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Evidence of climatic variations in loess and cave Palaeolithic sites of southern Poland and western Ukraine

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Abstract

Two main types of Palaeolithic sites in southern Poland and western Ukraine: caves or rock shelters and loess sites, offer different evidence concerning former climatic variations. The most characteristic cave deposits for cold climatic conditions are angular, cryoclastic limestone rubble and loess in cave entrances. In loess profiles, arctic conditions are clearly marked by the presence of ice wedge casts and soil wedges. In cold and humid conditions, solifluction and cryoturbation features characteristic of active layers and ground ice structures developed. During periods of warm and humid climatic conditions, cave loam and chemically weathered limestone rubble originated in caves. Intensive chemical weathering formed mineral crusts on surfaces of limestone particles. The most distinct indicators of temperate climate in loess profiles are fossil soils: forest or steppe ones, depending on humidity. Remnants of animals, especially those of stenothopic taxons, provide very important evidence of environmental and climatic fluctuations. The data from both types of sites complement each other.

Precisely documented profiles of cave and loess sites cover the time span from the decline of penultimate glaciation to the end of Vistulian time. Older cultural layers corresponding to the penultimate interglacial were found recently.

1. Introduction

The region situated to the north and northeast of the Carpathians (Carpathian foreland) consists of the Upper Wisła (Vistula) River and Upper Dnister River basins. It is characterised by the presence of loess covers. The Polish Jura Chain, rich in caves and rock shelters, is situated on the western side of the region. Several Palaeolithic sites are known from caves as well as from loess profiles, usually in sections situated along the river valleys. They were explored beginning in the last decades of the 19th century. Archaeologists have found many similarities between Palaeolithic cultural units throughout the region, so they are useful for stratigraphical correlation. From the points of view of environment reconstruction and climatostratigraphy, the two types of sites complement each other and give interesting information regarding past climatic changes.

2. Distribution of sites

Cave sites are certainly connected with the distribution of karstic rocks, mainly Jurassic rocky limestones. The most important group of sites is situated in the Polish Jura Chain (Fig. 1). Some of them have been known since the 1870s, and others were discovered in recent years (Madeyska and Cyrek, 2001). Besides these sites, other important sites are Raj Cave, situated in Devonian limestone of the Holy Cross Mountains; and Obłazowa Cave, in the Pieniny Klippen Belt of the Inner Carpathians. In the Ukrainian part of the Carpathians, limestone caves are rare and small; they only contain archaeological materials younger than Palaeolithic. Similar situations are observed in gypsum caves. Karst processes in gypsum progress rather quickly, and the entrance areas of gypsum caves, that could contain traces of Palaeolithic peoples' activity, were destroyed.

Loess sites are distributed in groups (Fig. 1). Usually they are situated close to large rivers such as the Dnister or Vistula, on rather high terraces by the mouth of tributary rivers, streams, or dry valleys. However, in places they are situated at the banks of small rivers as well. It is clear that the Palaeolithic people looked for places close to the water and suitable as observation points for hunters. An additional advantage was accessibility of raw flint in rocks or in river gravel. In the territory of Poland, the biggest concentration of Palaeolithic loess sites is situated in the vicinity of Kraków. The main sites of Piekary, Zwierzyniec and

