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Late Pleistocene Climate Changes in the Ukraine Territory (Based on Clay Matter Analysis Data)

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ABSTRACT. Development of nature in the territory of Ukraine in the Upper Pleistocene was characterized by the contrasting conditions. It led to alternation of warm and cold stages. Change of environmental conditions is fixed in mineral composition of clay matter in deposits. In different regions of the flat area of Ukraine, mineral composition of the clay matter (< 0.001 mm) of palaeosols and loesses of the Upper Pleistocene stages were investigated by a complex of methods. Mineral mass of loesses and loess loams is poorly weathered, it has 10–20% of silt and the hydromica-montmorillonite composition of the clay matter that prove cold (periglacial) climatic conditions of these deposits formation.

Palaeosols of the Upper Pleistocene are largerly clayed (28–45% of silt), they are characterized by the polymineral composition and chemical forms of weathering of the clay matter. Minerals of the smectite group (an indicator of temperate and warm conditions), mixed layer hydromica-montmorillonite formations are dominant; kaolinite, quartz, calcite and gypsum accompany them. Time and space variations of mineral composition of palaeosols and loesses are connected with the repeated changes of climatic conditions from periglacial to warm and arid in the Ukrainian area in the Upper Pleistocene.

KEY WORDS: climate, loesses, palaeosols, clay matter.

Introduction

The Late Pleistocene nature development was characterized by the change of warm and cold climatic conditions that led to alternation of stages of the intensive soil formation with stages of loesses formation. In the territory of Ukraine, 7 palaeogeographical stages (3 warm and 4 cold) of the nature development in the Late Pleistocene (Veklich et al., 1984, 1993) were recognized. The Upper Pleistocene lower boundary passes through the foot of the cold Tyasmin (ts) stage deposits (170 ka BP).

Palaeosols and loesses of various age differ by a number of signs (type, thickness, colour, morphology, granulometric, chemical, mineral composition, etc.) that proves various environments, climatic first of all, during separate palaeogeographical stages.

Predominant accumulation of this or that mineral depends on initial material and stage of weathering that in its turn is stipulated by a number of physico-chemical factors of the environment. Processes of mineral mass transformation are usually connected with climatic conditions. Intensity and direction of weathering processes depend on temperature regime, quantity of atmospheric precipitation in different seasons.

The formation and changes of mineral composition of loess-soil formations in the territory of Ukraine are defined by land-

scape-climatic conditions of the Upper Pleistocene paleogeographical stages.

Duration of palaeogeographical stages largerly influenced the mineral matter composition, and lithogeneous base and conditions of the deposits formations defined the character of formations and secondary changes of mineral mass. The clay component of the mineral matter rather strictly fixes environmental changes and serves as an indicator of conditions.

The clay matter of palaeosols and loesses is the most active part of the mineral phase of deposits and forms the object of our studies.

Methods

The thin dispersed section (< 0.001mm) of the Upper Pleistocene deposits has been studied by a complex of methods. The following methods were applied: X-ray diffraction of natural, oriented, enriched with glycerine or ethylen-glycole, heated up to 550 °C, enriched with warm HCl of preparations ("Dron-1", "Dron-05"devices, Cu radiation, Ni filter); differential thermal analysis ("Q-1500" derivatograph); total chemical analysis; electronic microscopy analysis ("Tesla", 17,500 and 20,000 magnification).

Mineral composition of the clay matter of the Upper Pleistocene deposits from 34 thoroughly stratified key sites and boreholes from different regions of the flat area of Ukraine (Middle and Porozhistoye Pridnieprovye, Pobuzhye, Donbass, Lower Pridniestrovye, left bank of the Lower Danube, the Kerch Peninsula, Prichernomorye) has been studied. It allowed us to get rather complete characteristics of spatial and temporal variations of the Upper Pleistocene conditions (Perederij, 1974, 1975, 1976, 1977, 1981, 1984, 1988a, 1988b, 1989, 1990, 1991, 1993, 1995, 1998a, 1998b, 1999a, 1999b).

Results and analyses

It is known that the degree of sediments dispersity testifies to weathering and soil formation and to the intensity of these processes, it is tightly connected with palaeogeographical conditions, that's why soil horizons are more clayed compared with loesses.

The clay matter of the Upper Pleistocene palaeosols and loesses has polymineral composition. Minerals of the smectite group, hydromicas, mixed layer formations of the hydromica-montmorillonite type, kaolinite in variable quantities are the main components. Chlorite, dispersed quartz, goethite, calcite and gypsum accompany them.

