Soil cover of the Southern Ladoga region

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Abstract: The buried soils of the North-West of Russia are the cornerstone for reconstruction of the history of development of the Southern Ladoga region landscapes and their exploration by ancient man. Specialists from the V. V. Dokuchaev Central Museum of Soil Science and students of the St. Petersburg State University, including the author, uncovered 42 profiles of daytime and buried soils on the territory of the Southern Ladoga region and identified such types of soils as podzols, sod-podzols, sod-podzolic, gray-humus, dark-humus, and peat eutrophic soils, among which podzols were the predominant type. Based on the studied soil characteristics, we can assume that the conditions for formation of the buried soils were not significantly different from the modern ones and in the Southern Ladoga region the following landscapes were present: spruce and pine forests on the upper terraces and deciduous forests along rivers at the medium terraces. Meadows and moisture-loving vegetation were common on low terraces. The buried soils of Staraya Ladoga could have been used by the inhabitants of early medieval settlements in a very diverse way, and vivianiite in the soils of the Earthen Settlement is most likely of anthropogenic nature.

1. Introduction
Many studies have been devoted to the history of Lake Ladoga and although the Baltic region has been studied in detail for over a century, there are still many controversial issues in the field of geology, geoeconomy, paleogeography, and soil genesis of this region, concerning the dynamics and scale of the Ladoga transgression, and the time prior to and after the formation of the Neva River. We can trace closely connected paleohydrological, paleoenvironmental and cultural-historical processes on the territory of the South Ladoga region. It allows addressing the interaction of the natural environment and society, and the dating and research of uneven-aged soils in the Southern Ladoga. This gives an opportunity to approach the question of the speed and direction of soil formation in the region during the second half of the Holocene. Since 2002 this information has had the fundamental importance for solving the problem of the Genesis of early medieval settlements in the Lower Volga Region, as well as the establishment of the time of agricultural development of alluvial landscapes, which underscored the question of the history line of water level decline after the maximum of the Ladoga transgression. However, many controversial issues in the field of paleosoil science remain unresolved despite such a long period of comprehensive study of buried soils.

2. Objects and methods
The objects of research are buried soils uncovered during field expeditions in 2005–2015 on the territory of the Southern Ladoga region. Specialists of the V. V. Dokuchaev Central Museum of Soil Science
3. Results and discussion

During the expeditions, the main types of soils were discovered: podzols (62%), sod-podzols (13%), sod-podzolic (1%), gray-humus (1%), dark-humus (14%), and peat eutrophic (9%). Buried soils were found in 71% of cases among which the predominant type was podzols with well-formed peat horizons.

In the Svir section, eutrophic peat soil (Histic Podzol (Novic)) represented by low-lying peat (55 cm thick) lies under the deposits of the 240 cm thick Ladoga transgression. According to T. A. Konstantinova [4], two carbon-14 dates were obtained for this low-lying peat: the age of the roof is 4,480±130 years BP, the sole is 5,630±170 years BP. Under the layered peat, the alfegumus profile of the soil with a well-developed eluvial horizon is distinguished with a thickness of 15 cm, in the upper part it is slightly colored with organic matter. Mineral horizons are characterized by low carbon content (no more than 0.5%) and acidic pH levels.

Buried soil (Histic Podzol (Novic)) in the village of Zaostrovye is located 3 km further from the modern shore of Lake Ladoga than the studied soil on the Svir River. Buried peat with a thickness of 25 cm in this profile lies at a depth of 70 cm, and the radiocarbon age of the roof is 5,300±130 years BP, according to the data by T. A. Konstantinova. Modern soils of Zaostrovye village and the Svir River valley are poorly developed podzols with a fragmentary eluvial horizon, where the carbon content of organic substances reaches 1.2%.

A unique buried soil (Entic Podzol Gleyic (Novic)) was described near the bank of the Oyat River. At a depth of 60 cm, an organo-mineral horizon was discovered with a capacity of 5 cm, characterized by dark grey color and carbon content of organic matter of 1.8%, with the carbon-14 age 6,180±140 years BP. The buried horizon is divided on one of the walls of this pit: part of it is shifted downwards to a depth of 85–100 cm, the resulting hollow was a secondary deposition of sand. This feature may indicate ancient seismic or landslide processes.