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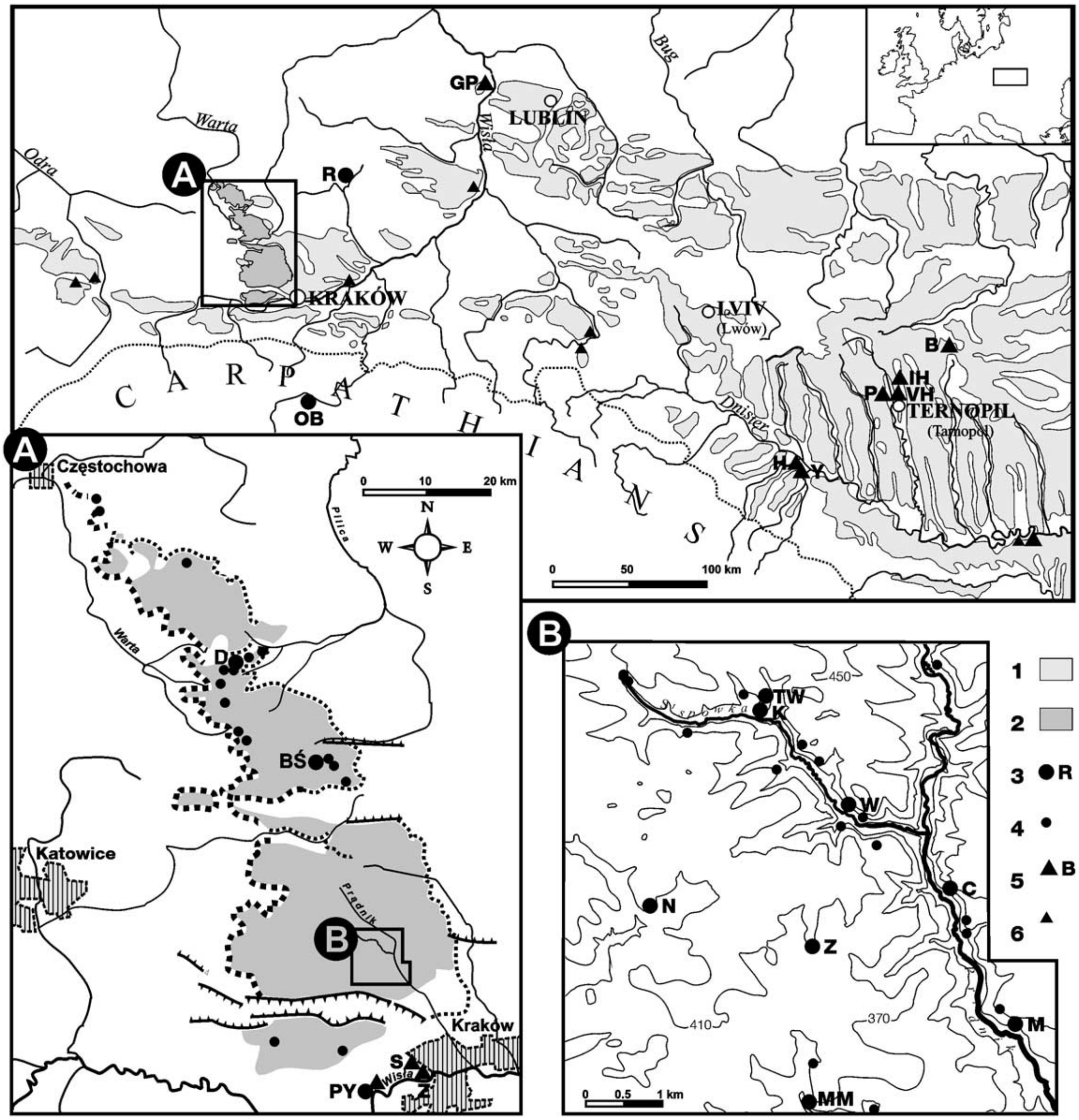

Fig. 1. Distribution of main cave and loess Palaeolithic sites. 1—loess covers, 2—Polish Jura Chain, 3—cave sites mentioned in the text, 4—other cave sites, 5—loess sites mentioned in the text and 6—other loess sites. Names of main sites: G—Góra Puławska, R—Raj Cave, O—Obłazowa Cave, B—Buhliv, VH—Velykyi Hlybochok, IH—Ihrovytsia, P—Proniatyn, Y—Yezupil, H—Halich, D—Deszczowa Cave, BŚ —Biśnik Cave, TW—Tunel Wielki Cave, K—Koziarnia Cave, W—Wylotne Rock Shelter, C—Ciemna Cave, M—Maszycka Cave, MM—Mamutowa Cave, Z—Żytnia Skała Roch Shelter, N—Nietoperzowa Cave, Py—Piekary, S—Kraków, Spadzista Street and Z—Kraków, Zwierzyniec.

Spadzista street, as well as several less important satellite sites, are situated there. The second concentration of sites is in Silesia. The most northern site was found in Góra Puławska along the Vistula River valley. To the east from Vistula River valley, in Poland, Palaeolithic sites are very rare (Madeyska, 2001).

Quite a different situation existed in the Carpathian Foreland at the Dnister River Valley and in Podillja. Many sites are situated along the Dnister River, with important concentrations close to the middle, canyon-like part of the valley. Two other concentrations are situated in Podillja, near Ternopil (Chernysh, 1973; Sytnyk, 2000).

3. Evidence of climatic changes in cave sites

Stable conditions in dry caves give the possibility for continuous sedimentation over a long time, affected by long-lasting climatic fluctuations. Lithological compositions of cave fillings reflect these fluctuations, so sedimentological methods were used for many years for reconstruction of past environment changes (Madeyska, 1979, 1981).

The amount of the limestone rubble—the main autochthonous component of the cave filling—resulted from the intensity of mechanical (mainly frost) weathering of the cave walls. This was documented by grain-size analysis. In cold and dry climatic conditions, the rubble remains fresh and angular. Chemical weathering of the limestone particles reflects warmer and wet conditions. The roundness coefficient and porosity of limestone rubble, as well as presence of corrosion traces, determines the intensity of the weathering processes. Mineral precipitations of iron and manganese compounds on limestone fragment surfaces originated according to stronger chemical weathering. Crusts of phosphates covering the limestone particles resulted from the activity of animals living in the cave. The presence of residual clay in cave loam, the product of limestone dissolution, also documented chemical weathering.

