist, fresh leaves of birch, larchneedles, remnants of grass andshrubs, boundary - clear distinctness,smooth topography</td><td rowspan="4">WRB
Cambic Protocalcic Turbic Cryosol (Siltic)

Soil Taxonomy
Typic Haploturbel

Russian
Палеваятипичнаякриотурби-рованная
Paletypiccryoturbic</td></tr>
<tr><td>A</td><td>AYpir</td><td>0-15(19)</td><td>10 YR 3/1 brownish black, slightly hard, moist, silt loam,granular with worm-casts structure, many roots, charcoalsof different sizesareall over thehorizon, individualearthworms, fragmentsof weakly decomposed organic matternotrelatedto themineral material, numerousfungal hyphae at the top of horizon; boundary - clear distinctness, wavytopography.</td></tr>
<tr><td>Bw@</td><td>BPL@</td><td>15(19)-45</td><td>10 YR 4/3 dull yellowish brown, slightly hard, silt loam, moist, platy fine granular structure, common roots, fragments ofthe overlyinghorizon includeddue tocryoturbation(10%), weak HCL induced effervescence from the depth of 25cm, boundary - clear distinctness, wavytopography</td></tr>
<tr><td>Bk</td><td>BCca</td><td>45-82</td><td>2.5Y 4/3 olive; slightly hard, moist, silt loam, platy fine granular structure, effervescence when reacted with HCL, at 65cmdepth - separateallocation of highly carbonated material in a form of 4x8 cm spots, commonroots,some placesalong the edgesof the structural units are covered by brownishproducts of root decomposition (in a form of films); boundary - gradual distinctness, wavytopography</td></tr>
</table>

2BC	2BC	82-93 (130)	10 YR 5/4 dull yellowish brown, difference from the previous horizon - the absence of effervescence, higher sand (sandy loam) and lower root content, at 80cmdepth - separateallocation of highly carbonated material in a form of 4x8 cm spots; boundary – abrupt distinctness, irregular (wedge-shaped) topography	
3Cf	⊥D	90(130)-190	2.5Y 6/3 dull yellowish gray, medium sand, the fragments of the upper horizon are included, 190 cm - permafrost	

Particle-size distribution

Horizon	Depth, cm	Bulk density	Sand >0,063	Silt 0,063-0,002	Clay <0,002
O	1-0	-	-	-	-
A	0-15(19)	0,7	14,2	61,4	24,3
Bw@	15(19)-45	1,4	19,9	55,5	24,6
Bk	45-82	1,4	31,8	53,4	14,7
2BC	82-93 (130)	-	66,4	28,4	5,2
3Cf	90(130)-190	-	95,0	2,2	2,7

Bulk chemical composition, % in ignited soil

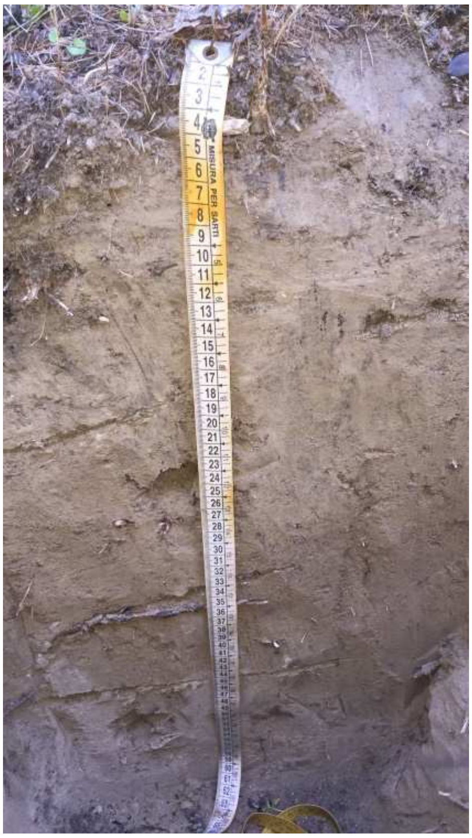
Horizon	Depth, cm	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	Cl	K_2O	CaO	TiO_2	MnO	Fe_2O_3
A	0-15(19)	1,40	1,54	12,78	54,74	0,12	0,21	0,02	1,93	2,48	0,61	0,07	4,12
Bw@	15(19)-45	1,64	1,88	12,88	59,98	0,05	0,11	0,01	2,16	1,64	0,64	0,06	4,60
Bk	45-82	1,68	2,36	15,18	57,76	0,13	0,15	0,02	2,28	3,15	0,66	0,06	4,28
2BC	82-93 (130)	1,73	1,67	15,28	62,88	0,12	0,14	0,03	2,32	1,97	0,64	0,04	2,86

Analytical data

Horizon	Depth, cm	pH H2O	pH KCl	EC, dS/m	C wetcomb., %	C drycomb., %	Loss on ignition, %	Fe_2O_3d (Mehra-Jackson)	Fe_2O_3o (Tamm)	Fe_2O_3 total	Al_2O_3d (Mehra-Jackson)
O	1-0	6,8	6,1		-	-	55,8	-	-	-	-
A	0-15(19)	7,3	6,5	0,09	5,10	6,65	15,1	1,01	0,30	4,12	0,24
Bw@	15(19)-45	7,7	6,5	0,04	0,41	0,48	-	1,00	0,23	4,60	0,24
Bk	45-82	9,0	7,7	0,10	0,29	0,48	-	0,76	0,14	4,28	0,21
2BC	82-93 (130)	9,2	7,7	0,06	0,25	0,30	-	-	-	2,86	-
3Cf	90(130)-190	8,5	7,0	0,03	0,04	0,10	-	-	-	-	-

Cation exchange capacity and exchangeable bases

		NH4OAC						*AgTU*						*BaCl2*	
Hori-zon	**Depth, cm**	**Bases, cmol/kg**					**CEC cmol/ kg**	**Bases, cmol/kg**					**ECEC, cmol/ kg**	**CEC mmol/ 100g**	**$CaCO_3$**
		Ca^{2+}	**Mg^{2+}**	**K+**	**Na+**	**Sum**		**Ca^{2+}**	**Mg^{2+}**	**K+**	**Na+**	**Sum**			
A	0-15(19)	28,1	10,3	0,7	0,3	39,3	27,2	23,8	9,8	0,6	0,3	34,5	34,6	36,7	-
Bw@	15(19)-45	13,6	6,9	0,2	0,2	21,0	12,8	13,9	7,2	0,2	0,3	21,7	19,2	21,7	-
Bk	45-82	18,5	7,2	0,3	0,2	26,1	10,1	18,5	6,5	0,2	0,2	25,4	20,7	19,2	1,5
2BC	82-93 (130)	6,5	3,5	0,2	0,1	10,3	6,1	5,6	3,3	0,2	0,1	9,1	8,1	12,5	0,1
3Cf	90(130)-190	1,1	0,9	0,1	0,0	2,1	1,0	1,1	0,9	0,0	0,0	2,1	0,4	2,5	-



Pedogenesis and classification

This is a soil with pronounced cryogenic features both on macro- and microlevel and with typical biogenic process of forest soils. In spite of low initial content of calcite this soil has neutral and alkaline reaction in the upper calcite-free horizons. It is typical for the ultracontinental areas because of semihumid climates and periodical upward migration of calcite to the freezing front in autumn time. The slight mineral change (illite transformation, ferrugination of mineral mass and organic residuals) and well-pronounced pedotransformation of the structure prove the cambic horizon in this profile and together with permafrost table at 190 cm and pronounced cryoturbations make the correlation of this profile easy in WRB - Cambic Protocalcic Turbic Cryosol (Siltic). Typic Haploturbel in Soil Taxonomy do not show the specificity of this soil as it is the same name with the soils of Antarctic and humid tundra areas – no Eutric Cambiturbels in ST.

Observation point.Badland on icy permafrost.

Description

The formation of badland after forest cutting and ploughing at the territory with icy permafrost. The change of temperature regime results in deepening of permafrost table and beginning of ice wedges thawing. The consequences of the processes are catastrophic - irreversible lost of the arable land due to thermokarst development. The pronounced abrupt border of ploughed horizon proves the existence of former agricultural field here.

Sand hills near Tabaga. Haplic Stagnosol Arenic Turbic.Profile 15.

This soil is characteristic for Sakha (Yakutian) soils formed on sandy materials under pine forests.

<table>
<tr><td colspan="5">Site 15 N61^{0}50’14,9” E129^{0}31’18,8”
To the south of Yakutsk, vicinities of Tabaga settlement, sandy depositions
Pine forest with no ground vegetation, large number of pine needles, cones, small branches
MAST$_{50CM(2003-2010)}$=-0,77^{o}C (Desyatkin et al., 2013)</td></tr>
<tr><td>O</td><td>O</td><td>+1-0</td><td>Litter with low decomposition degree of OM (aeromorphic mor), consists of woody remnants and pine needles</td><td rowspan="6">WRB
Hypereutric Albic Stagnosol
(Arenic Gelistagnic, Turbic)

Soil Taxonomy
Aquic Haplogelept
Or Typic Gelaquent
(No Gelipsam-ments in ST)

Russian
Подбуроподзоленныйглееватый
(крио)тур-бированный
Podboorpodzolizedgleyish
(cryo)turbated</td></tr>
<tr><td>A</td><td>AYao pir</td><td>0-4</td><td>10 YR 2/1 black
moist, mixture of sand grains and charcoal-like organic remnants, spreadable organic material, boundary – abrupt distinctness, wavy topography</td></tr>
<tr><td>Bh</td><td>BHe</td><td>4-9</td><td>Matrix 10YR 3/3 brownish black
Mottles 10YR 6/2 grayish yellow brown
loose consistence, moist, sand, many roots, not structured, boundary – clear distinctness, wavy topography</td></tr>
<tr><td>Bg@</td><td>BMg@</td><td>9-30</td><td>Matrix 10 YR 5/6 yellowish brown
Mottles 2.5Y 6/3 dull yellow
Stagnic horizon, distinct mottles, many roots, light coloured sand near roots and in single lenses due to forest windfall, in the lower part of horizon on 2 sides of the pit – inclusions of BHe material, boundary – clear distinctness, wavy topography</td></tr>
<tr><td>BCg</td><td>BCg</td><td>30-80</td><td>Matrix 10YR 5/4 dull yellowish brown
Mottles 2.5 Y6/3 dull yellow
Mottles boundaries 5YR 4/6 reddish brown
10-40 cm mottles on the general matrix, sand, moist, loose consistence, weakly expressed layers, boundary – clear distinctness, smooth topography</td></tr>
<tr><td>Cg</td><td>C</td><td>80-120</td><td>2.5Y6/4 dull yellow
layered, medium sand, few roots</td></tr>
</table>

Particle-size distribution

Horizon	Depth, cm	Bulk density	Sand >0,063	Silt 0,063-0,002	Clay <0,002
O	1-0	-	-	-	-
A	0-4	0,6	76,8	18,4	4,8
Bh	4-9	-	87,8	10,1	2,1
Bg@	9-30	1,6	92,5	4,6	2,9
BCg	30-80	1,5	91,5	4,5	3,9
Cg	80-120	-	95,7	1,6	2,7

Bulk chemical composition, %

Horizon	Depth, cm	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	Cl	K_2O	CaO	TiO_2	MnO	Fe_2O_3
A	0 - 4	1,16	0,54	9,29	54,15	0,29	0,47	0,03	1,94	3,83	0,28	0,35	1,32
Bh	4--9	1,48	0,54	11,91	62,28	0,21	0,17	0,02	1,69	1,52	0,37	0,10	1,36
Bg@	9--30	1,95	0,47	11,32	73,90	0,06	0,16	0,02	1,90	0,79	0,20	0,01	0,78
BCg	30 - 80	1,61	0,67	12,75	69,26	0,08	0,16	0,02	2,06	1,07	0,22	0,01	1,21
Cg	80 - 120	1,96	0,62	12,25	73,43	0,06	0,18	0,02	2,22	1,12	0,25	0,01	1,11

Analytical data

Horizon	Depth, cm	pH H2O	pH KCl	EC, dS/m	C wetcomb., %	C drycomb., %	Loss on ignition, %	Fe_2O_3d (Mehra-Jackson)	Fe_2O_3o (Tamm)	Fe_2O_3 total	Al_2O_3d (Mehra-Jackson)
O	1-0	5,5	4,5	-	-	-	81,5	-	-	-	-
A	0-4	6,2	5,4	0,03	3,72	4,62	15,9	0,53	0,23	1,32	0,14
Bh	4-9	6,8	5,5	0,02	1,24	1,45	4,9	0,29	0,29	1,36	0,39
Bg@	9-30	6,9	5,1	0,03	0,12	0,17	-	0,41	0,14	0,78	0,13
BCg	30-80	6,7	4,7	0,03	0,11	0,22	-	0,21	0,05	1,21	0.09
Cg	80-120	6,8	4,7	0,03	0,07	0,19	-	0,14	0,01	1,11	0,07

Cation exchange capacity and exchangeable bases

Hori-zon	Depth, cm	*NH4OAC*					
		Bases, cmol/kg					CEC cmol/kg
		Ca^{2+}	Mg^{2+}	K+	Na+	Sum	
A	0 - 4	15,0	0,9	0,3	0,0	16,2	17,7
Bh	4 - 9	6,3	0,4	0,0	0,0	6,7	8,5
Bg@	9 - 30	1,2	0,2	0,0	0,0	1,4	1,4
BCg	30 - 80	2,1	0,5	0,0	0,0	2,6	2,7
Cg	80 - 120	1,3	0,4	0,1	0,0	1,8	0,9

Pedogenesis and Soil Classification

The environment of this soil makes a feeling that one should see a soil like Podzol or Spodosol. However it is possible to see only weak features of Al-Fe-humus eluviation and illuviation in this profile. Neither color nor chemical criteria fit podzol-spodosol units of WRB and Soil Taxonomy systems. The most manifested features of this profile is redoximorphism in spite of the generally good drainage and (cryo?)turbations. The question mark is because of very similar features of uprooting turbations in sandy soils of permafrost-free areas. The stagnic features are because of seasonal freezing and temporary impermeable horizon occurring during spring time. The another ultracontinental characteristic is high base saturation in this soil in spite of sandy material and acid litter of pine forest.

The WRB correlation is good reflections of main features. Soil Taxonomy is not yet good elaborated for Entisols with gelic temperature regime. According to the basic logic of the system this soil should be Aquic Gelipsamment but there is no such a group in Soil Taxonomy now. So, it can be correlated now as Aquic Haplogelept or Typic Gelaquent. In both cases sandy material and turbations are not reflected in the soil name.It is also not clear position of this soil in Russian classification as there are no "Stagnozems" in it.

Lena terrace.Protocalcic Chernozem (Stagnic, Tonguic, Turbic). Profile 5.

