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DIVERSITY OF SOILS OF COLD ULTRA-CONTINENTAL CLIMATE

Guidebook-monograph for the “Mammoth” ultra-continental WRB field workshop. Sakha (Yakutia). August 17-23, 2013

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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 (2006), Soil Taxonomy (2010) and Russian classification system (2004, 2008).

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INTRODUCTION

The World Reference Base for Soil Resources (WRB) (IUSS Working Group WRB, 2006) was created as a common project of two international groups, working on improving the legend for the FAO-UNESCO World Soil Map, and an International Reference Base. The main objective of the WRB is to serve as a tool for the evaluation of global soil resources. Another important task is to help correlate numerous national classifications. It was not intended to replace national classifications, rather to permit working out a common language for the specialists, a kind of 'soil Esperanto'. Also it would help soil scientists communicate with specialists in close disciplines, who have been dissatisfied with the absence of a uniform simple soil classification. The last, but not the least function of the WRB is to serve as a legend for international soil maps. Though the precursor of the WRB, the legend for the World Soil Map (FAO-UNESCO, 1974), was made for a map of the scale 1:5,000,000, and reflected only the most general traits of soils; the latest versions were much more detailed. It permitted using it for medium-scale soil mapping in several countries, for example in Mexico, which used the FAO-UNESCO legend for soil resources inventory and then adopted the WRB as a basis for soil survey (Cruz-Gaistardo et al, 2006). A good example of successful use of the WRB for soil cartography is the recently published Soil Atlas of Europe (Jones et al, 2006). World Reference Base was adopted by the International Union of Soil Sciences as a basic system for classifying and correlating soils for international communication.

The history of the WRB started with the establishment of a group working on the legend of the Soil Map of the World in the 1960s. However, officially the work on an International Reference Base of Soil Resources started in 1980–81 after meetings in Sofia as a follow-up on the Soil Map of the World (IUSS Working Group WRB, 2006). In 1992 the International Reference Base was renamed as the World Reference Base, and it was decided that the World Soil Map legend should serve as a basis for the system whereas initially it have been developed independently. In 1994 the first draft of the WRB was presented (Spaargaren, 1994), and in 1998 the first official edition was published (FAO-ISRIC-ISSS, 1998). The second edition appeared in 2006 (IUSS Working Group WRB, 2006); since then minor corrections were made, but no official publications are available. Current progress in the development of the WRB can be monitored at the web sites and one can find more details on the history of the WRB in the texts of both editions (FAO-ISRIC-ISSS, 1998; IUSS Working Group WRB, 2006) and in a number of relevant publications (Nachtergaele et al, 2000; Deckers et al, 2005). The 3rd edition of the WRB is under preparation and is supposed to be published for the 20th World Congress of Soil Science (Jeju, Korea) in 2014.

The strength of the WRB as a world system is based on its continuous improvement with active participation of soil scientists from various countries. One of the most effective tools for the improvement of the WRB is the system of Field WRB Tours. Local scientists, who consider that their soils do not fit well in the classification, prepare a number of reference profiles that they consider difficult to classify in

the frames of the WRB, and invite the WRB Working Group members together with international and local experts, and discuss these profiles directly in the field. From the date of publication of the Draft version of WRB the Working Group encourages people to organize such tours, and the tours take place practically on an annual basis. The latest tours include field workshop in Norway (2010), in Wroclaw, Poland (2011) and Tasmania, Australia (2012). Also the WRB members use an opportunity to attend the tours linked to various scientific events not related directly with activities of the Working Group.
The idea to organize a WRB field tour to the extra-continental areas of Siberia appeared many years ago. The environments of Eastern Siberia, especially of the Sakha Republic, have no analogues in the other parts of the world. Consequently, the soils are also unique there, and the WRB only partly covers the diversity of soils found in the extra-continental areas of Russia, or just do not reflect the peculiarity of these soils. The region has a high variety of soils, some of which can be a nightmare for a soil geographer: steppe soils with deep dark A horizon over permafrost, saline and alkaline soils under coniferous forest, ubiquitous soils with pale-brown B horizon etc. These exotic soil profiles deserved special attention of soil classifiers, but only now the organizers managed to overcome all the issues related to the remoteness of the sites and the lack of infrastructure and finally invite the experts from all over the world for participating in this Ultra-Continental Mammoth WRB Tour. It was a result of a joint effort of the staff of the Institute of Biological Problems of the Cryolithozone (Yakutsk) and the Institute of Geography (Moscow) of the Russian Academy of Sciences (RAS), with an assistance and support of the Institutes of Biology of Komi and Karelian Research Centers of RAS, Melnikov Permafrost Institute (Yakutsk), Dokuchaev Soil Science Institute (Moscow) and Moscow State University. The tour would be impossible without a continuous support of the WRB Working Group, the Commission 1.4. “Soil Classification” and the 1st Division “Soils in Time and Space” of the IUSS. The Chair of the Division 1 Professor Karl Stahr receives a special gratitude for the financial support for conducting some complex chemical analysis.

We cordially welcome all the participants at this tour and hope that it will bring new concepts and ideas to the World Reference Base for Soil Resources.

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.

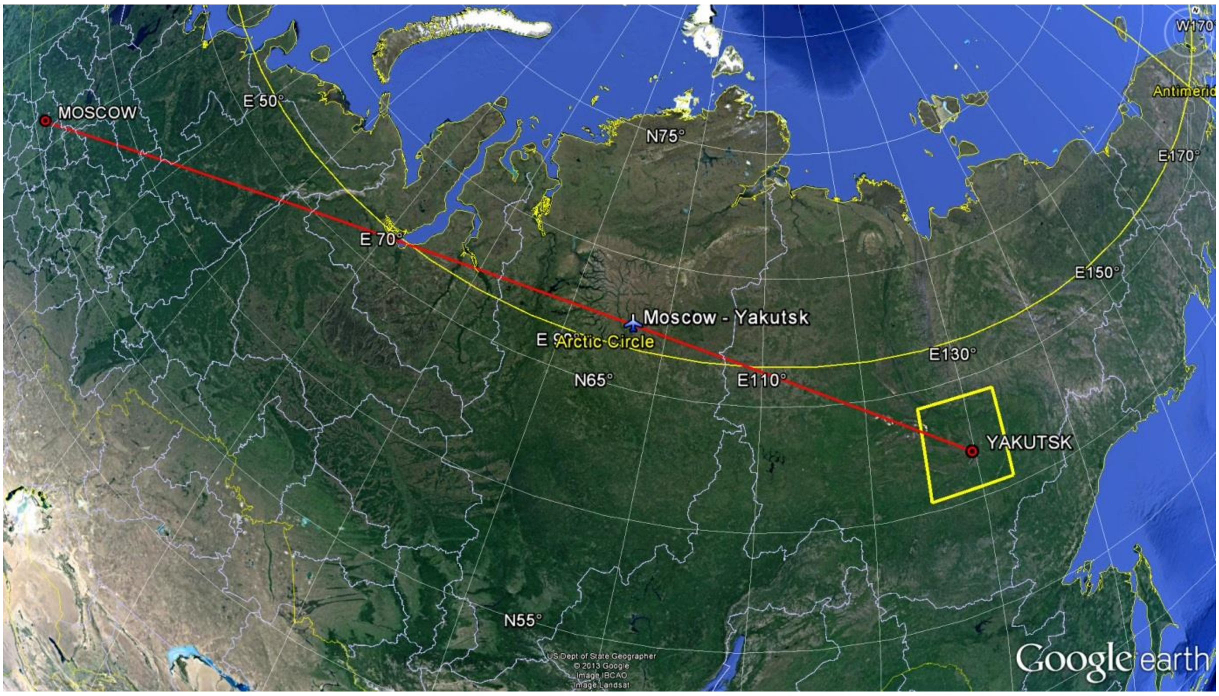


Fig. 1. Trip to Central Yakutia

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.

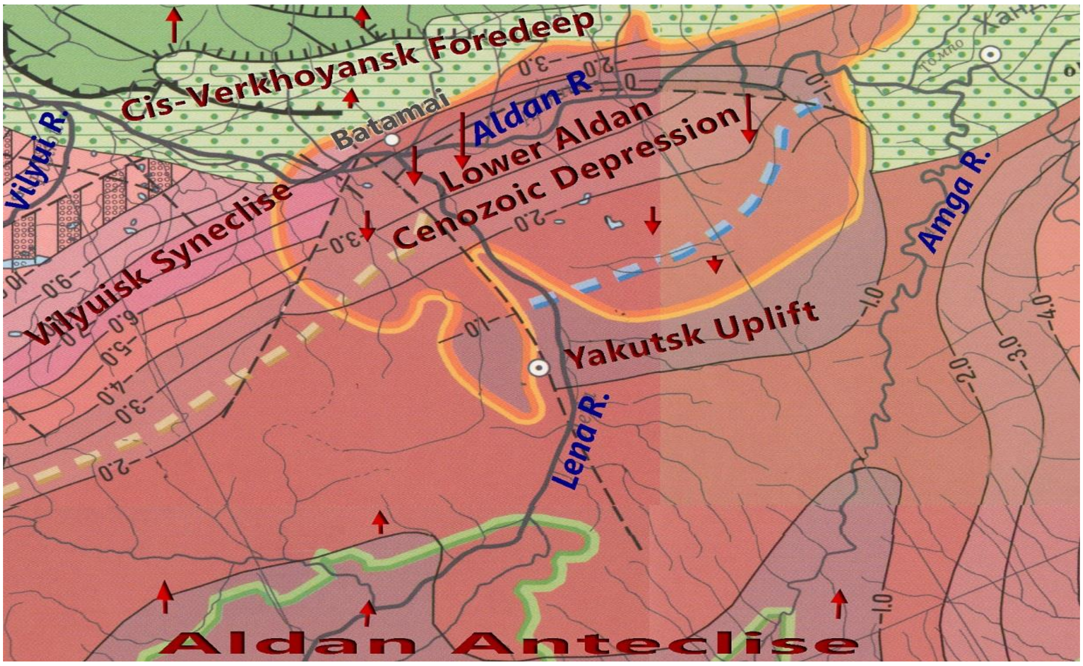


Fig. 2. Tectonic scheme of Central Yakutia (adapted from Milanovskii, 2006)

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.

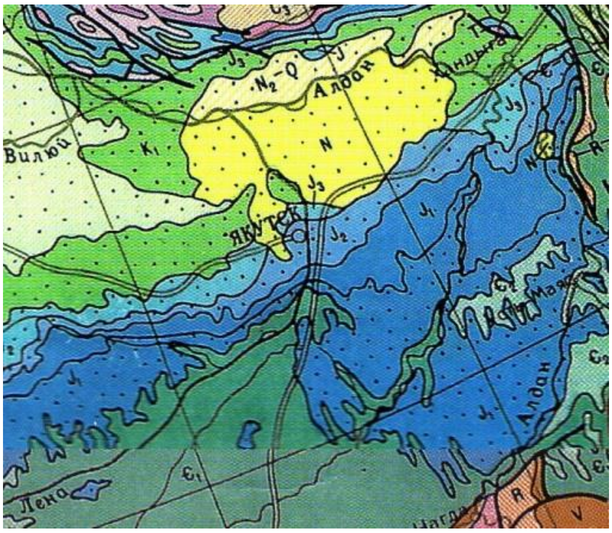


Fig. 3. Geological map of Central Yakutia.

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).

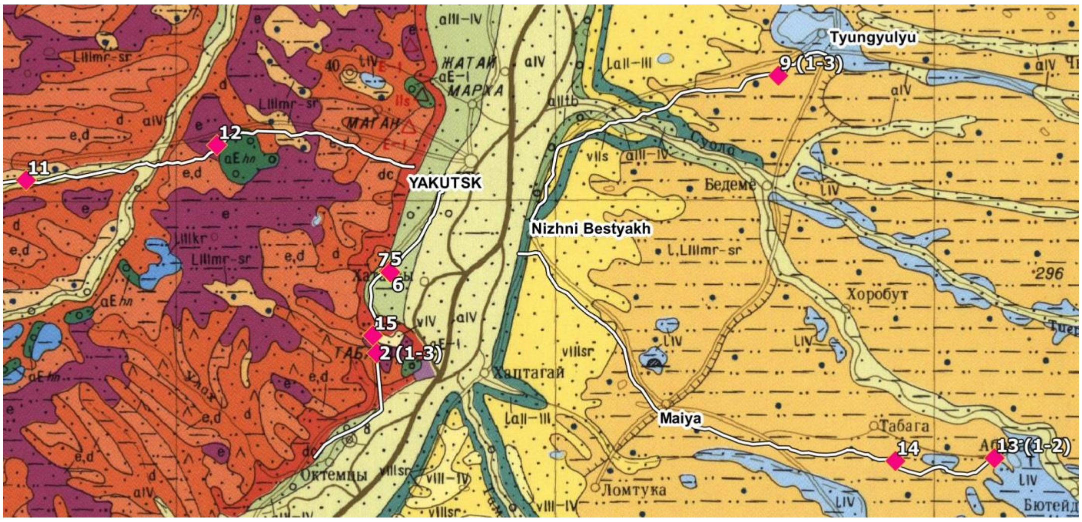


Fig. 4. Map of Quaternary deposits in the area of the WRB tour (from Kolpakov, 1992).

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.

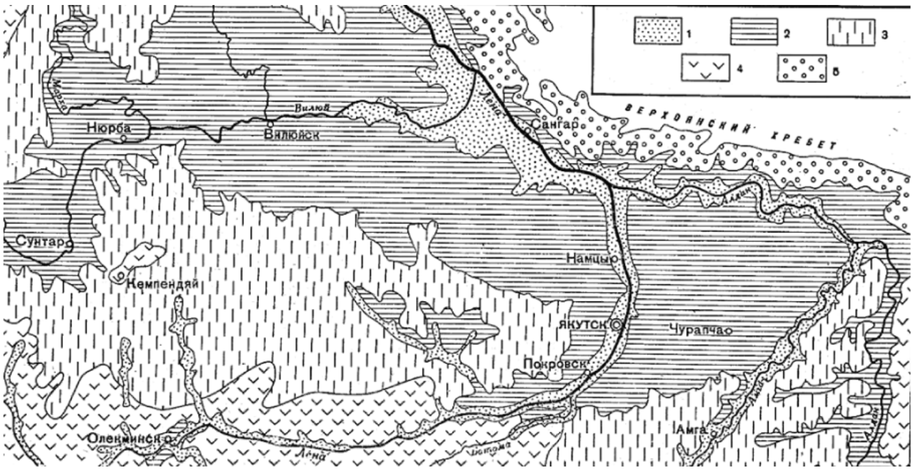


Fig. 5. Geomorphologic Map of Central Yakutia: (1) recent alluvial plains, (2) ancient alluvial plain, (3) denudation plateau composed of noncalcareous Mesozoic rocks (sands, clays, silts with gravelly interlayers), (4) denudation plateau composed of calcareous Paleozoic rocks, and (5) plain composed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

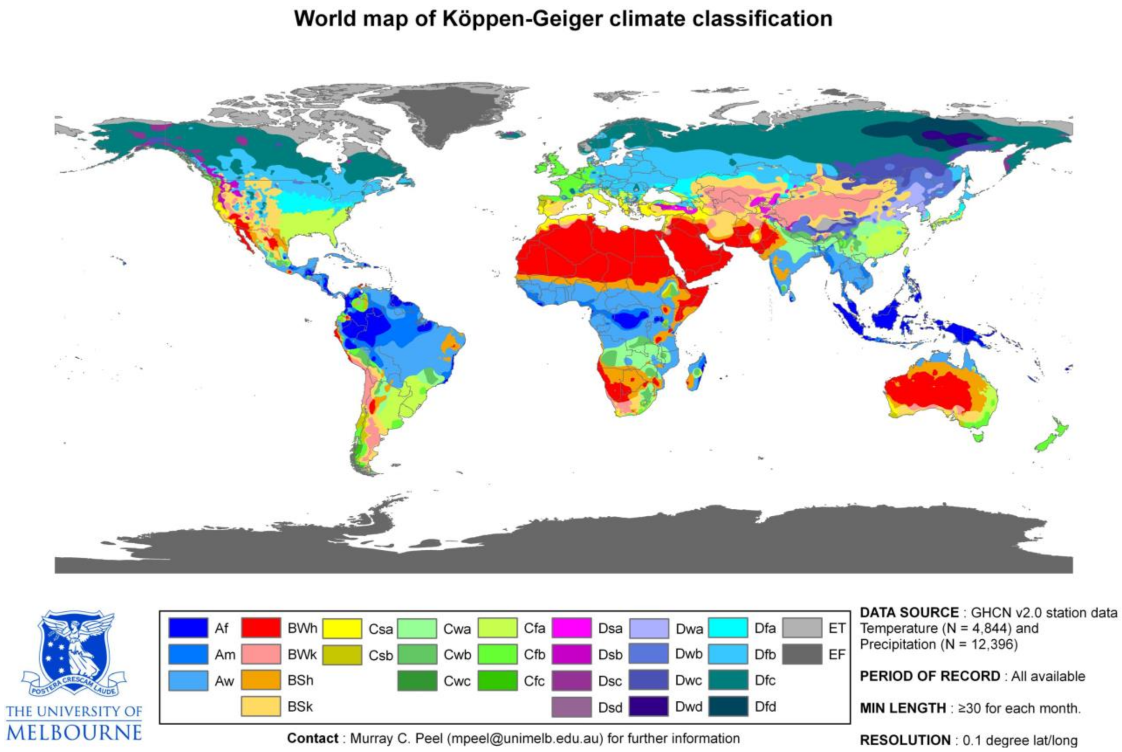


Fig. 6. Central Yakutia on the climatic map of the world (M. Peel et al., 2007).

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).

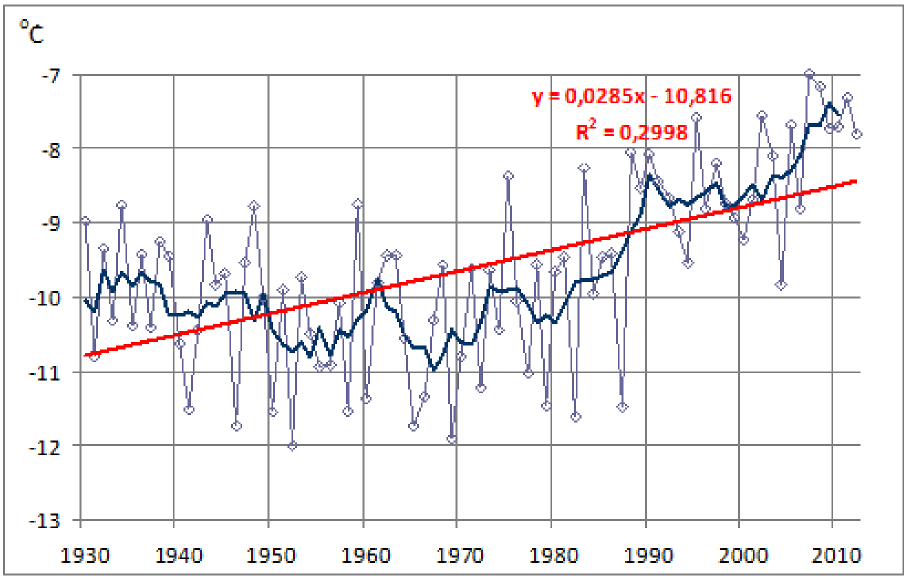


Fig. 7. Dynamics of annual air temperatures in Yakutsk.

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).

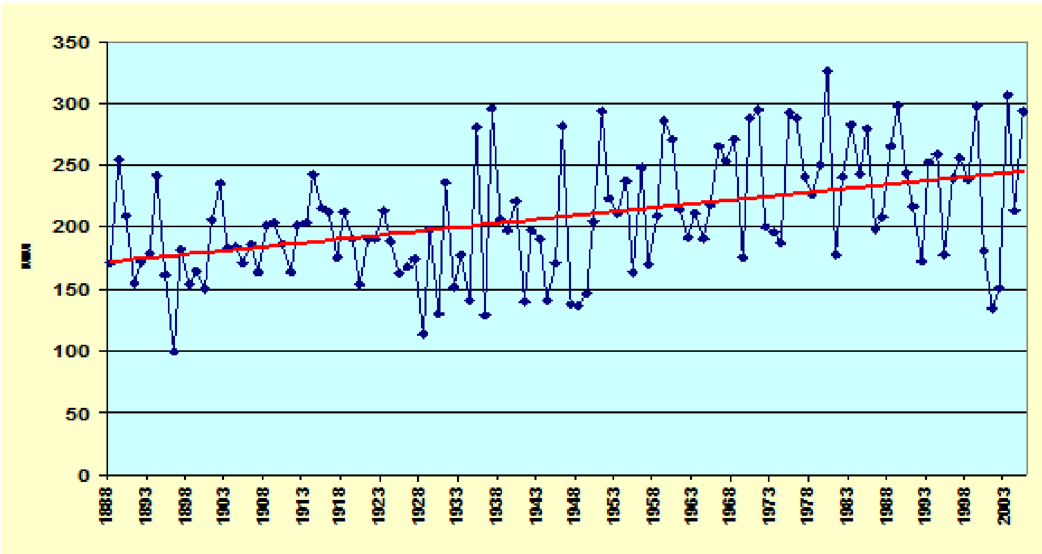
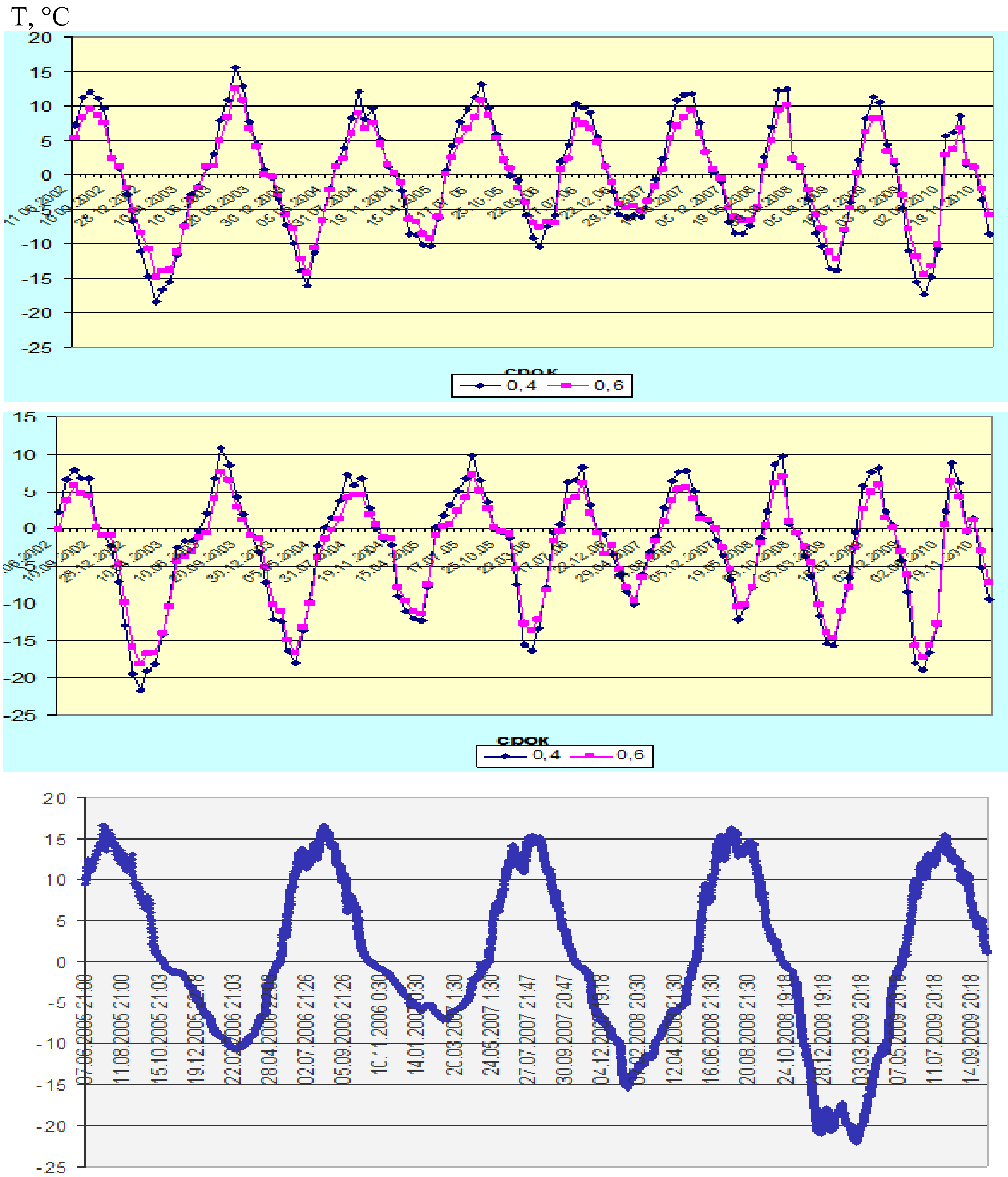


Fig. 8. Dynamics of annual precipitation in Yakutsk.

