Upper Pleistocene Climatic Variations in Ukraine Recorded by Loess-Paleosol and Vegetational Successions

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ABSTRACT. Main Upper Pleistocene units of Ukrainian loess-paleosoil series show multiple climatic oscillations during their formation. 4–6 paleosoils (2 thin loesses in between) and 9 pollen zones are characteristic for the Pryluky-Kaydaky interval (70–130 ka BP), 4 soils separated by loess interlayers and 8 pollen zones for the Vytachiv unit (30–50 ka BP), 2 soils and 3 pollen zones for the youngest Dofinivka soil unit. The Bug loess unit (younger 30 ka BP) include 4–5 embryonic soils and 10 pollen zones, the Prychernomorsk loess unit (younger 20 ka BP) - 2 embryonic soils and 5 pollen zones.

Upper Pleistocene soil-vegetational successions are derived from paleopedological and pollen results for the territories of the forest-steppe and steppe belts. The interglacial conditions are shown for lower forest soils of Pryluky-Kaydaky interval. Rather warm interstadial conditions (forest and forest-steppe) are presented by lower soils of the Vytachiv unit, whereas much cooler climates are indicated by soils of the Dofinivka unit and by embryonic soils.

KEY WORDS: Upper Pleistocene, Ukraine, loess-soil sequence, vegetational succession, paleoclimate.

Introduction

According to the Stratigraphical Framework of Quaternary of Ukraine (Veklitch et al., 1993), 8 main units above the till unit of Dnieper (Saale) glaciation are as follows (from the bottom): the Kaydaky (kd), Pryluky (pl), Vytachiv (vt), Dofinivka (df) soil units and Tyasmyn (ts), Uday (ud), Bug (bg) and Prychernomorsk (pc) loess units. Subunits, represented by paleosoil and loess interlayers within a unit, are designated by Arabic indices, e.g. kd1. The phases of pedogenesis are designated by indices: a, b, c, correspondingly for initial, optimal and final phases, e.g. kd3c. There could be several soils of a climatic optimum which are designated by additional Arabic indices, e.g. kd1b1.

Chronological framework of the Ukrainian Upper Pleistocene subdivision is based on the ^{14}C and TL dates younger than 30 ka BP for the Bug loess unit, TL dates in 35–45 ka BP for the Vytachiv soil unit and around 70 ka BP for Uday loess unit (Shelkoplyas et al., 1986). Pollen succession from the lower forest soils of the Kaydaky-Pryluky unit shows a pattern of the Mikulino (Eemian) interglacial (Gerasimenko,1988).

Methods and material studied

Paleopedological and pollen studies have been carried out in parallel for several Upper Pleistocene sequences in the present forest-steppe (the Kyiv region) and steppe (the Donetsk region) belts, in the Crimean mountains (Gerasimenko, 1988, 1999; Gerasimenko and Pedanyuk, 1991). Simplified diagrams of pollen and paleopedological results for two sections are shown in Fig. 1, and Fig. 2. The paleopedological study includes tests of humus and carbonate contents, bulk chemical and grain-size analyses. Processing for pollen analysis involved treatment with HCl, HF, $Na_4P_2O_7$, KOH and separation in heavy liquid. The transfer functions of vegetation and palynospectra based on surface samples were used in the interpretation of pollen diagrams.

Results

Environmental and climatic variability

The succession of environmental and climatic events for the Kaydaky-Pryluky interval is as following.

In the forest-steppe: kda - ferruginous gley, *Picea* forest, humid boreal climate; kdb1 - gray forest soil, *Betula-Pinus* forest with admixture of broad-leaved species, later *Ulmus-Quercus* forest, climate was changing from boreal to temperate; kdb2 - leached chernozem, meadow steppe, climatic aridification; ts - thin loess, Gramineae steppe, climatic cooling; plb1 - gray forest soil, pseudogley, *Quercus-Carpinus* forest, humid temperate climate, later *Picea-Pinus*, a few broad-leaved species, climatic cooling; plb2 - chernozem, forest-steppe, later Herbetum mixtum-Gramineae steppe, continental climate; plc - initial soil, *Betula-Alnus* forest-steppe, boreal climate.