Site 5 N61^{0}55'00,6" E139^{0}33'45,0", H~96 m Established on the steppe site				
Ak	AUpa ca	0-20	10YR 2/2 brownish black; moist; silt loam; blocky subangular with elements of granular structure; weak effervescence when reacted with HCL; slightly hard; many roots; boundary - abrupt distinctness, smooth topography.	WRB Protocalcic Chernozem (Siltic, Sodic, Stagnic, Tonguic,Turbic) Soil Taxonomy Typic Cryaquoll or Turbic Haplogeloll Russian Черноземглеев(ат)ый, темноязыковатый, криотурбированный; Chernozem gleyic dark-tounging cryoturbated
AB@k	AB@ ay ca g	20-32(40)	2.5Y 5/3 yellowish gray matrix with 2.5 Y 3/2 brownish black humus pockets; silt loam; fine isometric structure with sharp edges of peds, organized in plates, with elements of granular structure in dark tongue-shaped pockets; effervescence when reacted with HCL; slightly hard; common roots; many orange mottles on yellowish gray fragments; boundary - clear distinctness, wavy topography.	
Bk	BCA	32(40)-50	10 YR 6/3 dull yellow orange; hard; silt loam; platy to fine platy structure; strong effervescence when reacted with HCL; few pseudomycelia; boundary – clear distinctness, wavy topography.	
BCgk	BCgca	50-90	10 YR 5/4 dull yellowish brown; hard; silt loam; fine crumbly with elements of platy structure; many fine hard Fe-Mn concretions; few roots; effervescence when reacted with HCL; boundary - clear distinctness, irregular topography (influenced by cryoturbations).	
2Cg	D1g	90-150	2.5 Y 6/4 dull yellow matrix; alternating layers of sand and loamy sand, some darker layers, many orange mottles; not structured; NO effervescence when reacted with HCL; boundary - clear distinctness, smooth topography.	
3Cg	D2g	150-220	2.5 Y 6/4 dull yellow matrix with orange and light gray layers; sand to loam texture; very wet in the lower part due to the groundwater at 220 cm.	

Particle-size distribution

Horizon	Depth, cm	Bulk density	Sand >0,063	Silt 0,063-0,002	Clay <0,002
Ak	0-20	1,2	12,0	64,3	23,7
AB@k	20-32(40)	1,3	10,7	61,9	27,3
Bk	32(40)-50	1,5	10,4	69,2	20,3
BCgk	50-90	1,5	16,8	69,9	13,2
2Cg	90-150	-	81,3	16,7	1,9

Analytical data

Horizon	Depth, cm	pH H2O	pH KCl	EC, dS/m	C wetcomb., %	C drycomb., %	Loss on ignition, %
Ak	0-20	8,7	7,5	0,1	2,3	3,2	11,8
AB@k	20-32(40)	8,9	7,9	0,3	1,6	2,2	12,2
Bk	32(40)-50	9,0	8,0	0,4	0,4	2,2	-
BCgk	50-90	8,6	7,6	0,4	0,2	0,7	-
2Cg	90-150	9,3	7,7	0,1	0,1	0,4	-
3Cg	150-220	9,0	7,4	0,1	0,3	0,8	-

Cation exchange capacity and exchangeable bases

NH4OAC								*AgTU*						*BaCl2*	
Hori-zon	Depth, cm	Bases, cmol/kg					CEC cmol/kg	Bases, cmol/kg					ECEC, cmol/kg	CEC cmol/kg	$CaCO_3$
		Ca^{2+}	Mg^{2+}	K+	Na+	Sum		Ca^{2+}	Mg^{2+}	K+	Na+	Sum			
Ak	0-20	66,5	12,8	0,2	0,2	79,8	18,3	25,3	8,3	0,3	0,2	34,2	32,4	32,5	2,5
AB@k	20-32(40)	24,7	19,4	0,1	0,9	45,2	17,1	18,1	16,7	0,2	1,2	36,1	30,1	25,8	9,9
Bk	32(40)-50	20,0	12,9	0,1	1,3	34,3	9,2	17,4	11,7	0,2	1,6	30,9	23,9	15,8	13,1
BCgk	50-90	14,7	7,6	0,1	1,9	24,2	9,2	14,3	7,1	0,2	3,2	24,8	19,6	17,5	5,3
2Cg	90-150	9,5	1,3	0,1	0,1	10,9	1,3	10,2	1,2	0,1	0,2	11,6	8,9	5,0	1,0
3Cg	150-220	9,6	5,0	0,1	1,3	16,1	6,9	7,8	4,3	0,2	1,5	13,9	12,7	11,7	4,2

Bulk chemical composition, %

Horizon	Depth, cm	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	Cl	K_2O	CaO	TiO_2	MnO	Fe_2O_3
Ak	0-20	1,20	3,02	14,01	52,55	0,16	0,26	0,02	2,15	4,00	0,71	0,08	6,16
AB@k	20-32(40)	1,33	3,48	13,18	48,53	0,11	0,24	0,05	2,02	7,47	0,59	0,11	6,50
Bk	32(40)-50	1,41	3,78	13,35	49,52	0,12	0,26	0,06	2,15	8,35	0,62	0,10	5,57
BCgk	50-90	1,64	3,46	15,01	54,59	0,13	0,21	0,11	2,38	3,57	0,67	0,09	5,80

Pedogenesis and Soil classification

This soil is formed under grassland vegetation. The climatic conditions here are more arid and contrast in summer and winter temperatures because of winter inversions and summer heating. The soil has mollic horizon of 20 cm but while mixing with AB horizons it would fit criteria of mollic horizon at least till the depth of 25 cm. Secondary carbonates are manifested undoubtedly in the Bk horizon. Stagnic features are well-pronounced and thus this soil is classified as Protocalcic Chernozem (Siltic, Sodic, Stagnic, Tonguic, Turbic) in the WRB. For Soil Taxonomy it might be Turbic Gelaquoll, but there is no such a subgroup in the system, so it is nearer to Turbic Haplogeloll. In Russian system it is Chernozem gleyic (without Quazi) dark-tounging cryoturbated, so it also does not fit criteria of the last version of the RSC.

Profile 5

Profile 7

Lena terrace.Salic Solonetz.Profile 7.

<table>
<tr><td colspan="5">Site 7N61^{0}54’56,0”E129^{0}34’00,7”H~100 m
Established on the spot with predominance of Artemisia & Limonium with a touch of sedges, grasses, projective cover - 70%.</td></tr>
<tr><td>Ap</td><td>AUpa</td><td>0-10</td><td>10 YR 3/2 brownish black; moist; loose; silt loam; blocky subangular; many roots; weak effervescence when reacted with HCL; boundary - abrupt distinctness, smooth topography.</td><td rowspan="5">WRB
Protocalcic Salic Abruptic Solonetz (Endoarenic, Endofluvic)

Soil Taxonomy
Typic Natrudalf (no Gelalfs in ST)

Russian
Солонец темногуму-совыйзасоленный постагро-генный абрадиро-ванный
Solonetz dark-humussalinized post-agrogenic eroded</td></tr>
<tr><td>Btn</td><td>ASN</td><td>10-25</td><td>Intrapedal mass - 10 YR 6/4 dull yellow orange, on ped faces - 10 YR 3/4 dark brown; hard; loam; prismatic-blocky angular structure; all ped faces are covered by opaque humus-clay cutans; few roots; strong effervescence when reacted with HCL; few pseudomycelia; boundary - clear distinctness, smooth topography.</td></tr>
<tr><td>Bk</td><td>BCA</td><td>25-50</td><td>10 YR 7/4 dull yellow orange; hard; silt loam; platy-blocky subangular structure; strong effervescence when reacted with HCL; fewpseudomycelia; few roots; boundary - abrupt distinctness, smooth topography.</td></tr>
<tr><td>2C1</td><td>D1</td><td>50-70</td><td>2.5Y 6/4 dull yellow; loose; fine sand; not structured; moist; few roots; few soft Mn concretions in the upper part; boundary - abrupt distinctness, smooth topography.</td></tr>
<tr><td>3C2g</td><td>D2g</td><td>70-120</td><td>10 YR 5/4 dull yellowish brown; alluvial layers; alternation of yellowish brown, yellow and dull grayish yellow layers; sandy loam; bluish gray in the lower part;very wet
Permafrost at 220 cm (borehole data)</td></tr>
</table>

Micromorphology

Ap – 0-10 cm. It is patchy coloured. At a dark gray background brownish-red zones which are different in size and in sharpness of the boundaries (from very sharp to diffuse). Heterogeneity in color is due to the different composition of the micromass. The darkest colour is associated with the clay-humus isotropic fine material. and brown zones are characterized by the carbonaceous-clayey fine material and stipple-speckled b-fabric(Fig. 6a, b). In brownish-red areas, which are often fresh excrements, the micromass is humus-clay-carbonaceous with crystallitic b-fabric. Small fragments of iron-clay coatings, ferrugenous concentric nodules and small typical nodules sometimes occur in these zones (Fig. 6c). The major type of microstructure is complex crumb and fine platywith spheoidal biogenic peds. C/f related distribution pattern is open porphyric, with circular distribution pattern of coarse particles in some zones(Fig. 6d). Sand and coarse-silt size particles are feldspars (acid plagioclases), quartz, amphibole, microcline, fragments of quartzite,muscovite plates, andrare thin plates of biotite. Silicate grains are poorly rounded, angular particles prevail.Organic matter hasdiverse microforms: 1) strongly altered dark brown plant tissues with the remains of the cellular structure, 2) carboniferousfragments of plant tissues of different sizes, 3) small stronglyalteredtissue residues, 4) dark dispersedhumus (organic pigment) and micro-globularhumus (humus punctuations). Recentlargeroots, havingbirefringenceof cellulose, dissectplatyaggregates.

There are also met: 1) biogenic fromboids or their fragments, which are confined mainly to the areas and aggregates with clay-carbonate micromass and 2) multimineral infillings, fragments of clay and silty-humus coatings.

Btn – 10-25 cm. Brownish and light brownish material with a predominance of angular-prismatic and coarse-platy aggregates. Compared with the overlying horizon the number of coarse-sand skeletal grains markedly decreased, but the number of plates of biotite, mica, muscovite and carbonate framboidssignificantly increased (Fig. 6e, f). Mica platelets are randomly distributed in the soil mass. Micromass is clay-carbonate with crystallitic b-fabric.A variety of pedofeatures is typical for the horizon. Complex silty clay-humus coatings (cutans) in observed in some pores (Fig. 6e, f) and their twisted, deformed fragments - papules. Loose silt infillings and fine ferruginous nodules are rare. Biotite plates are splited into separate layers. Carbonatesare micritic.

Bk – 25-50 cm. Light brownish silty sand material with a banded (sedimentogenic) particle distribution. The quartz, feldspar and biotite plates dominates in coarse material. The content of fine particles is very low, they are distributed in the form of light gray, almost colorlessbands. The grains of iron-containing minerals (Fig. 6g), particularly plates of biotite and amphibole differ by strong degree ofalteration, iron accumulation and splitting into separate plates. Some plates of mica are deformed. Destroyed carbonate framboids are characteristic pedofeature, fine-grained carbonate are cryptocrystalline matrix features are characteristic (Fig. 6h). Micrit is a part of the fine material.

Conclusion. This profile as based on its micromorphological features, can be classified as Solonetz. The soil is formed onlayered alluvial deposits; from top to bottom the stratification of particles of different size is pronounced. The specific feature of the mineralogical composition of the soil-forming material is a high content of easily weathered minerals - biotite, plagioclase, amphibole, which have their signs of ferruginization. The humus horizon has a high diversity of microforms of humus and plant remains. The presence of framboids - biogenic carbonate pedofeatures - in the largest numbers occurring in aggregates with clay-carbonate micromass,suggest their allochthonous genesis with digging activity of worms.

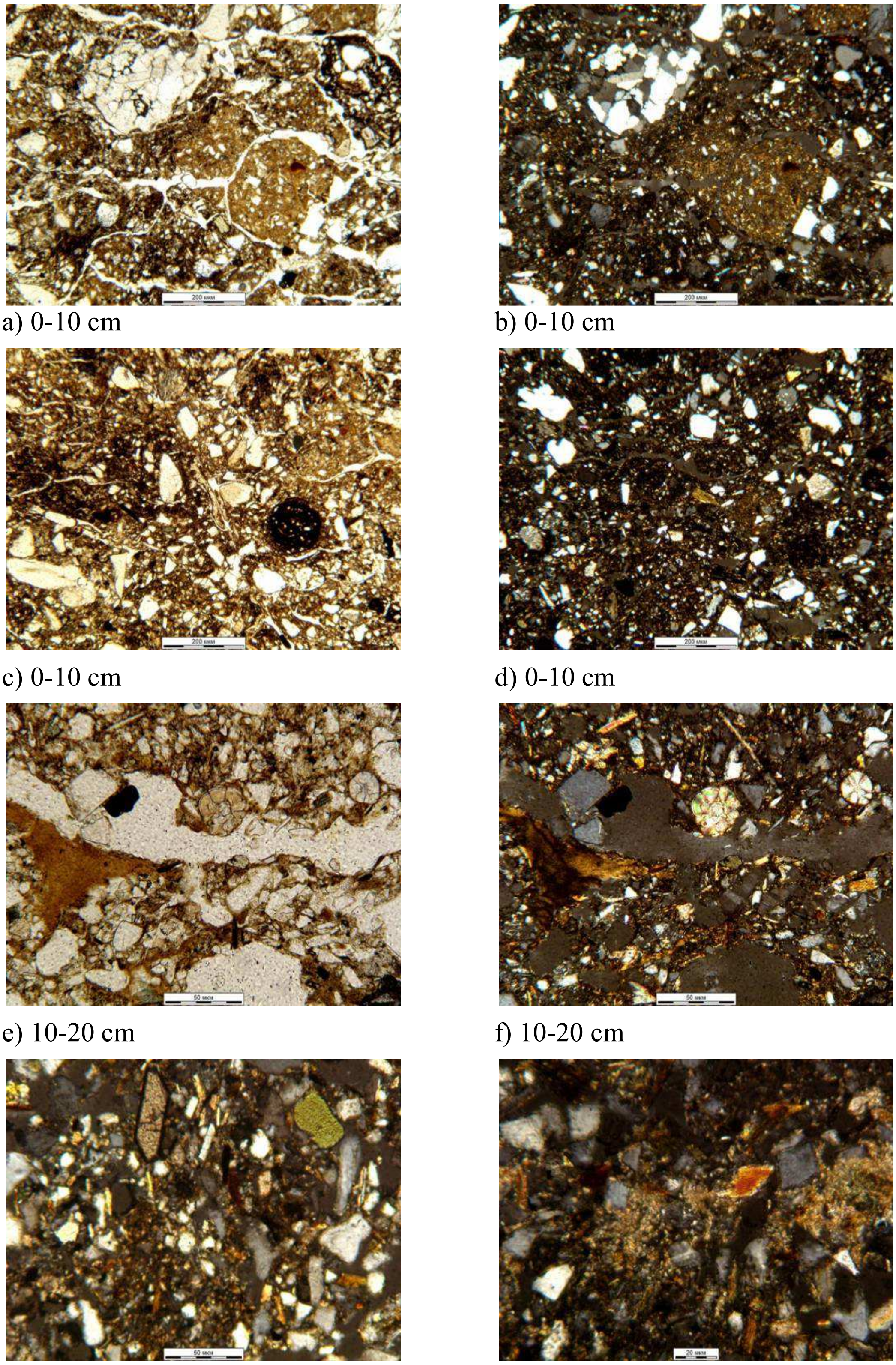


Fig. 20.Microfeatures of horizons in Salic Solonetz, prof. 7 (a–h):
a) non-uniformity of color and composition of the platy and coprogeneous aggregates, fragment of calcite (PPL); b) the same, isotropic clay-humus micromass in platy aggregates and carbonate-clay crystallitic micromass in excrements (XPL); c) ferruginous nodules and zones of ferruginous impregnation in intrapedal mass (PPL) d) circular distribution of fine sand size particles in the isotropic clay-humus material (XPL); e) humus-clay coating (PPL); f). the same, fresh biogenic carbonate framboids (XPL); g) clayey-silty aggregate among the fine sand grains, and iron coating surrounding mineral grains (XPL); h) cryptocrystalline loose matrix pedofeatures (XPL).

