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Radiocarbon dating of some Late Pleistocene faunal assemblages in caves in Poland*

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Abstract. 26 bone samples were radiocarbon (AMS) dated. The bones were almost exclusively those of birds and came from cave deposits correlated mainly with the Vistulian (Weichselian). The material came from six sites: Deszczowa Cave, Upper Rock Shelter of the Deszczowa Cave, Cave in Dziadowa Skała, Sąspowska Zachodnia Cave, Mamutowa Cave, and Obłazowa Cave. The ages of most of the radiocarbon-dated samples were not in agreement with the stratigraphy of layers from which they originated that is proposed in the literature.

Key words: radiocarbon (C-14) dating of bones, Vistulian (Weichselian), stratigraphy, cave deposits, fossil remains of birds, paleoenvironment, paleoclimate.

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I. INTRODUCTION

Studies of the evolution of the Quaternary climate and environment rely on a great variety of sources, e.g. paleobotanical (mostly palynological), paleozoological, isotopic, geomorphological, and the results of deposit analyses (lithological, sedimentary, structural, and textural characteristics). Several methods are employed in the research on cave material. They include the analysis of the species composition of assemblages of animal bones from cave deposits. This knowledge often allows one to determine the climatic and environmental conditions obtaining during the sedimentation as well as the age of the deposits in which the bones were found. An especially rich source of information on these subjects is bone remains of mammals, mainly rodents. Rodent remains are usually very abundant in cave deposits, and many species are good indicators of specific environmental and climatic conditions. In turn, the use of rodents in work on the biostratigraphy of cave deposits results from the rapid morphological changes occurring in those animals. The data collected from assemblages of rodent remains can be significantly supplemented with those from the research on bird remains. Bones of other vertebrates are usually much less abundant, and remains of inverte-

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brates like bivalves and snails are even less so, thus offering very limited possibilities of interpretation.

Whatever the systematic status of the bones under study, the knowledge of their absolute age is extremely valuable. It helps to correlate the conclusions concerning the paleoenvironment or paleoclimate drawn on their basis with fairly precise time intervals. It also allows a more accurate correlation of those conclusions with the already existing body of data.

The research reported here focused on bone remains of birds coming from Vistulian (Weichselian) cave deposits of southern Poland. Its aim was to identify the absolute age of bones from those layers which contained assemblages of bird remains of outstanding species diversity. Hence, the dated remains belong to bird assemblages on the basis of which conclusions have been presented in the literature concerning the paleoenvironment, or more rarely the paleoclimate, of specified time intervals of the Vistulian (BOCHEŃSKI 1974, 1981, 1988; MADEYSKA 1981; BOCHEŃSKI Jun. 1990; TOMEK & BOCHEŃSKI 1995; CYREK et al. 2000; TOMEK et al. 2003; LORENC 2004, in preparation). The knowledge of the absolute age of bird bones from those assemblages is especially valuable. The determination of the absolute age of those bones also throws some light on the age of other animal bones, i.e. the age of the faunal assemblages in the individual layers of the cave deposits. The results of radiocarbon studies can also make more precise the present stratigraphy of the layers of cave deposits under analysis, which is largely based on relative dating methods of poor accuracy.

The Vistulian remains of birds are known in Poland almost exclusively from deposits in caves and rock shelters, altogether from some dozen or so sites (BOCHEŃSKI 1974, 1989, 1993). Usually within single layers the remains of only a few species are recorded; more than ten or even several tens of species are found only rarely (LORENC 2004, in preparation). Thus, the assemblages of bone remains of birds whose species diversity justifies conclusions about the paleoenvironment and paleoclimate obtaining during their deposition are rare. Besides, those assemblages are only known from deposits that have formed over the last 50,000 years (BOCHEŃSKI 1989, 1993). This means that the radiocarbon dating method employed is sufficient to cover them all. The dated material comes from six sites: Deszczowa Cave, Upper Rock Shelter of the Deszczowa Cave, Cave in Dziadowa Skała, Sąspowska Zachodnia Cave, Mamutowa Cave, and Obłazowa Cave (Fig. 1).

