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Late Holocene soil and vegetational changes in the foothills of the SE Carpathians (Ukraine), based on the study of pedochronocatenas

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A study of pedochronocatenas which include soils of archaeological sites is a reliable approach to reconstruct environmental changes since the time of the settlements existence. The studied pedochronocatenas include: 1) soils buried under ancient earth ramparts, 2) soils formed on the surface of these ramparts, and 3) natural undisturbed soils located close to the ramparts. The studied sites are located on the plateau between the Prut and Siret rivers (in the Glyboka district of the Chernivtsi region, South-Eastern part of the Ukrainian Carpathians). At present, this area is covered mainly by Haplic Greyzems and Dystric Cambisols under broad-leaved forests.

Pedochronocatenas at two sites have been studied: 1) the Glyboka defensive rampart built during the IX-Xth centuries AD (1100-1000 yr BP, ^{14}C 1040±190, the Early Slavic time) and 2) the Grushivka rampart built as a defence from the Scythians during the Vth century BC (2500-2400 BP), but also with the new material deposited on the old rampart during the Early Slavic times. According to archaeologists [3–6] the ramparts were built in order to defend those sides of the settlements which were unprotected by natural barriers. Morphological and morphometrical soil analysis, as well as pollen study have been carried out in order to trace pedogenic, vegetational and climatic changes since the time of the rampart's construction.

At the ***Glyboka site***, the old Slavic settlement is located in a position defended by steep slopes on three sides and by several parallel earth ramparts on the northern side. As a result of the excavation, the soil buried under the rampart and the soil on its surface (section H-1B) have been studied and compared with the profiles of soils located between the two ramparts (sections H1 and H2). The parent rocks of the soils are clayey, partially re-worked by the initial pedogenesis and very dense. Both buried and present-day soils are related to Dystric Cambisols. Nevertheless, some characteristics of the buried soil show that it is actually transitional from Eutric Cambisol to Dystric Cambisol. The soils formed on the rampart have been intensely transformed by human activity. They include lenses of re-deposited material, pieces of burnt clay, ceramics, charcoal and vegetational remnants which were rotted through in the earth material of the rampart. The section H-1B includes such soil horizons (buried soil horizons are marked with brackets, depths in cm): A (2–48) – the upper humus horizon formed on the material of the earth wall and partially transformed by gravitational processes; Ahk (48–76) – transitional, within the earth wall material; [(Ae)] artifact (76–120) – the upper humus horizon of the buried soil, with artifacts; [AEgl] (120–148) – humus-eluvial (leached of clay); [Bthg)] (148–185) – humus-illuvial (with clay accumulation) metamorphic; [BtCg] (185–250) – illuvial, transitional to parent rock; [Ckg] (250–300) – parent rock; [Dkg] (300– visible up to 310) – underlying rock, intensely gleyed.

In section H2, the soil profile is thick (142 cm) and likely has not been transformed during the rampart construction. It includes these soil horizons: O1 (0–5) – humus horizon; Aehg (5–17) – humus-eluvial (leached of clay); ABhg (17–43) – humus-illuvial; Bt(h)g (43–82) – illuvial metamorphic, strongly gleyed; BtCg (82–visible up to 142) – illuvial, transitional to parent rock, metamorphic, less gleyed than the overlying horizon. Section H1 includes these soil horizons: O1 (0–5) – humus horizon; Aeh(g) (5–23) – humus-eluvial; Bhtg (23–40) – humus-illuvial, gleyed; BCtg(R) (40–visible up to 82) – illuvial metamorphic. This soil profile shows that it corresponds to the locality where from the soil material was taken to construct the rampart. Thus, the formation of the upper part of the soil profile lasted about 1000 years. Further soil development happened on the material of the reduced profile of the preceding soil.

Morphological and morphometrical comparison of the buried and undisturbed present-day soil (section H2) shows that the profile of latter soil is thicker, and the humus content increased (on 7–20%) during the period after the rampart construction. Clay translocation processes are better expressed in the buried soil. At the same time, carbonates are preserved only in the parent rock of the buried soil. This might indicate that since rampart construction, precipitation has been sufficient for further leaching of carbonates. The soil of the H2 section differs from that of the H1 site in having a lighter colour in its humus horizon.

The pollen surface sample from the present-day soil indicates the existence of mixed conifer and broad-leaved forest: arboreal pollen (AP) equals 68%, non-arboreal pollen (NAP) 15%, spores 17%, and the pollen sum of broad-leaved taxa is 19%. The last are represented mainly by *Fagus sylvatica* and *Carpinus betulus (*being *7*% each), and a few pollen grains of *Quercus robur*, *Juglans regia, Tilia cordata* and *Corylus avellana* are present. Pollen of *Picea abies* are very noticeable (19%), whereas percentages of *Pinus sylvestris* and *Abies alba* are not significant, like those of *Alnus* and *Betula* (3-4%). The NAP is dominated by Herbetum mixtum. Few pollen grains of Cerealia were found**.** Polypodiaceae (11%) prevail amongst the spores, though Lycopodiaceae and a few *Sphagnum* and Bryales spores occur.