Currently, in the humus zones they have the signs of disintegration and traces of recrystallization. Natric horizon is characterized by complex of clay, silty clay cutans and papules. We assume that the high degree of their alteration deformity and convolution associated with contemporary processes of intensive cryogenic structure formation.

Particle-size distribution

Horizon	Depth, cm	Bulk density	Sand >0,063	Silt 0,063-0,002	Clay <0,002
Ap	0-10	1,6	25,9	66,4	7,7
Btn	10-25	1,5	34,8	49,7	15,5
Bk	25-50	1,4	35,9	50,2	13,9
2C1	50-70	-	88,7	10,2	1,1
3C2g	70-120	-	58,4	34,2	7,4

Analytical data

Horizon	Depth, cm	pH H2O	pH KCl	EC, dS/m	C wetcomb., %	C drycomb., %	Loss on ignition, %	Fe_2O_3d (Mehra-Jackson)	Fe_2O_3o (Tamm)	Fe_2O_3 total
Ap	0-10	9,9	7,8	0,2	1,1	1,6	7,3	1,4	-	5,6
Btn	10-25	10,3	8,3	0,3	0,7	1,7	7,9	1,0	-	5,5
Bk	25-50	10,3	8,4	0,4	0,2	0,8	-	1,2	-	5,6
2C1	50-70	10,1	7,9	0,1	0,1	0,1	-	-	-	-
3C2g	70-120	9,3	7,7	0,1	1,4	2,1	-	-	-	-

Soluble salts – anions and cations, cmol/kg and electro conductivity(EC) of saturated extract, dS/m

Horizon	Depth	$CO3^{2-}$	$HCO3^{-}$	Cl^{-}	$SO4^{2-}$	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	EC
Btn	10-25	0,5	4,3	1,1	1,8	0,2	0,9	4,5	0,2	13,1

Cation exchange capacity and exchangeable bases

		NH4OAC						*AgTU*						*BaCl2*	
Hori-zon	Depth, cm	Bases, cmol/kg					CEC cmol/kg	Bases, cmol/kg					ECEC, cmol/kg	CEC cmol/kg	$CaCO_3$
		Ca^{2+}	Mg^{2+}	K+	Na+	Sum		Ca^{2+}	Mg^{2+}	K+	Na+	Sum			
Ap	0-10	35,1	4,9	0,2	5,6	45,8	7,2	16,0	2,9	0,1	5,3	24,4	21,5	22,5	1,5
Btn	10-25	19,1	8,0	0,2	10,4	37,7	10,5	14,9	8,0	0,0	9,6	32,5	26,5	19,2	6,9
Bk	25-50	14,2	6,5	0,1	7,33	28,2	5,9	14,5	7,3	0,0	7,2	29,1	21,8	11,7	4,9
2C1	50-70	2,7	1,1	0,1	0,9	4,7	1,4	2,2	0,7	0,1	1,0	3,9	2,8	4,2	0,2
3C2g	70-120	10,0	4,8	0,2	0,7	15,7	3,8	8,5	3,3	0,1	0,6	12,6	9,5	7,5	3,4

Bulk chemical composition, %

Horizon	Depth, cm	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	Cl	K_2O	CaO	TiO_2	MnO	Fe_2O_3
Ap	0-10	1,82	2,92	14,61	55,41	0,20	0,16	0,02	2,39	3,07	0,65	0,12	5,64
Btn	10-25	2,04	3,47	13,59	50,29	0,16	0,15	0,03	2,19	5,09	0,56	0,08	5,50
Bk	25-50	2,06	3,59	13,47	51,44	0,14	0,17	0,03	2,19	3,71	0,59	0,08	5,65

Pedogenesis and Soil classification

This soil was recognized as typical Solonetz of cryogenic area since it was found in the field. Then it was confirmed by analytical and micromorphological data. It is the driest version of Solonetzes of this workshop with pronounced solonetzic structure (surely, without columnar aggregates because of strong frost dissection), cutans and characteristics of exchange bases. The shallow upper horizon is probably related to its erodibility.

In respect to classification it is Protocalcic Salic Abruptic Solonetz (Endoarenic, Endofluvic) in the WRB and Typic Natrudalf, as there are no Gelalfs in Soil Taxonomy.

In Russian soil classification it is Solonetz dark-humussalinized post-agrogenic eroded.

Yakutsk-Churapcha-Tyungyulyu August 25-26, 2017

DAY 1

Churapcha.General information.

The reason for visiting Churapcha district is to show the results of a wrong agricultural practice and the policy of population distribution in 1960-70. There was decrease of the number of small communities and concentration of the population in a limited number of collective farms – in 1939 there were 625 communities and at the end of the XX century all 33,000 persons were living in 36 villages. That leads to the growth of the population density up to 30-40 persons per 1 sq.km in this district (the mean population density in Central Sakha (Yakutia) is 0.8 persons pet 1 sq.km). This process resulted in the widening of the agriculture practice from traditional alas areas onto forest lands with the permafrost of high ice content.

Together with global climate change the anthropogenic activity resulted in the irreversible degradation of permafrost, soils and vegetation (Figures 21-27).

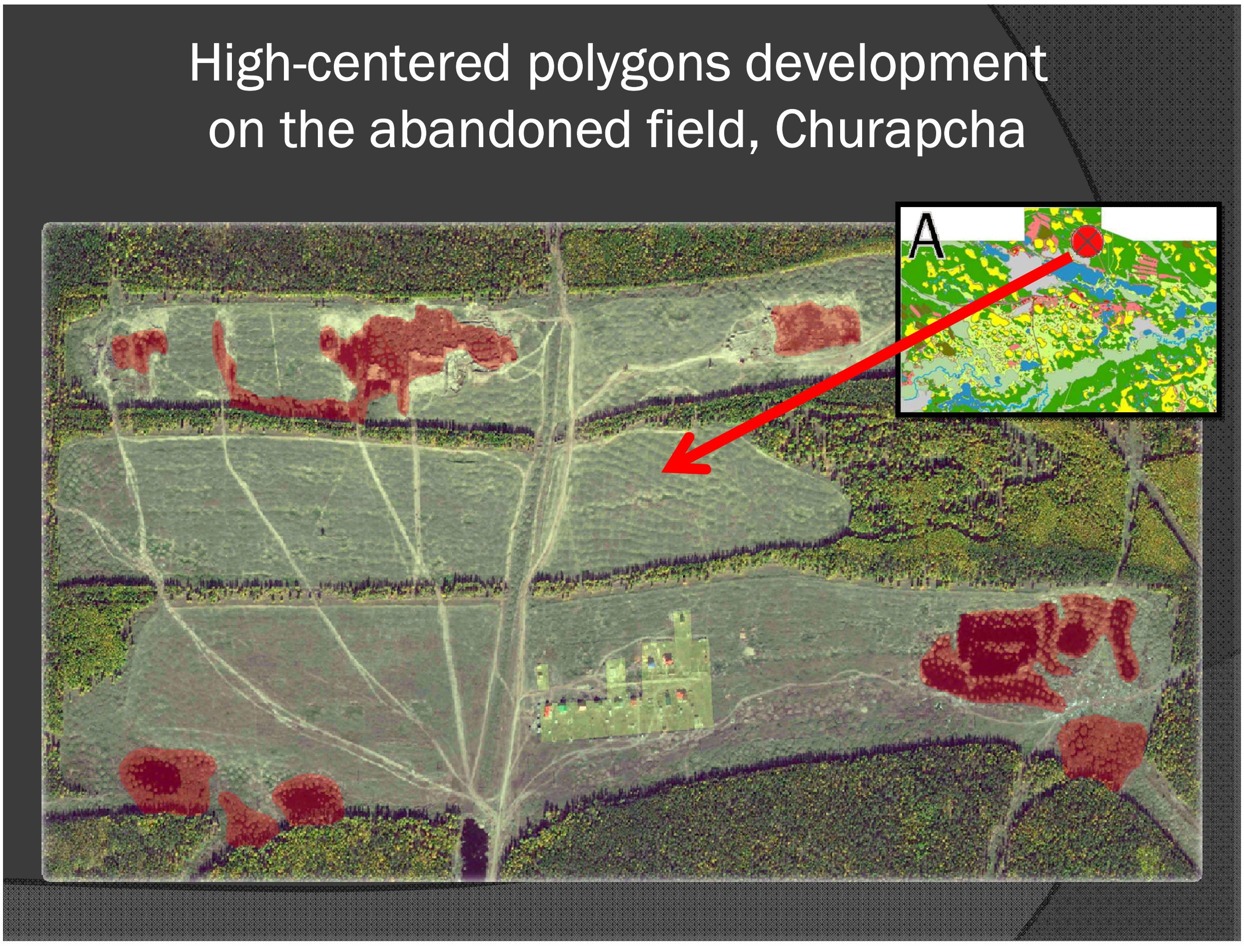


Fig. 21.

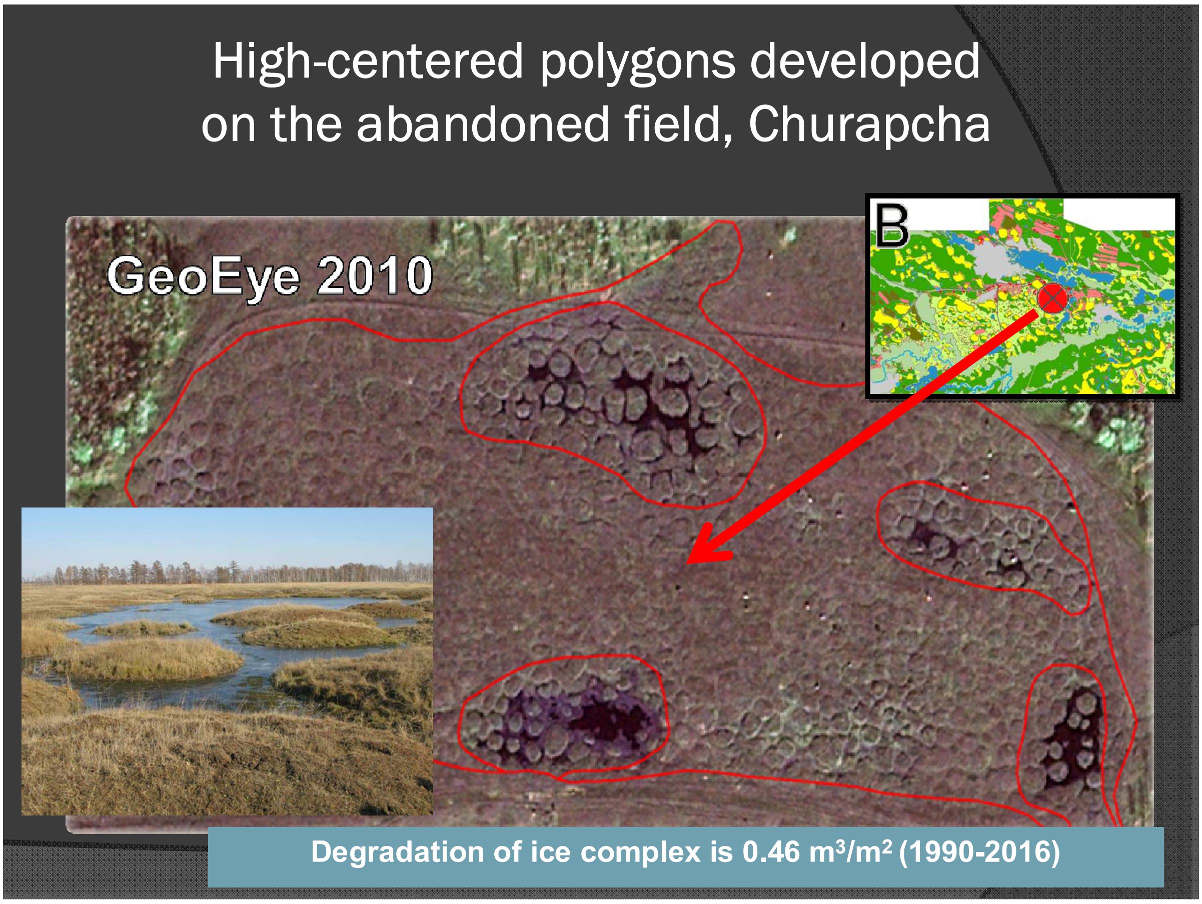

High-centered polygons developed
on the abandoned field, Churapcha
GeoEye 2010
B
Degradation of ice complex is 0.46 m³/m² (1990-2016)

Fig. 22.

