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ORIGINAL ARTICLE

Soils diversity and evolution trends within the terrace complex of the upper Ob near Kireyevsk

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The research presents the results of studying soil variability within the Ob river fluvial terraces near the village of Kireyevsk, Kozhevnikovsky District, Tomsk Region. The general regularities in the organization of the soil cover are determined by the lithological features of the sediments that build up various geomorphological levels, their age, the current hydrological regime and the directions of river valley geomorphological and hydrological evolution. Three geomorphological levels are distinguished for the Ob river valley within the study area: the high floodplain in backland regime, evolving into the first terrace, the first terrace and the second terrace. Gleyic Calcaric Fluvisols forming on buried Histic Gleysols or Histosols dominate within the high floodplain. Different variants of Albic Luvisols under mixed pine-birch forests with a developed grassy stage are predominant within the first terrace. The illuvial horizons of these soils have a lithogenic origin and develop from depredating dense alluvial layers. The soils of the second terrace are Albic Arenosols and Folic Entic Podzols. Oxidized-gley and residual-carbonate variants develop in the transition zone between the first and the second terraces. In general, the patterns of soil cover organization and the prevailing soil-forming processes correspond to the main trends in the development of the river valley during Holocene. The soils of the drained floodplain have recently completed the synlithogenic stage of their development and retain such features of alluvial soils as high content of carbonates, the presence of well-marked burial horizons, intermittency and variability of sedimentation that of the middle and lower parts of the profile. The soils of the first terrace evolve towards the zonal texturally differentiated soils. The main processes in these soils are humus accumulation and leaching of carbonates. The soils of the second terrace are distinguished by the predominance of the Al-Fe-humus process, which is explained by the fact that the surface of the second terrace underwent aeolian processing in the late Pleistocene. The obtained results testify to the extremely high dynamics of the soils and landscapes development within the fluvial terraces of the Ob, and, consequently, to their low resistance to anthropogenic impact.
Keywords: Sub-boreal forest; lithological-geomorphological organization; albic arenosols; folic entic podzols; fluvisols; gleysols; Western Siberia

Introduction

In the recent years, both Russian and international scientific communities pay considerable attention to hydrological, geochemical and ecological features of the Ob river basin (Vorobyev et al., 2015, 2016b; Zemtsov and Savichev, 2015; Rozhkova-Timina et al., 2016). The Ob plays a key role in the organization and functioning of the whole macroregion as a single hydrological-geochemical system (Moran & Woods, 1997; Gordeev et al., 2004; Kirpotin, 2015; Pokrovsky et al., 2016; Vorobyev et al., 2016a; Ala-aho et al., 2018). One of the most important components of the Ob geosystems is the soil cover of floodplains and terraces. Soils of these geomorphological surfaces one the one hand reflect modern hydrological and geochemical features of the river basin, on the other they are an important source of paleogeographic information about evolution of the environment in Late Pleistocene and Holocene. However, unlike the large rivers of the East European Plain, the soil cover of the Ob floodplains and terraces is practically unexplored.

The Ob river valley occupies vast areas within Western Siberia. In its upper course (up to the mouth of the Tom river in the southern part of the Tomsk region), the Ob river valley has a following structure: low floodplain, high floodplain, the first fluvial terrace, the second erosional-accumulative terrace, the third terrace (Zemtsov, 1988). The number of geomorphological surfaces can vary depending on the particular territory. Differences in the hydrological conditions, age and lithology of these surfaces are the main factors that form the diversity of soils within the fluvial terraces of the Ob.

The research territory has a long-standing anthropogenic history, which began long before the Russian colonization of the southeast of Western Siberia. For example, in the area of Kireyevsk village settlement local archaeological cultures appeared in the early Iron Age (about 2.5 thousand years ago) and existed almost continuously, replacing each other, until the appearance of the Russian population, when large villages were founded (Barsukov, 2012; Vodyasov, 2014; Vodyasov &

Zaitceva, 2015). High human activity on the Ob terraces in the late Holocene could observed as a possible reason for the activation of erosional processes and transformation of soil cover imprinted in the sediments of the Kireyevsky Log (Klimova et al., 2016).

The purpose of the following research is exploration of the soil diversity within the Ob river fluvial terraces in the area of Kireyevsk village settlement. A significant part of the proposed research is devoted to the role of lithological and geomorphological conditions as important factors that predetermine further evolution of the soil cover.