The allochthonous components of the cave loam testify to the processes outside the cave. Most important are sands and loess transported into the cave by wind through openings or with water seeping through fissures in the ceiling, during the time of aeolian activity or shortly after it, when vegetation cover was limited. Humus and iron compounds, originated primarily in soil above the cave, reach the cave sediments through the fissures with seeping water. Consequently, studies of the sediment composition give information about environment and climatic conditions outside the cave (Madeyska, 1981).

Rich in carbonates, the environment of cave sediments is conducive to bone preservation. That is why caves are the most important source of subfossil Quaternary vertebrate fauna: not only the animals living in caves, but also bones representing the prey of birds, mammal carnivores and humans. The taphonomical problems should be taken into account during interpretation of the animal assemblage for palaeoclimatic purposes. Aside from a few distinct species, the majority of mammals and birds are living at present in different environments and have different geographical distributions. For the reconstruction of climatic changes in the past, stenothopic animals, connected with particular biomes are most important. Very useful are rodents, because of their frequent occurrence in cave fillings and because one can find among them several species closely dependent on a particular kind of pasture.

Rare but very important are charcoals when found in cave fillings. Identification of wood gives information about the presence of particular taxons of trees or shrubs.

4. Evidence of climatic changes in loess sites

Climatic changes are marked in loess profiles by changes of mineral and chemical composition of sediments and by structural forms. Very important are traces of cryogenesis, periglacial structures connected with permafrost or seasonally frozen ground. The coldest and driest conditions resulted in the development of ice wedges that could be preserved in profiles as pseudomorphoses. Frost activity in wet environment gives solifluction and cryoturbation or post-ground-ice structures. Intermittent waterlogging, which could often be connected with the existence of frozen ground, resulted in gley formation.

The intensity of aeolian activity in the described region during the younger Pleistocene changed according to climatic fluctuations (Boguckij, 1986, 1987; Velichko, 1990). Several phases of aeolian activity are separated by phases of vegetation and soil development. Deflation and loess accumulation depend on the local landscape, and wind directions and intensity. The lack of loess cover in a particular place does not necessarily mean warming or an increase in humidity.

Increasing content of some chemical elements indicates chemical weathering connected with warmer climate and vegetation development. Fossil soils are the most important evidence of climatic conditions suitable for vegetation development. Podsolic soils are most characteristic of interglacial conditions; chernozems indicate dry periods; and tundra brown soils or tundra-gley ones represent cool and humid oscillations.

5. Important sites

Sediments from approximately 50 caves and rock shelters were investigated in Poland, 30 containing traces of Palaeolithic cultural layers, remains of fires, scattered flint or bone artefacts, and animal bones representing remnants of food. Usually they represent traces of short visits of human groups hunting in the vicinity, evidence of hunting in the cave, or use of the cave as a place for flint artefacts production. Only exceptionally do they document longer human occupation in a cave. In every site, animal remains were found, mainly vertebrate bones. They were collected from both the cultural horizons and from the layers separating them. The results of archaeological, geological and palaeontological investigation of these sites were published in several monographic studies and in synthesis (Bocheński, 1974; Chmielewski, 1975; Kozłowski and Kozłowski, 1977; Madeyska, 1981; Nadachowski, 1982, 1989; Kowalski, 1989). A list of cave sites with information and references can be found in Madeyska and Cyrek (2002).

Loess sites in Poland are not very numerous, and only some of them have geological documentation useful for climatic reconstruction (Kozłowski et al., 1974; Chmielewski et al., 1977; Kozłowski and Sobczyk, 1987; Sobczyk, 1995; Madeyska, 2001). Very important is the possibility of stratigraphical correlation with other loess profiles described by geologists.

Among many Palaeolithic sites in western Ukraine there are such famous multilayer sites as Molodova, Korman (Goretsky and Tzeitlin, 1977; Goretsky and Ivanova, 1982; Chernysh, 1987) and several sites investigated recently by interdisciplinary groups of scientists (Sytnyk et al., 1998a, b, 1999; Sytnyk, 2000). As a basis for reconstruction of climatic changes, geological study of profiles and fauna composition were used as well as correlation with other loess profiles studied in detail (Boguckij, 1986, 1987).