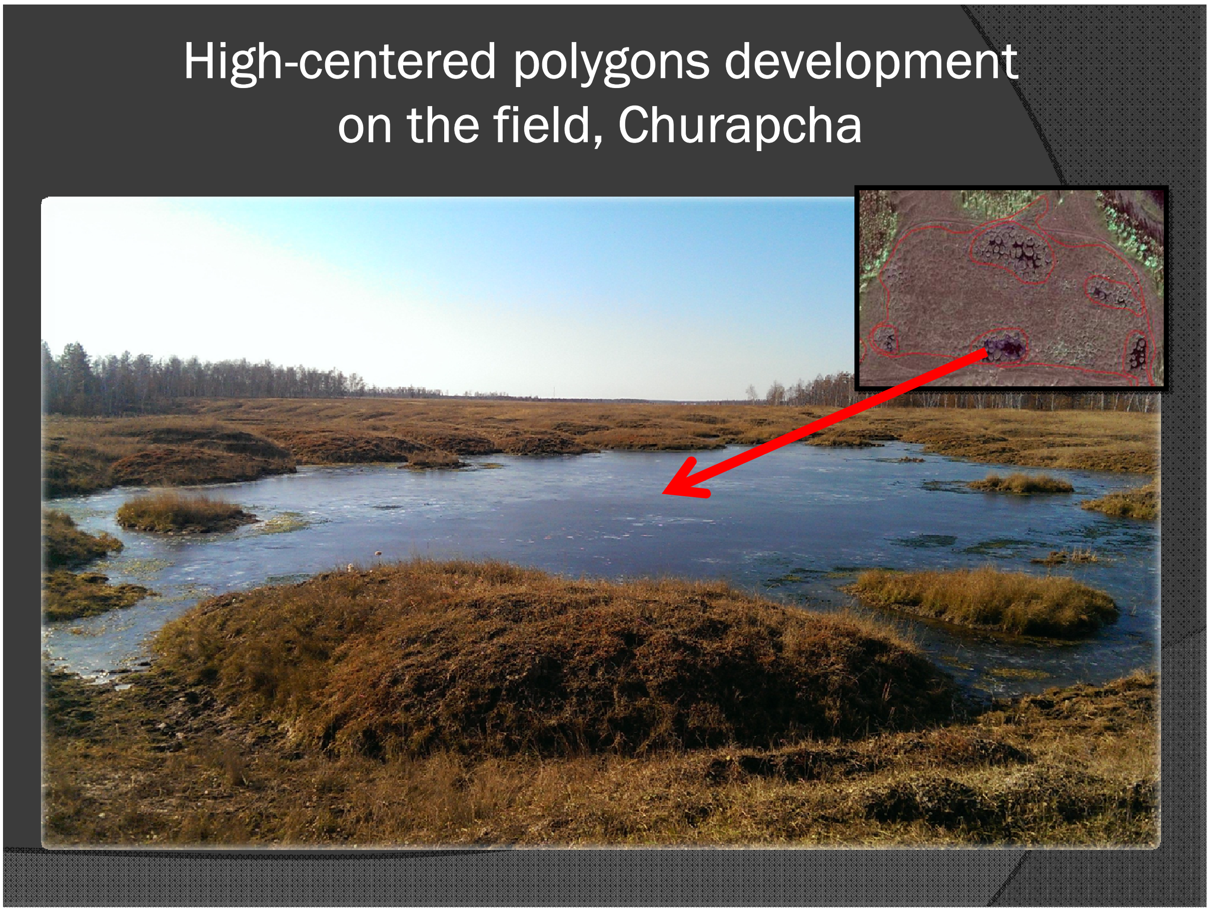

High-centered polygons development
on the field, Churapcha

Fig. 23.

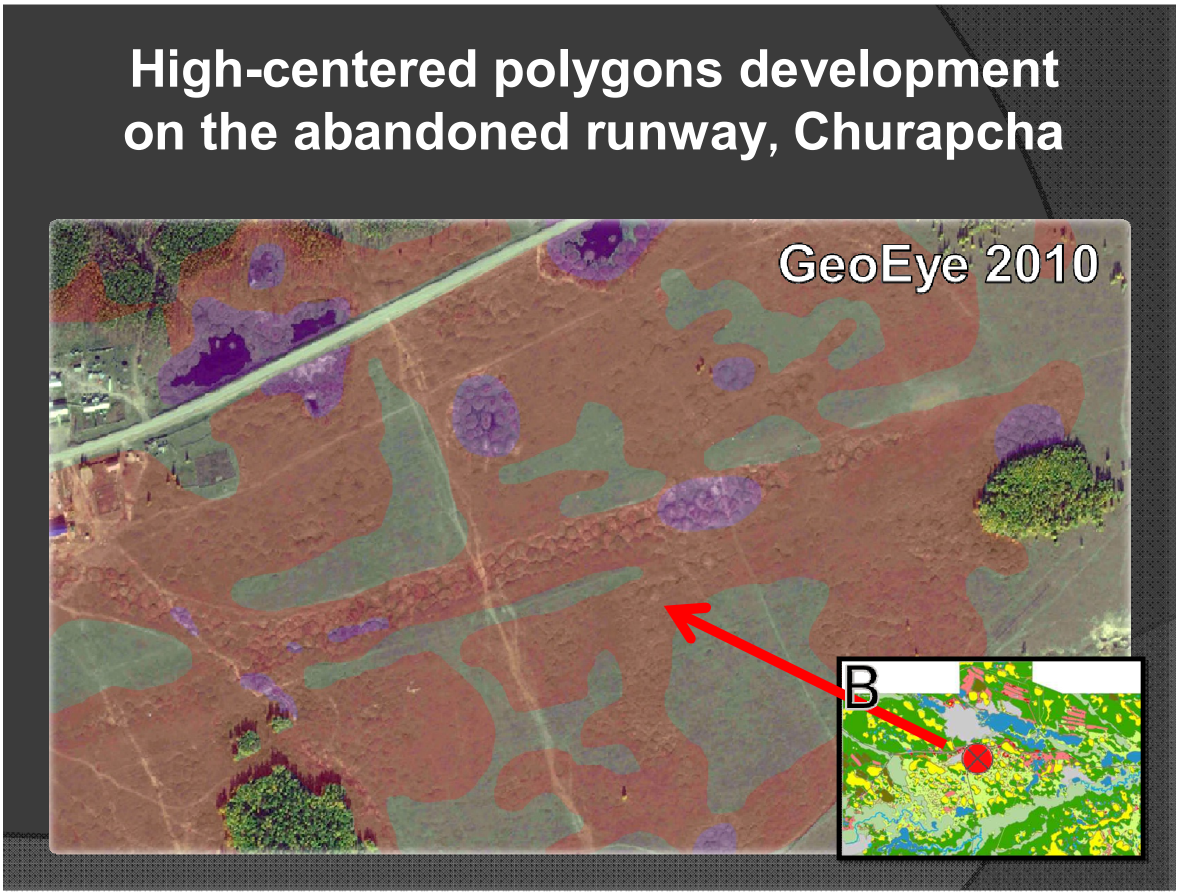

High-centered polygons development
on the abandoned runway, Churapcha
GeoEye 2010
B

Fig. 24.

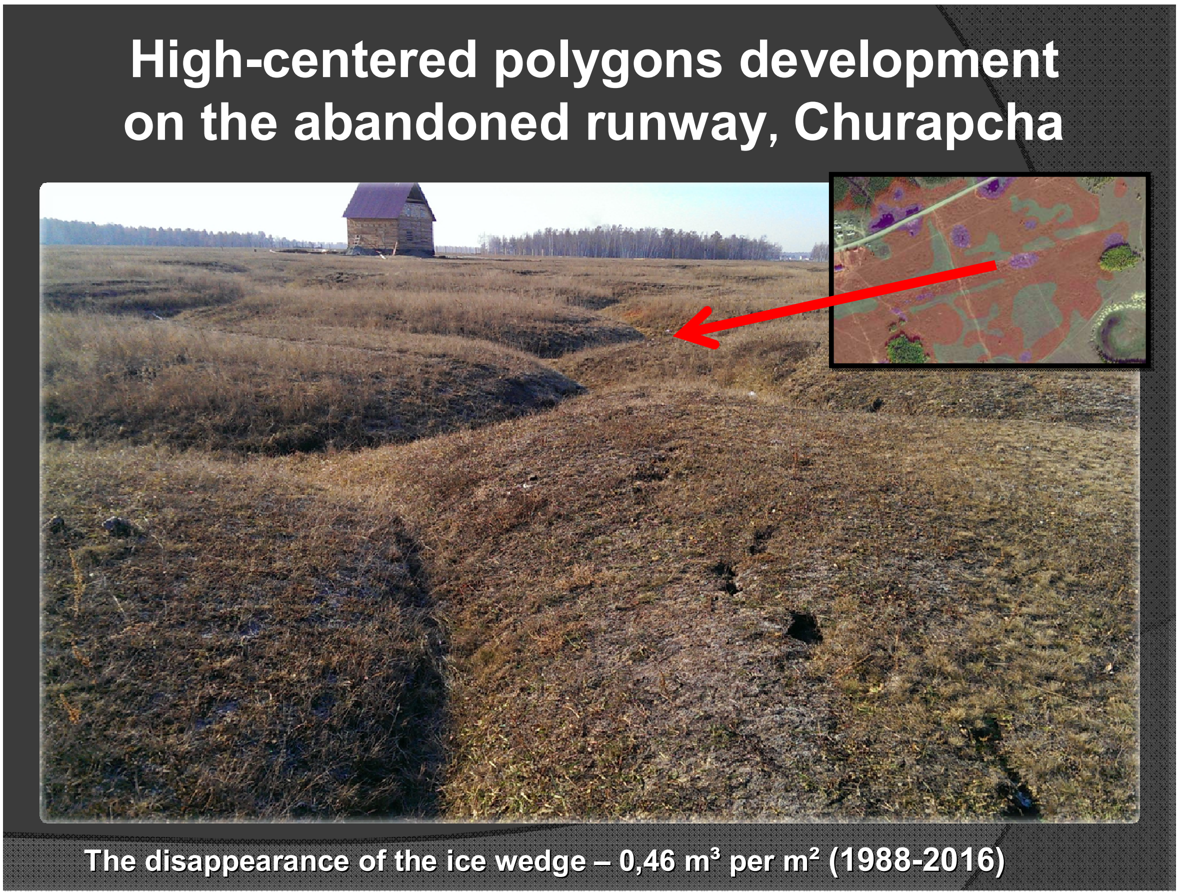

High-centered polygons development
on the abandoned runway, Churapcha
The disappearance of the ice wedge – 0,46 m³ per m² (1988-2016)

Fig. 25.

Fig. 26. Underground ice near Churapcha

Fig. 27. Underground ice near Tyungyulyu

Churapcha. Calcic Solonetz (Siltic, Turbic) - WRB. Dark cryoturbated solonetz - RSC.

Soil pit **P-01.12** (17.07.2012)

Location\height: N 61°59.136` E 132°29.807`, 201 m a.s.l. **Relief:** Watershed **Mesorelief:** the top of "byllar" (4-5 m in diameter) **Vegetation:** steppe wild grasses (sage, tufted vetch, dandelion) **Microrelief:** old creeping cracks up to 10 cm wide.			
A	AU	0-6(7)	Steppe mat (0,5 cm) on the surface. Brownish-grey, with dark brown patches, heterogeneous, slightly moist, medium-textured loam, mineral part is very compacted, big aggregates on roots, roots are abundant, slight reaction to HCl, transition is well-expressed, boundary is wavy.
E/Btn@	EL/BSN@	6(7)-14(27)	Organic patches and tongues over the brownish-grey mineral ground, heterogeneous, slightly moist, heavy-textured loam, cloddy-grain structure, compacted, heavy reaction to HCl, medium abundance of roots, transition is gradual, boundary is undulating.
Bk	BCA	14(27) – 70(74)	Light-brownish-grey, homogeneous, moist, medium-textured loam, cloddy-grain structure, compacted, heavy reaction to HCl, low abundance of roots, transition is gradual, boundary is wavy.
BCk	BCca	70(74)-113 (117)	Light-brownish-grey, homogeneous, moist, heavy-textured loam, nutty-blocky structure, compacted, single small organic patches (1-2 mm), heavy reaction to HCl, very low abundance of roots, transition is gradual, boundary is unevenly wavy.
Ck	Cca	113(117)-161⊥	Brownish-grey, homogeneous, moist, medium- to heavy-textured loam, blocky structure, medium-compacted, slight reaction to HCl, underlied by permafrost.

Physico-chemical properties:

Horizon	Depth, cm	pH_{H2O}	TOC %	$CaCO_3$, %	Exchangeable cations, mmol/100 g				
					Ca	Mg	K	Na	Σ
AU	2-6	9,5	3,2	11,0	2,5	4,0	0,6	16,8	23,9
EL/BSN@	6-14	9,7	1,6	15,6	1,7	6,1	0,3	10,2	18,3
BCA	14-70	9,7	0,7	12,5	2,4	6,2	0,4	8,0	17,0
BCca	70-113	9,6	1,1	10,6	2,5	6,4	0,4	9,4	18,7
Cca	113-161	9,5	1,4	13,1	2,1	7,5	0,3	7,6	17,5

Water extract:

Horizon	Depth, cm	Σ salts, %	CO_3^{2-}	HCO_3^-	Cl^-	SO_4^{2-}	Ca^{2+}	Mg^{2+}	Na^+	K^+
AU	2-6	0,361	-	0,018 0,30	0,049 1,40	0,178 3,70	0,017 0,85	0,008 0,70	0,086 3,72	0,005 0,13
EL/BSN@	6-14	0,302	0,006 0,20	0,195 3,20	0,023 0,65	0,002 0,05	0,013 0,65	0,007 0,60	0,060 2,59	0,002 0,06
BCA	14-70	0,203	0,003 0,10	0,125 2,05	0,007 0,20	0,016 0,33	0,009 0,45	0,004 0,35	0,040 1,72	0,002 0,06
BCca	70-113	0,226	0,003 0,10	0,131 2,15	0,007 0,20	0,027 0,57	0,008 0,40	0,007 0,55	0,043 1,89	0,003 0,08
Cca	113-161	0,234	0,012 0,40	0,159 2,60	0,004 0,10	0,011 0,23	0,008 0,40	0,007 0,60	0,043 1,87	0,002 0,06

Particle-size distribution:

Horizon	Depth, cm	Hygroscopic moisture, %	Soil density	Particles (%) with diameter, mm						Σ<0,01 mm
				1-0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	
AU	2-6	2,06	2,54	1,6	12,2	42,0	6,6	14,7	22,9	44,2
EL/BSN@	6-14	2,20	2,64	0,5	8,0	42,8	8,2	16,3	24,2	48,7
BCA	14-70	2,21	2,62	0,3	13,1	44,1	4,9	12,6	25,0	42,5
BCca	70-113	2,13	2,60	0,3	15,9	36,8	9,4	13,4	24,2	47,0
Cca	113-161	2,07	2,55	1,1	11,5	39,6	8,5	16,4	22,9	47,8

Churapcha.Protocalcic Solonetz (Albic, Siltic) – WRB.Typical light solonetz - RSC.

Soil pit **P-02.12 Ч** (17.07.2012)

Location/height:N 61°59.136` E 132°29.807`
Relief: Watershed
Mesorelief: the N slope of "byllar" (4-5 m in diameter)
Vegetation: steppe wild grasses, abundantsilverweed cinquefoil, poa, couch grass.

A	Ad	0-2(3)	Dark-brown, homogeneous, loamy, compacted, aggregates on roots, no reaction to HCl, transition is clear, boundary is uneven wavy.
A	AJ	2(3)-9(20)	Light-brownish-grey, with big pale patches in the lower part, geterogeneous, dry, cloddy-silty structure, sometimes platy-blocky, very compacted, crack (2-3 cm) with organic material in the central part, no reaction to HCl, average richness in roots, transition is very clear, boundary is tongue-like.
E	EL	9(20) – 20(28)	Whitish bleached, with dark-brown patch (15%), heterogeneous, sometimes fragmentary, dry but cold, loamy, nutty-silty structure, no reaction to HCl, poor with roots, transition is sharp, boundary is tongue-like.
Btnk	BSN	20(28)-34 (40)	Brown with dark and light patches, heterogeneous, fresh, medium-textured loam, clotty-pore structure, compacted, well-expressed reaction to HCl, poor with roots, transition is clear, boundary is tonguing, sometimes wavy.
Bk	BCA	34 (40)-47(56)	Light-greyish-brown, homogeneous, slightly moist, medium-textured loam, compacted, single small black patches of organic material, heavy reaction to HCl, very poor with roots, transition is gradual, boundary is undulating.
BCk	BCca	47(56)-110(115)	Light-brownish-grey, homogeneous, slightly moist, heavy-textured loam, clotty-pore structure, compacted, well-expressed reaction to HCl, transition is gradual, boundary is undulating sometimes wavy.
Ck	Cca	110(115)-171⊥	Brownish-grey, homogeneous, moist, middle-textured loam, sometimes heavy-textured, blocky structure, poor reaction to HCl, underlied by permafrost.