Materials and methods

Studies of the soil diversity within the Ob terraces were carried out near the Kireyevsk village, Kozhevnikovsky District, Tomsk Region (56°23'22.11" N, 84°5'11.75" E). The climate of the territory is continental, the average temperature for January is 20 °C, for July - +19 °C, and the annual precipitation varies from 450 to 500 mm. The following levels are present among geomorphological surfaces of the Ob Rive valley for the study area: high floodplain, transforming into the first fluvial terrace; the first fluvial terrace, transferring to the second fluvial terrace; the second fluvial terrace. These surfaces are represented fragmentarily and do not lie parallel to each other and. Meadow vegetation is dominant in the conditions of close groundwater occurrence within the floodplain. Mixed birch and pine forests represented by 22 species of woody plants (Manic et al., 2015) prevent on the first terrace. The second terrace is covered with pine forests with a developed grassy tier.

The object of the study is the soil cover of three geomorphological levels of the Ob fluvial terraces in the area of Kireyevsk. The proposed research is based on 23 morphological descriptions of the soil pits characterizing the features of soil cover within the terraces. Classification and diagnostics of soils was carried out according to the Classification of Soils of Russia (Shishov et al., 2004) and in the following paper, the names of soils are given according WRB. Determination of the color of the genetic horizons was carried out using the Munsell scale in a wet and dry state. In 5 representative pits, the following chemical-physical properties were additionally determined: the pH of the aqueous extract by the potentiometric method, the content of organic carbon by the Tyurin titrimetric method of wet oxidation, the content of amorphous iron compounds by the Tamm method, followed by the measurement of the concentration with atomic absorption method (Vorobyova, 2006).

Results and discussion

The highest degree of soil variability is typical for the floodplain, evolving in the first fluvial terrace. This geomorphological surface emerged from the floodplain regime, and the corresponding soils from the synlitogenic stage of their development. In the areas closest to the current riverbed, Gleyic Calcaric Fluvisols forming on buried Histic Gleysols or Histosols dominate (Figure 1). Thin humus horizons of these soils develop directly on the layers of alluvial deposits varying in thickness, sometimes enriched with shell rock, and horizons of buried organogenic soils. Rorensteins are the most common Fe neoformations. The reaction over the entire soil is slightly alkaline (pH 7-8), which is associated with the close bedding of the shell rock and the action of hydrocarbonate-calcium groundwater discharging from the higher levels of the terraces. The content of organic carbon takes a value in the interval from 0.2% in mineral horizons to 8.5% in buried peat layers. At a distance from the riverbed, Fluvisols are replaced Mollic Gleysols developed over buried Histic Gleysols. Gleysols developed in the transition to first fluvial terrace have weak diagnostic signs of eluvio-illuvial differentiation. Mollic Gleysols of the most drained areas of the floodplain are distinguished by thick organic profile with a well-developed humus horizon. In general, soils under consideration are characterized by a complex humus profile due to the presence of buried organogenic horizons marking different stages of the floodplain development. In the soils of this surface, modern humus horizons develop on the silty loam layer. This layer is widely distributed in the soils of similar transitional surfaces downstream of the Ob.