5.1. Older and Middle Palaeolithic sites

The oldest Palaeolithic materials were found recently in Biśnik Cave in the central part of the Polish Jura Chain. They represent the Acheulian stone tool tradition with lavalloisian and blade techniques of artefacts production (Madeyska and Cyrek, 2002). Based on lithological and mineralogical analysis of sediments (Mirosław-Grabowska, 2002) and on the sequence of fauna assemblages (Wiszniowska et al., unpublished materials), these materials could be probably dated to the penultimate interglacial (oxygen isotope stage 7) or even to the Odranian and to the Warthanian. The bones from that site were used in a methodological study of dating using different methods in a framework of the Polish State Committee for Scientific Research Project No. 6P04D 056 15 (Hercman and Gorka, 2001; Madeyska et al., 2001). Uranium–thorium analyses of bone samples from the Biśnik cave give an estimate of the range of ages of this part of the profile from 200 to 350 ka.

Chemical weathering of the limestone rubble and presence of phosphate crusts on its particles shows rather warm climatic conditions during sedimentation. The fauna assemblage is composed of forest animals in coexistence with steppe-tundra species and eurytopic carnivores. The sedimentation lasted for a long time, and surely some important climatic fluctuations occurred, but detailed reconstruction is not possible at present because the excavations are not finished.

The archaeological assemblages from Biśnik have some cultural analogies with materials from Piekary II dated probably to the Warthanian (Krukowski, 1939–1948; Kozłowski and Kozłowski, 1977; Morawski, 1992). They were found in the middle part of sandy loess corresponding to the upper older loess of Maruszczak (1995), correlated with the Warthanian. Two assemblages were present there: for the older one, the clactonian technique is characteristic, whereas the younger one shows an archaic blade technique and artefacts similar to backed points.

The second place where the Acheulian type materials were found is the Podillja region near Ternopil (Sytnyk, 2000). Two cultural layers were found in Velykyi Hlybochok site at the surface of the so-called Korshov fossil pedocomplex correlated with the penultimate interglacial and with the Ternopil solifluction-soil horizon (Boguckij, 1986, 1987; Sytnyk and Boguckij, 1998). According to Sytnyk, this Late Acheulian industry has a protolevalloisian character. A similar assemblage in a like stratigraphical position was found nearby, in the Buglov (Buhliv) site (Sytnyk et al., 1998b; Sytnyk, 2000).

The Mousterian materials in Ukraine were connected with the so-called Horokhov (or Mezin) fossil pedocomplex and the lowest layer of the Upper Pleistocene loess. After Boguckij (1986, 1987), Velichko (1990), and other authors, this pedocomplex corresponds to the Eemian and Early Vistulian interstadials. It is composed of an older part originated under forest vegetation and a younger one developed under steppe vegetation divided by a weak loess layer with cryogenic pattern ground structures. Soil wedges showing the existence of dry, seasonally frozen ground were present at places. The excavations performed in Jezupol (Yezupil) in a framework of the State Committee for Scientific Research Project No. 6PO4E 031 15 are not finished. This is the only site where the Mousterian was found in the lower part of the pedocomplex (Sytnyk et al., 1998a; Sytnyk, 2000). In several other sites (Proniatyn, Ihrovitza, Velykyi Hlybochok and Buhliv) it is connected with its upper-steppe part. It is very common, that the artefacts were redeposited together with the soil, by solifluction probably just after the soil origin. After a dry period of loess sedimentation and steppe development, the climate was humid and cold, and permafrost existed suitable for the development of solifluction and cryoturbations. Thick layers of typical loess cover all the series. In sites situated in the canyon-like part of the Dnister River Valley, including Molodova, Korman, and Ketrosy, Mousterian materials were found in loess and fossil soils series, partly redeposited on slopes (Goretsky and Tzeitlin, 1977; Praslov, 1981; Goretsky and Ivanova, 1982). This series is dated to the time corresponding to the older part of the last glaciation.

The existence of Mousterian culture with levalloisian technique is documented in Polish caves for a long period (Madeyska, 1982): from the decline of Warthanian, through Eemian to the end of the so-called Early Vistulian (corresponding to all of oxygen isotope stage 5). In the loess site of Zwierzyniec in Kraków, two Mousterian assemblages with levalloisian technique were found in the top part of river sands, the substrate of the lessivé-type fossil forest soil dated to the Eemian (Chmielewski et al., 1977).

It is characteristic for Polish loess archaeological sites that Early Vistulian sediments are redeposited along slopes by washing. The upper part of the fossil soil complex is not so clearly developed as in the other loess profiles in Eastern Poland and Ukraine. The archaeological materials also are redeposited (e.g. at Piekary

II, Zwierzyniec). It probably means that the period, following the time of Eemian soil development, was marked by heavy rainfalls. In comparison with Ukraine, the conditions were less continental.

