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VEGETATIONAL EVOLUTION IN THE TRANSCARPATHIAN LOWLAND (UKRAINE) DURING THE MIDDLE PLENIGLACIAL (POLLEN STUDY OF THE BEREGOVO I SITE)

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ABSTRACT: A reconstruction of the vegetational evolution during the Middle Pleniglacial has been carried out on the basis of a pollen study of the loess-palaeosol deposits from the Upper Palaeolithic site Beregovo I (Transcarpathian Lowland). The stratigraphy of the site is based on the Quaternary stratigraphical framework of Ukraine, the archaeological data and AMS ^{14}C-dating. At the end of the Uday time of loess formation (Early Pleniglacial), forest-meadow ecosystems (with predominance of birch and pine in the forests) existed under the cold and wet climate of a stadial. Three main stages of vegetation development (with several phases) have been identified within the Vytachiv time (the Middle Pleniglacial). During the beginning of the first stage (the Early Vytachiv time, the formation of the lower Cambisol), coniferous and broad-leaved forest grew under the rather warm climate of an interstadial. The second phase of this stage was characterized by a spread of a forest-steppe. The warm interstadial climate, indicated by the growth of broad-leaved trees, became less humid. During the second stage of the Middle Pleniglacial (the Middle Vytachiv time, represented by loess-like deposits), a boreal forest-meadow vegetation spread under the cool climate of a stadial. The Aurignacian cultural horizon corresponds to the deposits of this stadial. Three phases of vegetation development have been recognized within the third stage of the Middle Pleniglacial (the Late Vytachiv time). During the first phase (the beginning of the upper Cambisol formation), there existed a forest-steppe with predominance of boreal trees. The climate was relatively cool and corresponded to a transition from a stadial to an interstadial. The second phase of this stage (the formation of the upper Cambisol) was characterized by forest-meadow vegetation with a spread of broad-leaved trees. This phase corresponds to an interstadial warming. During the third phase (the transition from the Cambisol formation to the incipient pedogenesis, AMS dated to 27-26.6 ka uncal BP), an elm-hornbeam forest with admixture of spruce grew on fertile loamy soils, and pine-birch forest occupied the sandy terraces. The climate was still warm and humid. After the end of the Middle Pleniglacial (the beginning of the Bug time), there occurred a spread of meadow vegetation. The decline of arboreal and broad-leaved vegetation indicated the much colder climate of a stadial. The reconstructed vegetation composition of the site demonstrates that the microclimate of the low terrace of the Tysa River was milder than in the sites located on the high river terraces. Broad-leaved trees were permanently present in the site vicinities: their pollen percentages increased during the periods of the formation of the interstadial soils and drastically decreased during the times of reduction of forest areas and formation of non-soil deposits. This enables the suggestion that refugia of broad-leaved trees could survive in the Transcarpathian Lowland during the stadials of the Pleniglacial (at least before the Last Glacial Maximum).

Keywords: pollen analysis, palaeovegetation, palaeoclimate, Pleniglacial refugia of broad-leaved trees, Beregovo I, Ukraine.

1. INTRODUCTION

A study of palaeovegetation and palaeoclimate of the Transcarpathian Lowland is of a particular interest because this area, protected by the mountain ranges from the north and east, has less cold and continental climate than the plains of Eastern Europe. It might be suggested that it was suitable for the existence of refugia of broad-leaved trees during the Pleniglacial. Actually, this area is the easternmost part of the Middle Danube Lowland but, on the other hand, its vegetation was formed in connection with the Ukrainian Carpathian geobotanical province (Barabych, 1977). Thus, a reconstruction of the palaeovegetation of the Ukrainian Transcarpathia provides the bridge between Central and Eastern Europe.

The whole area of the Transcarpathian Lowland tectonically corresponds to the Transcarpathian depression, but its topography is quite diverse. Accumulative alluvial plain of the north-west (the Mukachevo Lowland) is replaced to the south-east by erosion-accumulative hilly terrains (the Solotvynska Area). In the east, there is the Vygorlat-Hutyn Ridge of Neogene volcanic origin, and separate volcano hills are scattered in the south-east (Vakhrushev et al., 2010). The Transcarpathian depression is filled with Neogene sediments – molasses and lagoonal-alluvial deposits. The Quaternary deposits form the continuous cover on the Lowland. They are mainly represented by alluvial deposits, which are frequently overlain by loess-palaeosol cover.

The climate of the area is very mild as for Eastern Europe. At the Beregovo town, the average July and January temperatures are +20°C and +3°C, respectively. The maximum July temperature is 40°C, the minimum January temperature is -28°C. The snow period (50 days in duration) is the shortest in the Transcarpathian Lowland. The annual precipitation is 650 mm (Lipinski, 2003). The area lies within the forest-steppe vegetational belt of the Pannonsky geobotanical province of heliophilous nemoral forests, meadows and meadow steppe (Barabich, 1977). An important characteristic of these forests is the presence of an admixture of the southern species of oak (*Querus petraea* and *Q. dalechampii*). The forests also include *Carpinus betulus*,