Deposits of the cold Tyasmin (ts) stage (170–130 ka BP) are represented by loesses and loess loams of pale-yellow, brownish-pale-yellow colour from 0.5 to 1.2 m thick, they are spread in the middle belt of the flat area and contain less clay (10–17% of silt). The clay matter is poorly weathered, in the Middle Pridnieprovye areas it is represented by hydromicas (an indicator of cold conditions), in a southerly direction the smectite content increases together with the hydromica component.

The Priluki (pl) stage (130–100 ka BP) was characterized by a rather warm and humid conditions that led to the formation of palaeosols of different types and of considerable thickness (up to 3.5 m). Zonal and regional variations are recorded in the soil cover of the Priluki time: in the northern part of the area - brown forest, brownish-grey soils; in the Middle Pridnieprovye - brown forest steppish soils and chernozems of the meadow steppes; in the Porozhistoye Pridnieprovye - the micelium-carbonate chernozems and meadow-chernozem soils; in the Donbass area chernozems, chestnut, cinnamonic-grey soils are dominant (Veklich et al., 1973, 1990; Sirenko, 1974; Sirenko and Turlo, 1986).

Brown steppish, chestnut, reddish- and cinnamonic-brown, alkaline soils (Veklich et al., 1990; Veklich and Sirenko, 1976; Veklich et al., 1993; Matviishina et al., 1990) are peculiar for the southern regions (Lower Pridniestrovye, Prichernomorye, Priazovye).

Changes of the environmental conditions during the Priluki stage favoured the formation of soil phases (pl_{b1}, pl_{b2}, pl_c) that are notable for the differentiated distribution of the clay matter (from 21 to 34% of silt) with a trend of its decreasing in the lower part of a horizon. In the Donbass and Prichernomorye areas, argillization of soils increases up to 40%.

The clay matter of the Priluki soils is characterized by a polymineral composition with traces of chemical forms of weathering and reworking. It is represented by smectites, mixed layer formations in different proportions. Minerals of the smectite group (an indicator of warm, temperately humid conditions) are dominant. An admixture of hydromicas, kaolinite, chlorite and quartz is not large. The mixed layer formations amount increases in the Middle Pridnieprovye and Donbass areas. The Priluki soils of the Lower Pridniestrovye, Kerch Peninsula, Prichernomorye are notable for the considerable quantity of the thin dispersed calcite and gypsum indicating more arid conditions.

The next cold Udaj (ud) stage (100–90 ka BP) favoured the formation of loesses and loess loams of pale-yellow, light-brown, reddish-brown colour and of small thickness (0.3–1.0 m) that are often absent in the elevated areas, and in the northern areas they are found sporadically. Not large argillization (14–20% of silt), hydromica-montmorillonite composition and poor weathering of the clay matter indicating periglacial conditions of these deposits formation are peculiar to them. Presence of the mixed layer formations and some reworking of the clay matter by the soil forming processes of the subsequent stage is recorded in the upper part of the Udaj horizon of the Donbass and Prichernomorje areas.

Palaeogeographical conditions of the Vitachev (vt) stage (90–75 ka BP) favoured the formation of different soil cover types, thad had different zonal and regional peculiarities (Veklich, 1965, 1968; Veklich and Sirenko et al., 1973; Sirenko, 1974). However, they have the common features as well: brown colour (with different tints), considerable argillization (30–40% of silt), large amount of sesquioxides, ferruginization, carbonization, not large thickness (0.7–1.5 m), development by phases (vt_{b1}, vt_{b2}), polymineral composition of the clay matter. Such features indicate contrast conditions of soil covers formation in the Vitachev time from warm dry to warm humid with intensive weathering processes and soil formation that is proved by the peculiarities in composition of the thin dispersed part of soils.

The main component of the mineral association of the Vitachev soils in the whole territory is represented by smectites, considerable amounts of the mixed layer hydromica-montmorillonite formations and sometimes kaolinite are recorded; an admixture of hydromica, quartz, calcite and gypsum is found. Zonal and regional variations are observed in mineral composition.