In the steppe: kda - initial soil, steppe, boreal climate; kd1b1 - gray forest soil, *Ulmus-Tilia-Quercus* forest-steppe and forest, humid temperate climate; kd1b2 - meadow chernozem, *Tilia-Quercus* forest-steppe, temperate climate; kd1c - 'pellet sands', *Betula-Alnus* forest-steppe with a few broad-leaved species, later steppe, temperate-boreal climate; kd2 - thin loess, Gramineae steppe, boreal climate; kd3b1 - thin brown forest soil, *Tilia-Quercus* forest-steppe, temperate climate; kd3b2 - chernozem, steppe, continental climate; kd3c - initial soil, boreal forest-steppe; ts - thin loess, xeric steppe, boreal climate; plb1 - thin brown forest soil, *Carpinus-Quercus* forest-steppe, temperate climate; plb2 - chernozem, Gramineae steppe, continental climate.

In the Crimean foothills: kdb2 - *Carpinus-Quercus* forest-steppe, few *Juglans*, temperate climate; ts - *Pinus* forest-steppe, boreal climate; plb1 - brown forest soil, *Quercus-Carpinus* forest, few *Juglans*, humid temperate climate, later *Pinus* and *Carpinus* forests, few *Abies*, temperate-boreal climate; plb 1–2 - *Betula-Pinus* forest-steppe, boreal climate; plb2 - turf soil, *Betula* and *Carpinus-Quercus* forest-steppe, boreal-temperate climate.

At the Uday loess stage, the Kyiv region was occupied by mesophytic steppe, the Donetsk region by xeric steppe. Boreal forest-steppe spread at the Crimean foothills. The presence of shrub *Betula* indicates periglacial climate at the north. At the east of Ukraine, climate was cold and dry.

The climatic and environmental changes during the Vytachiv stage were as following. In the forest-steppe: vtb1 - brown gley, *Pinus* forest with few broad-leaved species, temperate-boreal climate; vtb1–2 - loam, *Pinus* forest-steppe, boreal climate; vtb2 - initial brown forest soil, *Pinus* forest with a few broad-leaved species, temperate-boreal climate; vtb2–3 - thin loess, Herbetum mixtum-Gramineae steppe, boreal climate; vtb3 - leached turf soil, Gramineae-Herbetum mixtum steppe,

