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BIOGEOCHEMICAL ASPECTS OF THE GENESIS OF SALINE MARSHY SOILS

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Abstract
The marshy soils formed in Central Fergana have been studied along with other hydromorphic soils. The research investigates the role of suspended sediments in soils under the influence of irrigation waters and water accumulation, as well as the partial role of ancient lake-alluvial deposits in soil genesis.

Keywords: Marshy, grassland, hydromorphic, oxidation, reduction, gleying, alluvial, peat, accumulation, regeneration.

Introduction

The desert region is characterized by a high susceptibility to salinization, and the area consists mostly of flatland, where both hydromorphic and automorphic soils have formed. Under the influence of complex factors across the region, either in an introzonal manner or with the participation of anthropogenic factors, hydromorphic soils—specifically marshy soils—have formed, which are salt-affected to varying degrees, along with other soils. According to soil-climatic conditions, marshy soils should not ideally form in this region, but they are currently present. Therefore, investigating the genesis of these soils from chemical, biogeochemical, and agricultural usage perspectives has become an urgent issue in the region.

Object of study, saline marshy soils and vegetation formed in Central Fergana were selected. The methods used in the research are based on standard methods and methodologies accepted in soil science. Specifically, V.V. Dokuchayev's morphogenetic method was applied, while in pedobiogeochemical research, the landscape-geochemical approach methods of Polinov, Perelman, and Glazovskaya were utilized, along with literature and archival materials.

Related literature and other materials related to the topic, when discussing soil genesis, first and foremost, it would be appropriate to focus on Dokuchayev's soil-forming factors, which provide a basis for understanding the formation of marshy soils in desert regions.

According to Dokuchayev [1], factors such as climate, parent material, relief, plant and animal life, and the age of the land play a significant role in the formation of any soil, and these same factors are reflected in the genesis of marsh and gleyed soils. In the desert region, although rare, the process of hydromorphic soil formation often occurs alongside the gleying of soils.

At the end of the Quaternary period, the conditions for marsh formation in the Central Fergana basin correspond to its relatively deep areas. However, the current climatic conditions—such as dry spring, hot summer, occasional autumn, very little precipitation, and a very weak snow cover—do not favor the formation of marshes in this region. Several scholars have written on this issue [2, 3, 4].

In such conditions, the decisive factor for the formation of marshy and gleyed soils is the pressure, fresh, and varying degrees of mineralized groundwater. The sources of these groundwater are numerous and include, among others, waters from the southern Fergana mountain ranges, irrigation waters, water from canals and ditches, residual waters from lakes that were once filled with the Syr Darya and other mountain river waters, as well as waters from frozen and thawing soil layers. However, the dynamics of groundwater levels are hardly affected by the freezing and thawing of soil layers [5, 6]. This is because, in desert conditions, the soil layers that are prone to freezing are very thin. Moreover, the freezing of groundwater is minimal, especially if it is in an open-flow state. In Central Fergana, the average temperature in January is -2.4 °C, and in February it is +1.1 °C. The annual average temperature is around 13.5 °C, while the average soil temperature is -2 °C in January and +1 to +34 °C in the remaining months, with the annual average being around +17 °C.

However, during this period, i.e., in this range, soil temperature fluctuates with the seasons. The lowest soil temperatures occur in the winter months, while the highest temperatures occur in the summer, specifically in July and August. Accordingly, evaporation and evapotranspiration from the soil surface also change. The reason for this is that during the summer months, cloudy days and rainfall are rare. In this context, it is appropriate to mention the regional droughts, including those in Central Fergana, because climate is one of the primary factors influencing soil formation, even in desert regions.

Under normal conditions, water flows from surrounding areas to the relatively deeper soil layers and accumulates. In such a situation, if an impermeable layer is located on the surface, water accumulates, and the entire soil layer becomes moist up to the full field capacity, where it is retained for a long period. As a result, conditions favorable for the growth and development of marsh plants are created. Consequently, in soils that are saturated up to the full field capacity, the oxygen level, specifically the amount of oxygen in the air, sharply decreases, and the air exchange between the atmosphere and soil becomes extremely difficult. This leads to anaerobiosis, which in turn causes a significant reduction in soil microorganisms.

In this process, aerobic organisms primarily decrease. Under anaerobic conditions, the oxidizing conditions decrease significantly, resulting in a sharp reduction in the mineralization of organic matter [7, 8, 9]. In this case, intermediate compounds increase. Thus, oxygen deficiency leads to the formation of peat and, even in desert conditions, its slight increase [10, 11, 12]. Nitrogen and other nutrients involved in peat formation originate from soil-forming processes. The formation of peat and the gleying of the soil layer are key factors for the formation of marshy soils. Gleying occurs in the mineral mass of the soil [10]. Gleying is a complex biogeochemical process involving elements such as Fe, Mn, S, and N, which have variable valency, and occurs in anaerobic conditions, particularly in labil-organic environments, with the participation of anaerobic microorganisms.