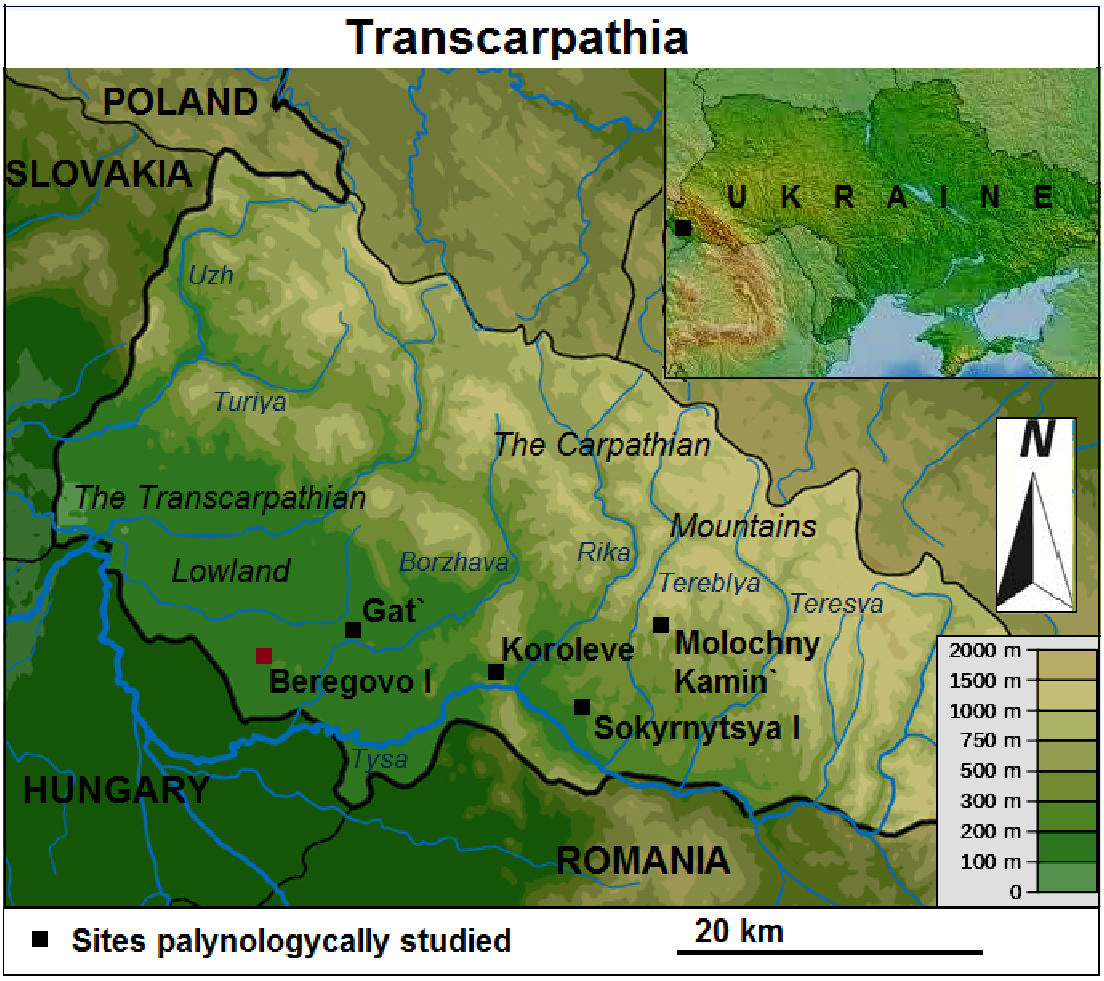

Fig.1 - Location map of the studied sites.

Acer campestre, Ulmus glabra, rarely *Fagus sylvatica. Fraxinus excelsior* grows at lower altitudes, and swampy areas are occupied by *Alnus glutinosa*. The understory is formed by *Corylus avellana, Crataegus* sp., *Euonymus verrucosa*, *E. europaeus*, *Frangula alnus, Viburnum opulus, Sambucus nigra,* and *Prunus spinosa*. The ground cover is dominated by *Carex brizoides*, *Galium odoratum, Elymus repens, Poa palustris*, *Festuca pratensis*, *Viola odorata*, and *Convallaria majalis*.

The Late Pleistocene vegetational evolution in the Transcarpathian Lowland has been studied since the 70s of the XX century. The location of the studied sites is shown in Fig. 1. The first pollen research has been carried out for the Upper Paleolithic site Molochny Kamin', situated in a cave at the foothills of the Carpathian Mountains (Gladilin & Pashkevich, 1977; Pashkevich, 1984). It has been shown that during the Würm, the lower boundary of the mountain belt of alpine and subalpine meadows was located topographically at lower elevations than nowadays. Sparse forest (*Pinus sylvestris, Larix* and *Juniperus*) with ferns in the ground cover spread on the adjacent lowlands. A pollen study has been also carried out at the multilayered archeological site Koroleve located on the highest terrace of the Tysa river (Pashkevich, 1984; Adamenko & Grodetskaya, 1987). Four stages of vegetational evolution during the Late Pleistocene have been established: 1) pine and oak-pine forests (the transition from Saalian to the Last Interglacial); 2) forests of *Pinus sylvestris, P. cembra, Picea* and *Larix* with an admixture of *Quercus, Fagus sylvatica*, and *Alnus* (beginning of the Last Interglacial, the Kaydaky time); 3) *Quercus-Carpinus* and *Quercus-Fagus* forests with an admixture of *Pinus sylvestris* and *Picea* (Last interglacial optimum, the Pryluky time); 4) *Picea* forest in the mountains, *Quercus* and *Pinus sylvestris* forests in the lowlands (the Vytachiv time).