The pollen spectrum of the humus horizon of the buried soil (section H-1B) shows the existence of broad-leaved forest (AP 87%, NAP 5%, spores 8%, pollen sum of broad-leaved taxa 76%). *Fagus sylvatica* pollen is dominant (58%), *Quercus robur* is second in abundance (16 %), and a few palynomorphs of *Carpinus betulus* and *Juglans regia* are present. Pollen counts of conifer trees, *Alnus* and *Betula* are very low. The NAP composition is poor, and Polypodiaceae prevails among the spores.

Thus, beech forest with an admixture of oak grew around the site during the construction of the rampart. The ground cover in this shadow forest was sparse. During formation of the humus horizon of the modern soil, broad-leaved trees became fewer, mainly at the expense of the spread of *Picea*. This indicates that the climate became cooler, as compared to the IX-Xth centuries AD. The latter period is known as the “Medieval climatic optimum”. The composition of broad-leaved trees became more diverse during formation of the humus horizon of the modern soil, and the ground cover became better developed. This is a possible reason of less intense clay translocation processes in the modern soil as compared with the buried one though the precipitation was sufficient for the further carbonate leaching. Human impact on the vegetation is seen in the occurrence of Cerealia and *Juglans* pollen even in the soils that were formed under forests. The presence of *Juglans regia* pollen in the buried soil indicates that cultivation of this warmth-loving tree had already occurred in the Prut-Siret area 1100-1000 years ago.

At the ***Grushivka site***, there are two defensive ramparts. One of them (180 cm high and followed by a 1m-deep ditch) had protected the Early Slavic settlement which was delimited on the other three sides by steep slopes. The other rampart, according to the archaeological study [4, 6], had been built for the protection of the settlement from the Scythians (VI–V centuries BC, the Early Iron Age). Later on (at the end of VII century − beginning of IX century AD), the area of this old settlement was occupied by the Slavs, who had re-used the remnants of the old rampart, and put new soil material on to it.

At present, the ramparts are located under the forest vegetation or at the forest-meadow boundary. The modern soils on plateau, as well as the soils buried under the rampart of the Slavic time, are represented by Haplic Greyzems. According to the regional palaeogeographical and archaeological data [1–2], the soils buried under the ramparts of the Scythian time in the Chernivtsi area, are Luvic Phaeozems, and, thus, the location area was covered by meadow vegetation.

The undisturbed natural soil near the studied ramparts (section Gr-1) is characterized by very thick clay-illuvial horizons and the appearance of $CaCO_3$ at the depth 135-140 cm. It consists of such soil horizons (depths in cm): AE (0–21) – humus-eluvial (leached of clay); Bthg (21–45) – humus-illuvial; Bt(h)g (45–127) – illuvial metamorphic; BtCkg (127–135) – illuvial transitional; Ckg (135–visible up to 152) – parent rock which is, at the same time, the gleyed carbonate horizon of the soil.

The section Gr-2B (excavation of the Slavic rampart) includes: 1) weakly developed soil on the top of the rampart with these soil horizons: A (0–10) + artifact (10–29) – humus horizon within the rampart wall material; AC, artifact (29–59) – transitional, within the rampart wall material, transformed by anthropogenic processes; 2) buried soil with these soil horizons: [Ae] (59–76) – humus horizon; [ABt] (76–94) – humus-illuvial; [Bhg] (94–147) – illuvial; [Btg] (147–180) – illuvial transitional, strongly gleyed; [BtCg] (180–200) – parent rock, with signs of secondary processes of illuviation and metamorphic clay accumulation. The humus horizon of the buried soil is ^{14}C-dated to 1160±170 BP.

The section Gr-3B (excavation of the rampart of the Scythian times) is represented by the soil with these horizons (buried soil horizons are marked with brackets, depths in cm): A+artifact (0–67) – humus horizon, artifact; AC, artifact (67–79), transitional from the Medieval humus artifact horizon to the buried humus horizon; [A] (79–100) – humus horizon; [Aeg] (100–135) – humus-eluvial; [ABtg] (135–185) – humus-illuvial, gleyed.

The soils profiles of the modern and buried soils are thick and do not have distinct lower limits with parent rocks. Humus deeply penetrates into the soil profiles (>100 cm in depth) that indicates the present and past development of humus-accumulative processes, though clay translocation also happened during the formation of these soils. Carbonates occur in the lower horizon of the modern natural soil, whereas the buried soils are completely leached of them. Thus, processes of forest and meadow-steppe pedogenesis both happened during formation of the modern and buried soils. Clay translocation is better expressed in the present-day undisturbed natural soil whereas humus accumulation is more pronounced in the soil under the rampart of the Scythian times. Thus, it is suggested that the modern Haplic Greyzem developed from the former Luvic Phaeozem during the last 2500 years. Judging from the characteristics of the buried soils, forest-steppe ecosystems existed in the studied area between 2500 and 1100-1200 years BP.