In the Nietoperzowa Cave, the oldest Mousterian layer was situated at the top of a loess layer with few bones of tundra animals, correlated with the decline of the Warthanian (Madeyska, 1982). A younger layer was found in cave loams with strongly chemically weathered limestone particles having characteristic phosphate crusts on the surfaces. Warm and probably wet climatic conditions also were documented by fauna composition. Forest species prevailed, among them beaver, indicating a stream nearby. *Fraxinus* wood as well as that of coniferous taxons among charcoals and dripstone found in this horizon confirms temperate climatic conditions characteristic for the Eemian interglacial.

In the Early Vistulian (corresponding to the younger part of the oxygen isotope stage 5) sediments in Nietoperzowa and Koziarnia caves, few Mousterian artefacts were found in several horizons. Other types of Mousterian materials were found in Obłazowa Cave in the Carpathians (Valde-Nowak et al., 1995). During the same period, another important culture developed, the Micoquo-prondnikian (Chmielewski, 1975) called also "assemblages of the Bockstein, Ciemna and Wylotne types" (Kozłowski and Kozłowski, 1977). It is characterised by the presence of hand axes, bifacial knives and scrapers. Rich materials of that culture were found in 3 Early Vistulian cultural layers in the Wylotne rock-shelter (Chmielewski, 1969) and as single artefacts in several other sites. The youngest assemblage of that culture was found in Ciemna cave, in the bottom part of the loess layer lying on the Early Vistulian series. Besides these two mentioned cultures, two other ones are found in Polish caves: East Charentian in Raj cave (Studies…, 1972) and Taubachian in Biśnik Cave (Madeyska and Cyrek, 2002)

The lithological composition of the sediments as well as fauna composition shows weak climatic fluctuations of cool temperate climate. Forest animals coexisted with tundra and steppe elements in changing proportions. In particular caves (taking into account also caves devoid of archaeological artefacts), two or three warmer fluctuations could be observed (Chmielewski, 1988). The fauna of a contemporaneous layer from the Obłazowa cave in the Carpathians shows cooler conditions than that of the Polish Jura Chain (Valde-Nowak et al., 1995). It resulted from the higher hypsometrical situation of that site and proximity of the Pieniny Klippen Belt and the Tatra Mountains.

It is common in fillings of the Polish Jura caves that the described sediments are often destroyed partly by redeposition or subsidence. The subsidence resulted from the development of karst processes: widening of fissures beneath the part of a cave filled with sediments. These processes document humid climates. Lithological composition of sediments lying above the described part of profiles shows cold and dry conditions. Loess layers were found there with fresh, angular limestone rubble. Fauna composition shows cold climatic conditions, and tundra elements prevail including steppe animals.

5.2. Upper Palaeolithic sites

The most characteristic Upper Palaeolithic culture found in Polish caves is Jerzmanowician, described by Chmielewski (1961). In the Nietoperzowa cave, the assemblages include leaf-shape points, almost exclusively used for spearpoints. Small assemblages of Aurignacian, Szeletian and later East Gravettian (e.g. Kowalski et al., 1967; Cyrek et al., 2000) are present in a few sites. The most interesting discovery from that time was the unique boomerang made from mammoth tusk found in the Obłazowa Cave (Valde-Nowak et al., 1987).

The main component of the cave sediments containing Upper Palaeolithic artefacts is rounded, smoothed and slightly chemically weathered limestone rubble. In comparison with sediments containing Middle Palaeolithic materials, these layers contain smaller amounts of residual clay and humus. In the entrance parts of caves and in rock shelters, traces of redeposition or even removal of sediments outside are found. The climate of that time was humid and cool. Despite the destruction in some sites (e.g. Mamutowa cave—Madeyska, 1992), two phases of warmer conditions could be documented, separated by a colder period. The fauna composition testifies to these observations (Nadachowski, 1976). Lemmings are present throughout, with different amounts of steppe elements and few forest animals, mainly characteristic of coniferous or tundra forests. In the colder phase, woolly rhinoceros and reindeer were present among other animals. Charcoals found in cultural layers originated from stone (*Pinus cembra*) and common pines, larch and probably birch.