A distinct alfegumus process is clearly traced in undisturbed buried soils at the points that occupy high positions in landscapes (12–15 m of absolute height). Buried podzols have a well-developed eluvial horizon, while in lower terrain areas (8–10 m of absolute height), peat formation and peat accumulation occurred in addition to the alfegumus process. The conducted analyses have shown the presence of peat type typical for transition and lowland swamps. Approximately a thousand years prior to peat accumulation, climate changes occurred that led to a change in vegetation, which affected the botanical composition of peat.

Special attention should be given to the buried soil that has preserved the traces of human activity. We will focus on the Staraya Ladoga Historical, Architectural and Archeological Museum-Reserve consisting of a large number of sites, such as Earthen settlement, Lyubshanskoe settlement, the Church of St. John the Baptist, Shahovskoy’s homestead, Church of the Dormition of the Mother of God, etc., but in this article, we will focus only on the buried soils from Earthen and Lyubshanskoe settlements, and the buried soils of the Staraya Ladoga fortress. The issue of landscape and climate reconstruction plays a key role historically. Presumably, in 753, when the Earthen settlement appeared the stone fortress did not exist yet.

The study of the Earthen settlement took place in 2005, 2010, and 2013. Analysis of the morphological characteristics of the paleopedocomplex (Gleyic Phaeozem (Novic)) of Earthen settlement revealed two buried humus horizons. The age of the upper gray humic horizon is 1,580±100 years BP, with a thickness of 20 cm and carbon content of 7.3% (and 12% carbon content in the contact
zone with the cultural layer); the bottom dark-humic horizon below the buried soil is 4,640±150 years BP, from 1 to 4 cm thick, with carbon content from 1.5 to 3%. According to the existing hypothesis, in the period 4,600–4,800 years ago there was a short-term formation of soils, on which forest vegetation was formed. After that, these territories were covered by the waters of Lake Ladoga, and the color boundaries between the layered clays suggest a rather sharp change in the conditions for accumulation of lake sediments (from deep to shallow). The formation of upper buried soils began after the retreat of the lake waters 2,000 years ago with the breakthrough of the Neva River and the clearing of significant territories to the North, with formation of forest-meadow communities. The process of glaying of soils could occur both during their formation, which took place in the conditions of high humidity and after their burial under the cultural layer. Probably, the formation of these soils stopped with the emergence of the Ladoga settlement, i.e. it lasted for at least 700 years. The next stage of soil evolution is associated with the period of land development which led to the processing of the upper part of the humus horizon of upper buried soils. Assuming that the territory was ploughed, the probable ploughing period is 750–850, when the settlement already existed, but the surveyed area was not yet built up.

Studies of the soil of the Earthen settlement at the meso-and micro-levels revealed a huge amount of such a mineral as vivianite. Vivianite, formed under reducing conditions, is found in alluvial and swamp soils. Vivianite has not been found in daytime alluvial soils and meadow and swamp territories of the Volkhovsky district of the Leningrad region, which may indicate an additional source of phosphorus for its formation in the buried soils of the Earthen settlement. A large amount of phosphorus is found in manure. It is known that solid secretions contain much more phosphorus than liquid ones which enter the soil in a form inaccessible to plants. Phosphorus becomes available only after mineralization of organic compounds. This fact may be an indication of the existence of cattle yards on the territory of the Earthen settlement.

According to the hypothesis of A.L. Alexandrovsky, the Earthen settlement of Staraya Ladoga area could be arable land, because seeds of flax, hemp, and hops were found in the soils during the 2013–2015 excavations [5–7]. It is also possible that the seeds of the specified crops could have grown as ruderal vegetation or the seeds got into the soil as a result of human activities not related to agriculture. From our point of view, the corrals and stalls for cattle were located on the berried soil of the Earthen settlement due to their significant hydromorphic nature. This is indicated by animal remains, wood chips, as well as a significant amount of phosphorus and vivianite veins.

When talking about the Lyubshanskoe settlement, we must not forget that the territory where the object under study is located has a high degree of agricultural development both in the past and in the present. After the Lyubshanskoe settlement was abandoned at the beginning of the tenth century after several fires, people never settled there. In the XVI century these lands belonged to the landowners Scriabin. For many years there were planting and gardening works that affected the river promontory. During the Second World War, the Volkhov front-line hospital was located here, and traces of trenches and utility pits, entrenchments, and graves partially damaged the cultural layer. Currently, the Lyubshanskoe settlement is "conserved" and archaeological research is not conducted there since most of the territory occupied by the historical site is not suitable for excavation at present.