During the last decade, a pollen study has been carried out for the Gat' site, located on the flat plain in the centre of the Transcarpathian Lowland (Gerasimenko, 2006), and the Paleolithic site Sokyrnytsya I, situated on the high terrace of the Tysa River, closer to the foothills of the Carpathian Mountains (Gerasimenko, 2011). Stages and phases of the vegetational evolution during the Late Pleistocene have been shown for the Last Interglacial (Kaydaky unit), Early Glacial (Tyasmyn and Pryluky units), and the Pleniglacial (Uday, Vytachiv and Bug units). The following stages of the Last Interglacial vegetation development have been recognized: pre-temperate (pine forest with an admixture of broad-leaved trees), early-temperate (*Quercetum mixtum*), the climatic optimum (broad-leaved forest with a high share of *Carpinus betulus* and *Corylus*), late-temperate (mixed forest: *Carpinus betulus*, *Abies* and *Picea)*, and post-temperate (*Picea-Pinus* forest). During the two Early Glacial stadials, arcto-alpine and arcto-subalpine meadow-steppe and meadow-forest spread. During the first Early Glacial interstadial, mixed forest from boreal and broad-leaved trees existed, whereas during the second interstadial, boreal forest-meadow occupied the area. During the Early Pleniglacial (the Uday time), arcto-alpine meadow and meadow-steppe expanded there. Birch-pine forest with a small admixture of broad-leaved trees existed during the Middle Pleniglacial (the Vytachiv time). The Late Pleniglacial (the Bug time) was characterized by a spread of subperiglacial meadows and meadow-steppes.

Despite the importance of the information obtained in the previous study, further investigation is necessary in order to reconstruct in details the different vegetational patterns in the Transcarpathian Lowland and to define short-period phases in the vegetational development, particularly during the Middle Pleniglacial. Such an important palaeobotanical issue is still unclear, as well as the existence of refugia of broad-leaved vegetation during the Pleniglacial.

2. SITE LOCATION AND STRATIGRAPHY

The Beregovo I site is located 1 km south of the Beregovo town, on the 3rd terrace of the Tysa river (15-20 m above the floodplain level), in a place where the terrace is cut by the valley of the Tysa tributary - the Werke river.

The archeological study of the Upper Palaeolithic site Beregovo I started in the 70-80s of the last century (Smirnov, 1974; Gladilin & Soldatenko, 1975; Tkachenko, 1989, 2003), as well as its pedostratigraphical study (Adamenko et al. 1981; Adamenko & Grodetskaya, 1987). Four Upper Pleistocene palaeosols were found and characterized within the loess cover of the terrace. The lowermost palaeosol was correlated with the Last Interglacial. The cultural layer corresponds to the loess unit separating the 1st and 2nd palaeosols, and it was related to the Upper Paleolithic (the late Aurignacian). A recent research (Usik, 2008, 2011) shows that the early Aurignacian industry of the Krems-Doufur type is represented there. The chronology of the sites has been based on the Quaternary stratigraphical framework of Ukraine (Veklitch, 1993). Later studies (Matviishyna at al., 2010) proved that the Uday loess unit is correlated with the Early Pleniglacial, the Vytachiv unit with the Middle Pleniglacial, and the Bug unit corresponds to the Late Pleniglacial. The Vytachiv unit is subdivided into subunits which are correlated with the Middle Pleniglacial of Western Europe in the following way (Gerasimenko, 2004): the Lower Vytachiv soil unit (vt_1) corresponds to the interstadials Moershoofd and Hengelo, the Middle Vytachiv loess unit (vt_2) is correlated with the Huneborg stadial, and the Upper Vytachiv soil uit (vt_3) corresponds to the Denecamp interstadial.

A short description of the upper part of the section, which was also studied palynologically (Gerasimenko, 2006), is provided below.

0.00-0.20 m - the former archaeological tip;
0.20-1.30 m - the Holocene (hl) - Luvisol;
1.30-1.85 m - Bug loess unit (bg) - loess, pale yellowish-brow, clayey loam;
1.85-3.10 m - Vytachiv palaeosol unit (vt) with subunits:
- 1.85-2.00 m - vt_{3c} - incipient soil, light-brown, clayey, compacted, with prismatic structure;
- 2.00-2.40 m - vt_{3b} - upper Cambisol, dark-brown, clayey, compacted, with prismatic structure and a lot of charcoal. The AMS ^{14}C date 27/26,6 ka uncal BP has been obtained on charcoal from the depth 2.08 - 2.18 m (Usik at al., 2014);
- 2.40-2.60 m - vt_{3b}/vt_2 - transitional horizon of the lower Cambisol, formed in the loess-like deposits, light-brown, less clayey, slightly compacted, with small spots of ochre and charcoal. The Aurignacian artifacts have been found here, mainly at the depth 2.40-2.50 m.
- 2.60-3.10 m - vt_1 - lower Cambisol, bright-brown, clayey, prismatic, strongly compacted, with clay cutans on ped surfaces, the downward transition is gradual;

3.10-3.50 m - Uday loess unit (ud) - loess-like loam, gleyey, light greenish-grey, clayey loam, blocky, much less compacted than the overlying soil, with tiny nodules and punctuation of manganese hydroxides, particularly at the upper layer.