Upper Palaeolithic in loess profiles is usually connected with fossil soils or weathering horizons. Commonly only one fossil soil horizon is seen, but in some sites, two weakly developed fossil soils could be distinguished, separated by a very thin layer of loess or other evidence of cooling. At the Zwierzyniec site in Kraków, such a division into two fossil soils is clearly seen (Chmielewski et al., 1977). In the older brown tundra soil, an Aurignacian assemblage was found, with a Jerzmanowician one in the younger soil. Cold climatic conditions prevailing during the hiatus in soil development were marked by frost disintegration of the Aurignacian flint artefacts. In other sites, the soil division is not so clear, but it could be stated that the Aurignacian probably is connected with the older soil. Pavlovian is found with the younger soil at the Spadzista street site (Kozłowski and Sobczyk, 1987; Kozłowski, 1996), and Kostienki–Avdeevo and other Eastern Gravettian (Sobczyk, 1995). In the other loess sites in Poland, the stratigraphical situation of the Upper Palaeolithic is less clear (Madeyska, 2001). Among animal remnants, mammoth bones prevail. Charcoals from loess sites are rare, and only the presence of larch, pine, birches and willow is documented. The older fossil soil in Zwierzyniec is arctic brown in type and probably corresponds to the soil from Spadzista street described as "brown lessivé hydromorphic". The younger soil in Zwierzyniec is an initial tundra soil, intensively gleyed. Traces of intensive gleification are also present in the bottom part of the loess covering the soil sequence. This part of loess series is strongly deformed by solifluction and other processes of cryoturbation. These forms document not only low temperatures but the presence of water as well. The existence of active layer is most probable at that time.

In multilayer Palaeolithic sites on the canyon-like part of the Dnister River valley in Molodova and Korman (Ivanova, 1977; Goretsky and Ivanova, 1982), the stratigraphy is more complicated, and several horizons of fossil soils were described. According to Ivanova (1977), forest-steppe type of vegetation prevailed during the entire Upper Palaeolithic, with short periods of coniferous forest development. These environments are documented by the presence of steppe–tundra and forest mammal remains. Such an interesting picture of environment and milder climatic conditions could result not only from the more southward situation of the region, but also from the position of the sites close to the slope of the valley of this large river. Traces of solifluction are rare and slope processes prevailed.

In loess profiles situated upstream from the canyon-like part of Dnister River and in Podillja, the Upper Palaeolithic sites are rare, but it could be stated that they are connected with Dubno (or Bryansk after Velichko, 1990) fossil soil. The stratigraphy of Palaeolithic sites could be correlated with other loess with fossil soil profiles of this region, rich in palaeoclimatic information. In Fig. 2, a sequence of these data are shown, based on the scheme described by Boguckij (1986, 1987). After a period of cool but rather mild climatic conditions during the main time of Upper Palaeolithic occupation, a period of very cold and dry climate follows (corresponding to the Last Glacial Maximum (LGM)), most severe during the Upper Pleistocene. Typical loess series ice wedge casts are very common in Poland, as in Ukraine—evidence of former low temperatures and permafrost. No traces of human presence were found in the region during the coldest oscillation.

The youngest Upper Palaeolithic assemblage presently investigated is at Halich (Sytnyk et al., 1998a; Boguckij et al., 2000; Wojtal et al., 2001). Flint artefacts (Epigravettian) with a large collection of mammoth bones were found in the Rovno solifluction horizon. In some other loess profiles, this horizon has a gley-soil character showing humid climatic amelioration. It corresponds to the decline of the LGM.

An example of human occupation during the final part of the youngest loess is the Magdalenian complex in the ice-wedge cast filling at Brzoskwinia near Kraków (Sobczyk, 1993). The Magdalenian complex from the famous Maszycka cave (Kozłowski et al., 1993) is dated to about 14–14.5 ka.

In cave sediments, the evidence of climate during that time is very poor. Based on sediment characteristics, the sedimentation of angular limestone rubble and aeolian loess had finished (e.g. Cyrek, 1999; Cyrek et al., 2000). Usually, it is not possible to distinguish sediments corresponding to particular periods of fine climatic oscillation at that time.

6. Conclusions

Two main types of Palaeolithic sites exist in southern Poland and western Ukraine. Caves or rock shelters and loess sites offer different evidence concerning former climatic variations. Furthermore, the data from both types of sites complement each other.

The most characteristic cave deposit under cold climatic conditions is angular, unweathered, cryoclastic autochthonous limestone rubble. Sedimentation was most intensive when the temperature fluctuated around $0^{\circ}C$ and when water was present in rock fissures necessary for intensive frost weathering. During dry periods, the process was less intensive. At that time, loess could be transported by wind into cave entrances, more or less intensively dependent on the cave entrance orientation to the wind direction. In loess profiles, the coldest, arctic conditions are clearly marked by the presence of ice wedge casts. For cold and dry conditions, soil wedges originating in permafrost or seasonally frozen ground are characteristic. Structures of ground ice are connected with seasonally frozen ground or with permafrost developed in humid conditions. Important solifluction series and cryoturbation structures show movement of saturated material in active layers over surfaces of frozen ground. Process of gley origin took place in waterlogged sediments, often connected with the existence of frozen ground.