The smectite component of the clay matter with large amount of the mixed layer formations is characteristic for the northern areas of the Middle Pridnieprovye (brown, burozem-like soils), besides them, kaolinite (an indicator of

humid hot conditions) is peculiar to the central part of the Middle Pridniestrovye and Pobuzhye. High argillization of soils (37–40% of silt), weathering of mineral mass, presence of ferromanganesian concretions indicate the activity of soil forming processes under the warm humid climate (vt_{b2}). The smectite group minerals and the mixed layer formations dominate the areas of Porozhistoye Pridnieprovye, northern part of Donbass (cinnamonish-brown, greyish-cinnamonic soils). The soils are less argillized (30–35% of silt), they have the reddish tint, considerable amounts of $CaCO_3$ indicate the alternation of humid and dry conditions.

In the Donbass area (the Pridonetsk plain, the dark brown soils with the cinnamonish tint), argillization (up to 43–46% of silt), carbonization, alkalization and gypsumization increase that is connected with the arid conditions.

The Vitachev soils of the Lower Pridniestrovye and Prichernomorye (reddish-brown alkaline) are less clayer (30–33% of silt), they are characterized by the dominance of the smectite group minerals and the mixed layer formations with some increase of the kaolinite share in vt_{b2}. Presence of a considerable amount of calcite and gypsum indicates the subarid conditions of development, while ferruginization and weathering of mineral mass indicate the alternation of humid and arid periods.

Loesses and loess loams of the cold Bug (bg) stage (75–50 ka BP) are notable for the different degree of argillization (12–23% of silt), high carbonization ($CaCO_3$ up to 20–27%), pale-yellow and yellow-pale-yellow colouring, different thickness (from 0.4 up to 15 m). In the Donbass, Prichernomorye and Priazovye areas it comprises 2–4 m (Veklich, 1968).

In the clay matter assemblage, the hydromica content together with smectites increases, especially in thick strata. The mineral matter bears traces of the physical forms of weathering that in combination with high carbonization is peculiar to cold and arid conditions. In the upper parts of the most thick sections of the Middle and Porozhistoye Pridnieprovye areas, content of the mixed layer hydromica-montmorillonite formations somewhat increases under the influence of the soil forming processes of the subsequent stage influence.

Formation of the Dofinovka (df) stage (50–21 ka BP) soils took place under the steppe conditions. The turf, turf-carbonate soils (Middle Pridnieprovye); chernozems, brown steppe, meadow-chernozem (Donbass, Lower Pridniestrovye, Prichernomorye) soils (df_{b1}, df_{b2}, df_{bc}) prevailed.

Not large thickness (0.5–1.7 m), medium loamy composition (22–26% of silt), considerable carbonization and gypsumization, weak weathering of mineral mass reflects the influence of a marked climate aridization that increased in the final phase (df_c) of the Dofinovka stage soil formation. It resulted in the appearance of soils of dry and semi-dry steppes in the Pri-chernomorye areas (Veklich et al., 1976).

The smectite group minerals dominate the Dofinovka soils, the calcite and gypsum amount increases in the Donbass, Prichernomorye, Kerch peninsula areas. The climate dryness did not favour the mineral mass reworking.

Loesses and loess loams of the subsequent cold, Prichernomorye (pč) stage (21–13.5 ka BP) are widely spread in the out-glacial zone, they have the brownish - pale-yellow colouring and are largely argillized (20–28% of silt) and carbonized. They are notable for the weak weathering of the mineral mass, for the presence of the embryonic soil ($pč_2$) interlayer; their thickness is 0.5–2.0 m, the clay matter is represented by the hydromica - montmorillonite . All these signs identify the cold dry conditions of the horizon formation with some warming in the Middle Prichernomorye time.

Conclusions

Summing up the investigation on the clay matter composition of the Upper Pleistocene deposits in the Ukraine territory we may state that:

- mineral composition of the clay matter of the Tyasmin, Udaj, Bug, Prichernomorye stages deposits reflects the cold conditions of the Upper Pleistocene nature development, it was formed under the influence of the periglacial climatic environment;
- the high degree of the mineral mass dispersity and weathering, its smectite composition that characterize the Priluki and Vitachev soils indicates the considerable warming during these stages;
- the smectite-kaolinite composition, considerable ferruginization of brown and burozem-like soils of the Vitachev stage reflect the most humid conditions of the environment in the Upper Pleistocene;
- the calcite, gypsum, sulphates, chlorides maximum content in the Dofinovka and Vitachev soils of Donbass and southern Ukraine proves the aridization of conditions during these palaeogeographical stages.

The analysis of mineral composition of the clay matter of palaeosols and loesses, of its temporal and spatial variations testifies repeated changes of palaeogeographical environments in the territory of Ukraine in the Upper Pleistocene from the temperate warm and humid to the arid and periglacial.

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