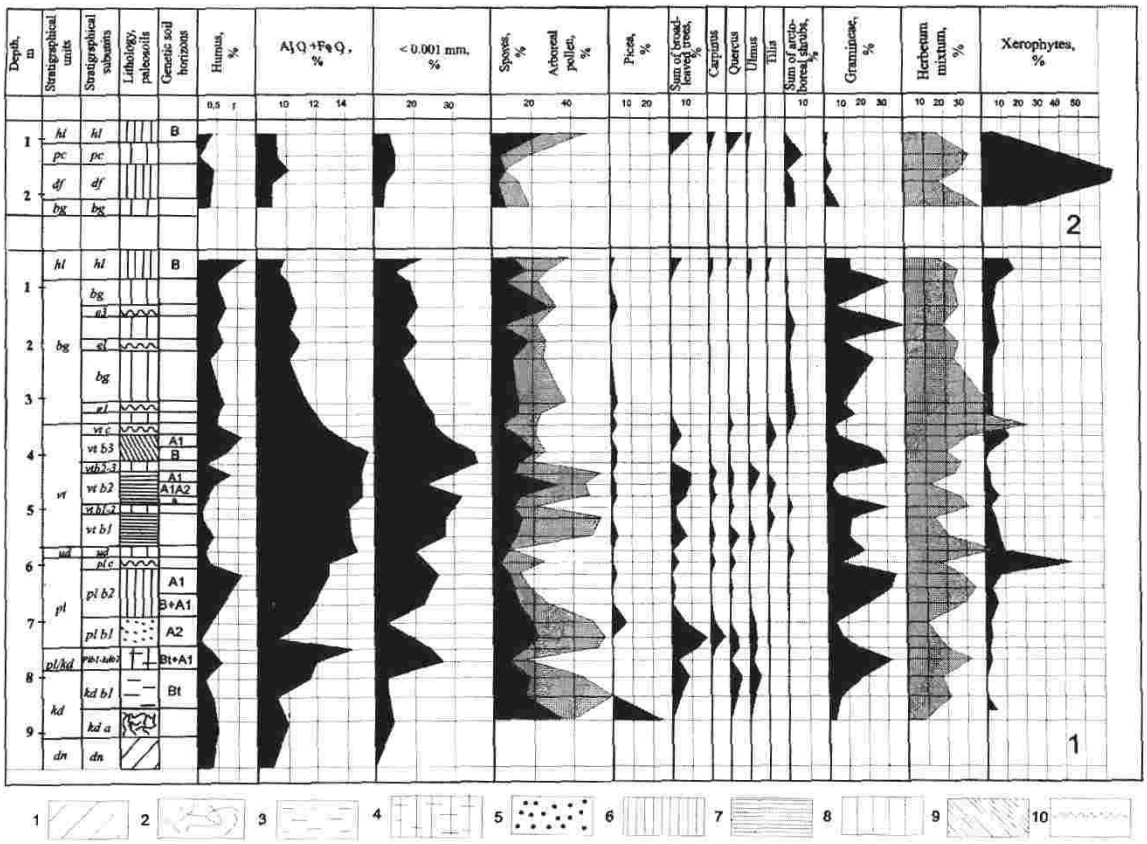

Fig. 1. Upper Pleistocene sequence Stari Bezradychy (the Kyiv region). Arboreal pollen is dominated by *Pinus*. Xerophytes are dominated by *Artemisia*. 1 - glacio-fluvial sandy loam, 2 - ferruginous gley soil, 3 - Bt horizon of gray forest soil, 4 - Bth horizon of gray forest soil, 5 - A2 horizon of gray forest soil, 6 - A1 horizon of chernozem, 7 - boreal brown forest soil, 8 - leached rendzina, 9 - loess, 10 - embryonic soil.

few *Tilia*, boreal climate; vtc - initial soil, mesophytic steppe, boreal climate. In the steppe: vtb1 - brown rendzina, boreal forest-steppe; vtb1–2 - thin loess, xeric steppe, cold dry climate; vtb2 - brown rendzina, boreal forest-steppe; vtb2–3 - thin loess, xeric steppe, cold dry climate; vtb3 - dark-brown steppe soil, steppe, boreal continental climate. At the Crimean foothills: vtb1 - brown rendzina, *Carpinus-Quercus-Pinus* forest-steppe, temperate-boreal climate; vtb1–2 - loam, boreal forest-steppe; vtb2 - brown rendzina, *Quercus-Carpinus-Pinus* forest-steppe, later Pinus forest, temperate to boreal climate; vtb2–3 - loam, boreal steppe; vtb3 - rendzina, *Carpinus-Quercus-Pinus* forest-steppe, temperate-boreal climate.

During the Bug loess stage, in Northern Ukraine, periglacial forest-steppe was later replaced by periglacial mesophytic steppe. Xeric steppes of cold continental climate covered the eastern regions, whereas in the Crimean foothills, steppes were mesophytic, without arcto-boreal plants. Climatic oscillations are fixed by 4–5 embryonic soils. During their formation, in the Kyiv region, Herbetum mixtum-Gramineae steppe was replaced by meadow steppe, arboreal plants increased while shrub *Betula* and *Alnaster* decreased. This indicates a slight climatic warming and humidification.

At the Dofinivka stage, in the northern Ukraine: df1 - brown rendzina, *Betula-Pinus* forest-steppe with both few broad-leaved and arcto-boreal species, boreal climate; df2 - thin loess, periglacial steppe; df3 - initial rendzina, *Betula* forest-steppe (high share of shrub *Betula* and *Artemisia)*, periglacial climate. In the eastern steppe: df1 - weak chernozem, steppe, few *Betula*, boreal continental climate; df2 - loess, semidesert, cold arid climate; df3 - brown steppe soil, *Artemisia* steppe, boreal arid climate.

At the Prychernomorsk loess stage, the Kyiv region was occupied by steppes with a high share of *Artemisia* and presence of shrub *Betula (*periglacial climate), the eastern regions by *Artemisia*-Chenopodiaceae semidesert (cold arid climate). Two embryonic soils at the top of Prychernomorsk loess are characterized by boreal forest-steppe ecotones.

Conclusions

Upper Pleistocene units of Ukrainian loess-paleosoil series show multiple climatic oscillations during their formation. The Pryluky-Kaydaky interval includes 2–3 pedocomplexes, separated by thin loesses. Each pedocomplex consists of forest soil at the bottom and steppe soil at the top. The position above the Dnieper (Saale) till, the pollen succession of Mikulino (Eemian) type from the lower forest soils and TL dating to 70 ka BP of the overlying loess (see above) allow preliminary correlation of this interval with marine isotopic stage 5. Four soils separated by loess interlayers and 8 pollen