During periods of warm and humid climatic conditions, chemically weathered limestone rubble originated in caves. The degree of weathering depends on temperature and chemical composition of seeping water, resulting mainly from the soil processes above the cave. Composition of mineral crusts on surfaces of limestone particles depends on composition of fine material—cave loam—the product of chemical weathering. Increases in

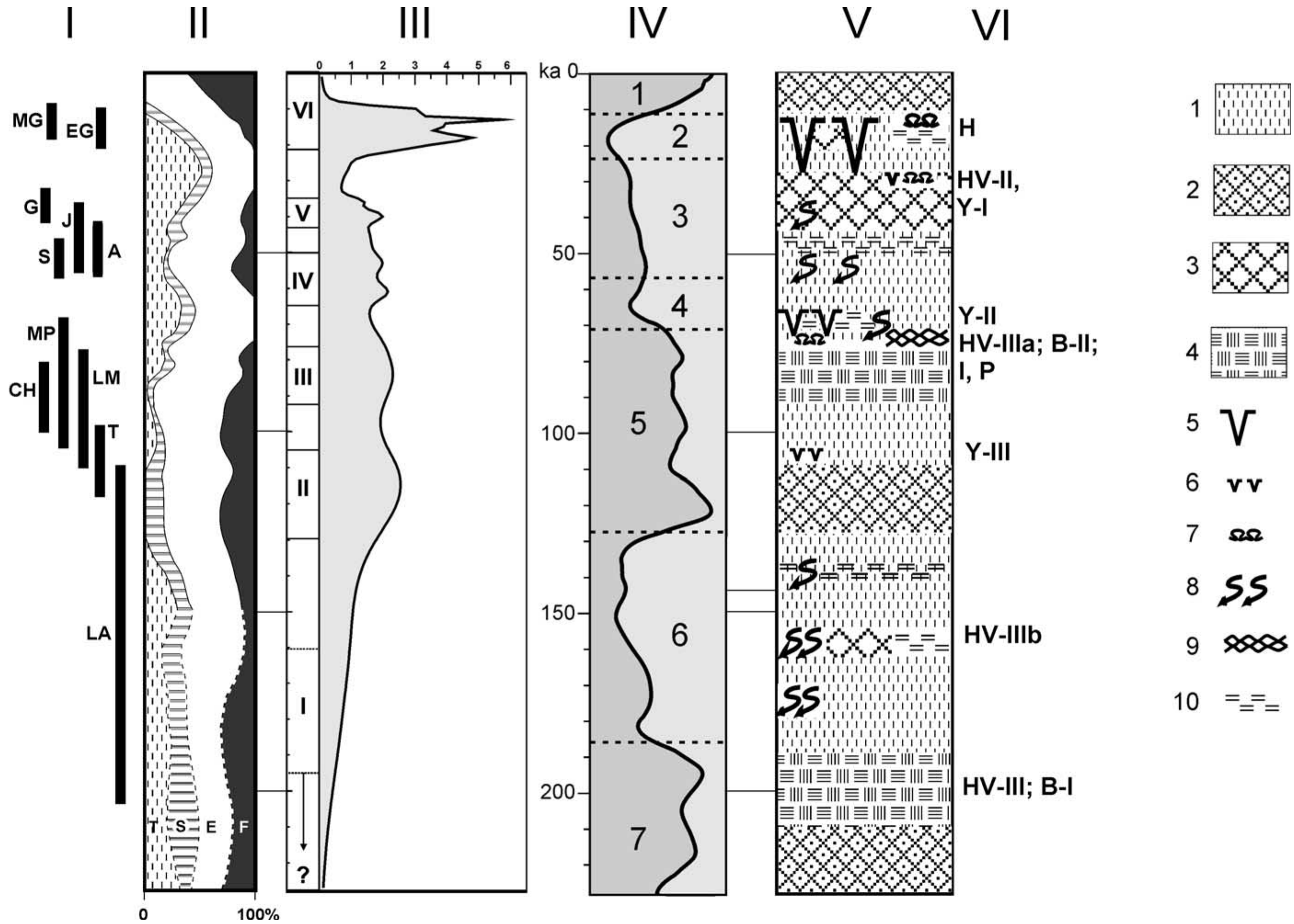

Fig. 2. Correlation of Palaeolithic culture ranges with evidence of climatic changes documented in Polish cave sites and Ukrainian loess sites. I—Palaeolithic cultures known from cave sites: LA—Acheulian-type with Levalloisian technique, T—Taubachian, LM—Levallois-Mousterian, MP—Micoquo-Prondnikian, CH—East Charentian, A—Aurignacian, J—Jerzmanowician, S—Szeletian, G—Gravettian, EG—Epigravettian, MG—Magdalenian; II—Schematic species spectrum of fauna from cave sites: T—tundra element consists of: rodents: *Dicrostonyx torquatus* (*D. gulielmi*), *Lemmus lemmus, Microtus gregalis, Microtus nivalis*; other mammals: *Mammuthus primigenius*, *Coelodonta antiquitatis*, *Rangifer tarandus*, *Ovibos moschatus*, *Alopex lagopus*, *Lepus timidus*. S—steppe element: rodents: *Citellus superciliosus*, *C. citelloides*, *Cricetulus migratorius*, *Cricetus cricetus*, *Lagurus lagurus*; other mammals: *Equus caballus*, *Bison priscus*, *Ochotona pusilla*. F—forest element: rodents: *Apodemus flavicollis*, *A. sylvaticus*, *Castor fiber*, *Clethrionomys glareolus*, *Eliomys quercinus*, *Glis glis*, *Muscardinus avellanarius*, *Sciurus vulgaris*, *Sicista betulina*; other mammals: *Crocidura* sp., *Talpa europea*, *Myotis bechsteini*, *Pipistrellus pipistrellus*, *Alces alces*, *Bos primigenius*, *Capreolus capreolus*, *Cervus elaphus*, *Sus scrofa*, *Felis silvestris*, *Gulo gulo*, *Lynx lynx*, *Martes martes*, *Meles meles*, *Ursus arctos*. E—eurytopic element: rodents: *Arvicola terrestris*, *Micromys minutus*, *Microtus agrestis*, *M. arvalis*, *M. oeconomus*, *Pitymys subterraneus*; other mammals: *Neomys fodiens*, *Sorex araneus*, *S. minutus*, *Lepus europeus*, *Oryctolagus cuniculus*, *Canis lupus*, *Crocuta spelaea*, *Mustela erminea*, *M. nivalis*, *M putorius*, *Panthera spelaea Ursus spelaeus*, *Vulpes vulpes* and many bats: *Barbastella barbastellus*, *Eptesicus nilssoni*, *Myotis brandti*, *M. dasycneme, M. daubentoni*, *M. emarginatus*, *M. myotis*, *M. mystacinus*, *M. natterei* and *Plecotus auritus.