The pollen surface sample from the modern soil (section Gr-1) is characterized by a forest type of pollen spectra (AP 63.5 %, NAP 13.8 %, spores 22.7%). The pollen percentage of broad-leaved trees (18.1%) is typical for mixed broad-leaved and conifer forest. The composition of broad-leaved taxa is diverse: *Carpinus betulus* (9.8 %), *Quercus robur* (3.6 %), *Juglans regia* (2.4 %), *Tilia cordata* (1.4 %) and *Fagus sylvatica* (0.9 %). The pollen percentage of *Picea abies* is noticeable

(8.8%) whereas those of *Abies alba* and *Pinus sylvestris* are not significant (especially judging on high pollen productivity of pine). The NAP is dominated by diverse mesophytic herbs from Ranunculaceae, Rosaceae, Brassicaceae, Lamiaceae, Apiaceae, Scrophulariaceae, Primulaceae, Plantaginaceae, Cichoriaceae and Asteraceae families. Pollen percentages of Poaceae and Chenopodiaceae are low (2.2%). The spores are dominated by Polypodiaceae (16.7%), though palynomorphs of *Pteridium* (2.8%), Lycopodiaceae (1.9%), Bryales (0.9%) and *Sphagnum* (0.3%) occur. This pollen spectrum adequately represents the modern vegetation.

The pollen spectrum from the humus horizon of the buried soil (^{14}C 1160±170 BP) reflects the existance of broad-leaved forest (AP 69.8%, NAP 23.8%, spores 6.4%, sum of pollen of broad-leaved trees 40.2%). Pollen of *Tilia* is most abundant (26.9%), and it includes both *Tilia cordata* and *T. platyphyllos*. The other broad-leaved taxa are represented by *Quercus robur* (5.3%), *Fagus sylvatica* (3.7%), *Carpinus betulus* (3.2%), *Ulmus laevis* (1.5%) and *Juglans regia* (0.5%). Pollen of conifers are represented by *Pinus sylvestris* (25.4%) and *Picea abies* (3.2%). Few pollen grains of *Alnus glutinosa* and *Corylus avellana* also occur. In the NAP, mesophytic herbs prevail (14.8%) which include Asteraceae (6.4 %), Ranunculaceae (4.7%), Apiaceae and Cichoriaceae (being 2.6% each), Rosaceae (2.2%), Primulaceae (1.6%), single pollen grains of *Lamiaceae, Caryophyllaceae* and *Urtica* sp. Only few pollen of xerophytes occur: Chenopodiaceae (2.2%) and *Artemisia* (0.5%). The spores include Lycopodiaceae (3.7%), Polypodiaceae i Bryales (being 1% each) and *Sphagnum* (0.5%).

During formation of this pollen spectrum, the studied area was occupied by broad-leaved forest which was dominated by lime-trees but it also included oak, beech, hornbeam and elm as admixtures. Spruce and pine had a very limited participation in the vegetation composition. The significant pollen presence of *Tilia platyphyllos* shows that the climate was favourable for growth of this warm- and wet-loving tree. Its pollen has not been found in the surface pollen sample. This, as well as the high pollen percentage of broad-leaved taxa, gives evidence that around 1200-1100 yr BP (the end of VII − IX cent. AD), the climate was significantly warmer and possibly somewhat drier than nowadays (the beginning of the “Medieval climatic optimum”). Pollen of *Juglans regia* indicates the early introduction of walnut in the area studied. As compared to the vegetation reconstructed for the similar time span at Glyboka site, the lime forest at Grushivka was lighter than the Glyboka beech forest, and, thus, the mesophytic herb cover was better developed.

Human impact on the vegetation cover was not significant during VIII-IX centuries AD, whereas, nowadays, it can be traced (even in the surface sample from the forest ecosystem) by pollen presence of weeds (*Centaurea cyanus* and *Plantago major).*The higher spore percentages of ferns in the modern surface samples as compared with those in the buried soils are evidently connected with forest clearings during the last 1000 years.

The obtained data show the following environmental changes in the studied area: 1) forest-steppe ecosystems which existed at the end of Subboreal − beginning of Subatlantic (VI-V centuries BC) were replaced by broad-leaved forests in the VIII-X centuries AD. Thus, the climate became significantly wetter. Judging from pedological data, the further increase in humidity happened during the last 1000 years. Judging from pollen data, the climate during VIII-X centuries AD was significantly warmer than during the XIX-XX centuries AD.

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