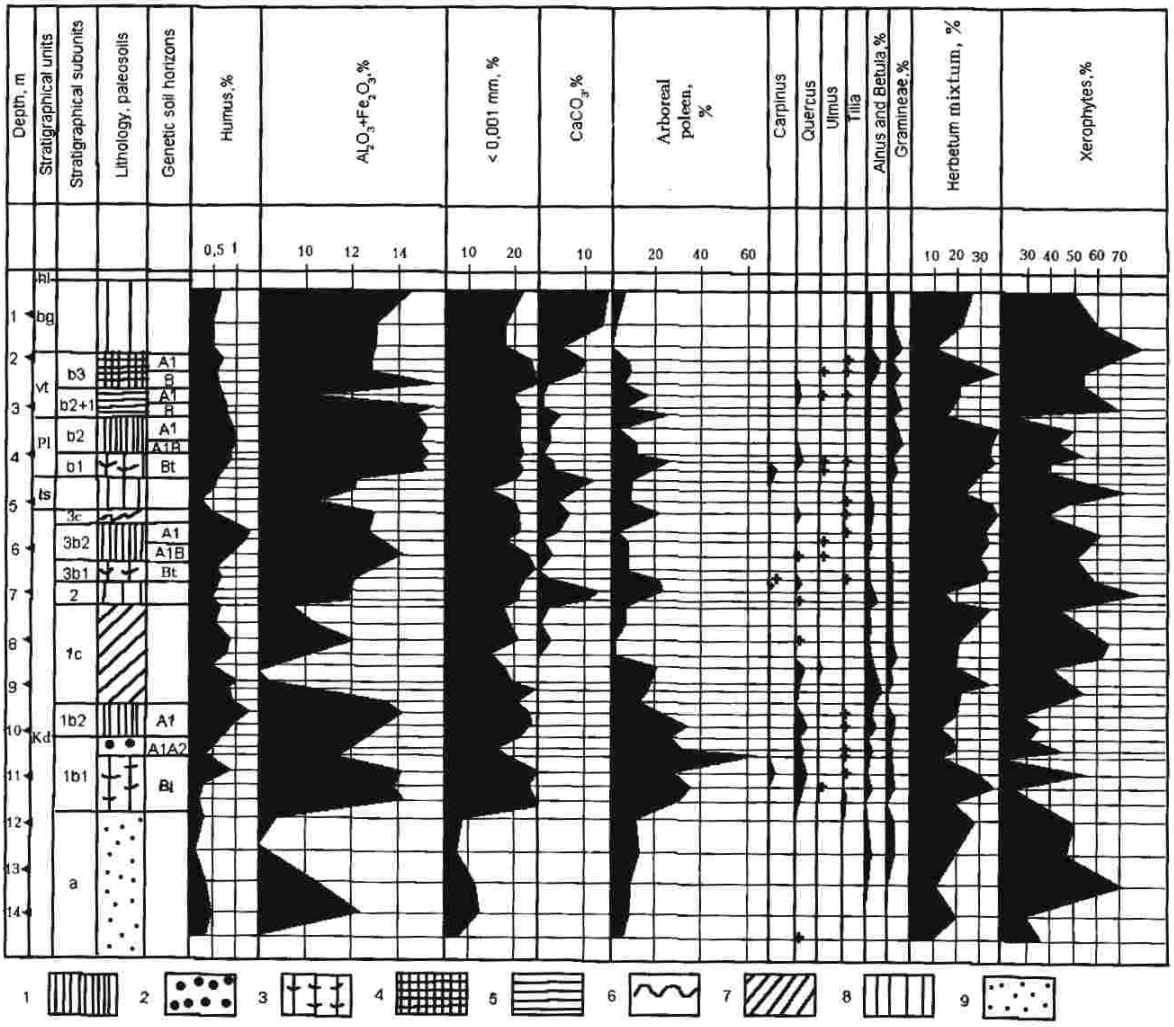

Fig. 2. Upper Pleistocene sequence Kryva Luka (the Donetsk region). Arboreal pollen is dominated by *Pinus*. Xerophytes are dominated by Chenopodiaceae. 1 - chernozem, 2 - A2 horizon of gray forest soil, 3 - Bt horizon of gray forest soil, 4 - dark-brown steppe soil, 5 - brown rendzina, 6 - embryonic soil, 7- pedosediment, 8 - loess, 9 - gully alluvium.

zones are characteristic for the Vytachiv unit, possible equivalent of marine isotopic stage 3 (by TL data), and 2 soils and 3 pollen zones for the youngest Dofinivka soil unit. The thickest Bug loess unit (younger than 30 ka BP) include 4–5 embryonic soils and 10 pollen zones, and the Prychernomorsk loess unit (younger 20 ka BP) - 2 embryonic soils and 5 pollen zones.

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