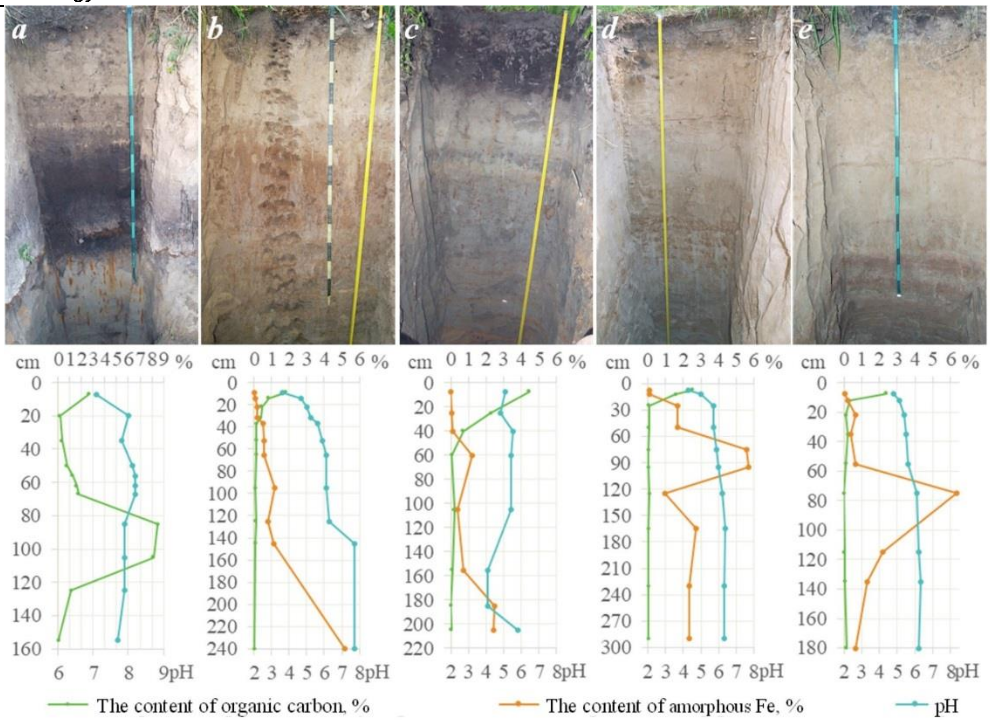

Figure 1. Soil pits representing different geomorphological surfaces of Ob river terrace complex and their properties: a-Gleyic Calciric Fluvisols formed on the buried Histic Gleysols of the drained floodplain; b-Albic Luvisol of the first terrace; c-Mollic Gleysol of the local depression within the first terrace; d-Folic Entic Podzol of the second terrace; e-Albic Arenosol (Lamellic) of the second terrace.

The first fluvial terrace is characterized by the prevalence of Albic Luvisols. However, textural differentiation in these soils is associated with the initial heterogeneity of the alluvial substrate but not the modern soil-forming processes. The thickness of humus horizon in Albic Luvisols of the first fluvial terrace ranges from 9 to 15 cm. The signs of floodplain sediments transformation under the influence of the modern soil-forming processes are most clearly visible in the soils of this geomorphological surface. The transitional eluvio-illuvial horizons, as a rule, are separated morphons of the upper part of cemented alluvial-layered sediments depredating in modern conditions. Some authors (Syso et al., 2010) classify the soils of the first youngest terrace of the Ob as Lamellic Albic Luvisols. The content of organic carbon in these soils gradually decreases with depth from 1.8% in humus horizons to 0.5% in the middle and 0.2% in the bottom. Soil reaction varies from acidic in topsoil (pH 3.6) to alkaline in deep subsoil (pH = 7.7) due to the peculiarities of the groundwater of Ob fluvial terraces and the initial high carbonate content of the alluvial sediments. The content of amorphous iron increases from 0.03% in humus horizons to 1.2% in soil-forming alluvium. Clarified areas depleted in amorphous iron do not coincide with chromatic maximum. The presence of small areas with soils demonstrating evolution from Mollic Gleysols to texturally differentiated Albic Luvisols, also testifies the recent floodplain conditions of the first terrace. Such soils are confined mainly to local depressions with elevated groundwater level and differ from common Albic Luvisols by a more thick (up to 30 cm) humus horizon with a well-defined fine-grained structure and the absence of distinct eluvial horizons. In soils of local depressions (Figure 1c), the content of organic carbon decreases with the depth from 4.5% to 0.7%. Alluvial stratification of sediments and presence of ochre ferruginous spots are well defined in the middle and bottom horizons. The pH values in such soils vary slightly from 5.1 in humus horizons to 5.8 in deep subsoil. The content of amorphous iron compounds increases from 0.02% in the humus horizon to 2.5% in gley alluvial sediments.

Albic Luvisols of the first fluvial terrace have several features of morphonic mosaic that set them apart from other soils of this type in the south of the Tomsk region. The main difference from zonal soils is in the fact that in the studied profiles we were unable to diagnose traces of pedoturbations caused by tree uprooting. This may be due to the long-term anthropogenic activity on the right-bank terrace complex of the Ob in the research area (Barsukov, 2012; Vodyasov, 2014) which lead to a permanent break-up of the successions between different forest-forming tree species generations. These disturbances could be associated with both logging for the needs of metallurgy, agricultural use, as well as forest fires. Traces of the last type of anthropogenic impact are well represented in the humus horizon, which is saturated with fine charcoals. At the same time, there are no charcoals below the humus horizon. Perhaps this is due to the undercutting, the usage of agricultural tools, which were found in archaeological sites of the pre-Russian population. It is important to note that traces of windfalls in background soils are widespread within the South of the Tom region (Loyko et al., 2013).

Soil cover of the second fluvial terrace is the most static in relation to changes in the river valley. The ancient alluvial deposits that make up the terrace are covered with a layer of sorted sand with a thickness of 1-1.2 m with signs of aeolian processing which is typical for the second terraces of rivers in Eastern Europe and in the extraglacial part of Western Siberia (Jankowski et al., 2011; Panin et al., 2016). Groundwater do not affect modern soil formation and signs of gleying occur only at depths of 1.2-2 m. The most common type of soils within the second fluvial terrace are Folic Entic Podzols (Lamellic) in some cases with signs of developing albic horizon. In general, the profile of these soils has the typical structure characteristic for the soils of the second fluvial river terraces in the subtaiga zone of Western Siberia: The Bhs horizons have a characteristic brownishocher coloration. The signs of gleying such as ortsteins, ochre spots are common for the C horizons. Stratification typical of alluvial deposits was found in the bottom part of these soils. The upper part of the profile is composed of well-sorted homogeneous aeolian sands. Folic Entic Podzols of the second fluvial terrace (Figure 1d) have a rather short humus profile. The content of organic carbon decrease from 2.5% in the upper horizons to 0.05% below 25 cm. The pH values gradually increase with the depth from 4.3 in AB horizons to 6.3 in the lower horizons. The content of amorphous iron compounds in a similar interval noticeably increases from 0.05% to 1.7% in the Bhs horizon, reaching a maximum of 5.7% in dense cemented layers at a depth of 70-100 cm.