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.



a

b

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 (40 cm).

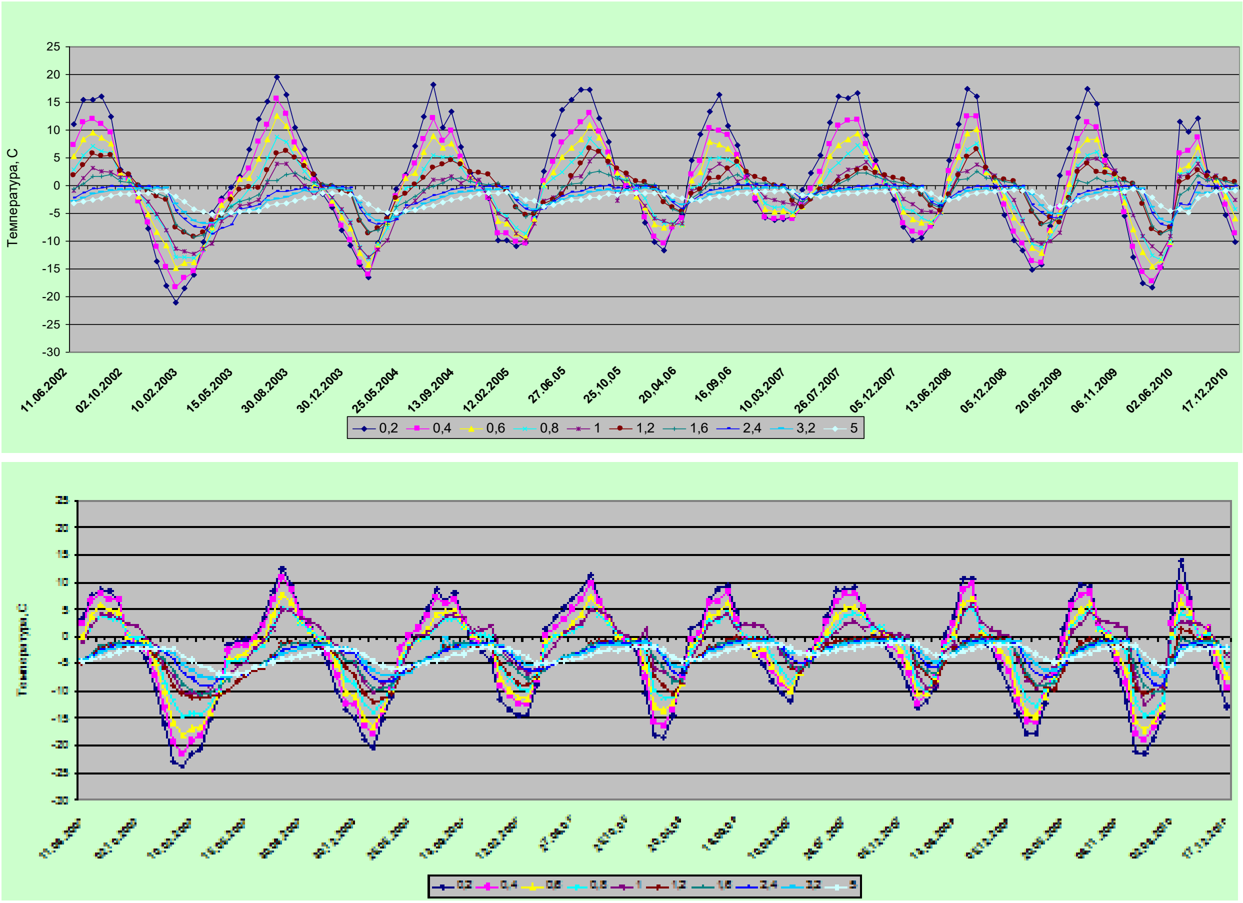


Fig. 9a. Soil temperatures at different depths in the (a) sandy soil under pine forest and (b) loamy soil under larch forest.

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).

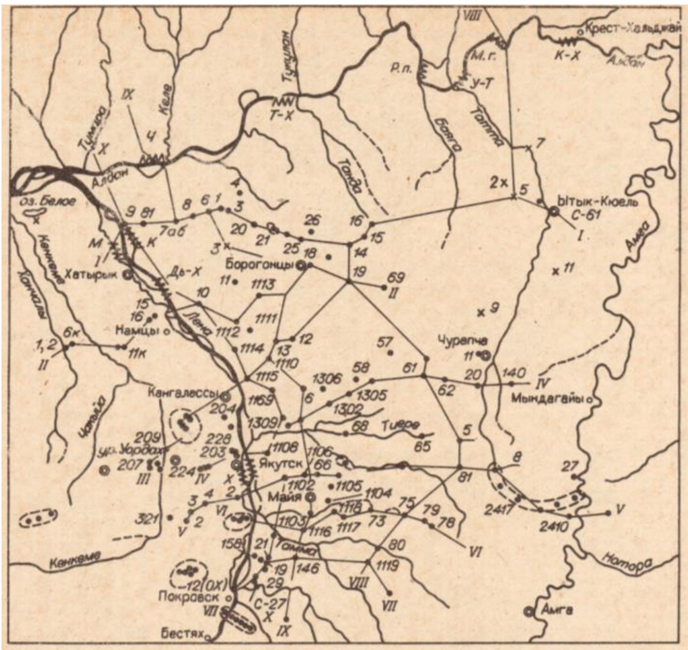


Fig. 11. Location of boreholes andgeocryological profiles (Ivanov, 1984).

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

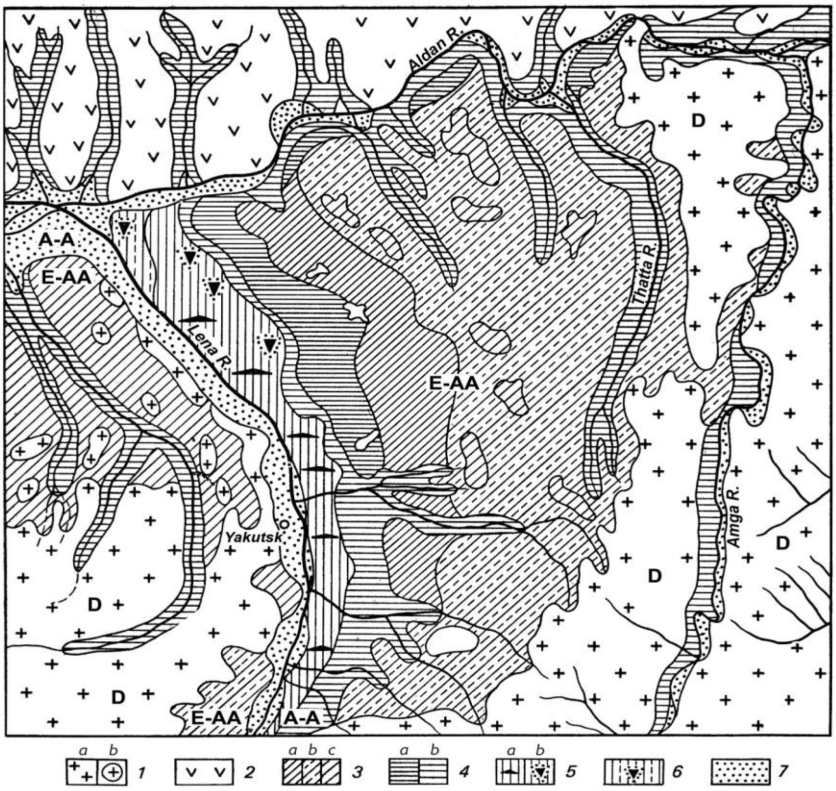


Fig. 12. Ground ice conditions in Central Yakutia (after Ivanov, 1984): (1) denudation plain; ground ice in the form of texture-forming ice and ice wedges (a) and without ice wedges (b); (2) accumulative glacial-glaciofluvial plain; (3) erosional-accumulative Abalakh plain; (a) tectonic escarpment of 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.

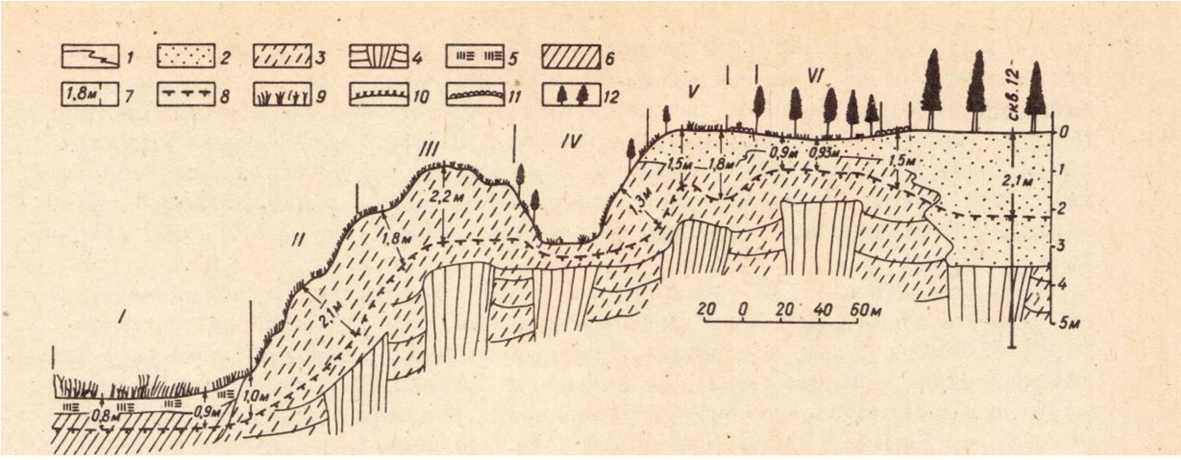


Fig. 13. Maximum depth of seasonal thawing on different elements of the Tyungyulyu terrace (from Ivanov, 1984): (1) lithological boundaries, (2) sand, (3) loamy sand, (4) upper part of the Ice Complex, (5) mineralized peat, (6) silt loam, (7) maximum seasonal thawing, (8) lower boundary of the active 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^{0}C	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).

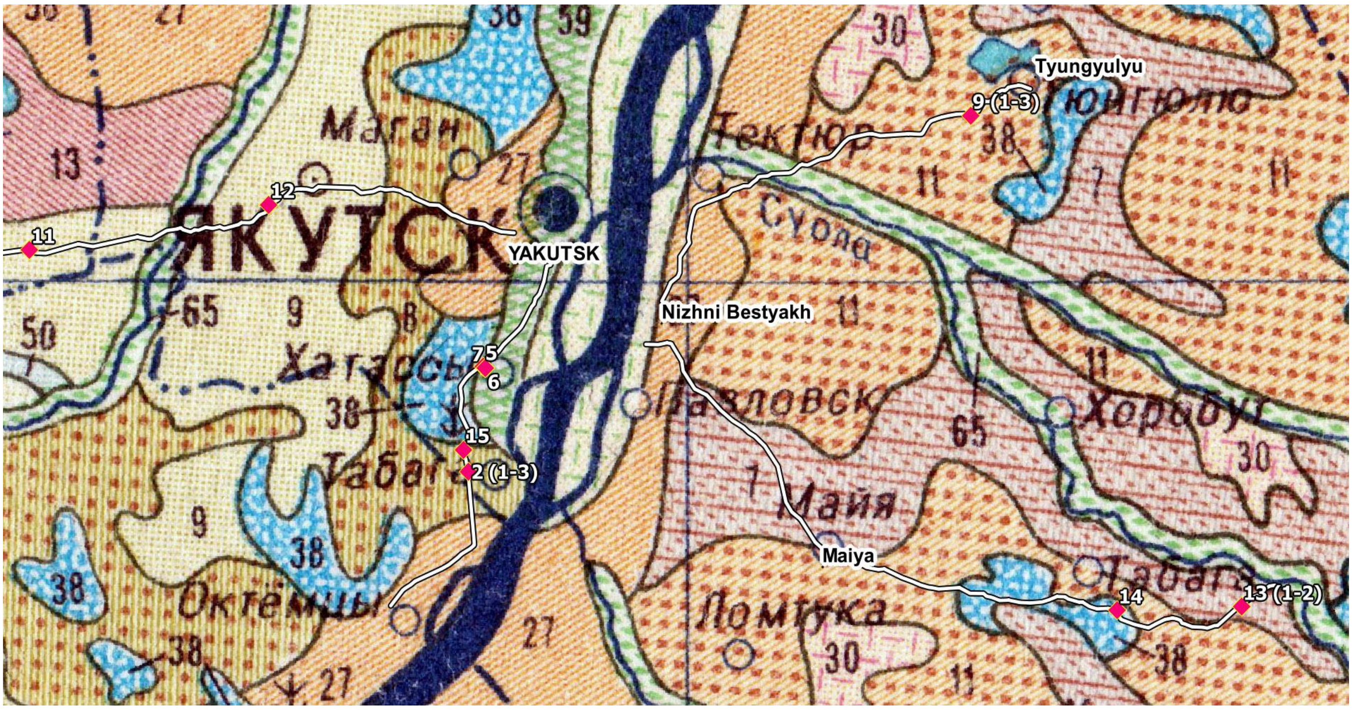


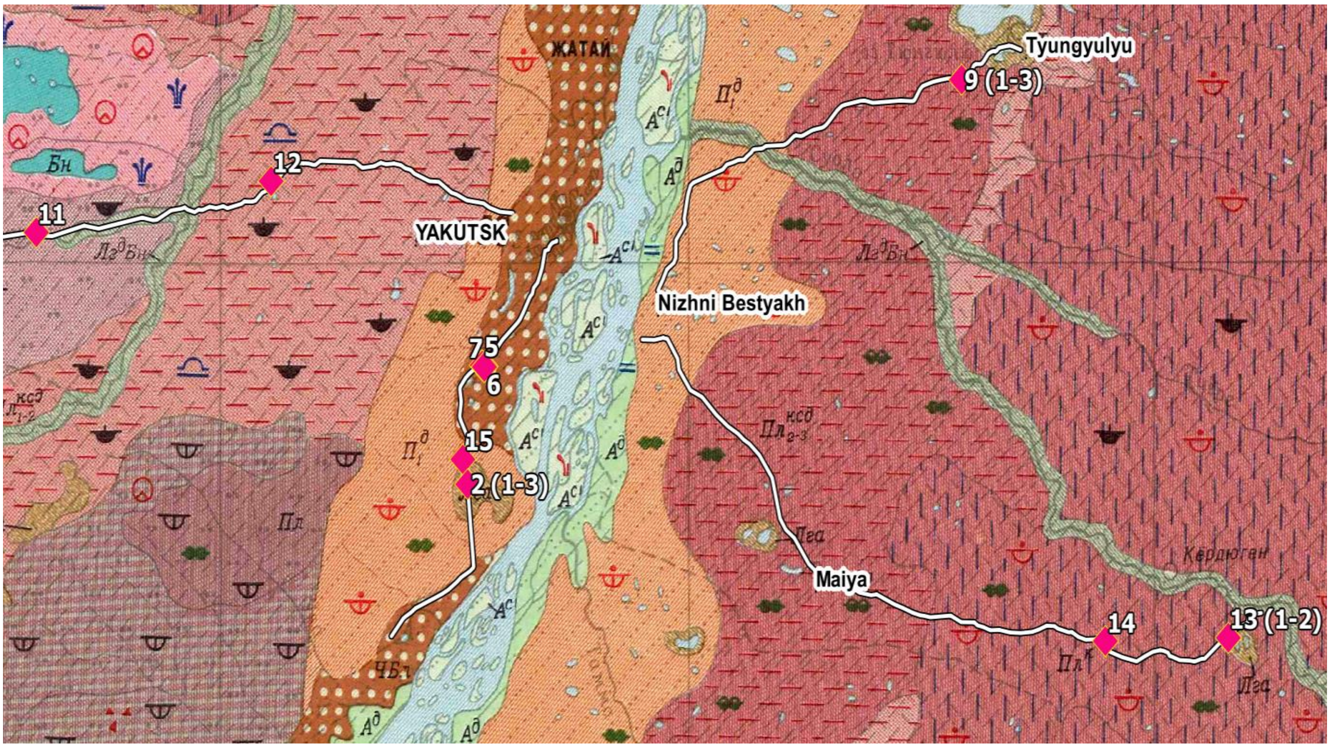
Fig. 14. Major types of vegetation in the study area.
Middle taiga Larch (*Larix gmelinii*, *L. Cajanderi*) forests with (7) cowberry and herbs (*Pyrola incrnata*, *Thalictrum minus*) in combination with grassy (*Alopecurus arudinaceus, Calamagrostis langsdorffii*) alas meadows; (9) cowberry and herbs (*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 can be 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.

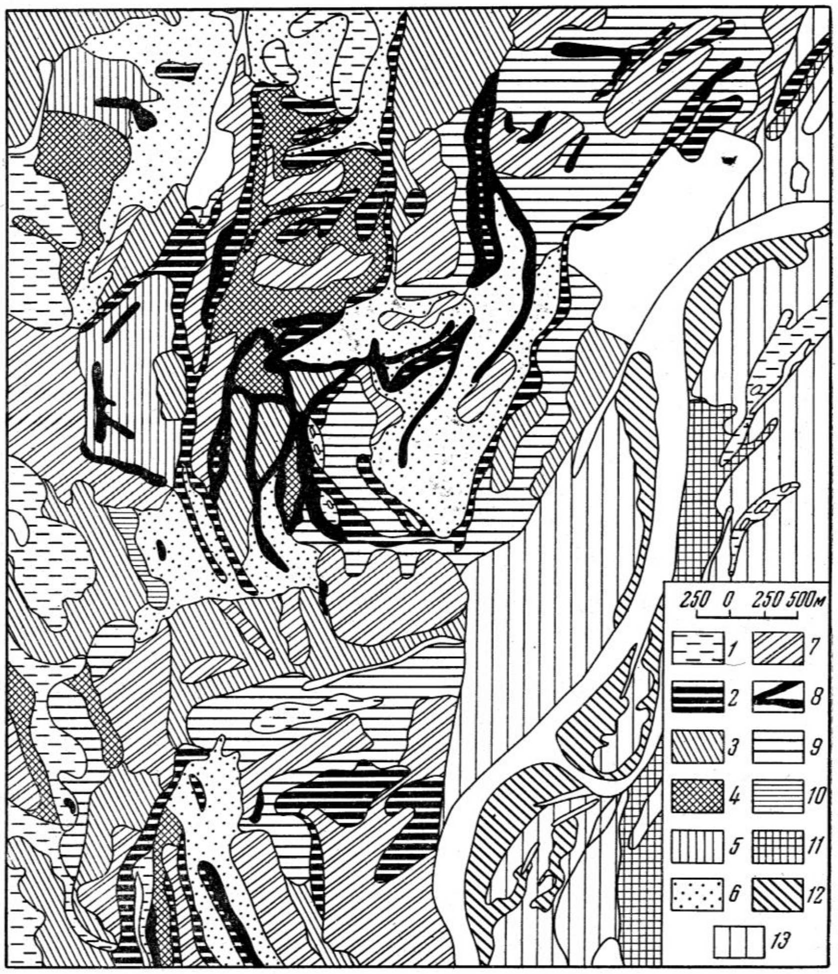


Fig. 16. Detailed soil map of a key site on the floodplain and low terrace (area of profiles 5, 6, 7). Soils and vegetation: (1) meadow-swampy (sedge-reed and sedge meadows); (2) soddy meadow, often solonchakous (forb-grassy and iris meadows); (3) meadow-chernozemic solonchakous and solonetzic (grassy–sedge 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 PHENOMEN: 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.

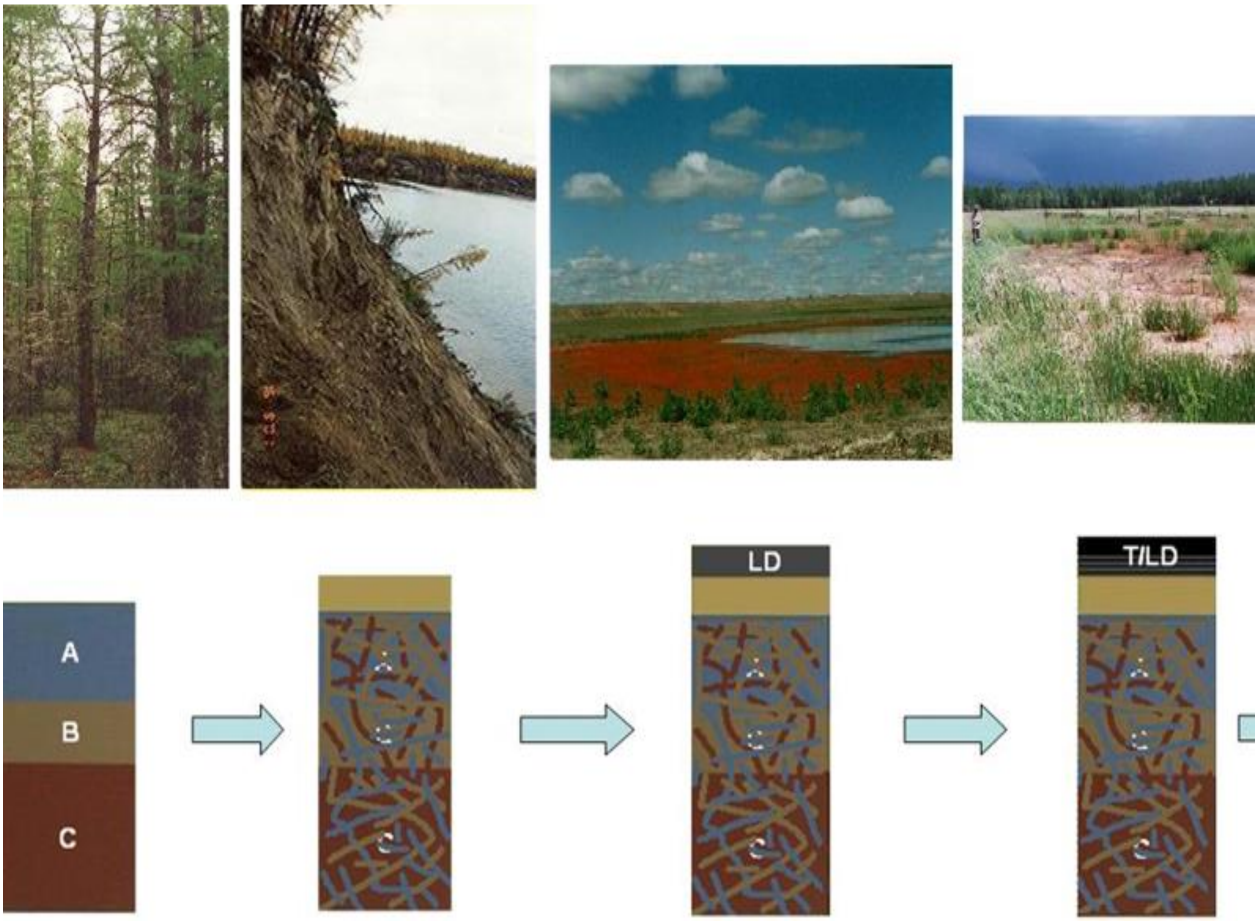


Fig. 19. Scheme of transformation of the parent material upon the alas formation.

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 or once mixing by hand and standing for 30 min (pH_{H2O}) or standing for 18-20 hours with mixing occasionally (pH_{KCl}). pH values 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 M HCl.

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 salinity of 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 was performed. Then exchange bases were 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 soils the 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 samples by 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.

Clay mineralogy

The clay fractions for mineralogical analysis were extracted from several soil horizons. Before the procedure the pedogenic carbonates have been removed by washing with 9% aceitic acid. No treatments for removing organic matter or iron (hydr)oxides were done in order to protect fragile clay minerals from possible dissolution. The obtained clays were saturated with Ca and then used for preparing oriented samples for X-ray diffraction studies. Each sample was analyzed in air-dried state, after heating to 550°C, and after saturation with glycerol.

The x-ray diffractograms were obtained using a Thermo Scientific ARL X'TRA Powder Diffractometer. The parameters of the analysis were: I = 35 mA, U = 40 kV, the lag was 0.04°, the range 2Θ was 2-32°, the radiation was $Cu_{K\alpha}$, t=1 second; the diffractometer was equipped with a Peltier cooled Si(Li) solid state detector.

DAY 1.