3. METHODS

Pollen was extracted from the sediments with the following procedure: a sample (100 g in weight) is boiled in a 10% solution of HCl, washed out with distilled water to neutral reaction, boiled in 25% solution of $Na_4P_2O_7$, and washed out again to neutral reaction. A second treatment in a 10% solution of HCl is undertaken in order to remove secondary carbonates, the sample washed out, and, finally, boiled in a 10% solution of KOH with the consequent washing out to neutral reaction. After maceration, the sample is centrifuged in distilled water and heavy liquid (CdI_2+KI). A heavy liquid of densities between 2.2 and 2.0 g/cm^3 is used, and the obtained material is washed out several times (with the removal of water above the residue) until its volume fits a lab tube. Then the residue is treated in a cold 45% solution of HF for 24 hours. Such a treatment enables to obtain not less than 200 grains of pollen and terrestrial spores from a sample of mineral deposits.

The preservation of palynomorphs in the studied samples was good. Non-pollen palynomorphs (NPP) are also represented, though they are not numerous in the studied samples. Palynological atlases (Bobrov et al., 1983; Kuprianova & Alyoshina, 1972, 1978; Reille, 1998) have been used for pollen identification.

The program Psimpoll 4.27 (Bennett, 2009) has been used to plot the pollen diagram. Percentages of arboreal and non-arboreal pollen (AP and NAP, respectively) and spores have been counted from a total sum including all of them. NPP were represented mainly by *Pseudoschizaea,* which is an indicator of local humidity in soils (Scott, 1992). They are shown in a separate graph of the pollen diagram.

4. RESULTS

Eight pollen samples, labelled with the site prefix B, have been analyzed from the deposits of the Beregovo I site (Fig. 2). Vegetation types are determined according to the results of the fundamental empirical studies of surface pollen samples in Eastern Europe (Grichuk, 1989).

B-1, corresponds to the upper part of Uday loess unit (ud) and it records a forest-meadow vegetation (AP 44%, NAP 8%, and spores 48%). The AP includes mainly *Pinus sylvestris* (23%), *Betula* (13%), and *Alnus* (4%) though broad-leaved taxa are also represented (*Tilia cordata,* 3%, and *Ulmus* sp.*,* 1%). The NAP consists of forbs (5%) and Poaceae (3%). The former includes Asteroideae (2%) and single pollen grains of Fabaceae, Dipsacaceae and *Rumex*. Lycopodiaceae (38%) dominate among the spores. The percentage of Bryales is 9%, and only single spores of Filicales monolete occur.

B-2, corresponds to the lower part of the Lower Vytachiv (vt_1) soil. The pollen spectrum reveals a forest-steppe (AP 62.0%, NAP 21.0%, and spores 17.0%). *Pinus sylvestris* pollen prevails in the AP (36.6%), and pollen of *Picea abies* is noticeable (8.5%). The pollen share of broad-leaved trees increases significantly as compared to B-1: *Quercus robur* (4.2%), *Ulmus* sp. (2.8%), *Carpinus betulus* and *Fagus sylvatica* (each being 1.4%). On the contrary, the pollen percentages of parvifoliate hardwood decrease, including *Betula* (1.4%) and A*lnus* (4.0%). Pollen of *Sambucus nigra* occurs in small numbers (1.4%). Forbs prevail in the NAP (17%), and they consist of Asteraceae (5.6%), Rosaceae (4.2%), including *Filipendula,* and single pollen grains of Scrophulariaceae, Ranunculaceae, Brassicaceae, and Fabaceae. The rest of the NAP consists of Chenopodiaceae (2.8%) and few Poaceae (1.4%). The pollen percentages of Lycopodiaceae significantly decrease (14.4%). Spores of *Sphagnum* and Filicales monolete (each being 1.4%) are present, and *Glomus*-type spores, as well as *Pseudoschizaea* spores also occur.

B-3, in the upper part of the soil vt_1, reveals a forest type of pollen spectrum (AP 46.9%, NAP 29.2%, spores 23.8%). Pollen percentages of *Pinus sylvestris* and *Picea abies* decrease (22.3% and 3.8%, respectively). On the contrary, pollen percentages of broad-leaved trees significantly increase: *Quercus robur* (4.6%), *Ulmus* sp. and *Carpinus betulus* (each being 1.4%). Single pollen grains of *Caprifoliaceae* and *Cornus mas* occur. Parvifoliate hardwood is represented by *Betula* (5.4%) and *Alnus* (3.1%). Forbs prevail in the NAP (18.5%). Pollen of Asteroideae is abundant (6.2%), Cichorioideae and Plantaginaceae are noticeable (3.8-3.1%), and single pollen grains of Caryophyllaceae,