Other soils typical for this geomorphological surface are Albic Arenosols (Lamellic) (Figure 1e). They occur under the conditions of the lithological heterogeneity, when dense loamy sediments, which, apparently, have an alluvial genesis underlain aeolian sands at a depth of 90-120 cm. The content of organic carbon in these soils decreases from 2.4% in organic horizon to 0.1% at a depth of 55 cm and lower along the profile, pH value varies from 4.3 to 6.2 respectively. The content of amorphous iron compounds varies from 0.03% in the humus horizon, while the maximum of 6.4% is observed in dense layers ("ortsand horizon"). The lower part of the profile is depleted in amorphous iron, which coincides with the chromatic maximum (2.5 YR=>10 YR). The dense loamy layers in the lower part of the profile could not be conditionally classified as ortsands, since they have a lithogenic nature. The heterogeneity of the lower part of the profile acts as a local confining layer, which prevents the development of well-expressed Albic horizons in these soils and leads to the formation of the thick low-contrast clarified stratum (Mahaney et al., 2016).

The patterns of soil cover organization within the terrace complex of the Ob for a studied territory are mainly determined by the current trend of river valley geomorphological evolution. A significant change in the configuration of the river valley has affected the second floodplain, which is currently transforming into the first terrace in terms of its hydrological regime. The surface, which is now the first fluvial terrace recently, was a part of floodplain. This geomorphological level was dried because of intensive meandering of the river and the decrease in the basis of the erosion. The most static surface is the second terrace, where the soil formation processes are determined by the properties of aeolian sand deposits overlapping ancient alluvial sediments.

Development of modern humus horizons, occurring synchronously with the destruction of the buried peat layers, as well as gleying, dominate among main soil-forming processes within the floodplain gradually transforming to the first fluvial terrace. These soils have recently completed the stage of synlitogenic pedogenesis. In the soils of the first fluvial terrace, processes of gleying and leaching of carbonates are manifested in addition to humus accumulation. The initial lithogenic textural differentiation of these soils creates prerequisites for their evolution towards zonal Albic Luvisols (Dyukarev & Pologova, 2011). Al-Fe-humus process is the most significant process for the Folic Entic Podzols of the second terrace level. Weak signs of podzolization occur in a form clarification of the lower part of AB horizons in Albic Arenosols. Pedogenic processes lead to the destruction of dense alluvial loamy sediments that underlain aeolian sands. The formation of thin lamellas in sandy soils of the second terrace maybe interpreted as an indirect sign of the initial podzolization (Kulizhsky et al., 2015).

Based on the results of our studies it is possible to suggest further directions of evolution for the soils of different geomorphological levels: for the first terrace towards zonal textural differentiated Albic Luvisols, for the second towards Entic and Albic Podzols. This trend is less obvious for the floodplain soils, although their similarity with Mollic Gleysols of local depressions of the first fluvial terrace is noted. The variability of soil cover indicates the extremely low stability of Ob river geosystems, which requires additional measures to protect and preserve these landscapes. Further studies of soil variability and evolution for the Ob river terraces with application of advanced research methods and approaches (Jongmans et al., 1991; Lin et al., 2005; Scarciglia et al., 2006; Tsai et al., 2007; Eppes et al., 2008; Roquero et al., 2015; Tsai et al., 2016) may be very important for the understanding the evolution of natural environment within the south of the Tomsk region in the Late Pleistocene and Holocene.

Conclusion

The soil cover of the young terraces of the Ob, in its upper reaches in the area of Kireyevsk is rather variable, which is largely due to the age of specific geomorphological surfaces, features of alluvial sediments, and the dynamics of the water regime. The soil cover of the drained fresh-water floodplain, which passes into the first terrace, is most diverse and consists of Gleyic Calciric Fluvisols forming on buried Histic Gleysols or Histosols and Mollic Gleysols. The predominance of Albic Luvisols is characteristic of the first terrace. Their assignment to this type is rather arbitrary and relies on the morphological structure of the profile, although the presence of textural differentiation is due to the lithological heterogeneity of the sediments composing the given surface. The Al-Fe-humus soils of the highest second terrace are similar to the soils of ancient continental dunes. The studied soils are a unique achieve of paleogeographical information about the evolution of the Ob river system in the Holocene and need special protection in the conditions of increased anthropogenic activity.

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