Vilyui road. Cambic Turbic Cryosol. Profile 11.

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. This remote site was chosen for two reasons. The parent material in this place has grayish color and the cambic horizon is better manifested than in loess-like yellow brown materials near the city. 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 11 N62°01’45” E128°36’18” H~220 m
63,5 km of the Vilyui tract, on its right side. 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, larch needles, remnants of grass and shrubs, boundary - clear distinctness, smooth topography</td><td rowspan="6">WRB
Cambic Turbic Cryosol (Episiltic, Hypereutric)

Soil Taxonomy
Typic Haploturbel

Russian
Палевая типичная криотурби-рованная
Pale typic cryoturbic</td></tr>
<tr><td>A</td><td>AYpir</td><td>0-10(17)</td><td>10 YR 3/1 brownish black, slightly hard, moist, silt loam, granular with worm-casts structure, many roots, charcoals of different sizes are all over the horizon, individual earthworms, fragments of weakly decomposed organic matter not related to the mineral material, numerous fungal hyphae at the top of horizon; boundary - clear distinctness, wavy topography.</td></tr>
<tr><td>Bw@</td><td>BPL@</td><td>10(17)-33</td><td>10 YR 4/3 dull yellowish brown, slightly hard, silt loam, moist, platy fine granular structure, common roots, fragments of the overlying horizon included due to cryoturbation (10%), weak HCL induced effervescence from the depth of 25 cm, boundary - clear distinctness, wavy topography</td></tr>
<tr><td>Bk</td><td>BCca</td><td>33-65</td><td>2.5Y 4/3 olive; slightly hard, moist, silt loam, platy fine granular structure, effervescence when reacted with HCL, at 65 cm depth - separate allocation of highly carbonated material in a form of 4x8 cm spots, common roots, some places along the edges of the structural units are covered by brownish products of root decomposition (in a form of films); boundary - gradual distinctness, wavy topography</td></tr>
<tr><td>2BC</td><td>2BC</td><td>65-90(120)</td><td>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 80 cm depth - separate allocation of highly carbonated material in a form of 4x8 cm spots; boundary – abrupt distinctness, irregular (wedge-shaped) topography</td></tr>
<tr><td>3Cf</td><td>⊥D</td><td>90(120)-150</td><td>2.5Y 6/3 dull yellowish gray, medium sand, the fragments of the upper horizon are included, 150 cm - permafrost</td></tr>
</table>

Micromorphology.

The substantial difference in mineralogical composition of the coarse fraction is not revealed within the profile. The dominated minerals are quartz, feldspar - plagioclase and potassium feldspars, quite a lot of grains of muscovite and biotite, amphibole and epidote grains are also found. Mineral grains are angular and subangular.

C/f-related distributionpattern is open porphyric staying constant along the profile.

A - 0-10 cm Non-uniform in color: there are light gray-yellow, light and dark brownish-gray (almost black) microzones, which is defined by different intensity of clay humus content ina micromass and an abundance of brown highly decomposed plant tissues assimilated of soil mass. It is characterized by a high prevalence of inter-aggregate porosity and complex crumb (related to excrements) and platy microstructure. Horizon feature is the abundance of excrements of soil microfauna –*Enchytraeus, Collembola, Oribatidae*s and other primary decomposers of plant tissues (Fig. 1a). Organic matter is represented by: plant residues of different size and decomposition stages, numerous small fragments of carbonized tissue both in pores, and in intrapedal mass. Hyphae and fungal sclerotia are associated to microzones including largest fragments of plant tissues. The dark gray colored areas have clay-humus micromass and undifferentiated b-fabric, the brownish-yellow areas are characterized by randomly arranged speckles of oriented clay: stipple-speckled b-fabric (Fig. 1b). There are discontinuous clay coatings around some coarse mineral grains, even around those located in pores. Numerous diatom skeletons and phytoliths were observed in a fine silt fraction.

Bw@ - 10-17(25)cm Light brownish-yellow, highly porous material with a predominance of inter-aggregate pores and well-pronounced crumb structure, there is a high content of mesofauna excrementsin some microzones (Fig. 1c). The organic material is dominated by small fragments of plant residues, fungal hyphae also occur. The large number of phytoliths was detected. Pores are characterized by loose, silt infillingscomposed of silicate minerals wich have discuntinuous thin clay coatings. Micromass isclayey with a stipple-speckled and porostriated b-fabric (Fig. 1d). Probably some of the thin clay coatingsare the stress-cutanswhich surrounds spheroidal aggregates with sharp edges. The small ferruginous nodules with areas of intensive ferruginization around them occur among the pedofeatures.

Bw@ - (25-33cm). The color of the matrix is similar to the overlying horizon, but the character and composition of the fine material changed. In addition to crumb microstructure of some microzones, there are lenticular and platy aggregates with subparallel distribution within the cracks. Micromass iscarbonaceous-clayey, b-fabric is calcitic speckled crystallitic and porostriated (Fig. 1e).Carbonate pedofeatures occur here.These are small loose and dense nodules, some onesare composed of acicular calcite (Fig. 1f). Probably these pedofeatures are composed of calcium oxalate (whewellite). Organic matter is represented by ferruginous reddish plant tissues. Besides lenticular aggreagatesthere was a large number of globular and ellipsoid coprolites in some areas (Fig. 1g).

Compared with the overlying horizon the clay coatingsaroundsand grains are betterexpressed. The iron-manganese dendritic forms were also found locally.

Bk - (33-60 cm) It is lighter and more compacted than the overlying horizon. Material is heterogeneous in respect to the degree of pedality: there are densely packed microzones with weakly developped pedality, and higly biologically alterred zones with well-developped pedality (Fig. 1h). Small fragments of higly altered plant tissuesprevailamong the organic matter, small carboniferous particles also occur. Micromass is clayey-carbonaceous, b-fabric is mostly calcitic speckled crystallitic in individual micro-zones it is granular (ooid).

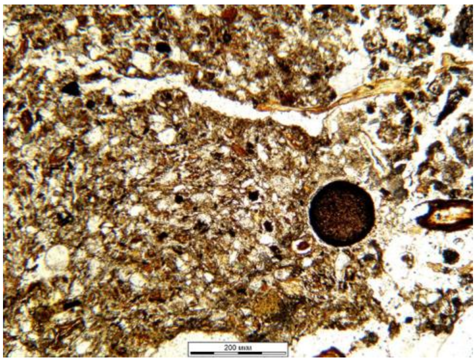
Conclusion. At the micro level, it was found that the profile 11is characterized by active contemporary biogenic processing of the groudmass on the whole studied depth of the profile, which was not described at the macro level.All horizons in some microzones reveal cryogenic microstructure –the platy one (0-10 cm) and the lenticular one (below 10 cm). These cryogenic aggregates incorporate numerous fragments of plant tissues and excrements of soil mesofauna. Strongly altered brownish plant residues prevail in the composition of the organic matter. There are also few carbonized and ferruginized root residues. Granostriated b-fabric - granular aggregates surrounded by thin clay coatings (stress cutans) - is observed in the top horizons. There are loose silty ifilling composed of silicate grains surrounded by thin clay coatings in pore space around the granular aggregates.

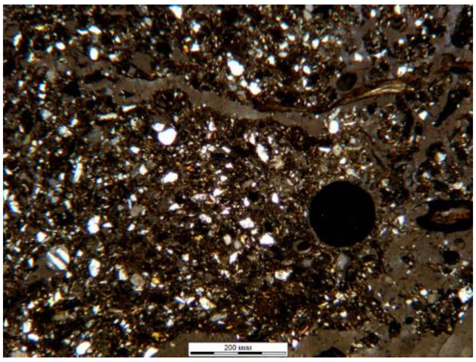
Particle-size distribution

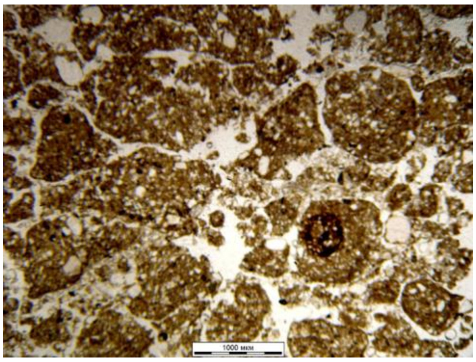
Horizon	Depth, cm	Bulk density	Sand >0,063	Silt 0,063-0,002	Clay <0,002
O	1-0	-	-	-	-
A	0-10(17)	0,72	14,24	61,42	24,34
Bw@	10(17)-25	1,41	19,87	55,51	24,62
Bw@	25-33	1,47	18,86	66,16	14,98
Bk	33-65	1,40	31,83	53,45	14,72
2BC	65-90(120)	-	66,42	28,42	5,16
3Cf	90(120)-150	-	95,03	2,23	2,74

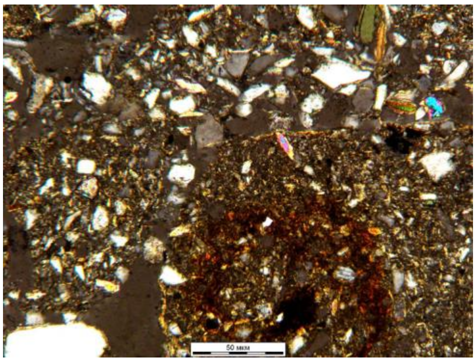
Bulk chemical composition, % in ignited soil

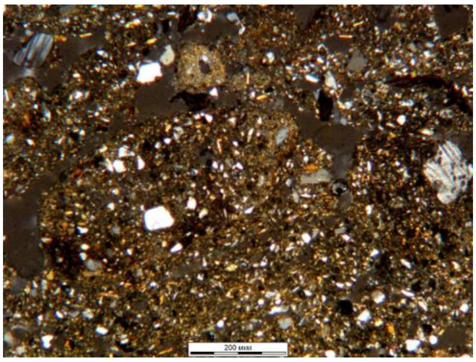
Horizon	Depth, cm	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	Cl	K_2O	CaO	TiO_2	MnO	Fe_2O_3
A	0-10(17)	1,40	1,54	12,78	54,74	0,12	0,21	0,02	1,93	2,48	0,61	0,07	4,12
Bw@	10(17)-25	1,64	1,88	12,88	59,98	0,05	0,11	0,01	2,16	1,64	0,64	0,06	4,60
Bw@	25-33	1,86	2,25	16,86	62,34	0,05	0,12	0,02	2,33	1,87	0,72	0,06	4,56
Bk	33-65	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	65-90(120)	1,73	1,67	15,28	62,88	0,12	0,14	0,03	2,32	1,97	0,64	0,04	2,86

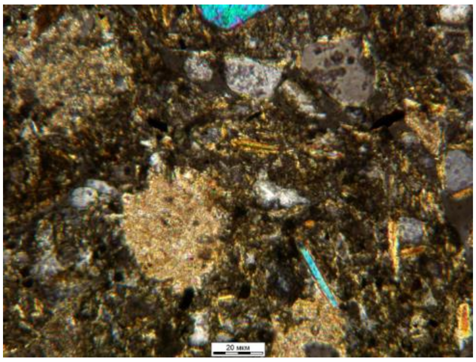

a) 0-10 cm

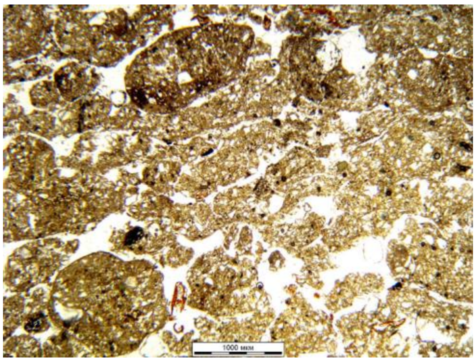

b) 0-10 cm


c) 10-17 cm


d) 10-17 cm


e) 25-33 cm


f) 25-33 cm


g) 25-33 cm

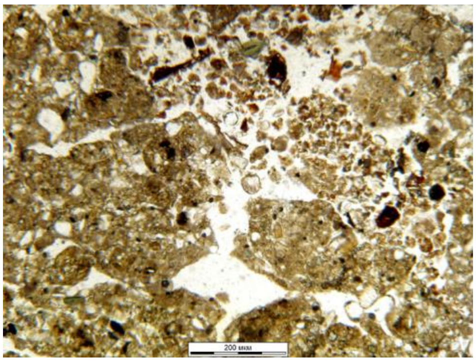
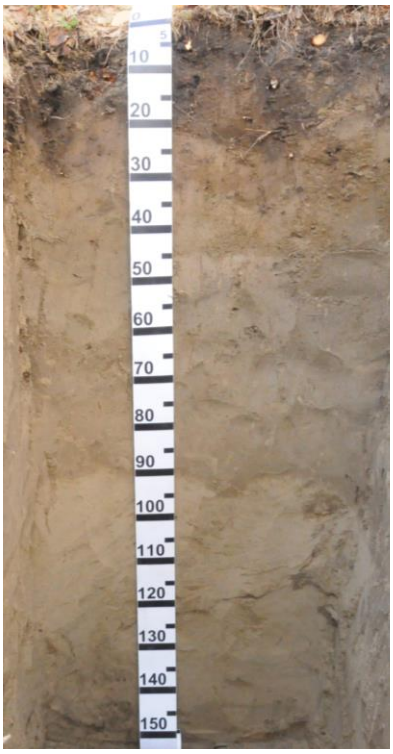

h) 33-60 cm

Fig. 1. Microfeatures of horizons in Cambic Turbic Cryosols, prof. 11 (a–h):
a) platy aggregates, assimilated small fragments of plant tissues, sclerotium and numerous excrements (right zone) (PPL); b) the same as isotropic clay-humus micromass (XPL); c) crumb structure, ellipsoidal excrements, silty infillings in pores (PPL); d) granular aggregate surrounded with clay-ferruginous thin stress-coating, silty infillings in pores (XPL); e) granular aggregates with carbonate-clay micromass, small calcareous nodules (XPL); f) different in density and shape of the boundary carbonate pedofeatures, the abundance of mica platelets (XPL); g) lenticular granular units with different contents of clay-humus fine material (PPL); h) compacted material with granular structure, loose infilling composed of excrements (PPL).



Pedogenesis and classification

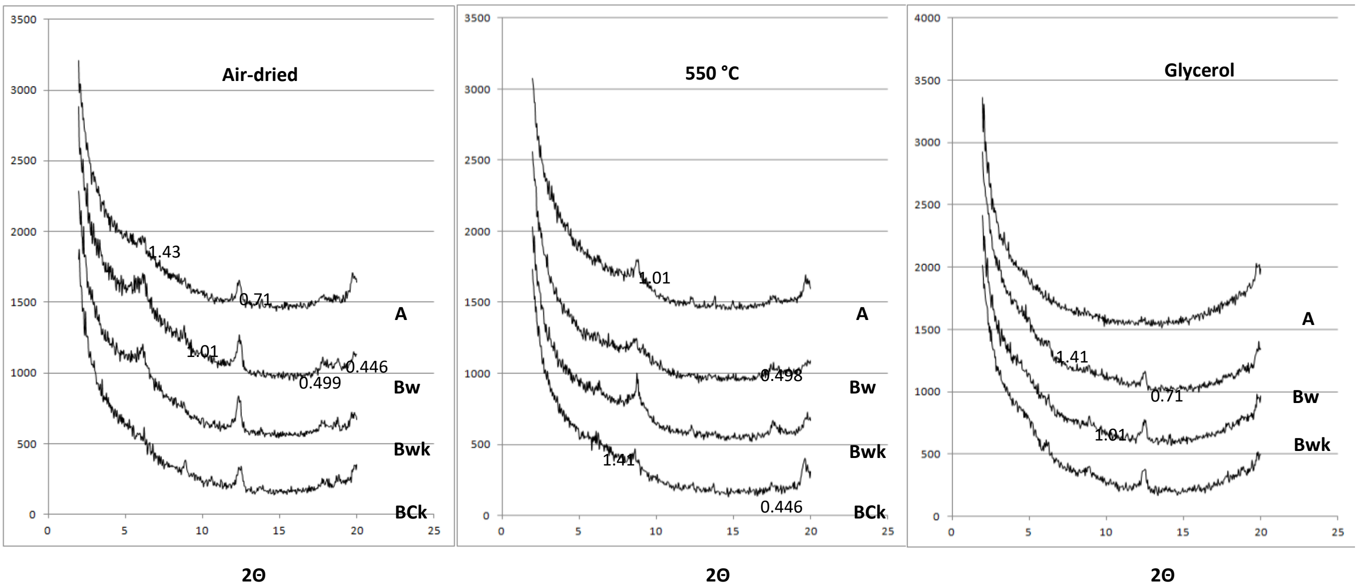
This is a soil with pronounced cryogenic features both on macro- and microlevel and with typical biogenic process of forest soils. In spite of low initial content of calcite this soil has neutral and alkaline reaction in the upper calcite-free horizons. It is typical for the ultracontinental areas because 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 150 cm and pronounced cryoturbations make the correlation of this profile easy in WRB - Cambic Turbic Cryosol (Hypereutric, 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.

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	6,85	6,10		-	-	55,82	-	-	-	-
A	0-10(17)	7,35	6,55	0,09	5,10	6,65	15,14	1,01	0,30	4,12	0,24
Bw@	10(17)-25	7,70	6,55	0,04	0,41	0,48	-	1,00	0,23	4,60	0,24
Bw@	25-33	8,85	7,55	0,09	0,64	1,24	-	1,10	0,16	4,56	0,22
Bk	33-65	9,00	7,75	0,10	0,29	0,48	-	0,76	0,14	4,28	0,21
2BC	65-90(120)	9,25	7,75	0,06	0,25	0,30	-	-	-	2,86	-
3Cf	90(120)-150	8,55	7,00	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	0-10(17)	28,06	10,29	0,66	0,26	39,27	27,18	23,85	9,78	0,56	0,28	34,47	34,57	36,67	-
Bw@	10(17)-25	13,65	6,93	0,22	0,23	21,03	12,82	13,95	7,21	0,24	0,27	21,67	19,20	21,67	-
Bw@	25-33	16,18	7,52	0,27	0,36	24,34	12,53	14,94	6,38	0,24	0,38	21,95	22,11	19,17	0,36
Bk	33-65	18,51	7,09	0,28	0,19	26,07	10,06	18,55	6,47	0,21	0,20	25,44	20,71	19,17	1,55
2BC	65-90(120)	6,46	3,55	0,17	0,10	10,27	6,13	5,63	3,27	0,16	0,08	9,14	8,15	12,50	0,14
3Cf	90(120)-150	1,10	0,92	0,05	0,03	2,10	1,04	1,12	0,90	0,05	0,04	2,10	0,42	2,50	-



The profile 11 contained chlorite-vermiculite, kaolinite, and minor amount of illite in all the horizons, and also chlorite in the horizons Bwk and BCk. The presence of swelling components was detected in the BCk horizon. The pedogenesis seems to lead to the destruction of swelling minerals and to the transformation of chlorite to mixed-layered chlorite-vermiculite.

Vilyui road. Turbic Cryosol Reductaquic. Profile 12.

This soil is typical for East Siberia where continuous permafrost is widespread.

<table>
<tr><td colspan="5">Site 12 N62^{0}04’21,4” E129^{0}06’34,5” H~231 m
36 km of the Vilyui tract, 20 m to the north from the road
Larch forest, in the undergrowth - ledum, dwarf birch, cranberry, blueberry, green mosses</td></tr>
<tr><td>O</td><td>O</td><td>+7-0</td><td>10 YR 2/2 brownish black
litter with low peat content, low to moderate decomposition degree of mosses, shrubs, larch needles residues, individual fungi hyphae, many roots, boundary – clear distinctness, wavy topography</td><td rowspan="4">WRB
Turbic Cryosol (Hypereutric, Reductaquic, Arenic)

Soil Taxonomy
Psammentic Aquiturbels

Russian
Глеезем мерзлотный
Gleyzem permafrost</td></tr>
<tr><td>AO</td><td>AO</td><td>0-4</td><td>10 YR 3/1 brownish black
mixture of mineral material and organic matter with strong degree of decomposition, many roots, boundary – abrupt distinctness, irregular topography with pockets of cryoturbation origin</td></tr>
<tr><td>Bg</td><td>Bg@</td><td>4-23</td><td>10 YR 5/4 dull yellowish brown, with many brown (7.5YR 4/6) mottles
soft consistence, moist, medium sand, fragments of the upper horizon, boundary – clear distinctness, wavy topography</td></tr>
<tr><td>Crf</td><td>⊥G</td><td>23-90</td><td>5 Y 5/2 grayish olive with many very dark reddish brown (2.5YR 2.5/4) and dull reddish brown (5YR 4/4) mottles,
wet, water from 50 cm depth, medium to coarse sand, 5YR 4/4 mottles consist of sandy loam, few roots, permafrost from 90 cm depth</td></tr>
</table>

Particle-size distribution

Horizon	Depth, cm	Bulk density	Sand >0,063	Silt 0,063-0,002	Clay <0,002
O	7-0	-	-	-	-
AO	0-4	0,72	-	-	-
Bg	4-23	1,46	95,29	2,43	2,28
Crf	23-90	-	97,49	0,53	1,98

Analytical data

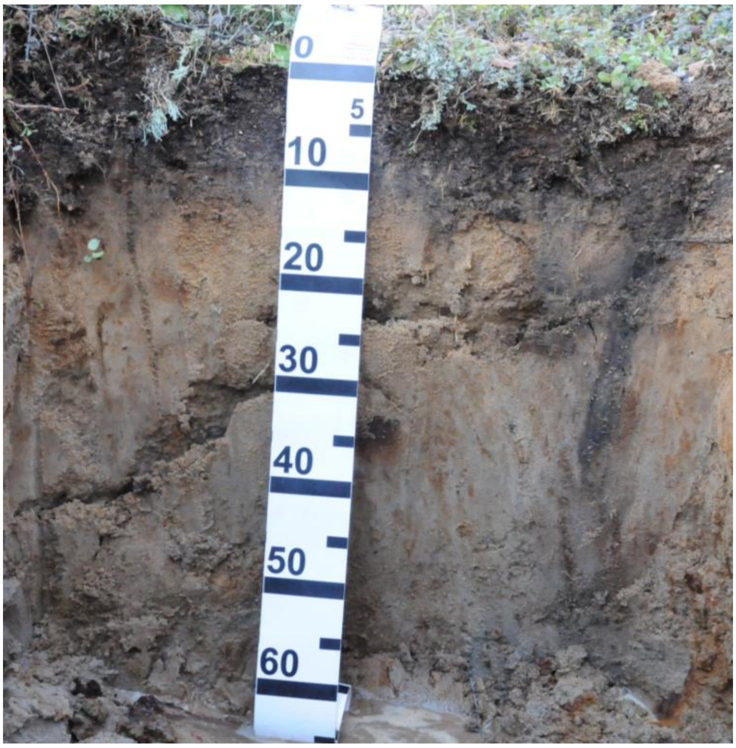
Horizon	Depth, cm	pH H2O	pH KCl	EC, dS/m	C wetcomb., %	C drycomb., %	Loss on ignition, %	Fe_2O_3d (Mehra-Jackson)	Fe_2O_3o (Tamm)	Fe_2O_3 total	Al_2O_3d (Mehra-Jackson)
O	7-0	6,45	5,05	-	-	-	53,98	-	-	-	-
AO	0-4	5,65	4,35	0,03	5,63	6,59	20,47	1,48	0,60	3,54	0,16
Bg	4-23	5,65	4,00	0,02	0,13	0,17	-	0,44	0,25	1,46	0,03
Crf	23-90	6,65	4,80	0,02	0,09	0,15	-	0,08	0,06	1,07	0,09

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
AO	0 - 4	0,95	0,40	6,29	48,35	0,32	0,59	0,05	1,24	2,48	0,25	1,14	3,54
Bg	4--23	2,09	0,33	10,20	73,78	0,02	0,15	0,02	2,02	1,17	0,17	0,02	1,46
Crf	23 - 90	3,20	3,37	14,13	63,07	0,17	0,13	0,09	2,73	3,94	0,23	0,02	1,07

Cation exchange capacity and exchangeable bases

Hori-zon	Depth, cm	*NH4OAC*					
		Bases, cmol/kg					CEC cmol/ kg
		Ca^{2+}	Mg^{2+}	K+	Na+	Sum	
AO	0 - 4	10,10	1,61	0,54	0,19	12,45	28,52
Bg	4-23	0,75	0,19	0,00	0,03	0,96	1,45
Crf	23 - 90	0,70	0,29	0,00	0,02	1,01	0,81



Pedogenesis and Soil Classification

This soil is formed on sandy material with well-pronounced overmoistening which results in formation of litter and raw-humus horizons which are very effective to keep the permafrost table shallow. So, the main feature of this soil is redoximorphism and cryoturbations. As for classification the Soil Taxonomy reflects all main characteristics of this soil in the name of its group – Psammentic Aquiturbels. The WRB recognizes the main characteristic of this soil – redoximorphism as a suffix qualifier and that is not adequate. It is strange that we have both Stagnic and Gleyic qualifiers as the prefix ones and Reductaquic qualifier as a suffix one. The specific feature distinguishing this ultracontinental soil from the soils with similar profiles of other permafrost regions is high basic saturation in spite of calcite-free sandy parent material. In Russian classification the strong reduction seeing from a profile is more important that the presence of permafrost. That is why this profile is correlated as Gleyzem permafrost cryoturbated.