Physico-chemical properties:

Horizon	Depth, cm	pH_{H2O}	TOC %	$CaCO_3$, %	Exchangeable cations, mmol/100 g				
					Ca	Mg	K	Na	Σ
AJ	2-9	9,1	2,4	7,5	2,7	6,2	0,2	8,1	17,3
EL	9-20	8,7	2,0	6,05	4,0	2,7	0,2	4,2	11,1
BSN	20-34	9,5	2,2	5,1	2,9	8,9	0,3	13,9	26,0
BCA	34-47	9,6	0,8	10,6	2,9	8,6	0,3	7,8	19,6
BCca	47-110	9,6	0,7	8,9	2,7	7,2	0,3	7,1	17,3
Cca	110-171	9,1	0,8	7,3	4,1	8,1	0,3	4,3	16,9

Particle-size distribution:

Horizon	Depth, cm	Hygroscopic moisture, %	Soil density	Particles (%) with diameter, mm						Σ<0,01 mm
				1-0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	
AJ	2-9	1,77	2,59	1,5	10,3	45,3	10,2	12,2	20,5	42,9
EL	9-20	0,87	2,61	0,5	19,8	50,6	9,8	11,9	7,4	29,1
BSN	20-34	3,27	2,57	0,2	11,6	35,1	11,8	10,2	31,1	53,1
BCA	34-47	1,93	2,63	0,3	9,4	42,1	6,5	11,8	29,9	48,2
BCca	47-110	1,71	2,63	0,2	10,3	47,4	5,7	12,6	23,8	42,1
Cca	110-171	2,02	2,65	0,2	11,1	44,1	6,6	14,3	23,7	44,6

Water extract:

Horizon	Depth, cm	Σ salts, %	CO_3^{2-}	HCO_3^-	Cl^-	SO_4^{2-}	Ca^{2+}	Mg^{2+}	Na^+	K^+
AJ	2-9	0,236		0,140 2,30	0,005 0,15	0,025 0,52	0,011 0,55	0,003 0,25	0,047 2,04	0,005 0,13
EL	9-20	0,097	0,003 0,10	0,040 0,65	0,004 0,10	0,026 0,55	0,006 0,30	0,002 0,20	0,017 0,76	0,002 0,04
BSN	20-34	0,353		0,098 1,60	0,005 0,15	0,146 3,04	0,017 0,85	0,007 0,60	0,073 3,17	0,007 0,17
BCA	34-47	0,220	0,003 0,10	0,156 2,55	0,004 0,10	0,004 0,09	0,011 0,55	0,007 0,57	0,037 1,59	0,001 0,03
BCca	47-110	0,253	0,006 0,20	0,159 2,60	0,004 0,10	0,024 0,51	0,014 0,70	0,007 0,60	0,043 1,85	0,002 0,06
Cca	110-171	0,151	-	0,079 1,30	0,004 0,10	0,030 0,62	0,007 0,35	0,008 0,70	0,021 0,93	0,002 0,04

Churapcha.Protocalcic Solonetz (Albic, Siltic) – WRB.Typical light solonetz - RSC.

Soil pit **P-03.12 Ч**(17.07.2012)

Location/height:N 61°59.136` E 132°29.807` **Relief:** Watershed **Mesorelief:** the “inter-byllar” depression **Vegetation:** steppe wild grasses, abundantsilverweed cinquefoil (~70%)			
A	Ad	0-2	Brown, soddy, with thin layer of steppe mat on the surface, loamy, compacted, aggregates on abundant roots, transition is sharp, boundary is flat.
A/E	A/EL	2-8(18)	Light-pale with dark-brown patches (15%) associated with cracks, heterogeneous, sometimes fragmentary, dry but cold, middle-textured loam, nutty-silty structure, no reaction to HCl, transition is sharp, boundary is tongue-like.
E	EL	8(18)-23(30)	Light-grey, with abundant patches of organic and bleached material, heterogeneous, dry, nutty-grainy structure, very compacted, small grains of quartz, no reaction to HCl, transition is clear, boundary is tongue-like.
Btn	BSN	23(30)-52(60)	Greyish-brown, with dark-brown patches of organic material (2-3 cm) associated with cracks up to 2 cm width, heterogeneous, slightly

			moist, middle-textured loam, grainy structure, compacted, no reaction to HCl, transition is clear, boundary is tongue-like.
Bk	BCA	52(60)-78(81)	Light-greyish-brown, heterogeneous, moist, heavy-textured loam, platy-caviar-like structure, compacted, heavy reaction to HCl, single roots, transition is gradual, boundary is wavy.
BCk	BCca	78(81)-110(113)	Light-greyish brown, homogeneous, heavy-textured loam, platy-caviar-like structure, less compacted, very heavy reaction to HCl, single roots, transition is gradual, boundary is wavy.
Ck	Cca	110(113)-156┴	Brownish-grey, homogeneous, moist, middle-textured loam, blocky structure, less compacted, poor reaction to HCl, underlied by permafrost.

Physico-chemical properties:

Horizon	Depth, cm	pH_{H2O}	TOC %	$CaCO_3$, %	Exchangeable cations, mmol/100 g				
					Ca	Mg	K	Na	Σ
A/EL	2-8	6,2	4,8	6,7	5,1	3,5	0,3	3,6	2,6
EL	8-23	7,3	2,6	6,0	6,1	7,3	0,3	3,8	17,5
BSN	23-52	8,6	1,3	7,5	6,6	16,1	0,3	4,7	27,7
BCA	52-78	8,9	0,8	11,3	5,1	9,4	0,2	3,6	18,4
BCca	78-110	8,9	0,9	11,9	4,1	8,3	0,2	2,9	15,6
Cca	110-156	8,9	0,9	12,1	4,1	7,8	0,2	3,5	15,6

Water extract:

Horizon	Depth, cm	Σ salts, %	CO_3^{2-}	HCO_3^-	Cl^-	SO_4^{2-}	Ca^{2+}	Mg^{2+}	Na^+	K^+
A/EL	2-8	0,083	-	0,018 0,30	0,005 0,15	0,036 0,75	0,005 0,25	0,005 0,40	0,012 0,50	0,002 0,05
EL	8-23	0,074	-	0,024 0,40	0,004 0,10	0,025 0,52	0,006 0,30	0,003 0,25	0,010 0,43	0,002 0,04
BSN	23-52	0,146	0,003 0,10	0,082 1,35	0,004 0,10	0,022 0,45	0,008 0,40	0,007 0,55	0,021 0,91	0,002 0,04
BCA	52-78	0,144	0,006 0,20	0,049 0,80	0,002 0,05	0,054 1,12	0,010 0,50	0,007 0,60	0,018 0,78	0,004 0,09
BCca	78-110	0,190	-	0,079 1,30	0,002 0,05	0,059 1,23	0,012 0,60	0,010 0,80	0,026 1,13	0,002 0,05
Cca	110-156	0,181	-	0,085 1,40	0,002 0,05	0,050 1,04	0,009 0,45	0,013 1,10	0,020 0,89	0,002 0,05

Particle-size distribution:

Horizon	Depth, cm	Hygroscopic moisture, %	Soil density	Particles (%) with diameter, mm						Σ<0,01 mm
				1-0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	
A/EL	2-8	2,11	2,50	1,4	15,3	46,9	10,2	11,4	14,8	36,4
EL	8-23	2,16	2,56	0,7	10,2	45,8	10,6	13,8	18,9	43,3
BSN	23-52	2,46	2,48	0,3	8,6	35,5	8,6	9,8	37,2	55,6
BCA	52-78	2,31	2,60	0,2	8,7	40,8	11,4	12,3	26,6	50,3
BCca	78-110	2,02	2,60	0,2	9,9	41,2	8,6	15,9	24,2	48,7
Cca	110-156	1,80	2,56	0,4	9,7	44,1	8,6	12,6	24,6	45,8

Churapcha.Tillage.Sodic Cambisol (Siltic Protocalcic) – WRB.Pale postagrogenic soil - RSC.

Soil pit **P-08.12 Ч** (19.07.2012)

Location/height: N 61,98006° E 132,50037°
100 meters from forest, on the old tillage.
Relief: watershed
Microrelief: flat
Vegetation cover: steppe wild grasses (mostly sage).

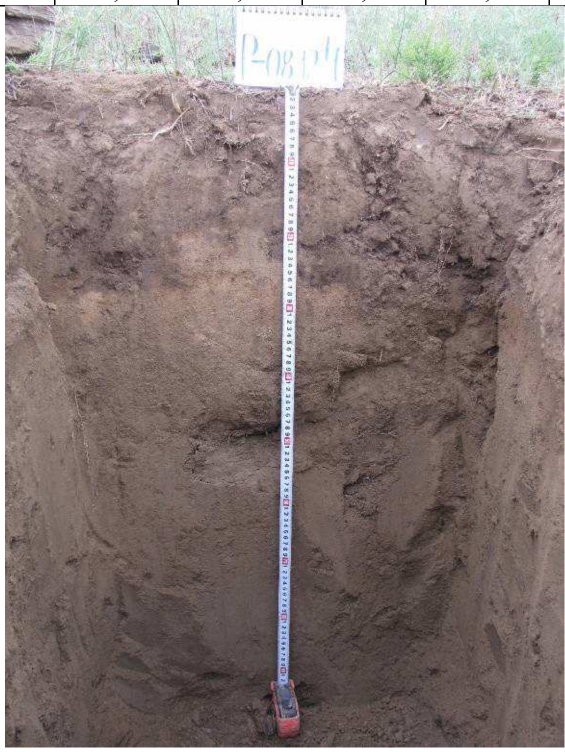
Ap	P	0-20(26)	Greyish-dark-brown, the uppermost part is darker than the lower one, heterogeneous, dry, light-textured loam, clotty-grainy structure, compacted (the lower part is very compacted), a lot of cracks and streaks, poor reaction to HCl, medium abundance of roots, the transition is sharp, boundary is very irregular. Ploughinghorizon.
Bk	BCA	20(26)-44(47)	Light-greyish-brown with yellowish tones, with ferruginous patches in the upper part, heterogeneous, slightly moist, medium-textured loam, nutty-clotty structure, compacted, heavy reaction to HCl, poor with roots, transition is well-expresses, the boundary is wavy.
BCk	BC(C)ca	44(47)-99	Brownish-grey, homogeneous, moist, heavy-textured loam, unstable nutty-silty structure (sometimes blocky), compacted, poor with roots, well-expressed reaction to HCl.

Water extract:

Horizon	Depth, cm	Σ salts, %	CO_3^{2-}	HCO_3^-	Cl^-	SO_4^{2-}	Ca^{2+}	Mg^{2+}	Na^+	K^+
P	0-20	0,466	-	0,061 1,00	0,075 2,15	0,186 3,87	0,032 1,60	0,015 1,25	0,095 4,13	0,002 0,04
BCA	20-44	0,382	-	0,061 1,00	0,082 2,35	0,121 2,53	0,017 0,85	0,016 1,35	0,084 3,65	0,001 0,03
BC(C)ca	44-99	0,231	-	0,067 1,10	0,026 0,75	0,072 1,49	0,011 0,55	0,010 0,85	0,044 1,91	0,001 0,03

Physico-chemical properties:

Horizon	Depth, cm	pH_{H2O}	TOC %	$CaCO_3$, %	Exchangeable cations, mmol/100 g				
					Ca	Mg	K	Na	Σ
P	0-20	8,4	2,9	6,9	6,2	7,3	0,3	8,7	22,6
BCA	20-44	8,9	1,2	11,9	4,3	9,1	0,2	6,4	20,1
BC(C)ca	44-99	8,9	0,8	9,6	3,2	9,1	0,2	5,4	17,9

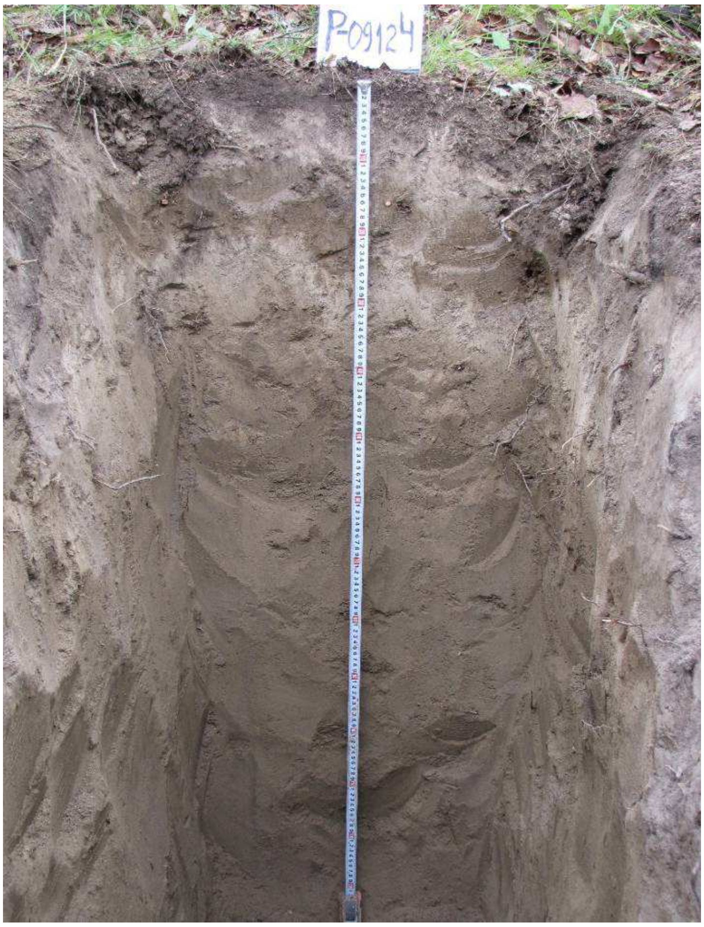


Particle-size distribution:

Horizon	Depth, cm	Hygroscopic moisture, %	Soil density	Particles (%) with diameter, mm						Σ<0,01 mm
				1-0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	
P	0-20	0,93	2,59	0,6	12,0	43,2	8,6	15,9	19,7	44,2
BCA	20-44	2,73	2,58	0,2	12,8	37,5	10,2	13,1	26,2	49,5
BC(C)ca	44-99	2,08	2,62	0,1	13,7	40,4	11,0	11,9	22,9	45,8

Churapcha.Birch forest.Turbic Calcic Cryosol (Siltic, Sodic) – WRB.Pale bleached cryoturbated soil.
Soil pit **P-09.12 Ч** (19.07.2012)

Location/height:N 61,98454° E 132,49757° **Relief:** watershed **Microrelief:** relatively flat, with small elevations around tree roots **Vegetation:** birch, larch, briar, lingberry, wild strawberry, sage, sedge.			
O	O	0-1(1,5)	Forest litter (birch leaves and larch needles), abundant roots, poorly connected with lower horizon, no reaction to HCl.
AO	AO	1(1,5) - 3(7)	Dark-brown, homogeneous, slightly moist, light-textured loam, poorly compacted, abundant poorly decomposed organic material, aggregates on roots, fragments of peat, no reaction to HCl, abundant roots, transition is sharp, boundary is wavy.
E/Bw/Bk @	[El-BPL-BCA]@	3(7)-13(16)	Beige with brownish and grey-brownish patches (15%), bleached, heterogeneous, dry, loamy, nutty-silty structure (sometimes platy), very compacted, with poorly decomposed organic material and plant roots (d up to 1 mm), single well-decomposed organic patches (d up to 0,8 mm), no reaction to HCl, transition is sharp, boundary is irregular.
E/Bw/Bk @	[El-BPL-BCA]@	13(16)-22(30)	Greyish-brown with yellowish-ferruginous tones and with bleached and brown patches, heterogeneous, fresh, loamy, clotty-grainy structure, very compacted, with small black organic patches (2%) and inclusions of charcoal, no reaction to HCl, average abundance of roots, transition is sharp, boundary is tongue-like (one of the “old” cracks has a tongue of 30 cm depth).
E/Bw/Bk @	[El-BPL-BCA]@	22(30)-36(45)	Very light-greyish-brown with bleached tones, homogeneous, cold, middle-textured loam, clotty-grainy structure, very compacted, heavy reaction to HCl, average abundance of roots, ferruginous patches associated with roots, transition is clear, boundary is tongue-like.
BCca	BCca	36(45) – 83	Light-greyish-brown with yellowish tones, homogeneous, slightly moist, heavy-textured loam, nutty-grainy structure, compacted, poor with roots, small ferruginous patches, clear reaction to HCl, transition is gradual, boundary is slightly wavy.
Cca	Cca	83-138┴	Light-brownish-grey, homogeneous, moist, heavy-textured loam, grainy structure, compacted, poor reaction to HCl, no roots.