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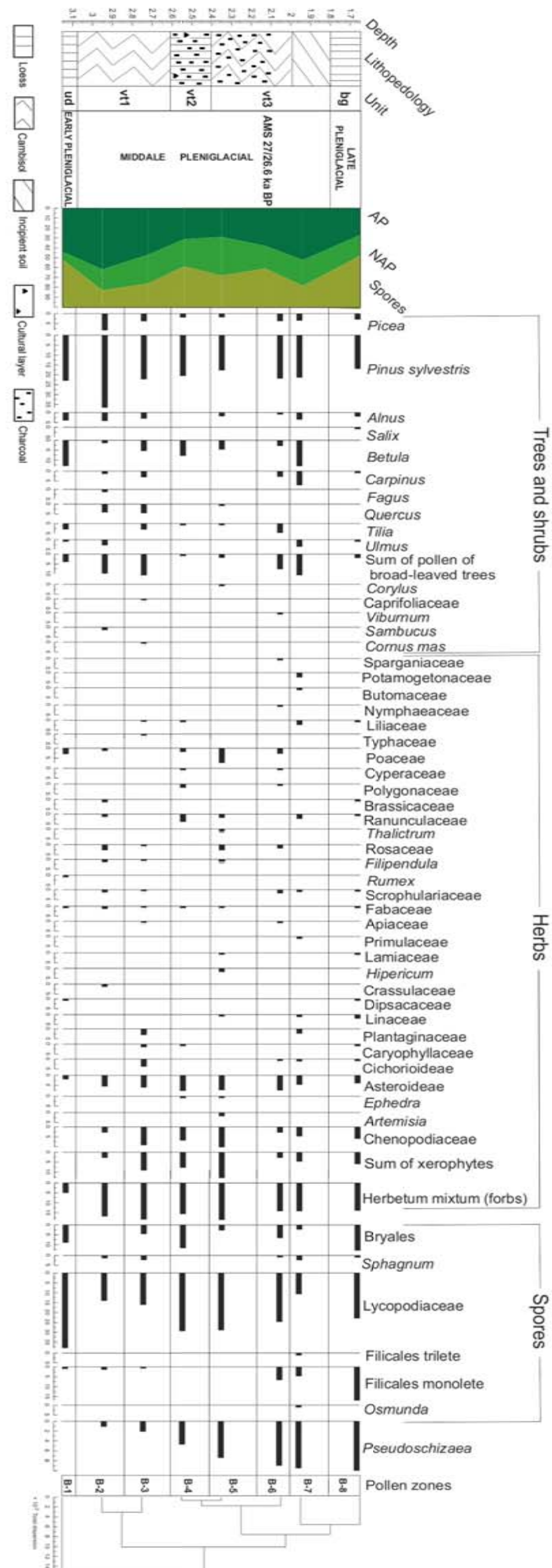

Fig.2 - Pollen percentage diagram from the Paleolithic site Beregovo I.

Rosaceae including *Filipendula,* Scrophulariaceae, and Fabaceae occur. Pollen percentages of herbal xerophytes increase (Chenopodiaceae, 9.2%). Pollen of hydrophytes (Typhaceae) also occur. The spores are represented by Lycopodiaceae (16.2%), Bryales (4.6%), *Sphagnum* (2.3%), and Filicales monolete (0.8%). The number of *Glomus*-type spores and *Pseudoschizaea* increases.

B-4, in the loess unit vt_2, has a forest-meadow type of pollen spectrum: AP 31.4%, NAP 27.5%, spores 41.2%. In the AP, *Pinus sylvestris* prevails (20.6%). *Betula* sp. (7.8%) and *Picea abies* (1.9%) are well represented. One pollen grain of *Tilia cordata* has been found. Forbs prevails in the NAP (15.7%) and consists of Asteraceae (7.8%), Ranunculaceae (3.9%), Polygonaceae (1.9%), Fabaceae and Caryophyllaceae (being 0.9% each). Pollen percentage of Poaceae is low (1.9%), as well as Cyperaceae and Liliaceae (being 0.9% each). Pollen of herbal xerophytes include Chenopodiaceae (6.8%) and *Ephedra* (0.9%). The spores are represented by Lycopodiaceae (29.4%) which prevail over those of Bryales (11.7%). The numbers of *Glomus*-type spores and *Pseudoschizaea* spores further increase, and abundant microcharcoal is present.

Three pollen samples correspond to the Upper Vytachiv soil (vt_{3b}). **B-5** corresponds to the lower part of the soil vt_{3b} and has a forest-meadow type of pollen spectrum (AP 29.0%, NAP 39.3%, spores 31.8%). *Pinus sylvestris* (17.8%) prevails in the AP, and only a few pollen grains of *Picea abies* (1.9%) are present. Single pollen grains of broad-leaved taxa (*Quercus robur*, *Tilia cordata* and *Corylus avellana)* occur. The parvifoliate hardwood is represented by *Betula* (4.7%) and *Alnus* (1.9%). Forbs prevail in the NAP (18.7%), but the percentage of Poaceae is quite noticeable (7.5%). Among forbs, pollen of Asteraceae is abundant (7.5%), Rosaceae (including *Filipendula*) and Ranunculaceae (including *Thalictrum)* are noticeable (being 4.4% each), whereas Polygonaceae is poorly represented (1.9%), and only single pollen grains of Lamiaceae, Fabaceae, Linaceae, and *Hypericum* have been found. The pollen percentages of xerophytes increase, including Chenopodiaceae (10.3%) and *Artemisia* (1.9%). The spores include mainly Lycopodiaceae (29.4%) and few Bryales (2.8%). The number of *Glomus*-type spores and *Pseudoschizaea* spores further increases, and microcharcoal is abundant.