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°50’14,9” E129°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°C (Desyatkin et al., 2012)</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
Haplic Stagnosol (Hypereutric Arenic, <u>Turbic</u>)

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

Russian
Подбур оподзоленный глееватый (крио)тур-бированный
Podboor podzolized gleyish (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	0,64	76,77	18,41	4,82
Bh	4-9	-	87,80	10,06	2,14
Bg@	9-30	1,61	92,49	4,61	2,90
BCg	30-80	1,55	91,48	4,54	3,98
Cg	80-120	-	95,70	1,62	2,68

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	5,55	4,50	-	-	-	81,53	-	-	-	-
A	0-4	6,25	5,45	0,03	3,72	4,62	15,93	0,53	0,23	1,32	0,14
Bh	4-9	6,85	5,55	0,02	1,24	1,45	4,97	0,29	0,29	1,36	0,39
Bg@	9-30	6,95	5,15	0,03	0,12	0,17	-	0,41	0,14	0,78	0,13
BCg	30-80	6,75	4,70	0,03	0,11	0,22	-	0,21	0,05	1,21	0.09
Cg	80-120	6,85	4,70	0,03	0,07	0,19	-	0,14	0,01	1,11	0,07

Cation exchange capacity and exchangeable bases

		NH4OAC					
		Bases, cmol/kg					CEC cmol/kg
Hori-zon	Depth, cm	Ca^{2+}	Mg^{2+}	K+	Na+	Sum	
A	0 - 4	15,01	0,87	0,29	0,01	16,18	17,74
Bh	4 - 9	6,26	0,38	0,04	0,02	6,71	8,49
Bg@	9 - 30	1,23	0,17	0,02	0,01	1,44	1,43
BCg	30 - 80	2,08	0,51	0,02	0,01	2,62	2,70
Cg	80 - 120	1,34	0,41	0,05	0,01	1,80	0,94

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 except the absence of Turbic qualifier for Stagnosols, that should be the prefix one. 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.

DAY 2.

Abalakh alas vicinities. Haplic Cryosol Albic Luvic Sodic. Profile 14.

This soil represents the most widespread kind of soil in Central Sakha (Yakutia) under larch forests.

Site 14 N61^{0}40'52,5" E130^{o}53'54,8"

Vicinities of Tabaga settlement (right bank of the Lena river), road from Maya village to Abalakh lake. A typical taiga of Central Yakutia. Larch forest with cowberry (red bilberry), old fire site, burnt stumps of old (100-150 years) trees, young larch trees of 40-50 years old, undergrowth – larch, cowberries, green mosses.

O	O	+10-0	10YR 3/3 dark brown; almost black in the lower part; moist; soft consistence; organic residues of moderate to strong (lower horizon part) degree of decomposition; many grasses; shrubs; trees roots; many small tree charcoals at the lower boundary; boundary – abrupt distinctness, smooth topography	WRB Haplic Cryosol (Calcaric, Siltic, Albic, Luvic, Sodic) Soil Taxonomy Natric Argiorthel Russian Палевые осолоделые Pale solodic
E	EL (BPLe)	0-5(12)	10YR 6/2 grayish yellow brown; soft consistence; moist; silt; platy - fine subangular blocky structure; porous; lower part of the plates is more dark than the upper one; few charcoal residues; many roots; fine iron mottles; boundary – abrupt distinctness, wavy topography	
Bt	BPLt	5(12)-14(20)	10YR 4/3 dull yellowish brown; moist; silt clay loam; weak angular blocky-platy structure; few clay cutans on peds surfaces; boundary – clear distinctness, wavy topography	
Bwk	BPLca	14(20)-45	2.5Y 4/4 olive brown; slightly hard; silt loam; platy-angular blocky structure; common roots; effervescence when reacted with HCL; boundary – gradual distinctness, smooth topography	
BCkf	⊥BCca	45-80	2.5Y 4/3 olive brown; silt loam; less structured and less roots than in the upper horizon. Permafrost at 80 cm depth.	

Temperature profile at site 14

Depth,	t^{0}C		
+8 (under moss)	4,6		
9	4,2		
20	3,7		
30	3,2		
40	2,7		
50	2,2		
60	1,6		
70	1,1		
80	0,5		
90	-0,1 (not frozen)		
100	-0,3 (frozen)		

Micromorphology

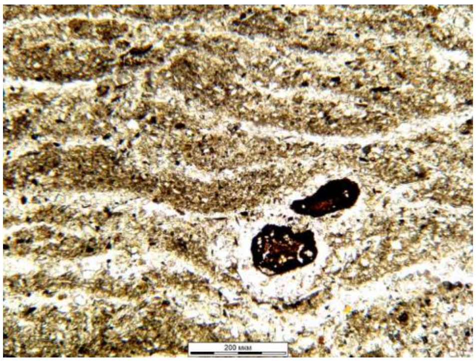
E – 0-12 cm. Light gray material with fine lenticular microstructure. Within the lenticular aggregates the differentiation of the particles is clearly visible: the silty micro-zones are characteristic for the upper part of peds and clayey one - for the lower part (Fig. 2a, b). Large number of carboniferous and ferruginous root residues are characteristic. Many of plant residues are fragmented, some of them are surrounded with ferruginous fine material due to their decomposition(Fig. 2c). Micromass is humus-clay, isotropic (undifferentiated b-fabric). There are fungi sclerotia. Quartz, feldspar, mica and amphiboles perdominate in coarse material. Phytoliths are also found. Mineral grains are angular.

Bt – 12-20 cm. The material is patchy coloured and different in structure in two thin sections from this horizon. In one of thin sectionsthe material is a reddish-brown, having complex granular-lenticular microstructure (Fig. 2d) with somegranular aggregates forming microzones of concentric striated (“ooid”) b-fabric. For this thin section loose silty infillings including excrementsof soil microfaunaare markedin the interped pores. Plant residues in the form of ferruginous cross-sections of roots dominate.

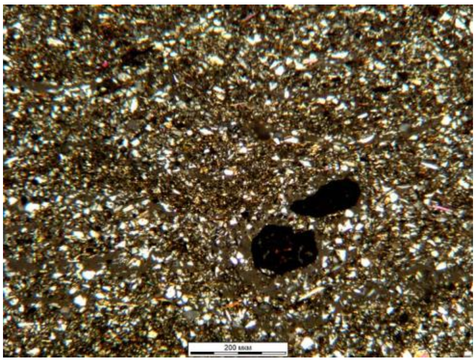
In another thin section clay material is darker because of microzonal high humus content, it has fine prismatic (blocky) structure (Fig. 2e) and high optical orientation of clay forming striated, and particularly granostriated b-fabrics. At higher magnifications thin clay coatings can be seen in interpedal and fine intrapedal pores (Fig. 2f). There are also isolated dendritic iron-manganese growths.

Bwk – 30-40 cm Light brownish material with an abundance of roots slices of different sizes and with traces of biogenic destruction (Fig. 2g). Structure is complex lenticular granular. Color of plant remains is less black than the overlying horizon. Micromass is humus-clay-carbonate with crystallitic b-fabric. In some microzones trending formation of carbonate nodules and cutanstake place at the background of iron-humus clots and ferruginous excrements (Fig. 2h). Calcite appeared as a part of minerals in a coarse silt size fraction. Also, there are coarse-silt infillings, which include those other than silicate minerals are coarse-silt grains of calcite.

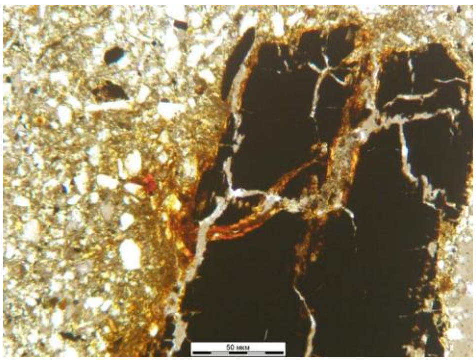
Conclusion. In In the wholeprofile complex granular-lenticular structure is characteristic, it tends to form porostriated b-fabric (around channels and root)(Fig. 2d, g). Features of high biogenic activityare marked in all horizons. Cryoturbation contribute to the formation of high heterogeneity in the microstructure in all horizons, including in the horizon with signs of textural differentiation. For the last onefine subangular prismatic structure and the formation of thin clay coatingsand hypocoatingswere observed (Fig. 2e, f). The formation of dense matrix micriticpedofeaturesat the background of local ferruginization and humus impregnation of the fine materialis characteristicfor the carbonate horizon (Fig. 2h).



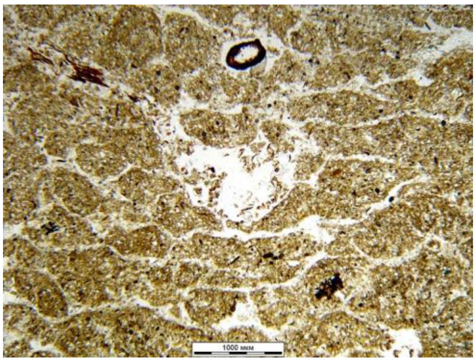
a) 0-12 cm



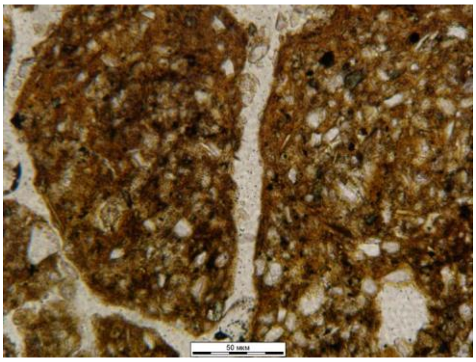
b) 0-12 cm



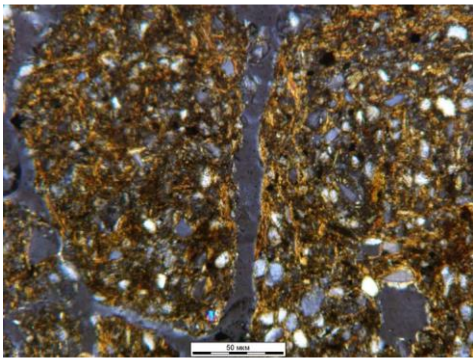
c) 0-12 cm



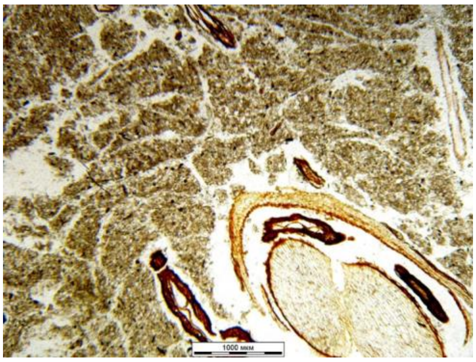
d) 12-20 cm



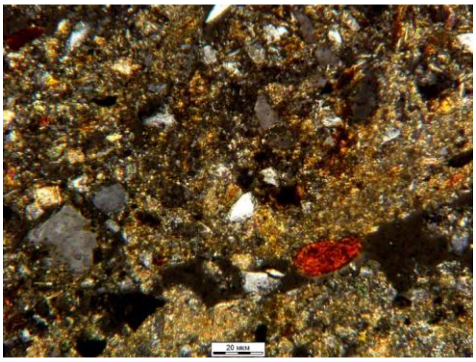
e) 12-20 cm



f) 12-20 cm



g) 30-40 cm



h) 30-40 cm

Fig.2. (prof. 14): a) Lenticular structure with the differentiation of the particles inside peds: dusty microzones in the upper faces and clayey ones in the bottom; carbonized remains of roots (PPL); b) the same, the isotropic clay-humus micromass (XPL); c) fissured ferruginized plant residue with a zone ferruginized groundmass around it (PPL); d) (PPL); d) a material with lenticular-crumb structure with excrements of soil microfauna along the slightly decomposed roots (PPL); e) clay-humus plasma in small prismatic aggregates (PPL); f) The same field - thin clay coatings and hypocoatings in interpedal and fine intrapedal pores (XPL); g) crumb-lenticular structure around the big crossections of the roots (PPL); h) zone with humus-clay-carbonate micromass and carbonate matrix pedofeatures, ferruginized excrement of soil microfauna (XPL)

Pedogenesis and Soil classification

This is texture-differentiated alkaline soil with shallow permafrost but without cryoturbations in standard profile (can be seen in larger one). The genesis of texture differentiation is likely related to sodium and magnesium in exchangeable bases but it is in contradiction with clay mineral distribution as smectite is relatively stable in alkaline conditions. Another explanation is that the differentiation was of acid origin, but the reaction is masked by periodical upward migration of the bases to the front of freezing. Anyway, the processes result in the strong clay translocation and the formation of E and Bt horizons. However, the cutans are not well-pronounced as cryogenic redistribution destroy them and involve the translocated clay into the matrix. This unusual combination of environment and soil properties (alkaline soil under acid litter and typical taiga vegetation) can add to WRB subunits. Now we classify the soil as Haplic Cryosol (Calcaric, Siltic, Albic, Luvic, Sodic), and last three qualifiers are suffix ones because they are not anticipated and Albic and Luvic ones are not in the list of Cryosol prefix qualifiers. They should be added. Soil Taxonomy is better in this case as it has the subgroup of Natric Argiorthels. This name fully reflects the properties and genesis of this soil. The correlation in Russian system is problematic as the texture differentiation is too strong for a Pale soil and neither eluvial nor illuvial horizon fit criteria of that of Podzolic soils or Solonetzes because of reaction, thin cutans and structure.

Particle-size distribution

Horizon	Depth, cm	Bulk density	Sand >0,063	Silt 0,063-0,002	Clay <0,002
O	10-0	-	-	-	-
E	0-5(12)	1,41	4,22	88,60	7,18
Bt	5(12)-14(20)	1,30	3,88	60,06	36,06
Bwk	14(20)-45	1,37	3,38	79,54	17,08
BCkf	45-80	1,39	3,85	80,63	15,52
BCkffrozen	80-90	-	4,44	82,6	12,96

Analytical data

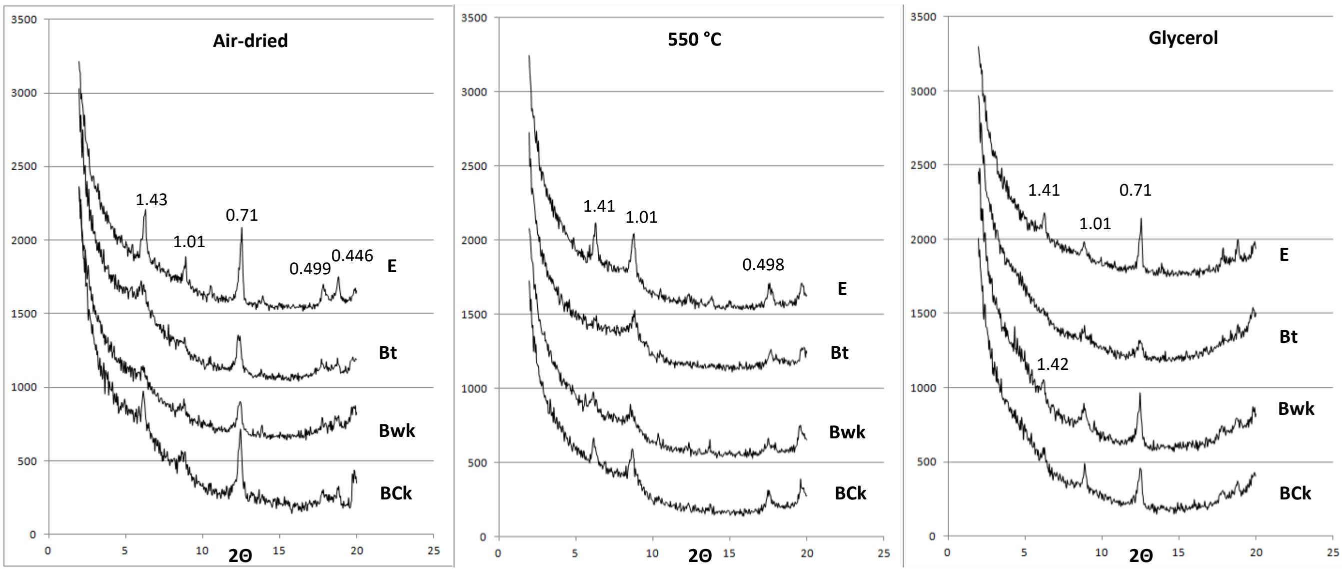
Horizon	Depth, cm	pH H2O	pH KCl	EC, dS/m	C wetcomb., %	C drycomb., %	Loss on ignition, %	Fe_2O_3d (Mehra-Jackson)	Fe_2O_3o (Tamm)	Fe_2O_3 total	Al_2O_3d (Mehra-Jackson)
O	10-0	6,40	5,20	-	-	-	77,39	-	-	-	-
E	0-5(12)	8,15	6,65	0,07	1,65	1,92	-	0,94	0,30	3,60	0,07
Bt	5(12)-14(20)	7,65	6,35	0,06	0,74	1,23	-	1,74	0,42	6,45	0,36
Bwk	14(20)-45	9,05	7,90	0,12	0,64	2,50	-	0,87	0,20	4,55	0,19
BCkf	45-80	9,30	7,90	0,11	0,48	0,94	-	0,97	0,20	5,07	0,16
BCkf frozen	80-90	9,35	7,95	0,14	0,33	0,97	-	1,02	0,20	4,69	0,14

Cation exchange capacity and exchangeable bases

Hori-zon	Depth, cm	*NH4OAC*						*AgTU*						*BaCl2*	$CaCO_3$
		Bases, cmol/kg					CEC cmol/kg	Bases, cmol/kg					ECEC, cmol/kg	CEC cmol/kg	
		Ca^{2+}	Mg^{2+}	K+	Na+	Sum		Ca^{2+}	Mg^{2+}	K+	Na+	Sum			
E	0-5(12)	4,02	3,81	0,00	1,05	8,88	6,24	4,11	2,88	0,00	0,99	7,99	5,39	8,33	
Bt	5(12)-14(20)	15,53	14,87	0,42	0,89	31,71	22,54	13,79	14,39	0,24	0,93	29,35	25,77	24,17	
Bwk	14(20)-45	21,23	10,86	0,21	0,60	32,90	8,15	21,86	10,75	0,04	0,52	33,17	26,46	16,67	9,37
BCkf	45-80	19,87	10,13	0,18	0,55	30,73	10,28	17,08	10,23	0,13	0,56	28,00	23,18	16,67	4,05
BCkf frozen	80-90	15,31	9,66	0,25	0,64	25,86	7,35	18,67	9,85	0,23	0,96	29,71	22,98	16,67	4,05

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
E	0-5(12)	2,87	1,54	14,09	68,32	0,08	0,18	0,02	2,64	1,64	0,66	0,04	3,60
Bt	5(12)-14(20)	1,49	2,71	17,35	57,66	0,12	0,12	0,02	2,61	1,64	0,76	0,06	6,45
Bwk	14(20)-45	1,46	3,14	13,61	56,08	0,12	0,16	0,03	2,51	5,89	0,61	0,06	4,55
BCkf	45-80	1,92	3,08	15,78	61,81	0,12	0,14	0,03	2,66	3,20	0,78	0,07	5,07
BCkf frozen	80-90	1,74	2,45	14,54	59,27	0,14	0,14	0,02	2,46	2,78	0,70	0,07	4,69



The E horizon of this profile contain mainly well-crystallized minerals: chlorite, illite, and kaolinite. Other horizons, namely Bt, Bwk and BCk, in contrast, have mainly illite-vermiculite, chlorite-vermiculite and kaolinite with minor presence of illite, chlorite (only in the Bwk and BCk horizons), and only traces of swelling components in the Bwk horizon. Taking into account common composition of the parent materials in the region (illite + smectite + kaolinite with some chlorite), we can hypothesize that pedogenetic processes resulted in the destruction of smectite and gradual transformation of illite and chlorite to mixed-layered minerals with vermiculite layers. In the upper horizon these metastable components seem to dissolve, leaving only resistant “pure” minerals.

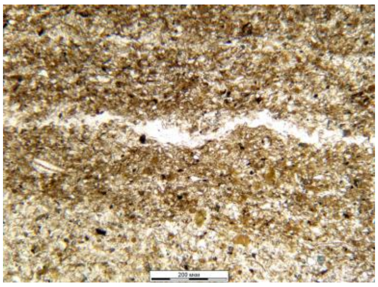
Abalakh alas. Salic Fluvisol. Profile 13-1.

This is very specific soils with sodium-carbonate-chloride salinization and deep talik under mass of water of Abalakh lake.

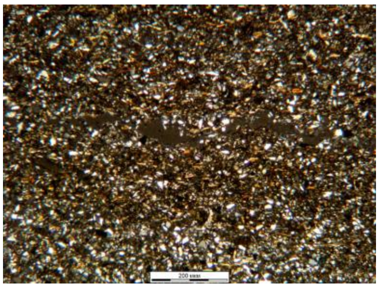
<table>
<tr><td colspan="5">Sites 13-1, 13-2 N61^{0}41’04,4” E131^{0}09’40,05” H~157 m
Salt lake Abalakh; profiles are on the terrace</td></tr>
<tr><td colspan="5">Site 13-1 near the lake shore, 100 m away from the water boundary, flat ground surface. Projective cover - 15%. Gray bare surface with some spots of Salicornia. The pit was established on vegetation pattern, the surface has greenish algal films, no salt crust.</td></tr>
<tr><td>Ak</td><td>Wca</td><td>0-2</td><td>2.5Y 4/1 yellowish gray; moist; soft consistence; silt loam; platy-subangular blocky structure; many roots</td><td rowspan="5">Gleyic Episalic Fluvisol (Sodic Siltic Alcalic Carbonatic)

Soil Taxonomy Typic Gelaquent

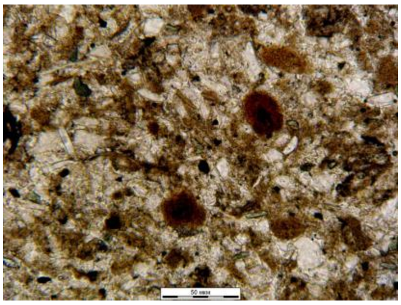
Russian Солончак глеевый содовый Solonchak gleyic sodium carbonate</td></tr>
<tr><td>Ck</td><td>Cca</td><td>0-10</td><td>2.5Y 5/2 dark grayish yellow; silt - fine layered material: alteration of gray and dark gray layers with higher content of clay and silt; layers thickness – first mm; slightly hard lacustrine sediments; boundary - abrupt distinctness, smooth topography.</td></tr>
<tr><td>2Ckzr</td><td>DG1ca s</td><td>10-40</td><td>10Y 5/1 gray, slightly hard; silt; alteration of layers with silty and sandy material; layers thickness – first mm to first cm; few vertically oriented intrusions of the upper horizon 1-2 cm wide and 12 cm long; platy structure; few roots; boundary - clear distinctness, smooth topography.</td></tr>
<tr><td>3Ckz</td><td>D2ca</td><td>40-60</td><td>2.5Y 4/2 dark grayish yellow; silt; weakly layered material; few roots; boundary - clear distinctness, smooth topography.</td></tr>
<tr><td>4Ckr</td><td>D3ca</td><td>60-90(105)</td><td>5Y 4/1 gray; more dark than the upper material</td></tr>
<tr><td>5Ckhr</td><td>D4hca</td><td>90(105)-120</td><td>5Y 2.5/2 olive black; slightly hard; moist; silt loam; matrix of lacustrine genesis with many inclusions of woody and grassy remnants some of which are coalified; fine orange mottles; boundary - abrupt distinctness, irregular (wedge-shaped) topography.</td><td rowspan="3">Borehole to 250 cm depth, t=+4^{o}C, no permafrost observed, probably due to the deep talik</td></tr>
<tr><td>6Ckr</td><td>D5g</td><td>120-170</td><td>Patchy – on olive-gray (5GY 5/1) matrix there are 7.5YR 4/4 brown mottles; silt loam; boundary - abrupt distinctness, smooth topography.</td></tr>
<tr><td>7Ckr</td><td>D6G</td><td>170-250</td><td>Borehole sample. 5 GY 5/1 olive-gray, slightly hard; wet; silt loam; plastic.</td></tr>
</table>



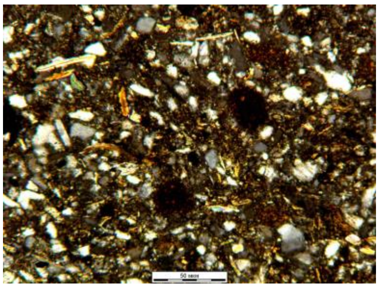
a) 0-10 cm



b) 0-10

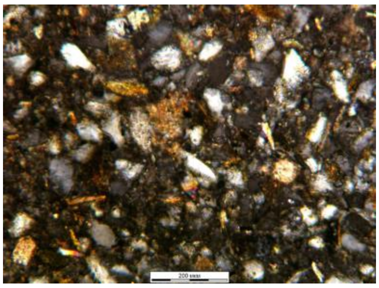


c) 0-10



d) 0-10

e) 0-10



f) 10-20

Fig. 3 . Microfeatures (prof. 13.1) a) sedimentogene bended distribution of fine and coarse particles (PPL); b) the same field, the sub-horizontal distribution of mica plates of (XPL); c) ferruginous coatings on minerals and small ferruginous nodules (XPL); d) the same, angular coarse grains and plates of mica (XPL) e) single thin carbonate coatings (XPL); f) fine carbonate micronodules, slightly crystallitic b-fabric (XPL).