P-09124

Physico-chemical properties:

Horizon	Depth, cm	pH_{H2O}	TOC %	$CaCO_3$, %	Exchangeable cations, mmol/100 g				
					Ca	Mg	K	Na	Σ
AO	1-3	6,8	28,1*	6,0	6,5	8,3	1,1	12,3	28,3
[El-BPL-BCA]@	3-13	6,8	1,8	8,9	3,5	4,9	0,3	2,9	11,6
[El-BPL-BCA]@	13-22	8,0	1,9	8,9	10,5	10,7	0,4	6,4	28,1
[El-BPL-BCA]@	22-36	8,6	4,1	21,0	7,4	6,5	0,2	4,9	18,9
BCca	36-83	9,2	0,9	11,7	3,5	8,9	0,2	5,6	18,2
Cca	83-138	9,0	0,8	10,6	3,2	9,3	0,2	5,0	17,7

* - Loss on ignition, %.

Water extract:

Horizon	Depth, cm	Σ salts, %	CO_3^{2-}	HCO_3^-	Cl^-	SO_4^{2-}	Ca^{2+}	Mg^{2+}	Na^+	K^+
AO	1-3	0,438	-	0,104 1,70	0,002 0,05	0,203 4,22	0,026 1,30	0,013 1,05	0,074 3,22	0,016 0,40
[El-BPL-BCA]@	3-13	0,072	-	0,018 0,30	0,002 0,05	0,034 0,71	0,006 0,30	0,005 0,45	0,006 0,28	0,001 0,03
[El-BPL-BCA]@	13-22	0,158	-	0,079 1,30	0,002 0,05	0,039 0,81	0,017 0,85	0,010 0,85	0,010 0,43	0,001 0,03
[El-BPL-BCA]@	22-36	0,141	-	0,073 1,20	0,004 0,10	0,030 0,63	0,016 0,80	0,009 0,75	0,008 0,35	0,001 0,03
BCca	36-83	0,276	0,003 0,10	0,119 1,95	0,009 0,25	0,073 1,52	0,018 0,90	0,009 0,75	0,047 2,04	0,001 0,03
Cca	83-138	0,300	0,003 0,10	0,095 1,55	0,082 0,35	0,061 1,27	0,013 0,65	0,010 0,84	0,038 1,65	0,001 0,03

Particle-size distribution:

Horizon	Depth, cm	Hygroscopic moisture, %	Soil density	Particles (%) with diameter, mm						Σ<0,01 mm
				1-0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	
[El-BPL-BCA]@	3-13	1,30	2,61	1,2	14,2	50,6	8,0	14,1	11,9	34,0
[El-BPL-BCA]@	13-22	0,75	2,55	0,4	12,6	34,7	8,9	9,0	34,4	52,3
[El-BPL-BCA]@	22-36	2,19	2,59	0,5	7,6	42,0	7,4	18,3	24,2	49,9
BCca	36-83	1,61	2,65	0,2	14,4	38,4	10,2	12,6	24,2	47,0
Cca	83-138	1,78	2,61	0,2	14,4	40,4	9,8	11,0	24,2	45,0

Churapcha.Larch forest.Turbic Protocalcic Cambic Cryosol (Siltic, Sodic) – WRB. Pale bleached soil.

Soil pit **P-10.12 Ч** (19.07.2012)

Location/height:N 61,98271° E 132,50781°
Relief: watershed
Microrelief: relatively flat, with small elevations around tree roots, small cracks.
Vegetation: larch, birch, willow, bedstraw, tansy, sage, sedge.

O	O	0-3	Forest litter from larch needles.
AO	AO	3 -8(13)	Dark brown with grey and brown patches, heterogeneous, moist, abundant plant remnants of different decomposition state, inclusions of charcoal, very rich with roots (~50%), transition is sharp, boundary is pocket-like.
E/Bw	[EL-BPL]	8(13)-15(17)	Fragmentary, bleached with brown patches, heterogeneous, dry, light-textured loam, very compacted, silty structure, no reaction to HCl, little less roots than in the upper horizon, transition is clear, boundary is pocket-like.
E/Bw	[EL-BPL]	15(17)-18(27)	Greyish-brown, with ferruginous and organogenic patches, heterogeneous, slightly moist, nutty-grainy structure, compacted, average abundance of roots, transition is clear, boundary is pocket-like.
Bk	BCA	18(27)-33(37)	Light-greyish-brown with bleached tones, homogeneous, fresh, middle-textured loam, unstable grainy-nutty structure, compacted, heavy reaction to HCl, average abundance of roots, transition is clear, boundary is tongue-like.
BCk	BCca	33(37) – 62	Light-greyish-brown with yellowish tones, homogeneous, slightly moist, loamy, platy-grainy with relatively big unstable blocks, single patches of organogenic material, poor with roots, transition is clear, boundary is flat.
Ck	Cca	62-118⊥	Light-greyish-brown with yellowish tones, homogeneous, slightly moist, loamy, platy-blocky structure, compacted, clear reaction to HCl, no roots, underlied by permafrost.


Р-10.12 Ч


Р-10.12 Ч

Physico-chemicalproperties:

Horizon	Depth, cm	pH_{H2O}	TOC %	$CaCO_3$, %	Exchangeablecations, mmol/100 g				
					Ca	Mg	K	Na	Σ
AO	3-8	6,5	16,5*	2,7	6,6	5,9	0,6	8,9	22,0
[EL-BPL]	8-15	7,3	1,6	3,3	2,9	3,2	0,1	3,3	9,5
[EL-BPL]	15-18	7,8	2,5	8,3	10,4	6,1	0,5	7,3	24,3
BCA	18-33	9,0	1,3	12,5	4,8	7,0	0,2	4,2	16,2
BCca	33-62	9,5	0,7	9,2	3,5	7,8	0,4	5,7	17,5
Cca	62-118	9,5	0,7	7,1	3,3	7,7	0,5	6,8	18,3

* - Loss on ignition, %

Water extract:

Horizon	Depth, cm	Σ salts, %	CO_3^{2-}	HCO_3^-	Cl^-	SO_4^{2-}	Ca^{2+}	Mg^{2+}	Na^+	K^+
AO	3-8	0,214	-	0,055 0,90	0,002 0,05	0,098 2,04	0,018 0,90	0,010 0,85	0,026 1,11	0,005 0,13
[EL-BPL]	8-15	0,092	-	0,024 0,40	0,004 0,10	0,040 0,84	0,004 0,20	0,006 0,50	0,014 0,63	сл 0,01
[EL-BPL]	15-18	0,192	-	0,092 1,50	0,004 0,10	0,048 1,00	0,024 1,20	0,010 0,80	0,013 0,57	0,001 0,03
BCA	18-33	0,136	-	0,073 1,20	0,002 0,05	0,027 0,57	0,010 0,50	0,007 0,55	0,017 0,76	сл 0,01
BCca	33-62	0,182	0,003 0,10	0,101 1,65	0,002 0,05	0,031 0,64	0,009 0,45	0,007 0,55	0,030 1,30	0,002 0,04
Cca	62-118	0,256	-	0,122 2,00	0,004 0,10	0,059 1,22	0,021 1,05	0,004 0,30	0,043 1,89	0,003 0,08

Particle-size distribution:

Horizon	Depth, cm	Hygroscopic moisture, %	Soil density	Particles (%) with diameter, mm						Σ<0,01 mm
				1-0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	
AO	3-8	4,41	2,32	5,9	23,0	42,9	6,1	6,5	15,6	28,2
[EL-BPL]	8-15	1,12	2,62	1,1	9,8	55,5	10,7	12,6	10,3	33,6
[EL-BPL]	15-18	3,02	2,55	1,4	10,8	41,2	8,2	11,4	27,0	46,6
BCA	18-33	1,50	2,60	0,5	9,6	44,5	10,2	13,5	21,7	45,4
BCca	33-62	1,95	2,64	0,2	9,9	45,3	9,8	12,3	22,5	44,6
Cca	62-118	1,88	2,60	0,1	6,3	49,3	9,0	13,5	21,8	44,3

Churapcha."Dyuedya".Protocalcic Gleysol (Siltic, Humic, Sodic) – WRB. Soddy-gleyic soil on alas Soilpit**P-14.12 Ч**(20.07.2012)

Location/height:N 61,99356° E 132,50082° **Relief:** watershed **Mesorelief:** the "interbyllar" depression on the bottom of "dyuedya" (stage of thermocarst lake forming) **Microrelief:** a lot of cracks and hillslides. **Vegetation:** Wild grasses of bogs and meadows with domination of sedges and foxtail grass.			
Ak	Adca	0-23	Brown with ferruginous and organogenic patches, heterogeneous, moist, loamy, poachy, with gleyization from the top, clotty structure, slightly compacted, abundant roots and plant remnants of different stage of decomposition, transition is sharp, boundary is slightly wavy.
Gk	Gca	23-55(60)	Ferruginous and organogenic patches (20-25%) on the dark-grey background, especially in the upper part, blocky structure, compacted, average root abundance, transition is sharp, boundary is irregular.
BCgk	BCgca	55(60) -82	Ferruginous and gleyic patches (15%) on the brownish-grey background, heterogeneous, moist, loamy, poachy, structureless, compacted, poor with roots, transition is gradual, boundary is irregular.
Cgk	Cg-ca	97-139┴	Brownish-dark-grey, homogeneous, very moist, heavy-textured loam, poachy, structureless, heavy reaction to HCl, gleyization in form of single ferruginous patches, underlied by permafrost.

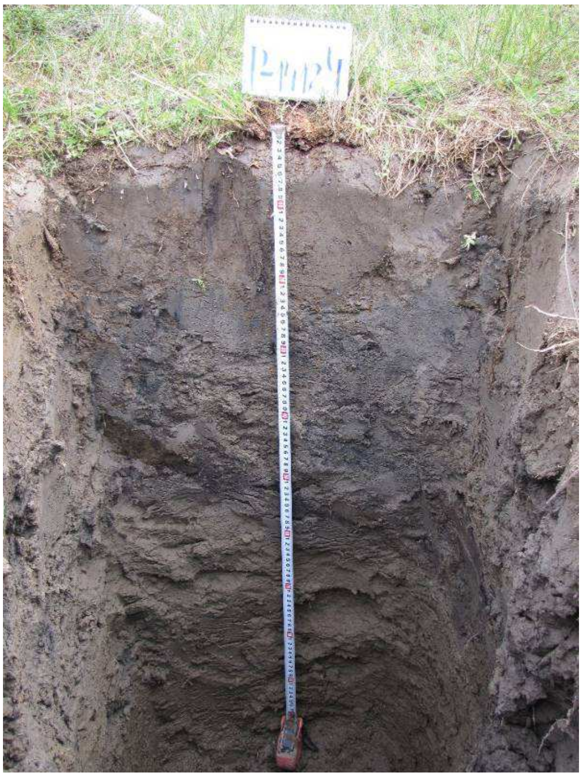
Physico-chemical properties:

Horizon	Depth, cm	pH_{H2O}	TOC %	$CaCO_3$, %	Exchangeable cations, mmol/100 g				
					Ca	Mg	K	Na	Σ
Ad	0-23	8,5	1,9	10,5	3,8	9,9	0,3	5,0	19,0
G	23-55	8,4	1,3	10,9	4,9	8,0	0,3	4,7	17,9
BCg	55-82	8,7	0,6	9,2	4,6	7,0	0,3	3,8	15,8
Cg-ca	82-107	8,5	0,8	8,9	6,7	7,0	0,3	4,7	18,7

* - Loss on ignition, %.

Water extract:

Horizon	Depth, cm	Σ salts, %	CO_3^{2-}	HCO_3^-	Cl^-	SO_4^{2-}	Ca^{2+}	Mg^{2+}	Na^+	K^+
Ad	0-23	0,362	-	0,110 1,80	0,011 0,30	0,145 3,03	0,021 1,05	0,021 1,75	0,053 2,30	0,001 0,03
G	23-55	0,252	-	0,073 1,20	0,004 0,10	0,109 2,27	0,020 1,00	0,013 1,10	0,033 1,46	сл 0,01
BCg	55-82	0,147	-	0,055 0,90	0,004 0,10	0,050 1,04	0,012 0,60	0,007 0,60	0,019 0,83	сл 0,01
Cg-ca	82-107	0,182	-	0,067 1,10	0,002 0,05	0,067 1,40	0,016 0,80	0,010 0,85	0,020 0,89	сл 0,01



Particle-size distribution:

Horizon	Depth, cm	Hygroscopic moisture, %	Soil density	Particles (%) with diameter, mm						Σ<0,01 mm
				1-0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	
Ad	0-23	1,47	2,58	0,4	15,8	47,4	4,9	13,9	17,6	36,4
G	23-55	1,12	2,62	0,4	14,2	49,0	6,5	13,5	16,4	36,4
BCg	55-82	1,33	2,65	0,1	15,7	44,9	6,2	13,0	20,1	39,3
Cg-ca	82-107	1,70	2,65	0,1	17,8	54,7	4,5	7,3	15,6	27,4

DAY 2

Desyatkin Alas. Cryic Sapric Histosol (Alcalic, Limnic, Magnesic, Sodic). Profile 9-1.