Marshy soils form in different soil zones under various natural conditions, depending on the relief and mobility of groundwater, the composition, depth, and permeability of the impermeable layers, the amount of precipitation, other climatic factors, as well as the region's vegetation cover and type. However, they are most commonly found in the gumid region landscapes. The climate conditions in gumid and semi-gumid areas play a decisive role in the formation of marshy soils.

In particular, the climate conditions and the nature of the area are favorable for the formation of marsh and marshy soils.

For example, according to Dobrovolskiy G.V. and Urusevskaya I.S. [3], marshy soils cover more than 3.5 million hectares in the desert zone alone. Marshy soils can form in all soil-climatic regions, depending on the conditions, with their formation and development mainly related to excess moisture. The water source for this can vary, such as surface water or groundwater.

Their chemical composition is not uniform. Surface waters can saturate soils with a relatively deep impermeable layer up to full field capacity, and if they accumulate, they may remain above the soil surface. Since the exit element is limited, it will only evaporate into the air or move through transpiration via plants. However, when the soil reaches full field capacity at the precipitation threshold, favorable conditions are created for the growth of plants in marshes, allowing them to thrive and blossom. Marshy soils can be peaty, and they form as a result of gleying processes. Therefore, they possess a number of unique pedobiogeochemical and other biological and chemical characteristics. The formation of gley is one of the factors in the formation of marshy soils and is itself a separate biogeochemical process. Gleying, in particular, requires a long period of time and is characteristic of areas formed under excess moisture conditions. Iron and manganese play a major role in the oxidation and reduction processes during gleying. These elements are reduced and migrate from the gleying layer to the underlying layers, where they settle in oxygen-rich layers. To put it simply, during the gleying process, the primary and secondary minerals undergo decomposition. In this process, elements with unstable, i.e., variable valency, such as Fe, Mn, Cu, Co, S, and others, may participate.

As a result, 3^+ valency iron is reduced to 2^+ valency, and 3, 4, and 5 valency manganese is reduced to 2 valency, forming concretions. On the other hand, Fe and Mn act as oxygen carriers or transmitting elements in this process. In an almost oxygen-free environment, in the contact zone with the parent material, the concentrations of these elements-namely 2-valent Fe and Mn-are significantly higher, even in groundwater. These elements can also be autochthonous in these waters. In the soil, the main oxidative processes are carried out by living organisms.

A number of elements in the soil exist in highly oxidized forms. Most minerals that are saturated with oxygen are also present in the soil. The organic matter in the soil is also rich in oxygen.

Thus, it is important to recognize the significant role of living organisms in the geochemistry of Mn and Fe. This is because, along with soil oxygen, living organisms create high-valency oxygen compounds of Fe and Mn, i.e., they form them. Mn ions are present in almost all marsh waters. Therefore, it can be said that its migration is governed by water.

In fact, the migration and accumulation of Fe and Mn are largely determined by plants, specifically by a number of compounds in their composition. Thus, the compounds formed during the oxidation process of Fe and Mn accumulate, while in the reduction process, they undergo migration. The migration and accumulation of Fe and Mn in the soil and parent material, i.e., their biogeochemical short-term movement, can be described as follows:

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Mn^{++} dissolved in $\rightleftarrows$ Mn^{++} in living organisms $\rightleftarrows$ $Mn^{+2,+7}$ in minerals

Similar processes can also occur with iron and gold. However, the migration of Mn and Fe in the Earth's crust differs sharply from that in water and plants. This situation can be observed in waterlogged grasslands. Elements like iron and manganese are oxidized under hypergenic conditions and can even be highly oxidized.

Such conditions can be seen in hydromorphic soil environments with evaporative and oxidizing pedobiogeochemical barriers. It should also be noted that these oxides, as they penetrate deeper into the inner layers of the soil under the influence of various factors, gradually reduce their oxygen content. This happens because the oxygen in the soil profile decreases as it moves deeper. As a result, organisms that require oxygen experience a growing deficiency, which theoretically intensifies. Despite being part of relatively high-valency oxidized compounds, they are forced to obtain oxygen from these compounds. In this way, the oxygen content of Mn, Fe, and S compounds decreases as they move deeper in the hydromorphic environment.