Micromorphology

A - 0-10 cm. The material is heterogeneous by color (pale light yellow and brownish-reddish layers) within the platy units. This heterogenity is due to banded distribution pattern of silty and clayey-silty materials (Fig. 3a). The content of the fine material is particularly low in layers with a predominance of coarse silt size grains (undifferentiated b-fabric; c /f related distribution - coarse monic), in the layers with highest content of claythefine material is carbonate-clay-humus(b-fabric is crystallitic), groundmass is dense silty clay (c / f related distribution is close porphiric). Subhotizontal distribution and orientation of the mica plates (biotite-phlogopite ones and light mica - muscovite) and thin fragments of carbonized plant tissues suggests that the deposition of the material took place in stagnant water (Fig. 3b). There is finely dispersed organic matter and fine charcoal particles in composition of the micromass.The live roots are large and they dissect platy aggregates. Mineral composition of the coarse fractions isvarious and includingquartz, feldspar, different micas, amphibole, epidote, calcite and aragonite. The grains of minerals are ocovered with Fe-coatings (Fig. 3c, d). The very small micritic coatings and carbonate nodules are met rarely (Fig. 3e, f).

Conclusion. The soil is formed on the lacustine sediments, which are characterized by alternating of fine silt, coarse silt and clayey silt layers. Subhorizontal distribution of mica platelets suggests periodically slow sedimentation of silt particles in the stagnant water. Microfeatures of soil formation are weakly manifested. You can note the weak migration of carbonates to form rare coatings and very small nodules (segregation embryos). Fresh roots dissect sedimentogenic platy aggregates and layers.Active biogenic processing is not identified. Fe-coatings on mineral grains are most likely inherited from the soil-forming material.

Particle-size distribution

Horizon	Depth, cm	Bulk density	Sand >0,063	Silt 0,063-0,002	Clay <0,002
Ak	0-2	1,30	5,66	79,68	14,66
Ck	0-10	1,41	6,44	84,18	9,38
2Ckzr	10-40	1,51	2,85	93,13	4,02
3Ckz	40-60	1,34	6,70	88,24	5,06
4Ckr	60-90(105)	1,59	5,10	90,92	3,98
5Ckhr	90(105)-120	1,49	3,12	80,30	16,58
6Ckr	120-170	-	4,57	76,71	18,72
7Ckr	170-250	-	3,64	76,90	19,46

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	0-2	2,45	4,52	14,44	64,08	0,18	0,13	0,06	2,85	4,17	0,72	0,07	3,74
Ck	0-10	3,07	3,87	13,66	63,82	0,15	0,15	0,18	2,75	3,81	0,62	0,06	3,51
2Ckzr	10--40	2,62	6,13	13,93	59,66	0,13	0,17	0,31	2,78	3,96	0,74	0,08	4,70
3Ckz	40-60	2,93	3,20	13,25	60,17	0,14	0,12	0,09	2,54	3,70	0,63	0,06	4,05
4Ckr	60-90(105)	2,25	2,55	14,75	62,47	0,15	0,17	0,03	2,69	3,41	0,69	0,06	4,31

Analytical data

Horizon	Depth, cm	pH H2O	pH KCl	EC, dS/m	C wetcomb., %	C drycomb., %	Loss on ignition, %
Ak	0-2	10,15	8,40	0,82	1,11	2,05	-
Ck	0-10	10,25	9,00	0,67	0,37	1,32	-
2Ckzr	10-40	10,15	9,00	1,18	0,54	2,01	-
3Ckz	40-60	10,30	8,80	0,52	0,27	1,11	-
4Ckr	60-90(105)	10,05	8,20	0,42	0,43	1,11	-
5Ckhr	90(105)-120	9,80	7,80	0,17	1,31	1,59	7,08
6Ckr	120-170	9,75	8,10	0,24	0,40	1,83	-
7Ckr	170-250	9,55	8,05	0,23	0,51	1,23	-

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	0-2	10,83	7,95	0,51	0,92	20,21	8,38	12,62	8,92	0,35	10,52	32,40	20,46	14,17	6,25
Ck	0-10	9,61	6,70	0,33	10,80	27,44	7,25	13,27	9,31	0,22	15,92	38,72	23,02	11,67	6,12
2Ckzr	10-40	9,39	10,91	0,55	16,64	37,49	11,50	9,23	12,71	0,29	24,64	46,86	31,12	16,67	9,05
3Ckz	40-60	11,61	7,84	0,32	9,38	29,15	7,10	13,42	11,91	0,17	12,53	38,02	27,60	10,83	5,59
4Ckr	60-90(105)	14,06	5,17	0,33	6,67	26,24	9,69	15,85	6,46	0,26	8,24	30,80	25,02	15,00	4,91
5Ckhr	90(105)-120	12,15	8,87	0,47	7,39	28,88	16,31	9,25	6,88	0,42	7,26	23,81	21,38	20,00	0,45
6Ckr	120-170	15,77	11,67	0,28	5,15	32,87	11,85	13,38	11,01	0,17	4,64	29,20	22,43	15,00	10,35
7Ckr	170-250	25,93	9,59	0,32	3,91	39,74	11,33	19,74	8,22	0,27	4,44	32,67	23,84	13,33	7,71

Pedogenesis and Soil classification

This soil is very unusual in cold conditions of the Northern hemisphere but more similar to those of arid areas of Antarctic. The soil is very primitive because of both the juvenility and the excess of toxic salts – see the table in the subchapter "General characteristics of investigated soils" at the end of "Day 4". These salts are mostly sodium carbonates and chlorides. The quantity of these salts are enough for the WRB criteria, but not fit criteria of salic horizon in Soil Taxonomy (electro conductivity >30 dS/m in saturated extract). The parent material is lacustrine sediment with well pronounced layers and lamellae differed in texture, carbon and other elements content. Reductic features are also pronounced in subsurface horizons. So, the classification of this soil is different in the systems we work with.

In the WRB system it is Gleyic Episalic Fluvisol (Sodic Siltic Alcalic Carbonatic), as Fluvisols are in front of Solonchaks in the key. Alcalic and Carbonatic are the new suffix qualifiers for Fluvisols. In Soil Taxonomy neither salic nor fluvic features are reflected in the name of the nearest subgroup - Typic Gelaquent. And in Russian system this soil is Solonchak gleyic sodium carbonate.

Abalakh alas. Stagnic Solonetz Turbic. Profile 13-2.

This is more developed soil on the lacustrine deposits of lake Abalakh.

<table>
<tr><td colspan="5">Site 13-2 15 m from site 13.1 and 85 m away from the lake water boundary. Halophytic meadow. 100% projective cover of grasses, dandelions, Salicornia.</td></tr>
<tr><td>Agk</td><td>AUgca</td><td>0-10</td><td>10YR 4/1 brownish gray; moist; slightly hard; silt; platy - fine crumbly; many roots; boundary - abrupt distinctness, wavy topography.</td><td rowspan="5">WRB
Mollic(?) Hyposalic Stagnic Solonetz (Magnesic, Siltic, Alcalic Turbic, Molliglossic?)

Soil Taxonomy
Mollic Natraqualf

Russian
Солонец темногуму-совый глееватый засоленный криотурби-рованный
Solonets dark-humus gleyish salinized cryoturbic</td></tr>
<tr><td>Btn@</td><td>ASNg@ca</td><td>10-20</td><td>2.5Y 2.5/1 black (similar colour on the intrapedal mass and on the ped surface but more dark on the last one presumably due to thin coatings); slightly hard; moist; silt; weak prismatic, but clear fine angular blocky structure; cryoturbations; few fine roots; boundary - abrupt distinctness, wavy and irregular (tongue-shaped) topography, tongues (<5 cm wide) of this horizon penetrate to 70 cm depth .</td></tr>
<tr><td>2Bgk</td><td>2BMgca</td><td>20-55</td><td>5 YR4/2 grayish brown matrix with many 5YR 4/6 reddish brown mottles (3-4 mm wide); slightly hard; moist; silt loam; platy to fine platy structure; boundary - gradual distinctness, smooth topography.</td></tr>
<tr><td>2BCgk</td><td>2BCgca</td><td>55-140</td><td>5Y 5/2 grayish olive; slightly hard; moist; silt loam; platy structure; redoximorphic patterns - few orange mottles and light gray fine mottles; boundary - clear distinctness, smooth topography.</td></tr>
<tr><td>3Cgk</td><td>Dgca</td><td>140-200</td><td>Layered material; altering of 2.5Y5/2 dark grayish yellow and 7.5Y 5/6 dark gray olive materials; silty loam; platy; few Mn induced mottles</td></tr>
</table>

Micromorphology

A (0-10) Non-uniform in color: on light grayish-brownish background lots of small brownish-yellow spots (Fig. 4a). Angular-blocky agregates are divided into separate coarse platy units. Matrix is characterized by high inter-, intra- and transpedal porosity. Plasma is humus-carbonate-clay, weakly anisotropic (Fig. 4b), with cryptocrystalline calcite, which is visible only at very high magnification. In intrapedal mass the organic material is represented by numerous carboniferiustissue fragments of different sizes, and in the pores and cracks the fragments of the roots of various degrees of decomposition are common. Dispersed dark humus (organinc pigment)predominates amoung humus microforms, andmicro-globular humus (humus punctuations) occur in certain microzones. The mineral composition of the skeletal grains includes quartz, feldspar, amphibole, pyroxene, thin plates of muscovite, thin crescent fragments of aragonite. The groundmass is greenish-yellowish in the reflected light. That indicates the impregnation of fine material with bivalent forms of iron. Clay and humus-clay coatings are characteristic. Many large pores and crackscontain silt infillings;clay coatings withlow birefringence of clay occur in smaller pores. The pedofeatures of different composition and probably agetake place. The groundmass is characterized by fine material which is relatively higher in content of carbonatesand lower in contents of fine sand and silt, incorporatingcomplex Fe-calcite nodules (Fig. 4c) and clayeyinterlayers. The dense clay infillings of small intrapedal pores include fine humus particles determining the small-spotted colourpattern of the material in thin sections.

Btn – 10-20 cm. Grayish-brown (darker than the upper A horizon, due to the lack of small brown spots of dense clay infillings), compacted and quite porous. The angular-blocky structureis characteristic. Horizon has a thick, almost isotropic clay-humus silty coatings (Fig. 4d). The microlamellaewith dark humus punctuations and fine silt size grains inclusions are characteristiceven for thin coatings (Fig. 4e). For intrapedal mass a high amount of carboniferous tissues (the size of their fragments is smaller than in the A horizon) is characteristic. Coatings are fragmented, in the form of small fragments (papules), they are assimilated into the groundmass like in the A horizon. The micromass is weakly anisotropic humus-carbonate-clay, carbonates are in the micritic form are scattered in the soil mass. The mineralogical composition as a whole is similar to the overlying horizon, but differ by the occurrence ofrandomly distributed angular grains of sand and larger plates of muscovite.

Bg- 20-55 cm. Heterogeneously coloured and generally contains less humus than overlying horizon. At the light brownish background the micro-zones are marked with a gray colour, their distribution is the chaotic(Fig. 4f). The structure is complex platy,angular blocky. There are nearly isotropic silty-clay-humus thin coatings and rounded papules in the intrapedal material. The matrix calcitenodules are found(Fig. 4g), these are visible only at very high magnification. The micromassis carbonate-clay, weakly anisotropic. Humus relics are found (Fig. 4g). Discret small particles of carboniferous plant tissuesoccur in small quantities.

Conclusion. Micromorphological features confirm that this soil can be classified as Solonetz, which is characterized by complex coatings indicating the multiphase input of fine material of different composition –fine silt, dispersed humus and clay. The heterogeneity of genetic horizons is related to cryoturbation. There are the relict humus aggregates with sharp boundaries(Fig. 4g) or humus micro-zones (with thin charcoal particles and dark dispersedhumus) with gradual transitions to the enclosing groundmass within the whole studied depth.

Particle-size distribution

Horizon	Depth, cm	Bulk density	Sand >0,063	Silt 0,063-0,002	Clay <0,002
Agk	0-10	1,33	3,03	89,53	7,44
Btn@	10-20	1,50	6,15	84,73	9,12
2Bgk	20-55	1,64	2,87	76,37	20,76
2BCgk	55-140	1,69	2,88	75,40	21,72
3Cgk	140-200	-	3,98	79,02	17,00

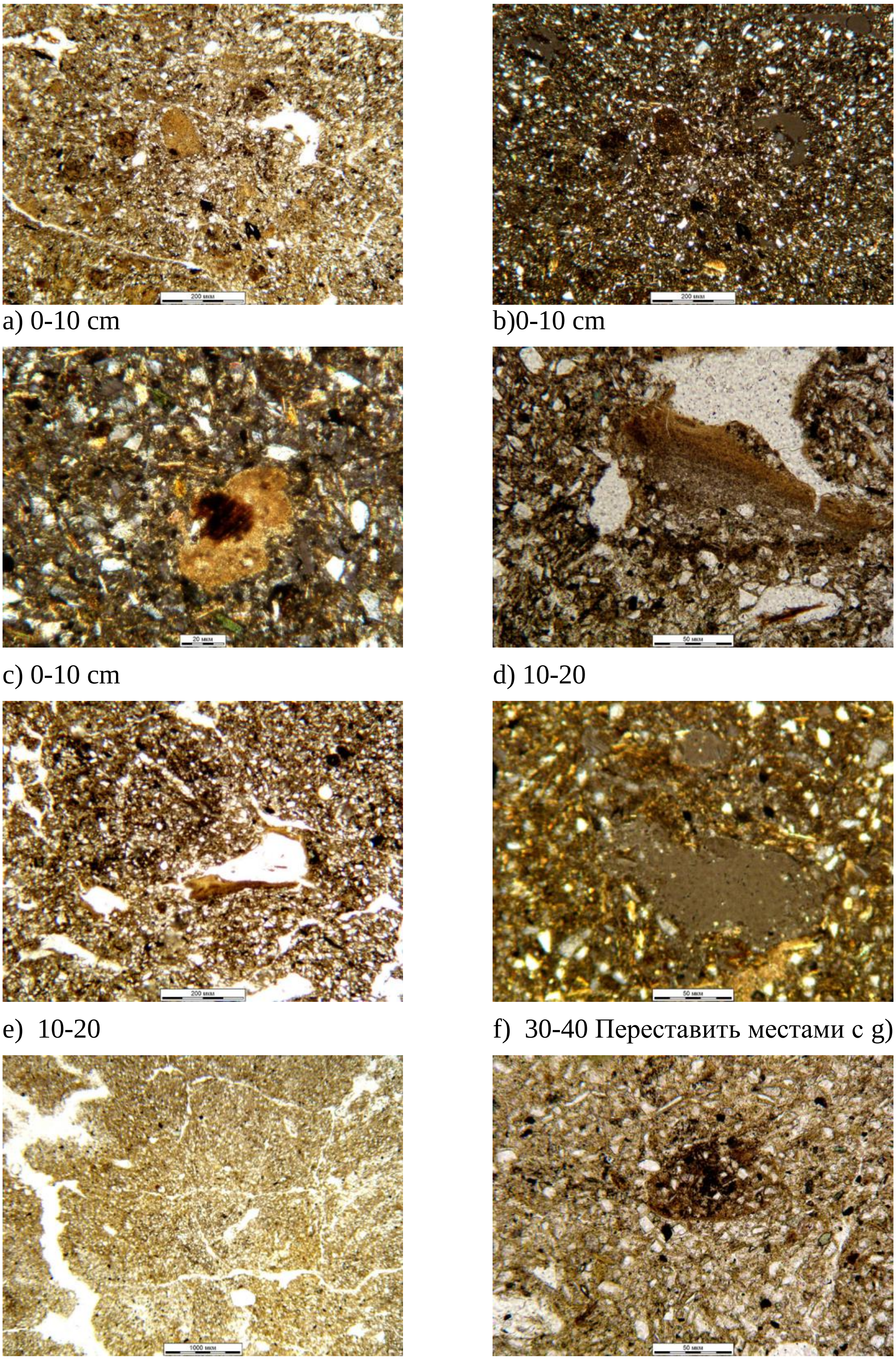


Fig. 4. Prof. 13.2 a) micro patchy colour pattern related to high amounts of yellow-brown clay infillings, concentrations of charcoal particles and humus impregnated microzones (PPL); b) clayey-silty-humus isotropic micromass (XPL); c) The complex iron-carbonate pedofeature (XPL); d) complex laminated silty-clay-humus coating (PPL); e) microlaminated humus-clay coating (PPL); f) crumb-platy structure of the inhomogeneous in composition groundmass (PPL); g) speckled-crystallitic b-fabric of the clay-carbonate-humus micromass (XPL); h) The humus relic pedofeature: ellipsoid with a sharp boundary (PPL)

Analytical data

Horizon	Depth, cm	pH H2O	pH KCl	EC, dS/m	C wetcomb., %	C drycomb., %	Loss on ignition, %
Agk	0-10	9,45	8,10	0,16	1,29	2,93	12,18
Btn@	10-25	9,95	8,35	0,30	1,10	2,30	9,55
2Bgk	20-55	9,70	8,30	0,52	0,31	1,39	-
2BCgk	55-140	9,50	8,10	0,33	0,24	1,03	-
3Cgk	140-200	9,05	7,90	0,28	0,46	0,93	-

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			
Agk	0-10	39,25	27,89	0,96	2,48	70,58	18,79	15,69	15,83	0,10	2,98	34,60	28,26	27,50	9,85
Btn@	10-25	28,97	36,97	0,37	8,46	74,78	17,66	10,69	22,89	0,23	7,73	41,53	29,59	21,67	8,91
2Bgk	20-55	14,90	14,79	0,19	7,02	36,89	9,26	13,93	17,75	0,16	9,25	41,09	28,43	17,50	8,73
2BCgk	55-140	17,34	12,47	0,20	4,52	34,53	11,54	17,91	12,01	0,21	4,97	35,11	26,55	13,33	7,28
3Cgk	140-200	21,99	8,75	0,35	2,40	33,50	12,68	19,71	7,71	0,25	2,88	30,54	24,13	13,33	4,14

Pedogenesis and soil classification

This soil is developed also on lacustrine sediments but not so layered than 13-1 profile because of more stable position. Solonetz with well manifested stagnic features is developed here. In WRB we classify this soil as Mollic(?) Hyposalic Stagnic Solonetz (Magnesic, Siltic, Alcalic Turbic, Molliglossic?). Last three qualifiers are not in the list of WRB 2006 edition for Solonetz. The question mark was put for Mollic because the horizon itself has 10 cm and while mixing with underlay it is not clear whether the structure fit Mollic criteria. Also not sure about if it is enough Molliglosic feature to name the soil. The correlation in the Soil Taxonomy is Mollic Natraqualf as there is no Gelaqualfs in this system. The properties fit Mollic subgroup criteria. In Russian system this soil is Solonets dark-humus gleyish salinized cryoturbic.

DAY 3.

Desyatkin Alas. Cryic Limnic Histosol. Profile 9-1.

Sites 9-1, 9-2, 9-3 62^{0}09’28,0” 130^{0}35’24,7” Vicinities of Tyungyulyu village, alas				
Site 9-1 2 meters from the lake edge. 100% projective cover of grasses, beadruby, knotgrass, rare mosses, sedges, reed along the shore.				
L1	LDv	0-3	10 YR 3/2 brownish black; moist; soft consistence; many grass roots; boundary – clear distinctness, wavy topography.	WRB – Cryic Sapric Limnic Histosol (Sodic, Alcalic, Magnesic) Soil Taxonomy Typic Sapristel Russian Торфяная эутрофная мерзлотная Peaty eutrophic permafrost
L2	LD1	3-50	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.	
Lf	⊥LD2	50-80	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	
Temperature profile at site9-1				
	Depth,	t ^{0}C		
	0	10,7		
	10	6,6		
	20	6,6		
	30	5,7		
	40	4,2		
	50	2,9		
	60	1,5		
	70	0,6		
	80-85	-0,3		

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	0,31	-	-	-
Lf	50-80	0,36	-	-	-

Analytical data

Horizon	Depth, cm	pH H2O	pH KCl	EC, dS/m	C wetcomb., %	C drycomb., %	Loss on ignition, %
L1	0-3	-	-	-	66,36*	35,69	-
L2	3-50	8,85	7,55	0,12	84,90*	68,26	86,17
Lf	50-80	9,35	8,05	0,13	61,03*	41,63	64,20

Cation exchange capacity and exchangeable bases

		NH4OAC						*AgTU*						*BaCl2*	
		Bases, cmol/kg						Bases, cmol/kg							
Hori-zon	Depth, cm	Ca^{2+}	Mg^{2+}	K+	Na+	Sum	CEC cmol/kg	Ca^{2+}	Mg^{2+}	K+	Na+	Sum	ECEC, cmol/kg	CEC cmol/kg	$CaCO_3$
L2	3-50	48,19	86,42	0,07	2,19	136,87	85,76	8,47	34,93	0,04	2,36	45,80	37,80	127,08	4,93
Lf	50-80	37,80	60,78	0,17	4,50	103,25	42,97	8,14	34,96	0,07	4,63	47,80	36,56	71,67	-

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 Limnic Histosol (Sodic, Alcalic, Magnesic) 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. Thapto-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
Gleyic
Thapto-Histic
Limnic Fluvisol
(Calcaric, Sodic,
Alcalic, Magnesic,
Turbic)

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

Russian
Иловато-Торфяная
эутрофная
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	0,81	43,5	47,84	8,66
L	10-20(35)	0,68	-	-	-
Lk@	20(35)-50(52)	1,04	-	-	-
Lk	50(52)-62	0,91	-	-	-
Cr	62-90	1,59	37,73	52,05	10,22
Crh	90-120	1,43	11,48	72,78	15,74
Crf	120-250	-	65,39	28,57	6,04

Analytical data

Horizon	Depth, cm	pH H2O	pH KCl	EC, dS/m	C wetcomb., %	C drycomb., %	Loss on ignition, %
AH	0-10	9,95	9,00	0,96	30,31*	14,24	28,40
L	10-20(35)	9,25	8,45	0,41	49,60*	39,64	37,26
Lk@	20(35)-50(52)	9,15	8,00	0,20	8,02	9,73	13,86
Lk	50(52)-62	9,00	7,90	0,08	7,26	7,61	15,60
Cr	62-90	9,25	8,30	0,15	0,76	1,23	6,25
Crh	90-120	9,10	8,20	0,15	1,64	2,38	8,98
Crf	120-250	9,25	8,30	0,20	0,55	1,56	-

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	13,10	77,38	0,17	9,92	100,58	31,31	0,54	39,02	0,02	11,03	50,61	37,06	49,17	6,53
L	10-20(35)	20,26	62,67	0,14	15,94	99,01	39,82	1,88	32,93	0,01	19,43	54,25	36,58	59,17	3,23
Lk@	20(35)-50(52)	23,70	17,28	0,21	1,10	42,30	11,73	9,84	14,16	0,13	1,22	25,35	20,27	20,83	3,77
Lk	50(52)-62	26,22	21,07	0,24	1,19	48,72	16,14	11,35	17,47	0,13	1,36	30,30	24,47	25,00	2,66
Cr	62-90	14,33	11,07	0,71	0,71	26,82	7,41	13,88	11,74	0,29	0,88	26,80	21,45	14,17	4,87
Crh	90-120	15,97	14,55	0,86	0,94	32,33	10,36	13,73	14,97	0,45	0,95	30,11	24,55	16,67	5,50
Crf	120-250	7,02	6,07	0,56	0,51	14,17	3,90	9,31	5,87	0,22	0,75	16,16	13,67	8,33	1,27