<table>
<tr><td colspan="5">Sites 9-1, 9-2, 9-3 $62^0$09’28,0” $130^0$35’24,7”
Vicinities of Tyungyulyu village, alas</td></tr>
<tr><td colspan="5">Site 9-1 2 meters from the lake edge. 100% projective cover of grasses, beadruby, knotgrass, rare mosses, sedges, reed along the shore.</td></tr>
<tr><td>L1</td><td>LDv</td><td>0-3</td><td>10 YR 3/2 brownish black; moist; soft consistence; many grass roots; boundary – clear distinctness, wavy topography.</td><td rowspan="3">WRB – Cryic Sapric Limnic Histosol (Sodic, Alcalic, Magnesic)

Soil Taxonomy Typic Sapristel

Russian Торфяная эутрофная мерзлотная Peaty eutrophic permafrost</td></tr>
<tr><td>L2</td><td>LD1</td><td>3-50</td><td>10 YR 3/2 brownish black; lacustrine peat with strong degree of decomposition; moist; large number of lake shells of 0.5 mm in diameter; effervescence when shells react with HCI; no effervescence of the general matrix; many roots in the upper part and few roots in the lower part; boundary - abrupt distinctness, smooth topography.</td></tr>
<tr><td>Lf</td><td>⊥LD2</td><td>50-80</td><td>10YR 3/1 brownish black; moist; becomes wet at the depth of 70 cm; sapropel – mixture of strongly decomposed organic matter and fine sand/aleurite fractions; in some places – plants residues with low degree of decomposition – stems and leaves of hydrophytes, fish bones; many lake shells but less number than in the upper horizon; slight effervescence of the matrix when reacted with HCL</td></tr>
<tr><td colspan="5">Temperature profile at site9-1</td></tr>
<tr><td></td><td>Depth,</td><td>t ^{0}C</td><td></td><td></td></tr>
<tr><td></td><td>0</td><td>10,7</td><td></td><td></td></tr>
<tr><td></td><td>10</td><td>6,6</td><td></td><td></td></tr>
<tr><td></td><td>20</td><td>6,6</td><td></td><td></td></tr>
<tr><td></td><td>30</td><td>5,7</td><td></td><td></td></tr>
<tr><td></td><td>40</td><td>4,2</td><td></td><td></td></tr>
<tr><td></td><td>50</td><td>2,9</td><td></td><td></td></tr>
<tr><td></td><td>60</td><td>1,5</td><td></td><td></td></tr>
<tr><td></td><td>70</td><td>0,6</td><td></td><td></td></tr>
<tr><td></td><td>80-85</td><td>-0,3</td><td></td><td></td></tr>
</table>

Particle-size distribution

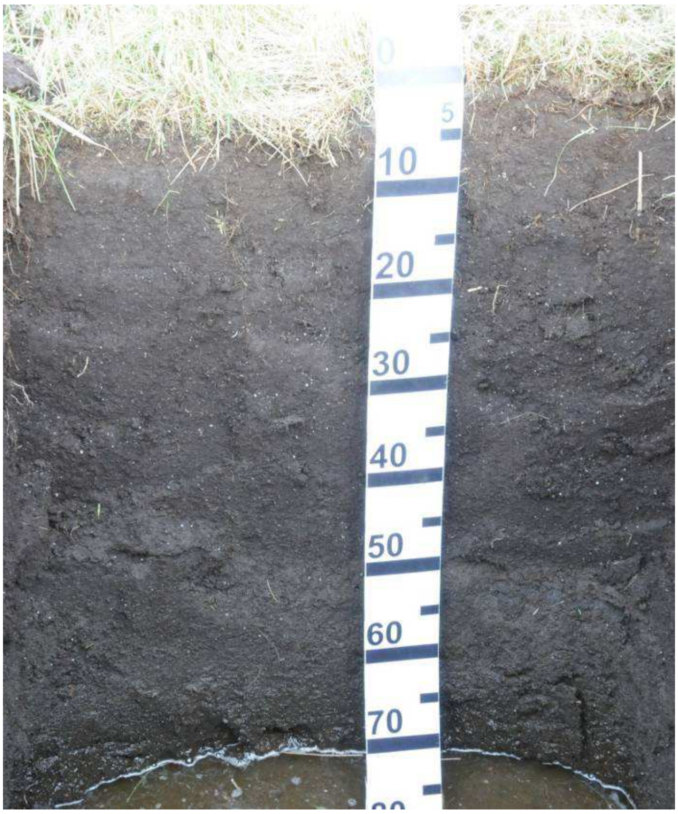
Horizon	Depth, cm	Bulk density	Sand >0,063	Silt 0,063-0,002	Clay <0,002
L1	0-3	-	-	-	-
L2	3-50	0,3	-	-	-
Lf	50-80	0,4	-	-	-

Analytical data

Horizon	Depth, cm	pH H2O	pH KCl	EC, dS/m	C wetcomb., %	C drycomb., %	Loss on ignition, %
L1	0-3	-	-	-	66,4*	35,7	-
L2	3-50	8,8	7,5	0,1	84,9*	68,3	86,2
Lf	50-80	9,3	8,0	0,1	61,0*	41,6	64,2

Cation exchange capacity and exchangeable bases

		NH4OAC						*AgTU*						*BaCl2*	
Hori-zon	**Depth, cm**	**Bases, cmol/kg**					**CEC cmol/kg**	**Bases, cmol/kg**					**ECEC, cmol/kg**	**CEC cmol/kg**	**$CaCO_3$**
		Ca^{2+}	**Mg^{2+}**	**K+**	**Na+**	**Sum**		**Ca^{2+}**	**Mg^{2+}**	**K+**	**Na+**	**Sum**			
L2	3-50	48,2	86,4	0,1	2,2	136,9	85,8	8,5	34,9	0,0	2,4	45,8	37,8	127,1	4,9
Lf	50-80	37,8	60,8	0,2	4,5	103,3	42,9	8,1	34,9	0,1	4,6	47,8	36,6	71,7	-



Pedogenesis and Soil Classification

This soil originates from lacustrine peat now exposed on the soil surface. The diagnostic feature of former formation in lake is a lot of shells in the peat horizon. The classification is both easy and difficult as Limnic features undoubtedly we have in this profiles are not anticipated for such cold soils. In WRB system this soil is Cryic Sapric Histosol (Alcalic, Limnic, Magnesic, Sodic) the last one is not on the list. In Soil Taxonomy it is correlated with Typic Sapristel, as there are no Limnic units in Histels. In Russian System it is Peaty eutrophic Peaty eutrophic permafrost soil because Limnic is absent in the system. Permafrost subtype for peaty soils is also forgotten in this system.

Desyatkin Alas. Histic Limnic Fluvisol. Profile 9-2.

<table>
<tr><td colspan="5">Site 9-2 35 m from lake water boundary, Dyodya stage100% projective coverage, less sedges, hayland</td></tr>
<tr><td>AH</td><td>AUca</td><td>0-10</td><td>10 YR 2/1 black; slightly hard; moist; mixture of mineral material and lacustrine organogenous sediments; granular-crumbly structure; sandy (clay) loam; carbonates and readily soluble salts in the lower part of horizon; many roots; especially in the upper 1-2 cm; effervescence when reacted with HCL; boundary - clear distinctness, smooth topography.</td><td rowspan="7">WRB
Sodic Gleyic Histic Limnic Fluvisol (Alcalic,Calcaric, , Magnesic, Turbic)

Soil Taxonomy
Thapto-Histic Endoaquoll
(no Gelaquolls in ST)

Russian
Иловато-Торфянаяэутрофная криотурбированная
Clayey-Peaty eutrophic cryoturbic</td></tr>
<tr><td>L</td><td>LD1ca</td><td>10-20(35)</td><td>10 YR 2/2 brownish black; moist; soft consistence; strongly decomposed lacustrine peat; few lacustrine shells; common roots; root channels with reddish yellow tubules; boundary - clear distinctness, wavy topography.</td></tr>
<tr><td>Lk@</td><td>LD1gcamr@</td><td>20(35)-50(52)</td><td>10 YR 3/1 brownish black; moist; soft consistence; lacustrine layer (sapropel?) significantly enriched with fine sand and silty material; numerous lacustrine shells; few roots; reddish yellow tubules along root channels; boundary - abrupt distinctness, smooth topography.</td></tr>
<tr><td>Lk</td><td>LD2camr</td><td>50(52)-62</td><td>2.5Y 2.5/1 black; lacustrine sapropel (?) layer; numerous lacustrine shells; few roots; boundary – abrupt distinctness, smooth</td></tr>
<tr><td>Cr</td><td>G1ca</td><td>62-90</td><td>5GY 4/1; dark olive gray; organic layer (1cm) in the upper part; moist; slightly hard; silt loam; fine platy structure</td></tr>
<tr><td>Crh</td><td>G2hca</td><td>90-120</td><td>5GY 2/1 differs from the upper horizon by more dark – olive black colour</td></tr>
<tr><td>Crf</td><td>Gca⊥</td><td>120-250</td><td>5GY 4/1 similar to G1ca horizon; but differs in higher hydrophytes and woody remnants content. Permafrost - 250 cm</td></tr>
</table>

Particle-size distribution

Horizon	Depth, cm	Bulk density	Sand >0,063	Silt 0,063-0,002	Clay <0,002
AH	0-10	0,8	43,5	47,8	8,7
L	10-20(35)	0,7	-	-	-
Lk@	20(35)-50(52)	1,0	-	-	-
Lk	50(52)-62	0,9	-	-	-
Cr	62-90	1,6	37,7	52,1	10,2
Crh	90-120	1,4	11,5	72,8	15,7
Crf	120-250	-	65,4	28,6	6,0

Analytical data

Horizon	Depth, cm	pH H2O	pH KCl	EC, dS/m	C wetcomb., %	C drycomb., %	Loss on ignition, %
AH	0-10	9,9	9,0	0,9	30,3*	14,2	28,4
L	10-20(35)	9,2	8,4	0,4	49,6*	39,6	37,3
Lk@	20(35)-50(52)	9,1	8,0	0,2	8,0	9,7	13,9
Lk	50(52)-62	9,0	7,9	0,1	7,3	7,6	15,6
Cr	62-90	9,2	8,3	0,1	0,8	1,2	6,2
Crh	90-120	9,1	8,2	0,1	1,6	2,4	8,9
Crf	120-250	9,2	8,3	0,2	0,5	1,6	-

Cation exchange capacity and exchangeable bases

		NH4OAC						*AgTU*						*BaCl2*	
Hori-zon	Depth, cm	Bases, cmol/kg					CEC cmol/kg	Bases, cmol/kg					ECEC, cmol/kg	CEC cmol/kg	$CaCO_3$
		Ca^{2+}	Mg^{2+}	K+	Na+	Sum		Ca^{2+}	Mg^{2+}	K+	Na+	Sum			
AH	0-10	13,1	77,4	0,2	9,9	100,6	31,3	0,5	39,0	0,0	11,0	50,6	37,1	49,2	6,5
L	10-20(35)	20,3	62,7	0,1	15,9	99,0	39,8	1,9	32,9	0,0	19,4	54,2	36,6	59,2	3,2
Lk@	20(35)-50(52)	23,7	17,3	0,2	1,1	42,3	11,7	9,8	14,2	0,1	1,2	25,3	20,3	20,8	3,8
Lk	50(52)-62	26,2	21,1	0,2	1,2	48,7	16,1	11,3	17,5	0,1	1,4	30,3	24,5	25,0	2,7
Cr	62-90	14,3	11,1	0,7	0,7	26,8	7,4	13,9	11,7	0,3	0,9	26,8	21,4	14,2	4,9
Crh	90-120	15,9	14,5	0,9	0,9	32,3	10,4	13,7	14,9	0,4	0,9	30,1	24,5	16,7	5,5
Crf	120-250	7,0	6,1	0,6	0,5	14,2	3,9	9,3	5,9	0,2	0,7	16,1	13,7	8,3	1,3

Pedogenesis and Soil Classification

This soil also originates from lake sediments but being in subaerial conditions for many years and having got some mineral fine earth from the slopes has a organic mineral horizon fitting criterium of Mollic horizon by Corg. content (not by depth), organic horizon beneath and reduction conditions in layered mineral horizon. In WRB this soil is Sodic Gleyic Histic Limnic Fluvisol (Alcalic,Calcaric, Magnesic, Turbic). In Soil Taxonomy it is Thapto-Histic Endoaquoll - no Gelaquolls in ST but criteria for epipedon are not as strict as for the WRB. In Russian system it is Clayey-Peaty eutrophic cryoturbic soil that is not adequately reflect the lacustrine origin.

Desyatkin Alas. Calcaric Albic Stagnosol.Profile 9-3.

<table>
<tr><td colspan="5">Site 9-3 20 m away from the site 9-2. Projective cover - 100%. Few mosses, flowering dandelions, less sedges. Three morphones in various parts of profile</td></tr>
<tr><td>A</td><td>AU-AJca</td><td>0-14</td><td>10 YR 4/1 brownish gray; slightly hard; sandy loam; weak fine subangular blocky structure; many roots; slight effervescence when reacted with HCL; boundary – clear distinctness, wavy topography.</td><td rowspan="7">WRB
Calcaric Albic Stagnosol(Alcalic, Endosiltic, Bathygleyic, Ruptic, Sodic, Turbic)

Soil Taxonomy
Turbic Gelaquept or Turbic Haplogelept

Russian
Элювоземглееватый криотурбированный
Eluvozem gleyishcryoturbic</td></tr>
<tr><td>E@</td><td>EL1gca@</td><td>14-25</td><td>10 YR 6/2 grayish yellow brown main matrix with olive gray and dull yellow hue 7.5Y 5/8, 2.5Y 6/3; moist; slightly hard; sand; not structured; common roots; fine orange mottles; boundary – abrupt and clear distinctness, wavy topography induced by cryoturbations.</td></tr>
<tr><td>[A]@</td><td>[AU-AJca]@</td><td>25-34</td><td>10YR 4/1 brownish gray; differs from surface analogue in the presence of orange-coloured mottles; boundary - abrupt distinctness, wavy topography.</td></tr>
<tr><td>E@</td><td>EL2gca@</td><td>32-36</td><td>2.5 Y4/3 olive, orange mottles, slightly hard; moist; sandy loam; weak platy-subangular blocky structure; few roots; boundary - abrupt distinctness, smooth topography.</td></tr>
<tr><td>Bwg@</td><td>BMgca@</td><td>14-32</td><td>10 YR 6/3, 5/3 dull yellow orange and dull yellowish brown, matrix with orange mottles; slightly hard; loamy sand; weak platy and weak subangular blocky structure; common roots; soil mesofauna channels; boundary - clear distinctness, wavy topography.</td></tr>
<tr><td>2BCg@</td><td>2BCg @</td><td>45-120</td><td>2.5Y 4/3 olive matrix with mottles of gray (10Y 5/1) colour; slightly hard; silty loam; platy/fine platy-crumbly structure; many orange tubules along root channels; lower part of horizon – orange grid on ped surfaces; boundary - clear distinctness, smooth topography.</td></tr>
<tr><td>3Cg</td><td>3Dg@</td><td>120-160</td><td>Silty loam layers of the same colour as the previous horizon alternating with sandy horizontal layers of orange-yellow colour and 1-4cm thickness; presumable permafrost level – 3m.</td></tr>
</table>