Under the cultural layer of the Lyubshanskoe settlement, a dark humic soil (Phaeozem (Novic)) was uncovered on top of a lime plate. Probably, there were some buildings in the fortress and their location can be only indicated by the accumulation of slag encountered. There may have been a blacksmith shop where crucibles and a series of bronze bars were found. The soil section of the Lyubshanskoe settlement is homogeneous in its morphological properties and contains only isolated inclusions of scales and coals. Micromorphological studies have also confirmed rare inclusions of charcoal in the soil. Three layers can be defined in this soil: 1) layer 1 is representing the modern soil, 2) layer 2 is the defensive wall embankment, and 3) layer 3 is buried soil with a well-preserved profile. The humus horizon of modern soils is characterized by a significant thickness, which is not typical for natural soils of this territory. This indicates that it was cultivated and it is consistent with historical data of the area in question. Analysis of morphological properties has shown that the defensive wall embankment is composed of alternating layers of buried soil material of varied thickness. The buried soil is clearly recorded along a
thick homogeneous humus horizon, mixed only in the upper part, with a slightly wavy border with the transitional horizon. The carbon content of the buried soil ranges from 2.8 to 0.2%.

According to the Tale of Bygone Years, the fortress was built by Prophetic Oleg in the IX century and later destroyed by the Norwegian Jarl Eric in the X century. And only in the XII century a new stone fortress was built, as well as the St. George Church. Currently, the fortresses of the VIII and IX centuries have been conserved, however restoration of these fortresses is still possible. The Vorotnaya and Klimentovskaya Towers were fully restored on the ancient basis. The restoration of the Arrow tower of the XV–XVI centuries has begun. In the coming years, it is planned to completely restore the North-Western facade of the fortress. During excavations in 2013, gray-humus soils were found on buried dark-humus soils, on limestone eluvium. In one of the soil sections, a boulder was found – the remains of a church porch of the XI–XII centuries. It means the buried soil had been preserved under the porch. Also, various slags were found in the buried soils, typical for places where blacksmiths were previously located, which is supported by historical data. The carbon content in the buried humus horizon is 1.6%. The lower carbon content of the humus horizon of the buried soil compared to the background soil corresponds to the data of various authors on the reduction of humus content after the burial of soils [8].

On the basis of the data obtained, the history of formation of the studied deposits and soils can be presented as follows:

1) For a long time from the late glacial period to the middle of the Holocene (starting from 12,000 years ago), layered sandy loam deposits were formed, containing layers of eroded carbonate moraine and having different genesis: mainly alluvial, including water-glacial, partially deluvial, and bottom origin. In general, this thickness of deposits can be associated with the formation of the Volkov River valley and fluctuations in the level of Lake Ladoga in the first half of the Holocene. As a result, above-floodplain terraces were formed, on the surface of which forest vegetation and buried soils are formed at the second stage of the subboreal period. The thickness of the humus horizon is insignificant (1–5 cm), the humus content is low (from 1.5 to 3.6%). The low thickness of the soil profile may indicate a short period of soil formation. The short-lived formation of this soil occurred between 4,600 and 6,800 years ago.

2) Slightly layered clay deposits associated with the Ladoga transgression began to accumulate on the soil surface in the second half of the subboreal period. Their lower part is light, the overlying layer is dark humus with signs of soil-forming processes in the upper and middle parts. These clay layers have a high phosphorus content which makes it possible to characterize them as silts or bottom sediments of lakes. The presence of these deposits demonstrates that during the Ladoga transgression the bottom of Lake Ladoga was located on the level of the Earthen settlement, the Stone Fortress, and other areas the absolute height of which is below 8–10 m. Maybe it was a bay. A noticeable color boundary between the whitish and dark gray layered clays indicates a rather sharp change in the conditions of lake silt accumulation. Presumably, the conditions changed from deep water to shallow (coastal) water. The transgression was quite long reaching a maximum at the end; it is currently dated as mid II millennium – beginning of I millennium BC (3,000 years ago). According to the received data, the deposition of light lake clays (deep-water stage) occurred between 4,600 and 2,000 years ago which fits satisfactorily into the modern perception of the stages of the Ladoga transgression. The subsequent sharp decrease in the level of Lake Ladoga as a result of the Neva breakout led to the accumulation of humus-rich lake silt, which could last for several centuries and ended in the early sub-Atlantic period with the draining of low terraces.