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 Gleyic Thapto-Histic Limnic Fluvisol (Calcaric, Sodic, Alcalic, 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. Endogleyic Stagnosol Albic Arenic Turbic. 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
Endogleyic Stagnosol (Albic, Calcaric, Sodic, Alcalic, Arenic, Turbic)

Soil Taxonomy
Turbic Gelaquept or Turbic Haplogelept

Russian
Элювозем глееватый криотурбированный
Eluvozem gleyish cryoturbic</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	1,18	74,31	22,61	3,08
E@	14-25	1,55	89,86	7,8	2,34
[A]@	25-34	1,54	77,52	12,9	9,58
E@	32-36		63,46	29	7,54
Bwg@	14-32	1,55	86,7	10,04	3,26
2BCg@	45-120	-	34,2	51,8	14
3Cg	120-160	-	29,69	57,19	13,12

Analytical data

Horizon	Depth, cm	pH H2O	pH KCl	EC, dS/m	C wetcomb., %	C drycomb., %	Loss on ignition, %
A	0-14	8,45	8,00	0,12	1,12	2,19	9,15
E@	14-25	9,60	8,45	0,08	0,27	0,70	3,41
[A]@	25-34	9,85	8,65	0,13	0,41	1,39	5,02
E@	32-36	9,85	8,60	0,16	0,21	1,22	5,42
Bwg@	14-32	9,70	8,50	0,09	0,16	0,75	-
2BCg@	45-120	9,25	8,05	0,16	0,27	1,01	-
3Cg	120-160	8,55	7,00	0,18	0,26	1,06	-

Cation exchange capacity and exchangeable bases

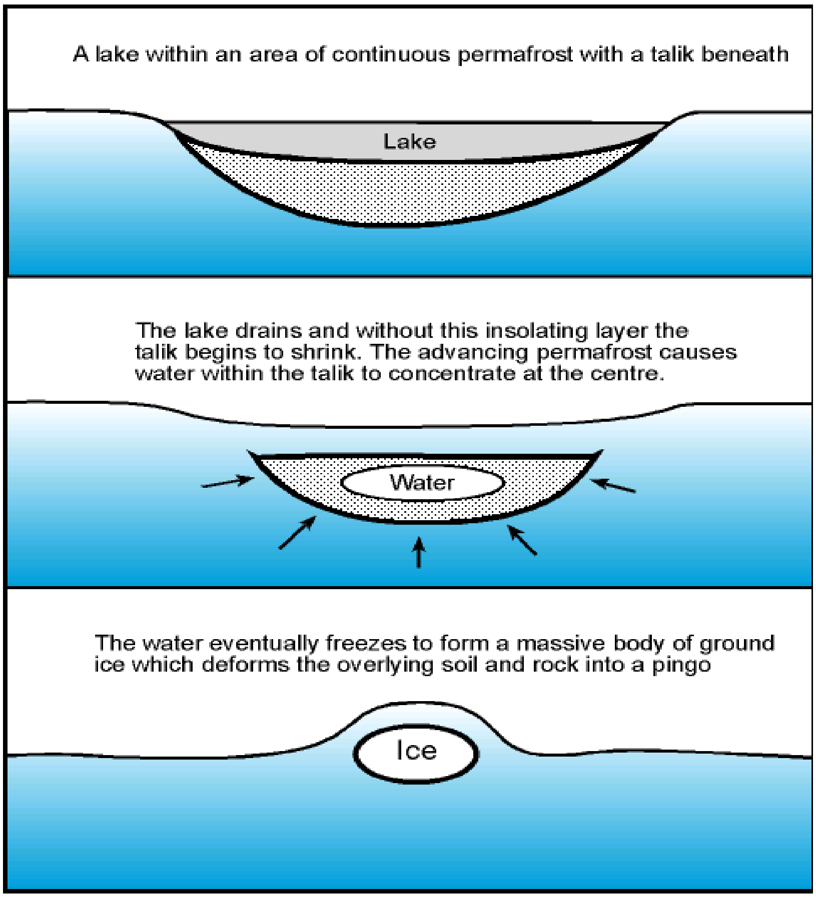
		NH4OAC						*AgTU*						*BaCl2*	
Hori-zon	Depth, cm	Bases, cmol/kg					CEC cmol/kg	Bases, cmol/kg					ECEC, cmol/kg	CEC cmol/kg	$CaCO_3$
		Ca^{2+}	Mg^{2+}	K+	Na+	Sum		Ca^{2+}	Mg^{2+}	K+	Na+	Sum			
A	0-14	23,50	15,02	0,81	0,10	39,43	8,09	13,42	11,17	0,17	0,06	24,83	20,59	18,33	4,23
E@	14-25	6,56	11,66	0,22	0,19	18,63	2,37	9,07	15,14	0,04	0,21	24,47	18,57	7,50	3,55
[A]@	25-34	9,79	17,72	0,22	0,69	28,42	3,41	11,41	20,64	0,04	0,19	32,28	24,41	6,67	6,55
E@	32-36	10,02	13,97	0,24	0,89	25,12	2,51	14,42	18,05	0,06	0,92	33,44	25,95	8,33	6,84
Bwg@	14-32	9,50	12,67	0,15	0,26	22,58	1,40	11,17	14,87	0,04	0,28	26,36	21,51	5,83	5,71
2BCg@	45-120	15,31	7,36	0,38	0,80	23,84	6,52	17,72	6,92	0,26	0,75	25,66	23,02	12,50	5,18
3Cg	120-160	14,49	8,84	0,35	1,05	24,73	6,48	17,42	5,89	0,18	0,68	24,16	20,90	11,67	4,80

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 Endogleyic Stagnosol (Albic, Calcaric, Sodic, Alcalic, Arenic, 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.

DAY 4.

Tabaga post-agrogenic soil. Stagnic Cambisol Calcaric. Profile 2-1.

Sites 2-1, 2-2, 2-3 trench established on the elements of cryogenic relief, "anthropogenic thermokarst". Abandoned arable land, close occurrence of polygonal ice wedges.

<table>
<tr><td colspan="4">Site 2-1 N61^{0}48’55,7” E129^{0}31’51,5”</td><td></td></tr>
<tr><td>A</td><td>AUpa</td><td>0-12(15)</td><td>2.5Y 3/1 brownish black; moist; loose; silt loam; fine blocky subangular with weak granular structure; many roots, earthworm channels; intrusions of the lower horizon in a form of fine mottles; boundary - abrupt distinctness, wavy topography.</td><td rowspan="5">WRB
Stagnic Cambisol (Calcaric, Endosodic, Alcalic, Turbic, Episiltic)

Soil Taxonomy
Turbic Haplogelept

Russian
Палевая темногуму-совая глеева-тая криотурби-рованная постагроген-ная
Pale dark-humus gleyish cryoturbic postagrogenic</td></tr>
<tr><td>Bwk</td><td>BPLca</td><td>12(15)-35</td><td>2.5Y 6/4 dull yellow; moist; silt loam; platy-blocky angular-blocky subangular structure; many roots; few fine calcareous soft concretions (d~2 mm); effervescence when reacted with HCl; earthworm channels; boundary - gradual distinctness, smooth topography.</td></tr>
<tr><td>BCkg@</td><td>BC1cag@</td><td>35-60</td><td>2.5Y 5/4 yellowish gray; similar to the overlying horizon, differs in heterogenity of colour – horizontal light gray and orange mottles and layers; loam, horizontal heterogenity in texture; big krotovinas at the 50-60 cm depth; platy structure, horizontal layers are locally deformated by cryoturbations; boundary - smooth topography.</td></tr>
<tr><td>BCkg</td><td>BC2cag</td><td>60-105</td><td>2.5Y 5/4 yellowish gray; differs from the overlying horizon in the absence of turbations and fewer roots; very old krotovina at the 80-90 cm depth.</td></tr>
<tr><td>2BCkg</td><td>2BC3cag</td><td>105-250</td><td>2.5Y 4/3 olive brown; silt loam, differs from the overlying horizons in less expressed horizontal layering, darker colour and higher content of Fe-Mn mottles. Permafrost at 250 cm.</td></tr>
</table>

Particle-size distribution

Horizon	Depth, cm	Bulk density	Sand >0,063	Silt 0,063-0,002	Clay <0,002
A	0-12(15)	1,27	33,86	59,96	6,18
Bwk	12(15)-35	1,54	32,23	58,77	9,00
BCkg@	35-60	1,50	50,75	38,37	10,88
BCkg	60-105	1,42	44,32	44,02	11,66
2BCkg	105-250	-	26,52	57,40	16,08

Analytical data

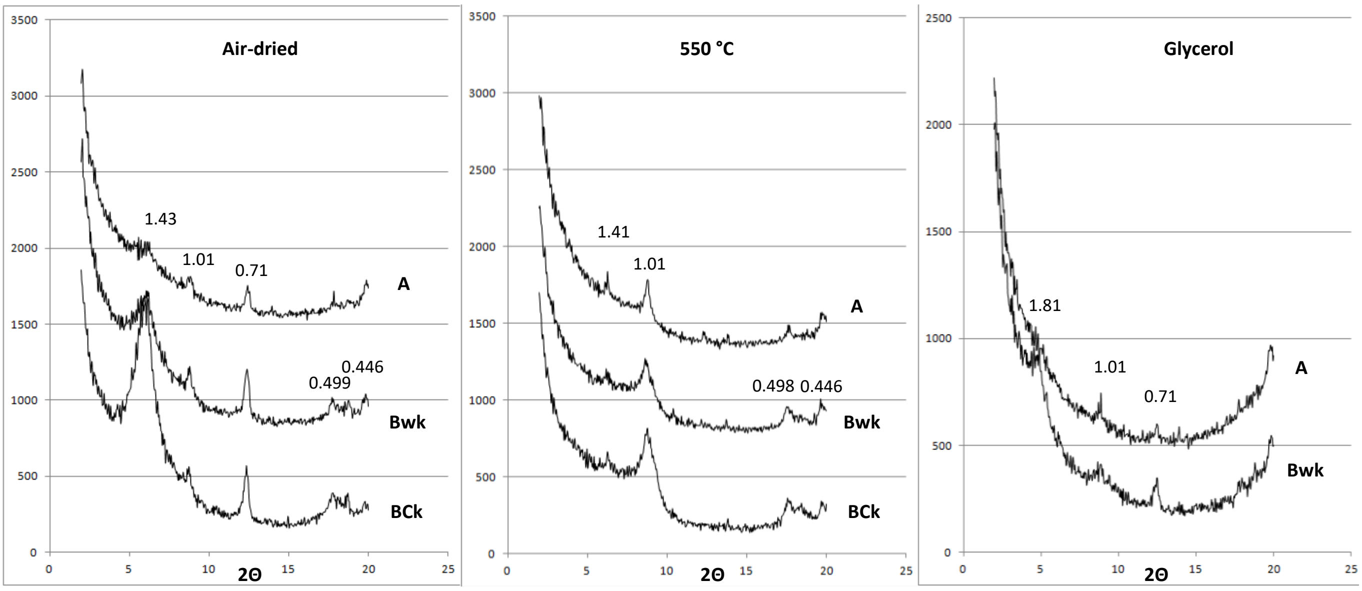
Horizon	Depth, cm	pH H2O	pH KCl	EC, dS/m	C wetcomb., %	C drycomb., %	Loss on ignition, %	Fe_2O_3d (Mehra-Jackson)	Fe_2O_3o (Tamm)	Fe_2O_3 total
A	0-12(15)	8,80	7,65	0,16	1,64	1,91	6,68	0,78	-	-
Bwk	12(15)-35	9,30	7,85	0,16	0,33	0,73	-	0,71	-	-
BCkg@	35-60	9,75	7,90	0,20	0,28	0,34	-	0,76	-	-
BCkg	60-105	9,75	7,95	0,22	0,42	0,42	-	-	-	-
2BCkg	105-250	9,60	7,85	0,25	0,42	0,67	-	-	-	-

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	0-12(15)	22,33	7,15	0,54	0,00	30,01	12,59	12,66	5,90	0,53	0,07	19,15	20,55	26,33	0,50
Bwk	12(15)-35	47,64	13,69	0,16	0,45	61,94	3,36	11,12	9,26	0,19	0,51	21,08	20,89	18,00	3,16
BCkg@	35-60	35,97	12,79	0,10	1,23	50,09	6,85	9,30	9,32	0,15	1,37	20,15	20,49	18,00	1,84
BCkg	60-105	31,40	13,25	0,16	1,71	46,52	5,04	8,42	9,83	0,16	1,89	20,30	21,54	16,33	2,09
2BCkg	105-250	28,03	11,13	0,20	2,17	41,53	6,29	7,54	8,74	0,22	2,30	18,80	22,50	15,50	1,91

Pedogenesis and Soil classification

This soil is also typical for the territory as soils in profiles 11 and 14 (Cryosols), however permafrost has gone from the control section because of forest cutting and ploughing in 1940s-50s. The soil is calcaric and probably slightly eroded as the upper ploughed horizon is only 12-15 cm in depth. Stagnic features result in classification of this soil in WRB as Stagnic Cambisol (Calcaric, Endosodic, Alcalic, Turbic, Episiltic).
In Soil Taxonomy this soil may be classified as Turbic Haplogelept. This name does not reflect stagnic features and the alkalinity of this soil.
Russian classification is adequately include main soil features - Pale dark-humus gleyish cryoturbic carbonate postagrogenic (eroded?).



The mineralogical composition of all the horizons of this soil is characterized by the presence of mixed-layered smectite-vermiculite, illite, and kaolinite. The 1.4 nm diffraction maximum is evident in all the horizons, but its intensity increases from the surface horizon to the BCk material. In the A horizon the signal is splitted into two peaks, of 1.43 and 1.48 nm. After heating only minor part of the peak remains at 1.4 nm; the intensities of the 1.4 nm peaks are identical in the samples from all these horizons. After saturation with glycerol the clay fraction of the Bwk horizon shows an expansion of the 1.4 nm mineral to 1.8 nm that confirms the presence of smectite. Strong asymmetry of the peak gives an evidence of the presence of vermiculite packages in the structure of this mineral. The signal at about 1.0 nm is similar in all the horizons. After heating to 550°C the intensity of the peak increases, and the increase is stronger in the BCk horizon than in the surficial horizon, reflecting the initial presence of the 1.4 nm phase. The diffraction maximum at 1.0 nm was interpreted as illite; the ratio of the intensities at 1.0 and 0.5 nm allows suggesting the presence of Mg-rich trioctahedral illite. Also there is a signal at 0.7 nm, which was interpreted as kaolinite, because it did not displace when the 1.4 nm mineral expanded. The intensity of this signal slightly increased with depth. Other minerals include quartz (peaks at 0.404 and 3.34 nm) and plagioclase (0.319 nm).

The interpretation of the mineralogical data is the following. The parent material contains expanding mineral, kaolinite, illite and chlorite. The expanding mineral is either high-charge smectite, or a mixed-layered regular vermiculite-smectite with low percentage of vermiculate layers. In the upper horizons the smectite mineral is destroyed, and the intensity of its signal decreases. The difference in the intensity cannot be ascribed completely to the partial disorientation of clay particles due to the presence of organic matter, because the intensity of the peaks correspondent to other minerals does not change much. The decrease in the intensity of kaolinite signal may be ascribed to the disorientation of clay particles or to the physical destruction of the clay particles; smaller fragments give less intensive signals.

Tabaga post-agrogenic soil. Luvic Phaeozem Albic Turbic. Profile 2-2.

Site 2-2 South-eastern side of the trench.				
A	AUv	0-4	10 YR 2/2 brownish black; moist; slightly hard; silt loam; fine blocky subangular structure; many grass roots; boundary - clear distinctness, wavy topography.	WRB Luvic Phaeozem (Albic, Sodic Siltic, Turbic) Soil Taxonomy Alfic Argicryoll or Turbic Haplogeloll Russian Солонец темногумусовый криотурбированный Dark solonetz dark-humus cryoturbated
A	AUpa	4-20	10 YR 2/1 black matrix with few mottles of the lighter hue; slightly hard; moist; silt loam; fine blocky subangular structure; many roots; boundary - clear distinctness, smooth topography.	
A	AU	20-30	10YR 2/1 black; slightly hard; moist; silt loam; blocky subangular-granular with elements of platy structure; common roots; boundary - clear distinctness, smooth topography.	
AE@	AU-SEL@	30-40	10YR 4/1 brownish gray matrix with numerous mottles of a lighter hue; moist; slightly hard; silt loam; platy-blocky subangular structure; few roots; boundary - clear distinctness, wavy topography.	
EA@	SEL-AU@	40-46	10YR5/2 grayish yellow brown; differs from the overlying horizon in a lighter hue, less expressed structure and fewer roots; boundary - abrupt distinctness, wavy topography.	
E	SEL@	46-60	10YR 6/1 brownish gray; slightly hard; slightly moist; silt loam; platy to fine platy structure; many very fine Fe concretions of 1-2 mm size; few roots; upper part of plates is lighter than the lower one; boundary - abrupt distinctness, wavy topography.	
EB	SEL-ASN	60-80	10YR 5/2 grayish yellow brown matrix with many fragments of the light gray colour; hard; silt loam; platy-fine blocky angular structure; silt-sized grains of light gray colour inside the plates; 2-4 mm thick horizontal and subhorizontal layers of dark slickenside-like material, probably originating from subsidence, these layers contain many roots; boundary - abrupt distinctness, wavy topography.	
Btn	ASN	80-100	Intrapedal mass - 10YR 4/4 brown, on ped faces - 10YR 3/1 brownish black; very hard; silt loam; slightly moist; strong prismatic-blocky angular structure; dark humus-clay cutans on ped faces; few roots; boundary - abrupt distinctness, wavy topography.	

Btn	BSN	100-120	Intrapedal mass - 10YR 4/3 dull yellowish brown, on ped faces - 10YR 4/2 grayish yellow brown; hard; slightly moist; silt loam; prismatic-blocky angular structure; structure is less expressed than in the overlying horizon; common shining humus-clay cutans on ped faces; few roots; boundary - clear distinctness, wavy topography.	
BCk	BCca	120-180	10YR 4/4 brown; slightly hard; moist; silt loam; platy and fine platy structure; few dark mottles along root channels; few roots; effervescence when reacted with HCL Permafrost at 250 cm depth (borehole data)	

Micromorphology

A – 20-30 cm. Dark gray-brown sandy-clayey-silty material with an opaque dark fine-dispersed materials (Fig. 5a, b), crumb microstructure. Some unevenness in color due to differences in the composition of the fine material of separate units takes place: the darker aggregates are of Fe-humus composition, more brown –of humus-clay ones.High microglobularity of the fine material is typical.Isotropic plasma includs very rare fine micritic grains, which are visible only at high magnification. A peculiarity of the horizon is the absence of large fragmentsof plant tissues. Therearefungalsclerotiamet.

E@ - 46-60 cm. For two thin sections of this horizon a fundamentally different structural organization and expression of clay cutansare characteristic(Fig. 5c, d). Common micromorphological features are sandy-clayey-silty matrix with an isotropic undifferentiated micromass, in some zones the fine humus-carbonate-clayey material have slightly crystallyticb-fabric. In thin section with a lighter color than the overlying horizon (light brownish) scaily lenticular structure is typical.There is banded distribution of fine particles in the lowerpart of peds and silty infillings on their upper faces (Fig. 5c). In thin section with a darker color a lot of small carbonized tissue fragments occur, the last ones are unevenly distributed and form separate clusters or nests. In some pores there are fresh thin clay coatings, which indicates a weak manifestation of the eluvial-illuvial process (Fig. 5d).

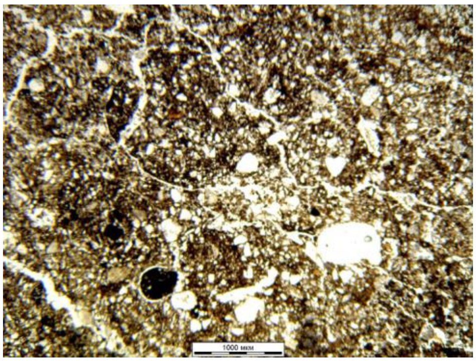
EB – 60-80 cm. Brown with well-pronounced structure – biglarge blocky and prismatic. Compared with the overlying horizon the content of carbonate-clay fine materialincreases, the micromass has distinct stipple-speckled (for one of the thin sections in this horizon) and crystallitic (for another thin section) b-fabric. Typical features are thin clay coatings and quasicoatings, relatively extensive ferruginous patterns and D-rings (Fig. 5e).

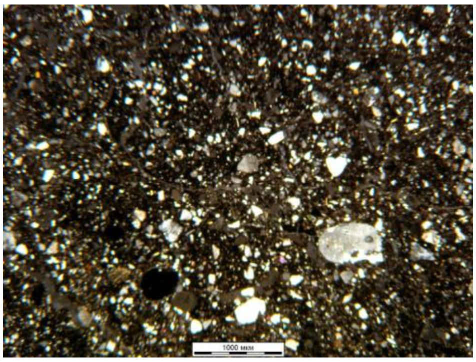
Btn – 90-95 cm. The main elements of the microstructure similar to a dark crumby spongy humus horizon with a tendency to form platy aggregates (Fig. 5g). The main micromorphological featuresallow an assumption that it is buried dark humus A horizon. The micromassis carbonate-clay-humus, isotropic (with a few micritic grains). Organic matter is microglobular (humus punctuations).

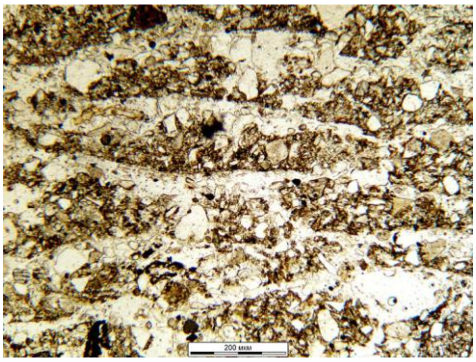
Bt – 100-120 cm. Dark, isotropicclay-silty-humusmaterial. The horizon is characterized by clay coatingsof different thickness, which are found both in the thin intra- and thick interpedal pores and channels (Fig. 5h). The thickestcutans are of humus-clay composition and splited into separate layers and fragments. Thelargestcharcoalparticlesarefragmented.

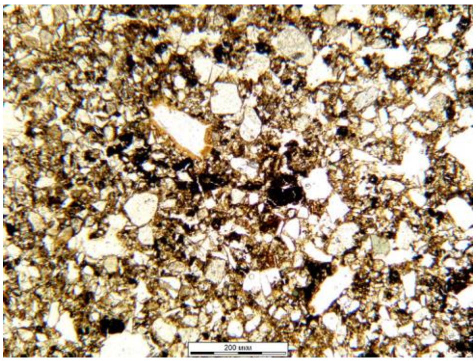
Conclusion. Currently the soil gets theeluvial-illuvial differentiation of the fine material. For the eluvial horizon (El @ 46-60 cm) microfeatures related to cryoturbations are characteristic resulted in neighbouring fragments of horizons which are different in microstructure and pedofeatures.Here the eluvial horizon with scaly-lenticular structure and silty infillings on top of the ped's faces (Fig. 5c) and illyuvial horizon with thin clay coatings (Fig. 5d) are distinguished.

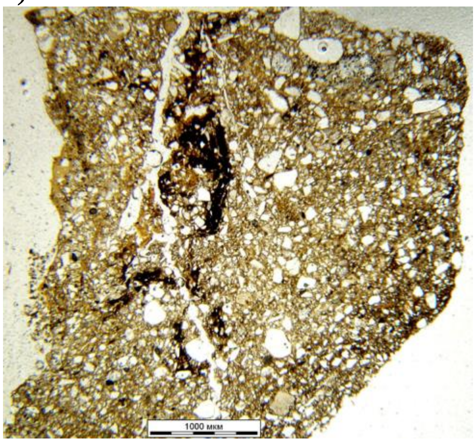
In the whole profile the high content of fine organic material is found in the micromass, this defines its isotropic, undifferentiated b-fabric. On this backgroundrecent layered clay coatings and hypocoatings are clearly visible(Fig. 5h).