B-6, corresponds to the upper part of the soil vt_{3b}, and it also has a forest-meadow type of pollen spectrum (AP 38.1%, NAP 22.9%, spores 39.0). *Pinus sylvestris* prevails in the AP (21.9%), and pollen of *Picea abies* (3.8%)*, Betula* (2.9%) and *Alnus* (1.0%) are present. The pollen percentages of broad-leaved taxa increase: *Tilia cordata* (4.8%) and *Carpinus betulus* (2.9%). One grain of *Viburnum opulus* is present. Forbs prevail in the NAP (14.3%), whereas pollen percentage of Poaceae is small (2.9%). The forbs include pollen of Asteraceae (7.6%), Scrophulariaceae and Rosaceae (each being 1.9%) and single pollen grains of Polygonaceae, Apiaceae and Cichorioideae. The pollen percentages of xerophytes decrease (Chenopodiaceae 2.9%). Pollen of hydrophytes (Nymphaeaceae and Sparganiaceae) appears. The pollen percentage of Lycopodiaceae is large (24.8%), spores of Filicales monolete and Bryales are noticeable (being 6.7% each), and spores of *Sphagnum* occur rarely (2.5%). The numbers of *Glomus*-type spores and *Pseudoschizaea* spores are rather large.

B-7, corresponds to the transition to the soil vt_{3c} and has a forest type of pollen spectrum (AP 52.4%, NAP 26.2%, spores 21.4%). *Pinus sylvestris* prevails in the AP (21.4%), and pollen of *Picea abies* (3.6%) is present. Broad-leaved taxa are represented by pollen of *Carpinus betulus* (7.1%) and *Ulmus* sp. (3.6%). The pollen percentages of parvifoliate hardwood are large (*Betula* 13.1% and *Alnus* 3.6%). The NAP consists of forbs: Asteraceae (4.8%), Ranunculaceae and Plantaginaceae (being 2.4% each), Scrophulariaceae, Linaceae and Primulaceae (being 1.2% each). Only few pollen grains of Chenopodiaceae have been found. Pollen of hydrophytes appear: Potamogetonaceae (2.4%), Butomaceae and Nymphaeaceae (being 1.0% each). Lycopodiaceae prevail among the spores (10.7%). Spores of Filicales monolete (4.8%), *Sphagnum* (2.4%) *Osmunda,* Bryales and Filicales trilete (being 1.2% each) have been also found. There are abundant microcharcoal particles, *Glomus*-type spores and *Pseudoschizaea* spores.

The lower part of the Bug loess unit (bg) has a meadow-steppe type of pollen spectrum (**B-8**): AP 25%, NAP 21%, spores 54%. The AP includes mainly *Pinus sylvestris* (17.0%). Pollen of *Picea abies* is present (3.0%) and single grains of *Carpinus betulus* and *Ulmus* sp. have been found. Pollen percentages of other trees are also small: *Alnus* (3%) and *Salix* (1.0%). The pollen of forbs (11.5%) consist of Asteraceae (4.0%), Linaceae (2.0%), and single grains of Brassicaceae, Ranunculaceae, Scrophulariaceae, Fabaceae, Lamiaceae, Caryophyllaceae, Dipsacaceae, and Cichorioideae. Thus, this sample is very diverse in its composition. Herbal xerophytes are represented by Chenopodiaceae (6.0%). Spores consist of Lycopodiaceae (23.0%), Filicales monolete (17.0%) and Bryales (13.0%). One spore of *Sphagnum* has been found. The numbers of microcharcoal, *Glomus*-type spores and *Pseudoschizaea* spores are still large.

5. PALAEOENVIRONMENT

The correspondence of pollen surface samples to the modern vegetational composition (Grichuk, 1989) has been used here to reconstruct the phases of vegetational evolution during the Vytachiv time (the Middle Pleniglacial), the end of the preceding Uday time (the Early Pleniglacial) and the beginning of the following Bug time (the Late Pleniglacial).

Before the beginning of the Middle Pleniglacial (the end of the Uday time), forest-meadow ecosystems existed (B-1). Club-mosses and green mosses formed the ground cover of birch-pine forests. Occurrence of pollen grains of *Ulmus* sp. and *Tilia cordata* indicate a possible existence of refugia of broad-leaved vegetation in the valleys. Alder groves grew in the wet localities. Meadows consisted of plants from Asteraceae, Fabaceae, Dipsacaceae, and Poaceae families. This type of vegetation is typical for a cool and humid boreal climate, that corresponds to the end of a stadial.

During the first stage of the Middle Pleniglacial (the Early Vytachiv time, vt_1), two phases of vegetation development have been recognized. During the first phase, coniferous and broad-leaved forests occupied the area under investigation. Elm-oak forests with an admixture of hornbeam, beech and spruce grew on the fertile loamy soils, pine groves occupied sand terraces and alder occurred near the river courses. Mesophytic herbs of the Asteraceae, Rosaceae, Brassicaceae and Fabaceae families grew in the ground layer of broad-leaved forests. The spread of broad-leaved trees indicates an interstadial warming. The replacement of club-mosses and mosses by herbs in the ground cover of forests might be connected with an increase in evaporation under a warmer climate, and, thus, with a decrease in ground moisture.

The second phase of vegetation evolution was characterized by a spread of a forest-steppe, as it is evidenced by the decrease in the AP and the spore percentages in B-3. Broad-leaved taxa included oak, hornbeam and lime-tree. The portion of wet-loving beech and spruce in the forest composition decreased as compared with the preceding phase. This, as well as the spread of herbal associations, indicates that the climate became less humid than during the preceding phase. Though it was rather warm, as suggested by the pollen percentages of broad-leaved taxa and the appearance of *Cornus mas* pollen. Open areas were occupied by meadow-steppe: mainly plants belonging to Asteroideae, Cichorioideae and Plantaginaceae, less frequently Caryophyllaceae, Rosaceae (including *Filipendula*) Scrophulariaceae, and Fabaceae. The appearance of Chenopodiaceae pollen indicates the replacement of meadows by meadow-steppe. Nevertheless, the abundance of *Pseudoschizaea* spores and pollen of *Typha latifolia* indicate a local increase in the ground moisture, connected with a higher water level in the river (Scott, 1992).