* III—Speleothem growth frequency curve, constructed for the Middle European Uplands by Hercman, 2000. IV—Relative temperature changes—SPECMAP curve. V—Sequence of sedimentation, pedogenetic and deformation processes in western Ukraine loess profiles (after Boguckij, 1986, 1987; Sytnyk et al., 1998a; Sytnyk 2000). 1—Loess sedimentation, 2—interglacial and Holocene soil formation, 3—initial or tundra soil formation, 4—chernosem-type steppe soil formation, 5—frost wedge origin, 6—pattern ground structures, 7—cryoturbations, 8—solifluction, 9—ground-ice structures formation and 10—gleification (gley formation). Cultural layers of main western Ukrainian Palaeolithic sites discovered last years (after Sytnyk et al., 1998b; Sytnyk, 2000; and others): Late Acheulian: VH-III, VH-IIIb: Velykyi Hlybochok layers III and IIIb, B-I: Buhliv layer I; Mousterian: Y-III: Yezupil layer III, VH-IIIa: Velykyi Hlybochok layer IIIa, B-II: Buhliv layer II, I—Ihrovytsia, P—Proniatyn; East Micoquian: Y-II: Yezupol layer II; Upper Palaeolithic: Y-I: Yezupil layer I, HV-II: Velykyi Hlybochok layer II, H—Halich.

some chemical elements mark the chemical weathering in loess profiles. But the most distinct evidence of temperate climate is the fossil soils. Podsolic or brown soils indicate warm and humid condition and forest vegetation, and chernozems or similar soils indicate dry conditions and steppe development.

Certainly, animal remains give very important evidence of environmental and climatic fluctuations. Bones of mammals and birds are so common in cave sediments that changes of fauna composition according to environmental requirements of particular groups of taxons can be recognised (Fig. 2—II). In loess sites, animal bones were found mainly in cultural layers. These prey species used by people are less important for reconstruction of environmental changes in the whole profile.

Archaeological sites of this region cover in detail the time span from the decline of Penultimate glaciation to the Holocene. Recent investigations have afforded materials concerning older periods in loess site investigations in Ukraine and cave site research in Poland (Fig. 2). Chronostratigraphical correlation is based on the reconstructed sequence of climatic changes, and the presence of Palaeolithic materials identified by archaeologists. It is correlated with the Specmap Oxygen isotope curve and the curve of crystallisation frequency of speleothems from Middle European Uplands, constructed by Hercman (2000). Main phases of speleothem crystallisation (I–VI) represent warm and humid periods, when biological activity was intensive.

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