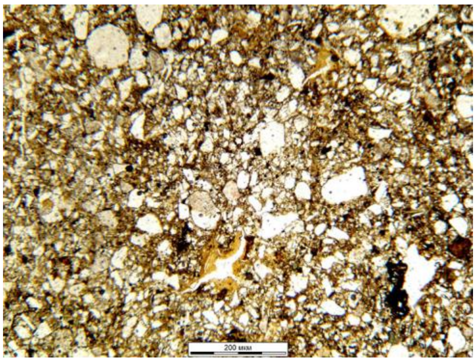

a) 20-30 cm

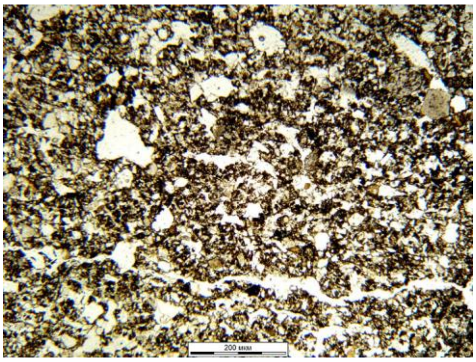

b) 20-30 cm


c) 46-60 cm


d) 46-60 cm


e) 60-80 cm


f) 60-80 cm


g) 90-95 cm

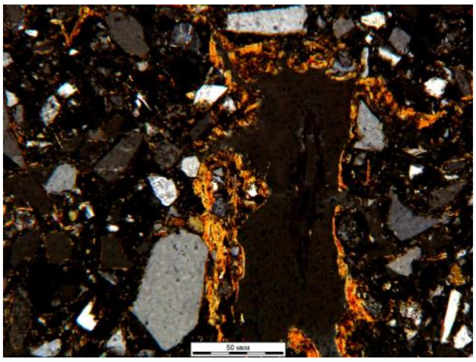

h) 110-120

Fig. 5. (prof. 2.2): a) Dark gray, crumb porous material with some difference in the content of iron-clay-humus fine material (PPL); b) the same field, sandy-clayey-silty material with isotropic fine material (XPL); c) area with a lenticular structure with a banded distribution of clay and silty infillings (PPL); d) area with a massive microstructure and thin clay coatings (PPL); e) large blocky structure with thin clayey and thick ferruginous pedofeatures (PPL); f) the same clay coatings in intrapedal mass at higher magnification (PPL); g) high porosity in the buried humus horizon (PPL); h) clay coatings and hypocoatings in isotropic sandy-clayey material (undifferentiated b-fabric) (XPL).

Particle-size distribution

Horizon	Depth, cm	Bulk density	Sand >0,063	Silt 0,063-0,002	Clay <0,002
A	0-4	1,21	34,47	49,67	15,86
A	4-20	1,55	32,92	51,18	15,90
A	20-30	1,34	28,76	52,80	18,44
AE@	30-40	1,38	30,83	53,09	16,08
EA@	40-46	-	33,52	55,24	11,24
E	46-60	1,47	38,14	53,84	8,02
EB	60-80	1,13	29,84	57,80	12,36
Btn	80-100	1,60	29,17	51,23	19,60
Btn	100-120	-	36,59	43,83	19,58
BCk	120-180	-	36,52	47,04	16,44

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
A	0-4	6,95	6,85	0,14	2,95	3,22	8,16	1,26	0,35	3,70
A	4-20	7,20	6,35	0,09	1,96	2,95	6,99	0,88	0,24	3,48
A	20-30	7,50	6,30	0,20	2,23	2,51	8,53	1,06	0,40	4,00
AE@	30-40	7,70	6,25	0,16	1,67	1,98	6,87	1,02	0,27	4,03
EA@	40-46	8,70	6,95	0,16	2,40	2,74	5,57	0,87	0,19	3,28
E	46-60	8,65	7,15	0,20	0,75	0,86	3,20	0,63	0,26	3,04
EB	60-80	7,75	6,75	0,55	1,34	1,62	8,08	1,04	0,28	3,52
Btn	80-100	8,80	7,00	0,28	0,53	1,20	6,24	0,91	0,25	4,05
Btn	100-120	9,00	7,25	0,29	0,47	0,49	-	0,83	0,19	3,83
BCk	120-180	9,55	8,10	0,46	0,54	1,84	-	0,85	0,20	3,51

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	0-4	16,60	4,48	0,87	0,00	21,95	13,88	11,30	3,92	1,04	0,08	16,34	18,85	25,00	-
A	4-20	14,53	5,49	0,23	0,20	20,46	14,37	9,61	5,00	0,22	0,30	15,13	18,73	22,50	-
A	20-30	16,50	7,73	0,08	2,39	26,70	13,65	8,69	6,03	0,11	2,90	17,72	20,82	29,17	-
AE@	30-40	12,94	7,10	0,07	2,21	22,32	10,56	7,60	5,72	0,05	2,46	15,83	20,07	26,67	-
EA@	40-46	10,44	7,88	0,02	2,70	21,03	10,51	4,54	4,97	0,05	2,81	12,37	19,53	20,83	-
E	46-60	4,93	5,33	0,00	2,37	12,63	4,21	2,22	3,20	0,03	2,20	7,63	16,31	15,00	-
EB	60-80	14,01	13,20	0,03	5,18	32,40	17,14	3,98	6,46	0,03	4,67	15,14	25,23	29,17	-
Btn	80-100	8,56	13,48	0,11	3,85	26,00	9,60	3,21	7,13	0,07	3,41	13,81	23,98	25,00	-
Btn	100-120	5,19	11,56	0,13	3,73	20,61	7,93	2,66	7,50	0,08	3,29	13,52	23,65	19,17	-
BCk	120-180	127,59	20,27	0,12	2,86	150,84	6,92	8,57	8,92	0,07	2,62	20,18	26,94	12,50	7,87

Bulk chemical composition, %

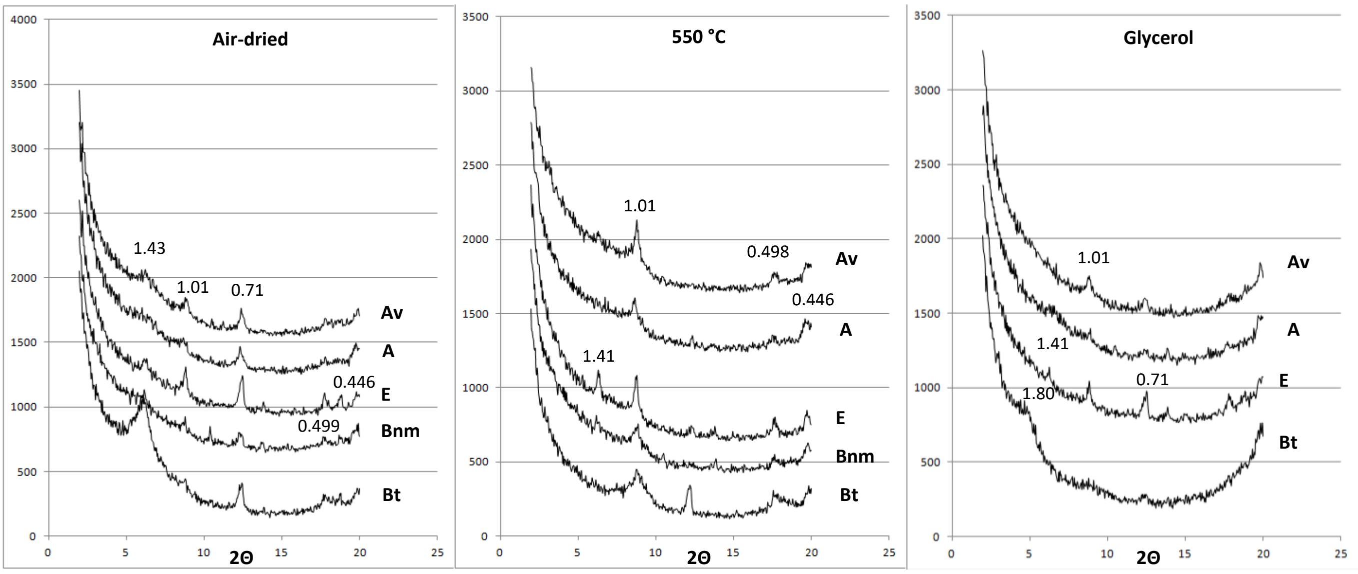
Horizon	Depth, cm	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	Cl	K_2O	CaO	TiO_2	MnO	Fe_2O_3
A	0-4	1,67	1,66	13,87	58,85	0,17	0,26	0,02	2,68	1,95	0,64	0,07	3,70
A	4--20	2,00	1,60	13,61	59,36	0,16	0,25	0,03	2,44	1,75	0,60	0,06	3,48
A	20-30	1,39	1,58	13,09	56,15	0,19	0,23	0,02	2,12	1,67	0,61	0,09	4,00
AE@	30-40	1,62	1,64	13,26	57,63	0,12	0,16	0,02	2,22	1,60	0,63	0,04	4,03
EA@	40-46	2,25	1,53	12,30	59,31	0,14	0,17	0,03	2,28	1,56	0,60	0,04	3,28
E	46-60	2,62	1,35	12,11	61,04	0,07	0,17	0,04	2,40	1,42	0,59	0,04	3,04
EB	60-80	2,14	1,52	12,02	56,18	0,15	0,32	0,04	2,19	1,63	0,61	0,06	3,52
Btn	80-100	1,74	1,99	13,81	56,22	0,12	0,21	0,03	2,21	1,41	0,64	0,06	4,05
Btn	100-120	1,89	1,85	13,80	55,74	0,06	0,16	0,03	2,21	1,24	0,55	0,05	3,83
BCk	120-180	1,32	2,54	11,96	50,41	0,09	0,25	0,05	2,03	7,36	0,50	0,04	3,51

Pedogenesis and Soil classification

The profile of this soil is not easy to interpret in respect of its genesis. It is mainly related to the subsidence of the surface because of thawing of ice (thermokarst) due to forest cutting and ploughing of this soil. Upper horizons can be accreted and alkaline sodium-induced differentiation can be overlapped by periodical overmoistening and dark humus migration. It is so dark that in parts looks like buried ancient humus horizon, but the whole set of properties confirm the illuial character of it. Now illuvial horizon fits criteria of natric horizon because of cutans and structure but not fit them in exchangeable sodium content.

Now this soil can be classified as Luvic Phaeozem (Albic, Sodic Siltic, Turbic) in the WRB system.
In Soil Taxonomy Alfic Argigeloll (like Alfic Argicryoll) would be adequate correlation but now we can classify this soil only as Turbic Haplogeloll, as soils with gelic regime are rare in the USA and thus poorly represented in the Soil Taxonomy.

In Russian classification this soil might have been classified as Dark solonetz dark-humus cryoturbated because of predominance of morphological criteria for Solonetzes in the Russian system.



The mineralogical composition of this profile is complex, and varies greatly between the horizons. A semiquantitative evaluation of the components is presented in the Table.

Semiquantitative mineralogical composition of the Profile 2-2

Horizon	m	ch	s	k	m-v	m-s	ch-v
Av	++			++	++		+
A	+			++	+		+
E	++	++		++	+		
Bnm	+	+		+	+		
Bt	+	+	+	+		++	

m – mica (illite); ch – chlorite; s – smectite; k – kaolinite; m-v – illite-vermiculite; m-s – illite-smectite; ch-v – chlorite-vermiculite

The entire profile has diffractograms of poor qualitythat can be partly ascribed to the presence of organic matter that favors disordering of clay particles. The two upper horizons A contain a mixture of illite, illite-vermiculite, and kaolinite with a minor presence of chlorite-vermiculite. The content of illite and mixed-layered illite-vermiculite is slightly higher in the surficial horizon than in the deeper subhorizon of A. The E horizon contains illite, chlorite and kaolinite with minor content of illite-vermiculite. The Bnm horizon has an unclear picture, but still it is possible to identify some illite, chlorite, kaolinite, and illite-vermiculite. The Bt horizon has a significant content of swelling mineral, presumably illite-smectite with smectite, with minor addition of illite, chlorite, and kaolinite. Most probably, the initial composition of clays was the same as in the neighboring profile, i.e. included illite, smectite, kaolinite, and chlorite. The pedogenetic processes resulted in the destruction of swelling components in the upper horizons, chlorite transformed to mixed-layered chlorite-vermiculite, and illite and kaolinite showed a relative accumulation in the surface horizon.

Tabaga post-agrogenic soil. Calcic Mollic Solonetz Albic. Profile 2-3.

<table>
<tr><th colspan="5">Site 2-3</th></tr>
<tr><td>A</td><td>AUpa</td><td>0-22</td><td>Similar to AUpa horizon at site 2-2.</td><td rowspan="6">WRB
Calcic Mollic Solonetz (Albic, Magnesic, Siltic, Turbic)

Soil Taxonomy
Typic Natricryoll or Turbic Haplogellol

Russian
Солонец темногуму-совый (но со светлосолон цовым горизонтом) криотурбиро ванный
Solonetz dark-humus cryoturbated</td></tr>
<tr><td>A</td><td>AU@</td><td>22-30</td><td>Similar to AU horizon at site 2-2, but more turbated – with invasions of the fragments from lower horizon, platy structure</td></tr>
<tr><td>E</td><td>SEL@</td><td>30-41</td><td>10YR 7/2 dull yellow orange; slightly moist; slightly hard / hard, silt loam; platy to fine platy structure; few roots; boundary - abrupt distinctness, wavy topography.</td></tr>
<tr><td>Btn</td><td>BSN</td><td>41-60</td><td>Intrapedal mass- 10YR 5/4 dull yellowish brown matrix, on ped faces - 10 YR 4/2 grayish yellow brown; hard; slightly moist; silt loam; prismatic-blocky angular structure, grayish brown clay cutans on ped faces, from 47 cm depth cutans become more rare; have a tendency to subhorizontal separation; boundary - abrupt distinctness, smooth topography.</td></tr>
<tr><td>Bk</td><td>BCA</td><td>60-110</td><td>10 YR 5/3 dull yellowish brown; slightly hard; moist; silt loam; fine platy structure; many carbonates (pseudomycelia and linear forms); few roots; boundary - gradual distinctness, smooth topography.</td></tr>
<tr><td>BCk</td><td>BCca</td><td>110-150</td><td>10 YR 4/4 brown, loam, similar to the same horizon at site 2-2, but differs in less expressed structure</td></tr>
</table>

Particle-size distribution

Horizon	Depth, cm	Bulk density	Sand >0,063	Silt 0,063-0,002	Clay <0,002
A	0-22	1,48	31,88	52,88	15,24
A	22-30	1,49	31,58	53,28	15,14
E	30-41	1,58	37,57	56,11	6,32
Btn	41-60	1,64	31,73	52,85	15,42
Bk	60-110	-	29,04	52,78	18,18
BCk	110-150	-	42,36	44,74	12,9

Analytical data

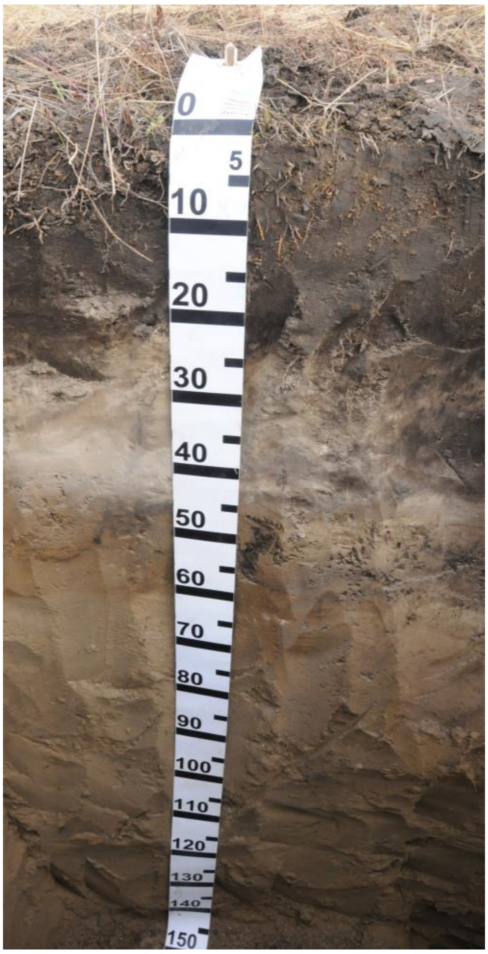
Horizon	Depth, cm	pH H2O	pH KCl	EC, dS/m	C wetcomb., %	C drycomb., %	Loss on ignition, %	Fe_2O_3d (Mehra-Jackson)	Fe_2O_3o (Tamm)	Fe_2O_3 total
A	0-22	7,35	6,30	0,05	2,01	2,39	7,20	1,04	0,19	3,60
A	22-30	8,55	6,85	0,05	1,66	1,95	6,74	1,08	0,20	3,37
E	30-41	8,55	6,95	0,16	0,33	0,36	-	0,62	0,12	2,78
Btn	41-60	9,45	8,00	0,20	0,65	0,79	-	1,18	0,18	4,19
Bk	60-110	9,55	8,15	0,54	0,59	2,53	-	0,69	0,10	3,16
BCk	110-150	9,50	7,80	0,19	0,29	0,64	-	-	-	3,46

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	0-22	14,26	5,49	0,52	0,11	20,37	11,59	11,05	5,11	0,63	0,16	16,95	18,06	20,83	-
A	22-30	14,87	5,82	0,14	0,98	21,80	9,84	12,37	5,60	0,17	1,09	19,22	19,85	16,67	-
E	30-41	4,88	2,89	0,02	1,46	9,24	4,06	3,26	2,43	0,05	1,65	7,40	5,96	7,50	-
Btn	41-60	6,65	14,29	0,18	4,04	25,15	6,99	6,57	13,42	0,16	5,06	25,21	22,70	17,50	0,09
Bk	60-110	167,62	27,55	0,09	4,19	199,44	6,42	19,33	14,59	0,10	4,66	38,68	27,52	14,17	15,42
BCk	110-150	38,45	12,89	0,15	2,35	53,85	6,19	18,60	10,92	0,21	2,73	32,46	24,33	15,83	2,20

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	0-22	1,79	1,61	13,44	58,82	0,16	0,23	0,02	2,51	1,80	0,60	0,06	3,60
A	22-30	1,60	1,60	13,26	58,91	0,15	0,19	0,02	2,39	1,87	0,63	0,06	3,37
E	30-41	2,45	1,27	12,83	64,38	0,07	0,15	0,03	2,40	1,69	0,61	0,03	2,78
Btn	41-60	1,82	2,56	15,00	56,45	0,09	0,24	0,03	2,28	1,69	0,62	0,05	4,19
Bk	60-110	1,13	2,96	10,00	44,56	0,05	0,38	0,07	1,89	14,47	0,41	0,03	3,16
BCk	110-150	1,52	2,34	13,83	54,92	0,06	0,15	0,02	2,26	2,64	0,52	0,04	3,46



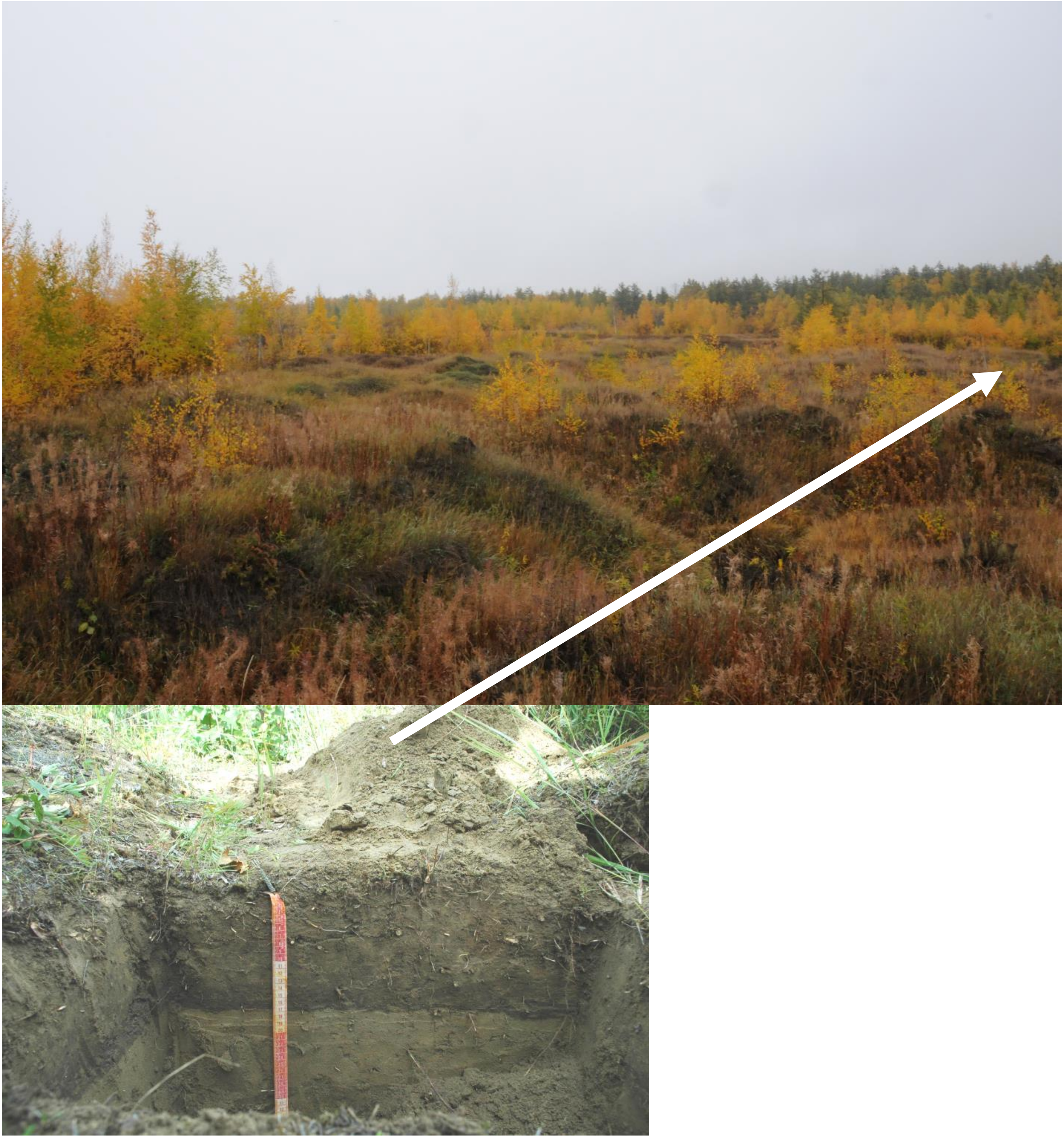
Pedogenesis and soil classification

This soil has the typical properties of Solonetz both in morphological and chemical ones. The only ultracontinental feature of this soil is well-pronounced cryoturbations. It should be classify as Calcic Mollic Solonetz (Albic, Magnesic, Siltic, Turbic) in the WRB.

Soil Taxonomy in this case is also not adequate because of poor elaboration of the systemsfor soils with gelic temperature regime. Ideally, it should be Turbic Natrigeloll i.e. something in between of Typic Natricryoll and Turbic Haplogeloll as it is classified now.

Russian name is Solonetz dark-humus cryoturbated, however the combination of dark-humus and light-solonetz horizon is not existed in the recent edition of the Russian system.

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.

Lena terrace. Stagnic Chernozem Molliglossic Turbic. Profile 5.