The second stage of the Middle Pleniglacial (the Middle Vytachiv time, vt_2) was characterized by the spread of a forest-meadow vegetation (B-4). A reduction in forest areas occurred. Forests consisted mainly of birch and pine, and the portion of broad-leaved trees decreased as compared to the previous stage. This indicates a significant cooling, that is typical for a stadial. However, few refugia of broad-leaved trees still existed, and lime-tree evidently continued to produce pollen. The low pollen percentages of pine indicate that its portion in the arboreal vegetation was very small. Mesophytic plants from the Asteraceae, Ranunculaceae, Polygonaceae, Fabaceae and Caryophyllaceae families prevailed in the open ecosystems, whereas steppe components of herbal coenoses (Chenopodiaceae and sparse *Ephedra)* were less frequent than during the previous phase. The decrease in warmth and evaporation was a possible reason for the spread of meadows to the expenses of meadow-steppe. The composition of forbs became more diverse, and club-mosess, mosses and microspores (indicators of soil humidity) were abundant. It was a time when the carriers of the Aurignacian industry arrived at the site.

The third stage of the Middle Pleniglacial (the Late Vytachiv time, vt_3) was characterized by three phases of vegetation development. During the first phase, there existed a forest-steppe vegetation (B-5). The low pollen percentages of pine and spruce indicate that they did not grow near the site (their pollen was probably wind-transported from the Carpathian Mountains). Birch forests with club-mosses and green mosses in the ground cover prevailed, and alder grew in the lowest localities. Oak, lime-tree and hazel occurred rarely. The portion of broad-leaved trees slightly increased as compared to the vt_2 time, but climate still was cool and corresponded to a transition from a stadial to an interstadial. Herbal associations were of a meadow-steppe type. Forbs prevailed, and their composition became more diverse than before, including plants of the Asteraceae, Rosaceae, Ranunculaceae (including *Thalictrum*), Polygonaceae, Lamiaceae, Fabaceae, Linaceae families and *Hypericum*. The steppe elements included Poaceae, Chenopodiaceae and *Artemisia.*

The second phase of vegetation evolution (B-6) was characterized by a spread of the forest-meadow vegetation. Forest areas became larger, and the participation of broad-leaved trees, represented by lime-tree and hornbeam, increased, as well as the spread of ferns in the ground cover. Spruce became more abundant, and *Viburnum opulus* occurred in the undergrowth. This phase corresponds to an interstadial warming. Meadows included mesophytic herbs from Asteroideae, Scrophulariaceae, Polygonaceae, Apiaceae and Cichorioideae. The portion of grasses and xerophytes significantly decreased. Wet localities were occupied by alder, club-mosses and green mosses. The increase in pollen of hydrophytes (Nymphaeaceae and Sparganiaceae) and *Pseudoschizaea* spores indicates a local raise in the water level.

The third phase of vegetation evolution (B-7) was characterized by a spread of elm-hornbeam forest with admixture of spruce on fertile loamy soils and pine-birch forest on sandy terraces. A spread of wet-loving hornbeam and spruce was maximum as compared with the previous phases. This indicates a further increase in humidity during the interstadial, AMS dated to 27/26.6 ka uncal BP (Usik at al., 2014). The ground cover of broad-leaved forests consisted of ferns and mesophytic herbs from Asteraceae, Ranunculaceae, Plantaginaceae, Scrophulariaceae, Linaceae, and Primulaceae families. Pine-birch and alder groves had club mosses and green mosses in the ground cover. The presence of hydrophytes (Potamogetonaceae, Butomaceae, Nymphaeaceae and *Osmunda*), as well as *Pseudoschizaea* spores indicate a high-water level in the river.

After the end of the Middle Pleniglacial (the beginning of the Bug time), there occurred a spread of meadow vegetation (B-8). The arboreal vegetation grew along the river course and consisted of spruce, alder and willow. The low pollen percentages of pine indicate a very limited growth of this tree in the studied area. The presence of few pollen grains of elm and hornbeam shows that their refugia still existed in the Transcarpathian Lowland. Club-mosses, green mosses and ferns formed the ground cover under the trees, but they could also grow in the meadows. The maximum of *Pseudoschizaea* spores shows an excess of water in the ground. Meadow plants were diverse (Asteroideae, Linaceae, Brassicaceae, Ranunculaceae, Scrophulariaceae, Fabaceae, Lamiaceae, Caryophyllaceae, Dipsacaceae and Cichorioideae). The strong reduction in forested areas and the significant decrease in broad-leaved taxa indicate that the climate became much colder than before. It was the beginning of a stadial.