This situation can be observed when describing the morphogenetic features of marsh, meadow, meadow-marsh, marsh-meadow, and other hydromorphic soils, particularly in specific layers, such as black, bluish, or bluish-yellow spots. Such conditions are frequently encountered in the hydromorphic soils of Central Fergana. Thus, the genesis of each soil is determined by its chemical composition, the state of elements, and compounds within it.

Additionally, the gleying process involves the decomposition of primary and secondary minerals and the formation of secondary aluminosilicates. In this case, the role of iron(III) oxide is significant. During this process, dispersion occurs in the soil particles, and the density of this layer increases.

As a result, water and air permeability decreases sharply. The gleyed layer thus forms in marsh and other hydromorphic soils. Consequently, marshy soils also form in desert and steppe regions. These soils develop in depression forms of the relief, ancient river terraces, and floodplain deposits, as previously mentioned.

Specifically, with regard to the residual marsh and gleyed soils in Central Fergana, they form in the lower-lying areas of the region, in depressions that emerged after the Sirdarya receded. These areas have sandy upper layers and impermeable subsoil layers, and the soils are shaped by both mineralized and non-mineralized groundwater sources. In these areas, plants such as reeds, bulrushes, rushes, cattails, and brown sedge grow. In Uzbekistan, azonal marsh and meadow-saline soils cover about 0.9 million hectares.

Marsh soils, at the same time, act as special accumulators for fresh waters and participate in water exchange with the surrounding environment. The formation of marsh soils thus enters the soil formation process.

In gleyed soils, at the same time, through phytocenosis, the organic matter produced in the area plays a certain role in the parent material. However, the formation of marsh soils is primarily influenced by the relief and the soil cover of the region.

Marsh soils, in terms of their genesis, are poor in silicon, which contributes to the productivity of marsh plants. In marsh soils, it is not water, but rather the soil itself, which has undergone gleying

and even turned into a suspension, that plays the primary role in providing the base for mineral elements.
It is well known that the formation of marsh soils follows a natural mechanism and is not outside the general soil formation process. In this process, the evolution of plants plays a significant role. Biogeochemical processes in the soil, with the participation of microorganisms, lead to the evolution of its mineral and organic world. According to the literature, the upper, middle, and lower marshes form a unified process of marsh soil formation. In the formation of marsh soils, the role of plant remains is significant; their decomposition, humification, and peat formation are dependent on a range of factors. The majority of their root systems are located in the top 20–30 cm, rarely reaching up to 70 cm. This is related to the oxygen content and its deficiency. The formation of marsh soils in arid regions is a process of lithospheric and hydrospheric interaction.
The hydrospheric factor, that is, the groundwater in desert conditions, plays a leading role in forming the mineral part of marsh soils, contributing to the accumulation of mineral elements and substances in the relatively deeper layers. However, the primary factor is the minerals in hydrogen-rich conditions, and the composition of the initial soil or bedrock suspension. Ultimately, the primary factors for the formation of marsh soils are the relief and the initial soil cover or bedrock. Theoretically, in the evolution of these soils, especially in the direction of marsh-meadow soils, changes occur in the electrokinetic potential and potential energy in the layers. In other words, as the layers deepen, the energetic potential involving organic substances decreases, while the electrokinetic potential increases. This process is influenced by irrigation, particularly in areas with paddy cultivation, affecting soil-forming processes and the lateral and radial migration of elements and substances. The migration coefficients of certain ions in water also play a role. As a result, significant changes occur in the morphological characteristics of the soil, as well as in its pedobiogeochemical properties and features.

Conclusion

In swamp soils, the processes of oxidation and reduction change during the regeneration process. Over time, the gleying process intensifies in these soils. The oxidation process occurs in the upper layers, while reduction takes place in the lower layers, leading to changes in the profile. As a result, the genesis and evolution of swamp soils are modified. Specifically, as swamp soils evolve toward meadow, semi-automorphic, and automorphic types, the gleying process initially halts, then the thickness of the gleyed layer decreases, and positive changes occur in the soil properties.
In these processes, the main elements, such as iron (Fe), manganese (Mn), and sulfur (S), play a crucial role in oxidation and reduction reactions. For instance, the oxidation process of iron occurs as follows:
$2Fe^{+}-2e \rightarrow 2Fe^{+3}$ while in the reduction of manganese, the following reaction involves the transfer of five electrons: $Mn^{+7}+5e \rightarrow Mn^{+2}$
Thus, under the appropriate conditions in hydromorphic soils, gleying takes place. During this process, the size of ions changes: when electrons are lost, the ion size decreases, and when electrons are gained, the ion size increases. As a result, this process affects the density of the clayey layers.

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