<table>
<tr><td colspan="5">**Site 5** N61^{0}55’00,6” E139^{0}33’45,0”, H~96 m

Established on the steppe site</td></tr>
<tr><td>Ak</td><td>AUpa ca</td><td>0-20</td><td>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.</td><td rowspan="6">WRB
Stagnic Chernozem (Molliglossic, Sodic, Siltic, Turbic)

Soil Taxonomy
Typic Cryaquoll
or
Turbic Haplogeloll

Russian
Чернозем глеев(ат)ый, темноязыковатый, криотурбированный; Chernozem gleyic dark-tounging cryoturbated</td></tr>
<tr><td>AB@k</td><td>AB@ ay ca g</td><td>20-32(40)</td><td>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.</td></tr>
<tr><td>Bk</td><td>BCA</td><td>32(40)-50</td><td>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.</td></tr>
<tr><td>BCgk</td><td>BCgca</td><td>50-90</td><td>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).</td></tr>
<tr><td>2Cg</td><td>D1g</td><td>90-150</td><td>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.</td></tr>
<tr><td>3Cg</td><td>D2g</td><td>150-220</td><td>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.</td></tr>
</table>

Particle-size distribution

Horizon	Depth, cm	Bulk density	Sand >0,063	Silt 0,063-0,002	Clay <0,002
Ak	0-20	1,19	12,00	64,30	23,70
AB@k	20-32(40)	1,27	10,69	61,97	27,34
Bk	32(40)-50	1,51	10,43	69,25	20,32
BCgk	50-90	1,53	16,85	69,99	13,16
2Cg	90-150	-	81,29	16,73	1,98
3Cg	150-220	-	31,85	55,53	12,62

Analytical data

Horizon	Depth, cm	pH H2O	pH KCl	EC, dS/m	C wetcomb., %	C drycomb., %	Loss on ignition, %
Ak	0-20	8,70	7,55	0,13	2,32	3,22	11,85
AB@k	20-32(40)	8,95	7,90	0,26	1,59	2,20	12,17
Bk	32(40)-50	9,00	8,00	0,39	0,37	2,19	-
BCgk	50-90	8,60	7,60	0,42	0,24	0,67	-
2Cg	90-150	9,35	7,70	0,13	0,15	0,39	-
3Cg	150-220	9,00	7,40	0,12	0,31	0,81	-

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	66,55	12,79	0,18	0,24	79,76	18,30	25,35	8,35	0,30	0,25	34,24	32,45	32,50	2,55
AB@k	20-32(40)	24,71	19,42	0,10	0,93	45,17	17,10	18,10	16,67	0,16	1,19	36,12	30,12	25,83	9,96
Bk	32(40)-50	20,02	12,93	0,08	1,30	34,33	9,21	17,42	11,67	0,17	1,59	30,86	23,91	15,83	13,12
BCgk	50-90	14,66	7,61	0,05	1,88	24,19	9,21	14,30	7,15	0,17	3,18	24,81	19,65	17,50	5,32
2Cg	90-150	9,49	1,27	0,05	0,12	10,94	1,34	10,16	1,17	0,10	0,16	11,59	8,88	5,00	1,00
3Cg	150-220	9,65	4,99	0,15	1,31	16,09	6,91	7,84	4,26	0,22	1,55	13,87	12,75	11,67	4,16

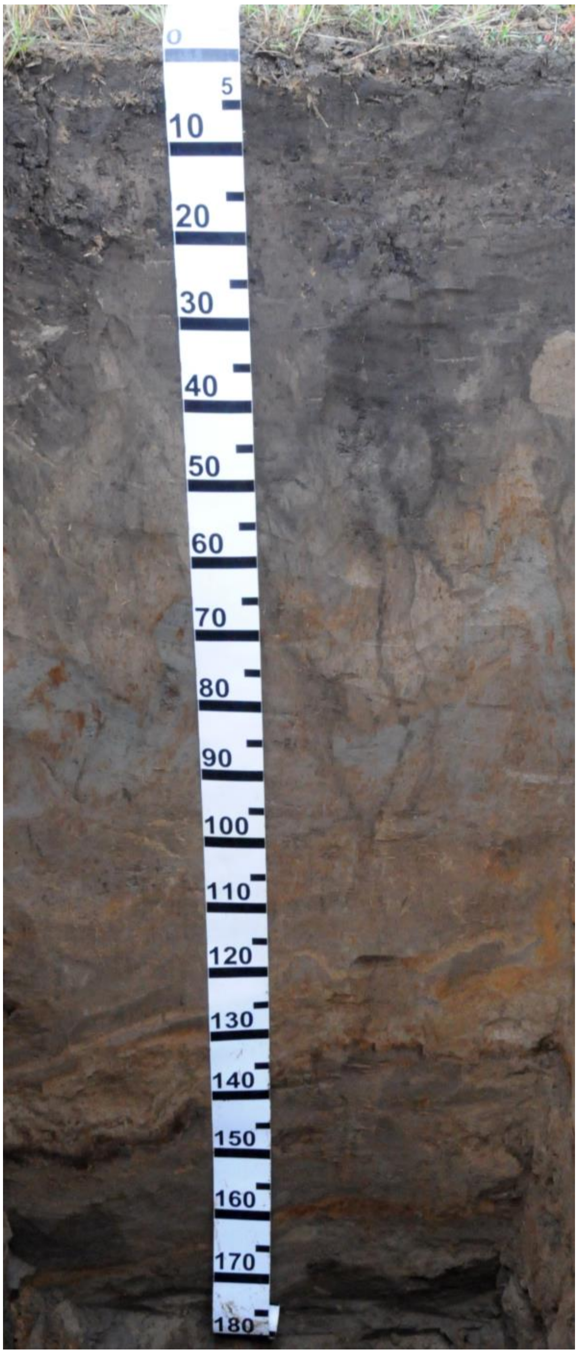
Bulk chemical composition, %

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 on Lena terrace under grassland vegetation. The climatic conditions here are more arid and contrast in summer and winter temperatures because of winter inversions and summer heating of treeless surfaces. 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 and the Bk horizon does not fit criteria of calcic horizon very little (<2% of CaCO3). Stagnic features are well-pronounced and thus this soil is classified as Stagnic Chernozem (Molliglossic, Sodic, Siltic, 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 6

Lena terrace. Mollic Endogleyic Solonetz Turbic. Profile 6.

Site 6 N61^{0}54’57,0” E129^{0}34’02,2” H~98 m Established on the steppe site in the local depression. Meadow.				
A	AU1	0-10	2.5Y 2.5/1 black; slightly moist; silt loam; blocky subangular with elements of granular structure, when wet granular structure is predominating; slightly hard; weak effervescence when reacted with HCL; many roots; boundary - clear distinctness, wavy topography.	WRB Mollic Hyposalic Endogleyic Solonetz (Siltic, Turbic) Soil Taxonomy Mollic Natraqualf (no Gelaqalfs in ST) Russian Солонец темногуму-совый глеевый криотурби-рованный Solonetz dark gleyic cryoturbated
Btn	ASNg	10-35	2.5Y 3/1 brownish black, almost black on ped faces; moist; hard; silt loam; prismatic-blocky angular structure; thin black coatings on ped faces; many roots; various sized channels of soil macro- and mesofauna filled with material from underlying horizons; many fine Fe and Fe-Mn soft concretions; weak effervescence when reacted with HCL; boundary - smooth topography.	
Bng @	ASN-Bg@	35-55	2.5Y 3/1 brownish black material is alternating with 2.5Y 4/1 yellowish gray parts; thin tongues of the upper horizon are observed till the 95 cm depth; slightly hard; silt loam; platy-fine blocky subangular structure; common fine roots; many Fe and Mn soft concretions of dark orange to black colour; weak effervescence when reacted with HCL; boundary - clear distinctness, wavy topography.	
Br@	BG@	55-95	2.5Y 4/3 olive brown matrix with coarse gray olive (10Y5/2) and fine/medium 7.5 YR 4/6 brown mottles; moist; silt loam; platy-blocky subangular structure; slightly hard; many soft Fe concretions from orange to black colour; 5Y 6/2 grayish olive mottles deformated by cryoturbations; boundary - gradual distinctness, smooth topography.	
BCg @	BCg@	95-120(130)	2.5Y 4/3 olive brown matrix with10 YR 4/4 brown mottles; silt loam; slightly hard; platy-fine blocky subangular structure; many soft Fe concretions; few roots; intrusion of material from lower horizon due to cryoturbations; boundary - abrupt distinctness (change of deposit type), wavy topography.	
2C@	DG@	120(130)-210	Crumpled into folds layers of alluvial genesis of loamy to coarse sandy texture; alternating layers of 5Y 4/3 dark olive and 10YR 5/6 yellowish brown, 7.5YR 4/6 brown colours; many soft Fe-concretions. Permafrost at 210 cm depth; no additional wetting above permafrost table.	

Particle-size distribution

Horizon	Depth, cm	Bulk density	Sand >0,063	Silt 0,063-0,002	Clay <0,002
A	0-10	1,46	32,21	61,87	5,92
Btn	10-35	1,60	33,06	50,14	16,80
Bng@	35-55	1,50	41,36	50,28	8,36
Br@	55-95	1,44	26,20	56,16	17,64
BCg@	95-120(130)	1,43	16,44	67,78	15,78
2C@	120(130)-210	-	33,15	54,77	12,08

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)
A	0-10	9,65	7,65	0,22	1,42	1,75	7,42	1,60	0,67
Btn	10-35	10,15	8,30	0,54	0,89	0,96	7,08	1,90	0,90
Bng@	35-55	9,90	7,90	0,34	0,66	1,28	-	1,92	0,55
Br@	55-95	9,25	7,70	0,16	0,43	0,80	-	1,58	0,58
BCg@	95-120(130)	8,65	7,10	0,09	0,50	1,02	-	1,70	0,97
2C@	120(130)-210	8,90	7,25	0,10	0,27	0,50	-		-

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	0-10	14,29	6,72	0,21	8,08	29,30	15,31	10,43	5,42	0,25	9,59	25,69	24,38	25,00	-
Btn	10-35	17,91	7,75	0,22	16,37	42,25	18,84	16,01	6,33	0,23	21,79	44,36	36,96	29,17	0,66
Bng@	35-55	16,74	8,19	0,11	7,90	32,95	12,31	14,43	6,82	0,20	10,01	31,47	26,66	21,67	1,86
Br@	55-95	13,48	7,50	0,12	1,48	22,58	10,86	10,91	6,33	0,21	1,42	18,87	17,86	16,67	-
BCg@	95-120(130)	9,26	7,43	0,14	1,31	18,13	10,90	7,49	7,24	0,13	1,30	16,16	15,53	15,83	-
2C@	120(130)-210	5,05	5,12	0,12	0,80	11,08	3,99	4,56	5,07	0,11	0,78	10,51	10,05	10,83	-

Pedogenesis and Soil classification

This soil is interesting in the fact that being in microlow it is almost leached for calcite but it has tremendous percentage of sodium (up to >50%) and other criteria for nitric horizon.

So, according to the WRB it is classified as Mollic Hyposalic Endogleyic Solonetz (Siltic, Turbic).

In Soil Taxonomy it fits the diagnostics of Mollic Natraqualf, as there are no Gelaqalfs in ST.

In Russian classification it is Solonetz dark gleyic cryoturbated.

Lena terrace. Hyposalic Solonetz. Profile 7.

<table>
<tr><td colspan="5">Site 7 N61^{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 Hyposalic Solonetz (Siltic, Alcalic)

Soil Taxonomy Typic Natrudalf (no Gelalfs in ST)

Russian Солонец темногуму-совый засоленный постагро-генный абрадиро-ванный Solonetz dark-humus salinized 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; few pseudomycelia; 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

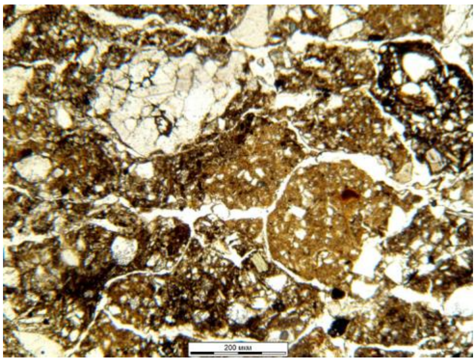
Ap – 0-10 cm. It is patchy coloured. At a dark gray background brownish-red zones which are different in size and in sharpness of the boundaries (from very sharp to diffuse). Heterogeneity in color is due to the different composition of the micromass. The darkest colour is associated with the clay-humus 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 platy with 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 has diverse microforms: 1) strongly altered dark brown plant tissues with the remains of the cellular structure, 2) carboniferous fragments of plant tissues of different sizes, 3) small strongly altered tissue residues, 4) dark dispersed humus (organic pigment) and micro-globular humus (humus punctuations). Recent large roots, having birefringence of cellulose, dissect platy aggregates.

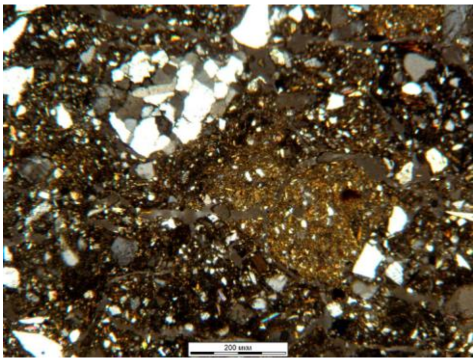
There are also met: 1) biogenic fromboids or their fragments, which are confined mainly to the areas and aggregates with clay-carbonate micromass and 2) multimineral infillings, fragments of clay and silty-humus coatings.

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 framboids significantly 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. Carbonates are micritic.

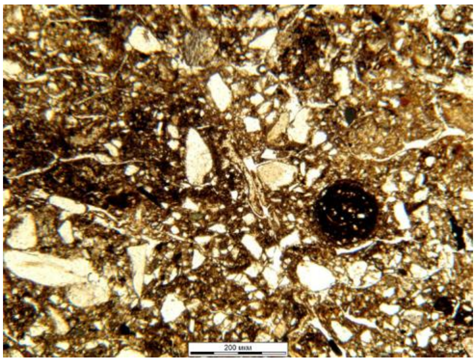
Bk – 25-50 cm. Light brownish silty sand material with a banded (sedimentogenic) particle distribution. The quartz, feldspar and biotite plates dominates in coarse material. The content of fine particles is very low, they are distributed in the form of light gray, almost colorless bands. The grains of iron-containing minerals (Fig. 6g), particularly plates of biotite and amphibole differ by strong degree of alteration, 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.

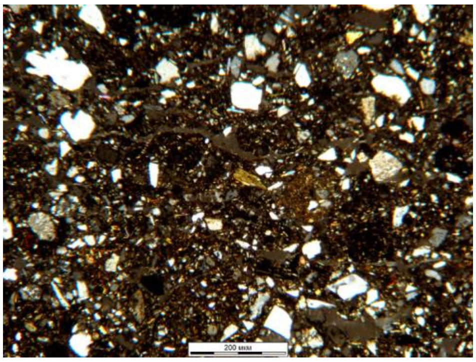
Conclusion. This profile as based on its micromorphological features, can be classified as Solonetz. The soil is formed onlayered alluvial deposits; from top to bottom the stratification of particles of different size is pronounced. The specific feature of the mineralogical composition of the soil-forming 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. 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.



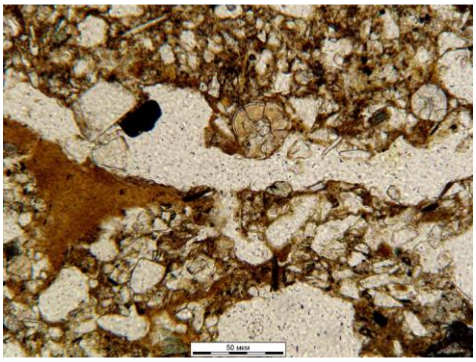


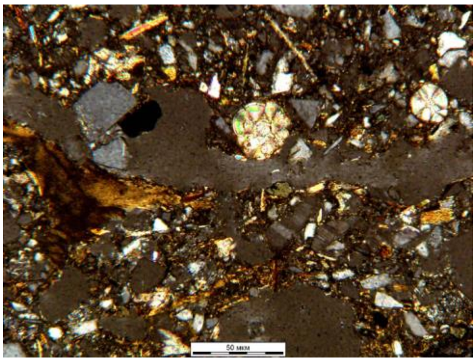
a) 0-10 cm b) 0-10 cm



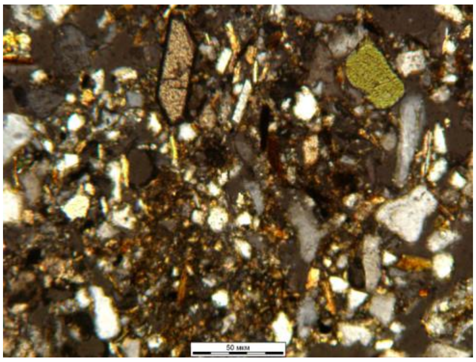


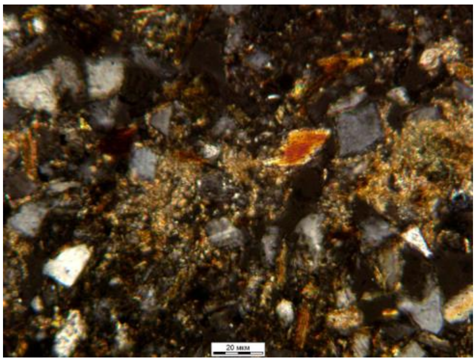
c) 0-10 cm d) 0-10 cm





e) 10-20 cm f) 10-20 cm





g) 25-50 cm h) 25-50 cm

Fig. 6. Microfeatures of horizons in Hyposalic 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).

Particle-size distribution

Horizon	Depth, cm	Bulk density	Sand >0,063	Silt 0,063-0,002	Clay <0,002
Ap	0-10	1,64	25,90	66,40	7,70
Btn	10-25	1,51	34,78	49,72	15,50
Bk	25-50	1,45	35,92	50,16	13,92
2C1	50-70	-	88,72	10,20	1,08
3C2g	70-120	-	58,40	34,22	7,38

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	9,90	7,80	0,18	1,12	1,60	7,33	1,41	-	5,64
Btn	10-25	10,30	8,35	0,35	0,69	1,74	7,91	1,04	-	5,50
Bk	25-50	10,30	8,40	0,37	0,23	0,83	-	1,23	-	5,65
2C1	50-70	10,10	7,95	0,13	0,07	0,10	-	-	-	-
3C2g	70-120	9,30	7,70	0,12	1,40	2,10	-	-	-	-

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 cmol/ kg**	**$CaCO_3$**
		Ca^{2+}	**Mg^{2+}**	**K+**	**Na+**	**Sum**		**Ca^{2+}**	**Mg^{2+}**	**K+**	**Na+**	**Sum**			
Ap	0-10	35,08	4,93	0,19	5,59	45,79	7,16	16,02	2,97	0,07	5,30	24,36	21,54	22,50	1,55
Btn	10-25	19,13	8,00	0,16	10,39	37,68	10,51	14,91	8,03	0,03	9,57	32,54	26,51	19,17	6,96
Bk	25-50	14,18	6,55	0,13	7,33	28,18	5,98	14,53	7,35	0,01	7,17	29,06	21,76	11,67	4,87
2C1	50-70	2,68	1,08	0,04	0,96	4,75	1,37	2,21	0,69	0,06	0,99	3,96	2,76	4,17	0,20
3C2g	70-120	10,05	4,82	0,16	0,72	15,75	3,78	8,50	3,28	0,15	0,65	12,58	9,55	7,50	3,43

Bulk chemical composition, %

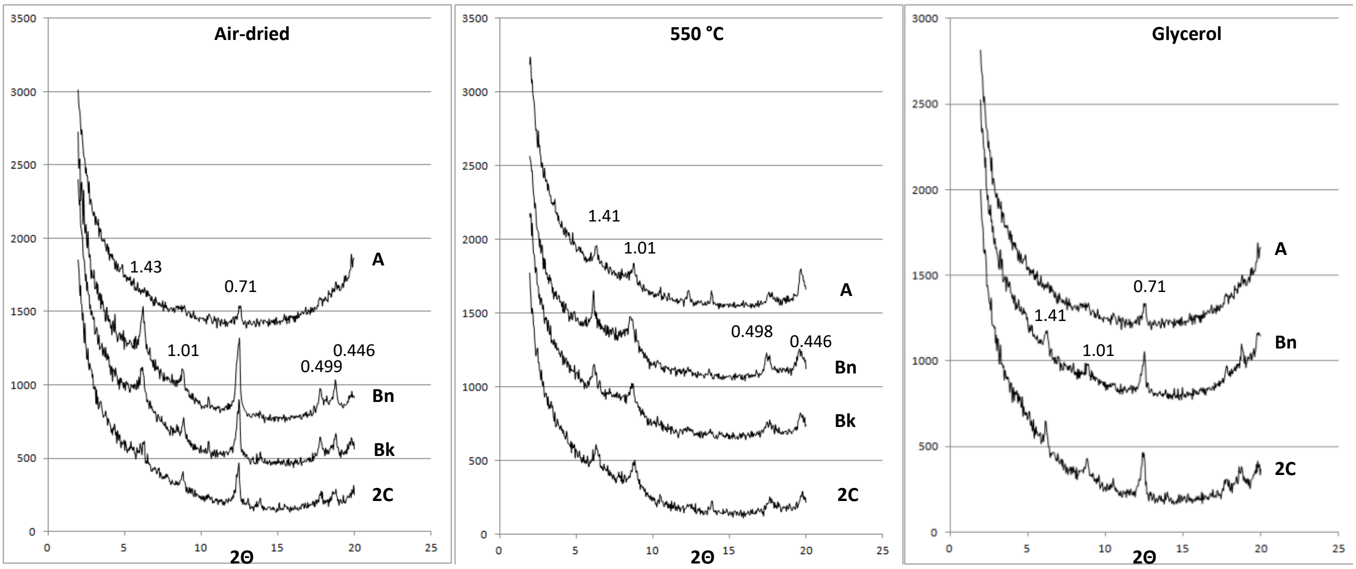
Horizon	**Depth, cm**	**Na_2O**	**MgO**	**Al_2O_3**	**SiO_2**	**P_2O_5**	**SO_3**	**Cl**	**K_2O**	**CaO**	**TiO_2**	**MnO**	**Fe_2O_3**
Ap	0-10	1,82	2,92	14,61	55,41	0,20	0,16	0,02	2,39	3,07	0,65	0,12	5,64
Btn	10-25	2,04	3,47	13,59	50,29	0,16	0,15	0,03	2,19	5,09	0,56	0,08	5,50
Bk	25-50	2,06	3,59	13,47	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 Hyposalic Solonetz (Siltic, Alcalic) in the WRB and Typic Natrudalf, as there are no Gelalfs in Soil Taxonomy.

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



The mineralogical compositions of clays in all the horizons of this profile are similar, but the crystallization of clays differs between the horizons. All the horizons have as the main components chlorite, illite, illite-vermiculite, and kaolinite. The best shape of the diffraction maximums was observed for the horizons Bn and Bk, and the worst one – to the A horizon. Poor quality of the diffractogram for the A horizon was ascribed both to the presence of organic matter and to the possible mechanical destruction of clay particles on the soil surface. This profile shows almost no evidence of pedogenic transformation of phyllosilicates.

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 orienta-tion 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 Hyposalic Solonetz	+++*	++	+++	+	+++	+++	++	+++
Profile 11 Cambic Cryosol	+	-	+++	+++	++	+++	-	++
Prof.13-1 Salic Fluvisol	-	-	-	-	-	-	-	+++
Prof. 13-2 Stagnic Solonetz	+++	-	-	-	-	-	+++	+
Prof. 14 Cryosol Luvic	-	+++	-	-	-	+++	-	+
Prof. 2.2.- Luvic Phaeozem	+++	+++	-	-	+	++	+++	+

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

Soluble salts in investigated soils

As it was shown in the tables for every profile most of soil horizon has low electric conductivity (EC) and thus low, if any, salinity. Only 9 soil samples have high EC and the calculation of the ES of saturated extract and analyses for different cations and anions content were done for them. The results are in the table. These data were used for soil classification and pedogenic interpretation of the profiles having these horizons.

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

Profile	Horizon	Depth	$CO3^{2-}$	$HCO3^{-}$	Cl^{-}	$SO4^{2-}$	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	EC
2-2	EB	60-80	0	0,93	0,85	1,16	0,08	0,22	2,74	0,10	7,74
6	Btng	10-35	1,20	5,95	0,90	1,04	0,16	0,69	7,42	0,17	5,13
7	Btn	10-25	0,50	4,33	1,10	1,80	0,18	0,93	4,49	0,20	13,13
9-2	AH	0-10	n.d.	13,7	n.d.	2,14	0,04	7,69	8,94	0,11	2,88
13-1	Ak	0-2	1,50	4,97	n.d.	1,03	0,17	3,11	4,79	0,23	10,78
13-1	Ck	0-10	3,08	6,69	3,37	1,57	0,17	2,68	8,72	0,19	10,90
13-1	2Ckzr	10-40	4,05	7,50	11,7	0	0,13	1,99	11,11	0,18	11,70
13-1	3Ckz	40-60	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	8,52
13-2	2Bgk	20-55	0,50	2,12	2,40	1	0,07	0,47	4,31	0,16	8,52

DAY 5.
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 it 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 Mammoth WRB tour is both to enrich the existing classification systems by the knowledge on the soils of this exclusive region and help the local and national specialists to find the positions of the soils they do with in the world soil context.

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 lack of many pedogenic indicators for cold soils in classification systems, e.g. Luvic and Albic qualifiers for Cryosols. Some of them should be shifted from suffix qualifiers to prefix ones, e.g. Reductaquic, as they have the features of the pedogenic character. Our experience showed that the list of prefix qualifiers should be expanded for Cryosols.

3. The not enough number of units in the WRB and subgroups in Soil Taxonomy, as well as subtypes in the Russian system, indicating cryoturbations. There should be added Turbic qualifier to Solonetzes, Stagnosols, Chernozems, Fluvisols, Phaeozems.

4. 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 freesing 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 2, 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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