6. DISCUSSION

In general, the fulfilled reconstructions are correlated with those obtained from the other sites of the Transcarpathia but the local characteristics of the vegetation on different forms of relief are rather distinct. During the Uday time (the Early Pleniglacial) on the high river terraces, grasses and sedges dominated, and few alder, willow and pine occurred in gullies. At the end of this time, trees disappeared completely (Gladilin & Pashkevich, 1977; Pashkevich, 1984). A spread of cryophytes (shrub birch and arcto-boreal forms of club-mosses) during this time (Gerasimenko, 2006) is an indicator of a periglacial climate. Thus, refugia of arboreal and broad-leaved trees existed only on the slopes of the low river terraces as in the case of the Beregovo I site.

In Western Ukraine, the complete successions of the Vytachiv deposits (the Middle Pleniglacial) are represented only in the Middle Dniester valley (Bolikhovskaya, Pashkevich, 1982; Bolikhovskaya, 1995) and at the Beregovo I site. The first stage of the Middle Pleniglacial (the vt_1 time) is correlated by ^{14}C dating with the two first interstadials of the Middle Valday (Gerasimenko, 2004). During the warmest interstadial (39-37 kyr BP), the forest-steppe (with admixture of *Quercus robur, Carpinus betulus, Tilia cordata* and *Ulmus* sp. in pine forest) was distributed on the low terraces of the Dniester River. On the low terraces of the Tysa River, the forests included more broad-leaved taxa, and mesophytic trees such as *Fagus sylvatica* and *Picea abies*, as well as the warm-loving *Cornus mas.* During the second stage of the Middle Pleniglacial (the vt_2 time, ^{14}C 36-30 kyr BP) which is correlated with the second Middle Valday stadial (Gerasimenko, 2004), the Middle Dniester valley was occupied by periglacial vegetation. Shrub associations of *Betula fruticosa, B. nana* and *Alnaster fruticosus* on *Sphagnum* peat bogs, on one hand, and xeric herbs, on the other hand, formed a mosaic vegetational pattern (Bolikhovskaya, 1995). During this time on the lower terraces of the Tysa River, forested areas became much smaller than during the preceding interstadial, but *Tilia cordata* persisted, and herbal cover consisted mainly of mesophytes. There are no indications of the presence of cryophytes.

During the third stage of the Middle Pleniglacial (the vt_3 time, ^{14}C 30-27 kyr BP), which is correlated with the third Middle Valdai Interstadial (^{14}C 29-25 kyr BP), *Carpinus betulus* was a main component of the forests of the Middle Dniester valley. *Fagus sylvatica, Quercus robur*, *Tilia platyphyllos*, *Acer* and *Fraxinus* also lived there (Bolikhovskaya, Pashkevich, 1984; Bolikhovskaya, 1995). On the lower terraces of the Tysa River, during the climatic optimum of the Late Vytachiv time, *Carpinus betulus* also prevailed among broad-leaved trees, but the portion of meso-hygrophytic *Betula pubescens* was significant. The latter is evidently connected with a rise of water level in the river, indicated by the spread of hydrophytes and abundance of *Pseudoschizaea* in the soils. Thus, during the correlative stages of the Middle Pleniglacial, the vegetation of the low river terraces in Transcarpathia was formed under more humid and warmer climate than in the Middle Dniester valley, although during the third phase, the lower river terraces of Transcarpathia were over-wetted as compared with the Dniester terraces.

The vegetation of the Vytachiv time around the other Transcarpathian site, located in the low landform, also included abundant hygrophytes (Gerasimenko, 2011). *Alnus glutinosa* and Cyperaceae were abundant, though oak was common in the forest composition. On the contrary, on the high terraces of the Tysa River, oak formed a small admixture in light pine forests with herbal ground cover. The portion of wet-loving ferns and club-mosses was lower than at the Beregovo I site (Pashkevich, 1984; Gerasimenko, 2006). Thus, during the Vytachiv time, the vegetation of the low terraces was richer in mesophytic and hygrophytic components than in the higher levels of the relief.

During the Late Pleniglacial (the Bug time), alpine and subalpine meadows including cryophytic plants (*Alnaster fruticosus, Betula nana, Botrychium boreale,* and *Lycopodium selago),* occupied the foothills of the Carpathian Mountains, whereas in the gullies that dissected the foothills, pine and larch were growing (Pashkevich, 1986). More xeric periglacial meadow-steppe vegetation spread on the high river terraces (Gerasimenko, 2006), although at the beginning of the Bug time cryophytes were absent in these meadows, which indicates the existence of a less harsh boreal climate. Meadow vegetation also dominated on low terraces of the Tysa River. Here, arboreal vegetation included boreal trees and a few elms and hornbeams. Thus, the distribution of cold-tolerant and warmth-demanding plants in Transcarpathia was controlled by the elevation. At the beginning of the Bug time, broad-leaved trees did not grow in the Middle Dniester valley. As opposite, arcto-alpine plants formed a significant part of the tundra-steppe and tundra-forest-steppe vegetation (Bolikhovskaya & Pashkevich, 1982; Gerasimenko at al., 2012). Thus, the climate of the Transcarpathian river valleys was essentially milder than in the Middle Dniester valley. Pollen and plant macrofossil evidence indicates that broad-leaved trees grew in the eastern part of the Middle Danube Plain (Hungary) even during the LGM (Willis at al., 2000). Judging from these data, refugia of broad-leaved trees were present indeed in the Transcarpathian Lowland during the Late Pleniglacial, and they were located on the lower terraces of the Tysa River. Judging from the position of the Beregovo I site near the palaeogully, which was dissecting the terrace, it is suggested that such palaeogullies might be the places for refugia of broad-leaved trees during stadial periods.

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