Particle-size distribution

Horizon	Depth, cm	Bulk density	Sand >0,063	Silt 0,063-0,002	Clay <0,002
A	0-14	1,2	74,3	22,6	3,1
E@	14-25	1,5	89,9	7,8	2,3
[A]@	25-34	1,5	77,5	12,9	9,6
E@	32-36		63,5	29	7,5
Bwg@	14-32	1,5	86,7	10,0	3,3
2BCg@	45-120	-	34,2	51,8	14,0
3Cg	120-160	-	29,7	57,2	13,1

Analytical data

Horizon	Depth, cm	pH H2O	pH KCl	EC, dS/m	C wetcomb., %	C drycomb., %	Loss on ignition, %
A	0-14	8,4	8,0	0,1	1,1	2,2	9,1
E@	14-25	9,6	8,4	0,1	0,3	0,7	3,4
[A]@	25-34	9,8	8,6	0,1	0,4	1,4	5,0
E@	32-36	9,8	8,6	0,2	0,2	1,2	5,4
Bwg@	14-32	9,7	8,5	0,1	0,2	0,7	-
2BCg@	45-120	9,2	8,0	0,2	0,3	1,0	-
3Cg	120-160	8,5	7,0	0,2	0,3	1,1	-

Cation exchange capacity and exchangeable bases

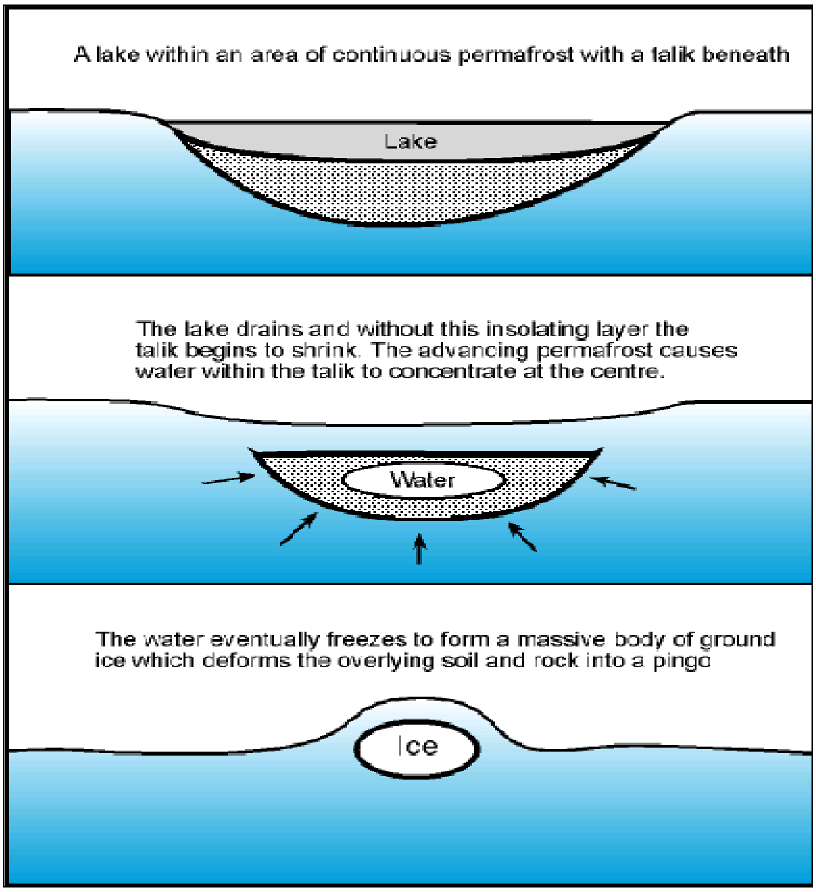
		NH4OAC						*AgTU*						*BaCl2*	
Hori-zon	Depth, cm	Bases, cmol/kg					CEC cmol/kg	Bases, cmol/kg					ECEC, cmol/kg	CEC cmol/kg	$CaCO_3$
		Ca^{2+}	Mg^{2+}	K+	Na+	Sum		Ca^{2+}	Mg^{2+}	K+	Na+	Sum			
A	0-14	23,5	15,0	0,8	0,1	39,4	8,1	13,4	11,2	0,2	0,1	24,9	20,6	18,3	4,2
E@	14-25	6,6	11,7	0,2	0,2	18,6	2,4	9,1	15,1	0,0	0,2	24,4	18,6	7,5	3,5
[A]@	25-34	9,8	17,7	0,2	0,7	28,4	3,4	11,4	20,6	0,0	0,2	32,2	24,4	6,7	6,5
E@	32-36	10,0	13,9	0,2	0,9	25,1	2,5	14,4	18,0	0,1	0,9	33,4	25,9	8,3	6,8
Bwg@	14-32	9,5	12,7	0,1	0,3	22,6	1,4	11,2	14,9	0,0	0,3	26,4	21,5	5,8	5,7
2BCg@	45-120	15,3	7,4	0,4	0,8	23,8	6,5	17,7	6,9	0,3	0,7	25,7	23,0	12,5	5,2
3Cg	120-160	14,5	8,8	0,3	1,0	24,7	6,5	17,4	5,9	0,2	0,7	24,2	20,9	11,7	4,8

Pedogenesis and Soil Classification

The genesis of the soil is related to former lacustrine sediments, but of the other – coarser formation than previous one soil. The most mysterious element of this soil is eluvial horizon with pH value >9!! Exchangeable sodium percentage is low. Pronounced stagnic features and deep redoximorphic properties allow classifying this soil as Calcaric Albic Stagnosol (Alcalic, Endosiltic, Bathygleyic, Ruptic, Sodic, Turbic) in WRB.

Soil Taxonomy possible correlation is Turbic Gelaquept or Turbic Haplogelept as one can differently access if it is enough manifestation of redoximorphic features to insert “aqui” in the name. Russian classification has no relevant soil unit (Stagnozem) for this soil. Ignoring pH, we can name this soil as Eluvozem gleyish cryoturbic.

Observation point.Khonorosh alas.Bulgunyakh (pingo).



Description

This point illustrates the common phenomenon of continuous permafrost – bulgunyakh (in Sakha language) or pingo (in Inuvialuktun– western Innuit language). The formation of such phenomenon is shown on the scheme. The shells on the bulgunyakh surface prove the former lacustrine origin of the surface layers. The estimated 11,000 pingos exist on the Earth. The highest one is Kadleroshilik pingo in Alaska has 54 m of height.

SOME GENERAL CHARACTERISTICS OF SOILS

Cryogenic microfeatures

The basic processes of cryogenic transformation of parent material are the soil-forming processes of pedoturbation - cryoturbation and cryogenic structure formation. These processes overlap and largely transform many diagnostic features of other soil-forming processes - solonetzic, humus-accumulative, redoximorfic iron migration.

Numerous studies of the microstructure of freezing soils on the silty parent material and/or in the course of the experiments resulted in distinguishing of major diagnostic mikrofeatures of cryoturbation and cryogenic structure formation (Van Viliet-Lanoe 1988, 2010; Gubin & Gulyaeva 1997; Rogov, 2009; Konishchev, Rogov, 1977; Ershov, 1988).

In the studied soils of Yakutia there were found different cryogenic microfeatures of structure formation, sorting of particles and cryoturbation (Table). The nature of freezing and thawing determines the resulting structural change, which depend on the degree of dispersion, mineralogical composition, density, moisture saturation of soil-forming material, as well as the conditions and regime of soil freezing and thawing.

Occurrence of microfeatures of cryogenesis in soils of Yakutia

Microfeature/ section	Hetero-geneity of micro-structure within a horizon	Lenticu-lar platy aggre-gates	Granular aggre-gates	Circular orientation of coarse mineral grains	Grano- and concentric-striated (ooid) b-fabrics	Silty infillings	Convoluted and fragmented clay coatings and plant residues	Fe nodu-les, stains, coa-tings
Profile 7 HyposalicSolonetz	+++*	++	+++	+	+++	+++	++	+++
Profile 11 Cambic Cryosol	+	-	+++	+++	++	+++	-	++

*Occurrenceofmicrofeatures: "+++" - high, "++" - medium; "+" - low, "-" the absence of

YAKUTSK-LENA PILLARS AUGUST 27, 2017

Lena pillars

Lena Pillars Nature Park is famous for its spectacular rock pillars that reach a height of approximately 100 m along the banks of the Lena River in the central part of Yakutia. This natural monument is composed primarily from Cambrian limestone formed more than 500 million years ago. Sediments are richly fossiliferous and have various marine genesis. Fanciful shape of rocks is a result of karst and erosion processes. The pillars are stretching along the shores of the Lena River both as the separate forms and as the cogged walls. The pillars often form rocky buttresses isolated from each other by deep and steep gullies developed by frost shattering directed along intervening joints. Penetration of water from the surface has facilitated cryogenic processes, which have widened gullies between pillars leading to their isolation. Fluvial processes are also critical to the pillars.

The drainage area of the Lena River equals 2490 km^2 and occupies the 8th place in the world. Starting from the Baikal Ridge branches, it is running to the Arctic Ocean, with a total length of 4,400 km. Tremendous masses of water transfer great amount of heat from the south to the north, where insufficient thermo-supply is the main limiting factor. In such a way the Lena not only forms unique mezzo-climatic conditions for plants and animals inhabiting its shores, but also provides a unique "ecological channel" for southern species of flora and fauna, entering far to the North. In the region of the Lena Pillars the river is 5-10 km wide. Just from the concerned point the Lena river bed changes its character. Sandbanks give place to numerous big and small towheads, and the left bank is isolated from a fairway by nearly continuous chain of islands. Due to plenty of islands, sandy rifts and shoals Lena has a very instable fairway in this section.

In the region of the Lena Pillars there is a very peculiar drainage network associated with the main tectonic fractures what determines rectangular structure of the modern river drainage to a large extent. Lena pillars could be considered as the specific form of the underground (deep) karst, dissected by the Lena River under episodic incisions into Lena plateau. Development of deep karst is associated with the work of intra and beneath permafrost waters.

The Lena Pillars area contains variety of Cambrian fossil remains of numerous species, some of them are unique. The representatives of the Siberian faunistic complex with the elements of South taiga and Arctic fauna make up the base of the rather rich contemporary fauna of the park. 21 species of rare and endangered plants grow in the park. In the basin of the middle stream of Lena River the fish fauna counts 31 species. Nesting of 101 bird species was determined on the territory of the park. Fauna as a whole here is typical for the middle taiga subzone of Palearctic with the distribution of such animals as sable, brown bear, squirrel, elk, chipmunk and others. Musk deer, northern pika, mountain-forest form of the reindeer refer to the inhabitants of the mountain-taiga complex. A number of species like Manchurian deer, field vole, some representatives of cheiroptera and insectivore are characteristic for southern taiga fauna and here is the northern limit of their distribution. The larch-pine or pine-subshrub forests in combination with steppe plots are common for southern slopes, larch forests with spruce are located on the northern ones.

Texts and photos updated from the official website of the Lena Pillars Nature Park: www.lenskiestolby.ru

CONCLUSION

The territory of Central Sakha (Yakutia) is exclusive as it has no analogs in the world because of extremely continentality of the climate, expressed in the highest amplitude in the world of the air and soil temperature within a year, in semihumid character of the climate and in the continuous permafrost development. This territory is also characterized by the high variety of the active layer depth (0.7->3 m) induced by local environmental conditions predetermined by topography and related to its natural vegetation and the landuse. All these factors, together with the large age of most surfaces result in the high diversity of soils of Central Sakha (Yakutia) and their specificity and exclusiveness have not been always adequately reflected in the recent systems of soil classification (both national and international ones).

The problems of existing soil classification systems as it is seen from the ultracontinental region are as follows.

1. Very large contrast of the classification of soils with the permafrost shallower and deeper than two meters. This difference may be induced by slight change of the vegetation cover and the landuse, but in the first case we do with Cryosols of the WRB and in the second one we have not any mention of the permafrost in the soil name. This situation is better in the Soil Taxonomy as it has Gelic order and Geli-suborders and great groups, however in most cases they are poorly elaborated yet, e.g. there is no Gelic suborder in the Alfisol order. Even for the recent Russian soil classification this problem is on the agenda, as permafrost subtype is only taking place in soils with icy permafrost in 1 m. It is in contrast with the local systematics of soils for ultracontinental regions (Sakha, Buryatia), as they have permafrost in a name of any soil with the permafrost, independently of its depth. We suggest to insert the term "supragelic" as a suffix qualifier for the WRB system and for the family level of the Soil Taxonomy for the soils if they have permafrost >2 m and any evidence of its results in the control section, e.g. cryoturbations, redoximorphic and/or salic features. We also recommend inserting the supra-permafrost or deeply-permafrost subtype to the Russian system.

2. The not enough number of units in the WRB and subgroups in Soil Taxonomy, as well as subtypes in the Russian system, indicating cryoturbations.

3. Not-elaborated (or not enough elaborated) Limnic properties for cold soils. There should be added fresh water mollusk shells as the indicators of limnic character. The term "limnic" should be insert in Histel suborder. The post-limnic trend of the pedogenesis should be reflected in the Russian system and relevant horizons should be inserted.

5. The problem of different methods and criteria for diagnostics of natric and salic horizons in permafrost- affected soils. All the methods show that sum of bases could be more than CEC. Criteria for salic horizons are very tough in Soil Taxonomy for cold soils as they can have halophytes at lower EC.

Besides classification items there are exist problems, which are in close concern with the classification ones - the problems of soil genesis and climate-induced change in Central Sakha (Yakutia). The genesis of the studied soils is related to both well-known soil-forming processes widely occuring beneath cold regions (solonetzic differentiation, related to sodium and magnesium effect on soil colloids, mollic horizons formation due to roots decomposition and biota activity, mineral weathering, etc.) and specific cryogenic processes, part of which is good readible morphologically on macro- and microlevels. However, not all of them are easily recognized. The periodical upward migration of salts to the freezing front can form the complicated combination of eluvial leaching and carbonates accumulation. The extremely dynamic character of soil moisture and salts content from season to season and from year to year can also result in the intrinsic genetical model of soil formation. Many measurements of important dynamic soil parameters, e.g. pH, should be done for different seasons and years in order to confirm these hypotheses. It also concerns the monitoring of climate change and their consequences for soils, because as we see from the example of site Churapcha, these consequences can be catastrophical.

Speaking about soil genesis of ultracontinental area, we may stress the widespread stagnic features formation in different substrate condition because of the impermeability of seasonally frozen horizons, as well as the crucial role of sodium and magnesium which cannot run away from pedogenic arena because of locking effect of the permafrost. The strong pedogenic effect of little change in environment is also characteristic for ultracontinental areas.

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