3) Forest vegetation settled on the surface of the cleared terrace and the formation of daytime soils began (in the case of the Earthen settlement, the upper buried soil was formed) after the recession of the lake about 2,000 years ago. A humus horizon 20 cm thick was formed in the upper part of the lake clays. The carbon content of organic compounds is high (7.3–7.8%). This was due to the initially high content of phosphorus and organic carbon in the upper layer of lake sediments, as well as the clay composition of these deposits. However, the process of soil formation did not involve the entire thickness of humus lake clays, since their lower part retained the original stratification of the sediment and humus coloring did not penetrate the layer of whitish clay.
4) Significant territories to the North of the Staraya Ladoga settlement were cleared after the recession of Lake Ladoga. Settlements such as the Lyubshanskoe settlement were built in the highest places (15–20 m abs. height).

4. Conclusions

As a result of the study, we discovered both hydromorphic soils on the alluvium and automorphic soils on limestone and sand deposits in the Southern Ladoga region, which indicates a significant spatial heterogeneity of the soil cover associated with the area relief and heterogeneity of the parent rocks. Based on the studied features of buried soils it can be assumed that the conditions for the formation of these soils were slightly different from modern ones.

The comprehensive analysis of all exposed soils in this area provided data for identification of the following landscapes: spruce and pine forests on the upper terraces, deciduous forests along the rivers on the middle terraces on dark humus soils underlain by a limestone slab. On the low flooded terraces there were meadows and moisture-loving vegetation, in particular sedges, on dark-humus gley soils.

The buried soils of Staraya Ladoga could have been used by the inhabitants of early medieval settlements in a very diverse way, for example, as local vegetable gardens, pastures, cattle pens or ruderal territories. In this regard, the accumulation of various phosphorus-containing organic material, such as manure, bones, fish scales, took place in the soils of the Zemlyanoe settlement for a long time. Based on the data obtained, we can conclude that vivianite in the soils of the Zemlyanoe settlement is most likely of anthropogenic nature.

References

[1] Shishov L L, Tonkonogov V L, Lebedeva I I and Gerasimova M I 2004 Classification and diagnostics of soils in Russia (Smolensk: Oikumena) p 342 (in Russian)
[2] World reference base for soil resources. International soil classification system for naming soil and creating legends for soil maps 2015 World Soil Resources Reports 106 (Rome: FAO) p 181
[3] Rastvorova O G, Andreev D P, Gagarina E I, Kasatkina G A and Fedorova N N 1995 Chemical analysis of soils (St. Petersburg: St. Petersburg University Press) p 264 (in Russian)
[4] Konstantinova T A 2010 Mixed-age buried soils of the Southern Ladoga area Proc. Conf. XIII Dokuchaev’s Youth Readings (St. Petersburg. Russia: St. Petersburg University Press) p 145–6 (in Russian)
[5] Aleksandrovsky A L, Krenke N A and Nefedov V S 2010 Research of soils and deposits under the cultural layer of the Staraya Ladoga earthen settlement Archeology, history, art and culture of Russia and neighboring countries (Moscow: Lomonosov Publishing house) 1 pp 43–61 (in Russian)
[6] Chukhina I G, Radic D V and Grigorieva N 2014 Preliminary results of the study of macro remains of plants on the basis of 2010 excavations in Staraya Ladoga Ladoga in the context of the history and archaeology of Northern Eurasia p 244 (in Russian)
[7] Shitov M V, Konstantinova T A, Loskutov I G, Pleshivtseva E S, Sumareva I V, Chukhina I G and Shcheglova O A 2007 Vestnik St. Petersburg University Ser. 7 (3) 3–16 (in Russian)
[8] Shcheglova K E 2017 Buried soils of the archaeological site of Staraya Ladoga Book Proc. Mater. Study Soils Russia 9(36) pp 301 (in Russian)