The conclusions concerning the relations between the age and genesis of the cave deposits under study and the age of bones found in them can also apply to many other caves not examined in the present research. Hence, its results can be of value not only to paleobiologists, but also to paleoclimatologists, geologists and archeologists relying in their studies on broadly understood cave material.

The research reported below is part of a wider-ranging work designed to reconstruct Vistulian paleotemperatures on the basis of assemblages of bird remains coming from the Vistulian cave deposits of southern Poland (LORENC 2001a, b, 2004, in preparation).

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II. METHODS

Bone samples were dated using the technique of accelerator mass spectrometry (AMS) in the Poznań Radiocarbon Laboratory of the Adam Mickiewicz University Foundation. Taking into consideration the age and character of the material studied (bones under 50,000 years of age) and small sample masses, this is the most appropriate and accurate method today (PAZDUR et al. 1999, the Poznań Radiocarbon Laboratory website). All dating results are given in radiocarbon years.

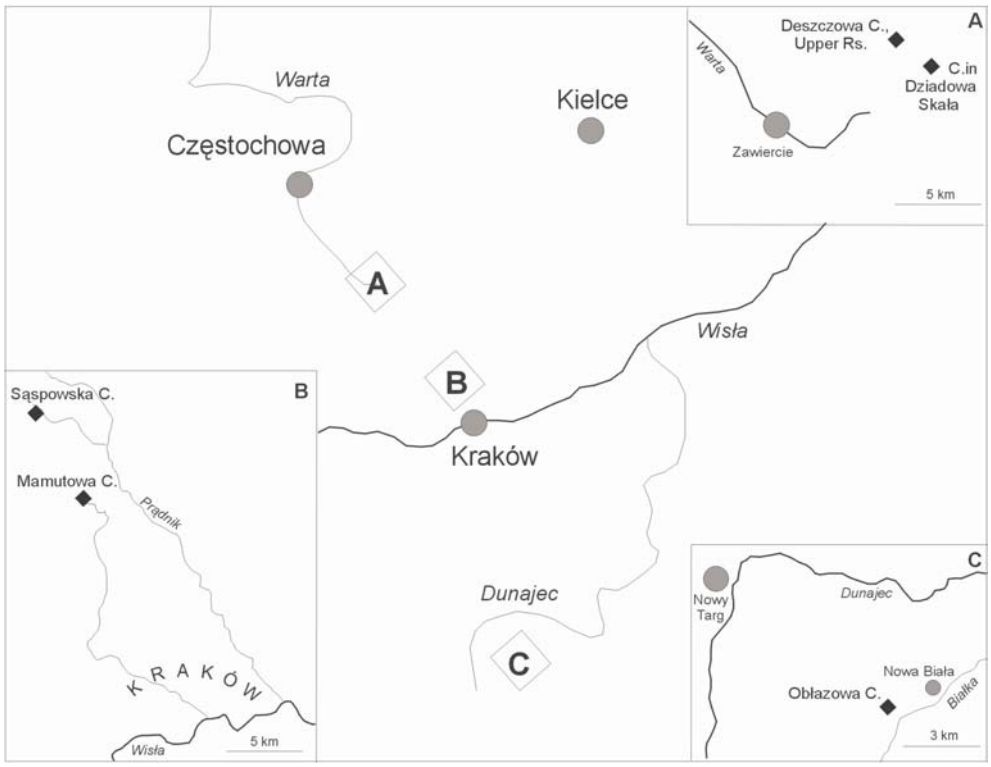

Fig. 1. Location of caves and rockshelters from which bones were dated (abbreviations used: C. – cave, Rs. – rockshelter).

Samples selected in the first place came from layers containing the remains of at least ten bird species. Some derived from layers with less species-rich bone material. In the case of two stratigraphically interesting layers, bones of mammals were dated owing to an insufficient bird bone mass. All the dated bones come from the collection of the Institute of Systematics and Evolution of Animals, Polish Academy of Sciences, Cracow. The dated bird bones were kept in polystyrene bags and in paper envelopes, usually several or even more than ten per bag, but without the use of any preservatives, glues, varnishes etc. that might have affected the dating. Bird bones are very light, hence to prepare a sample weighing a few grams it was often necessary to take several bones. Frequently poorly identified bones were chosen (as the least valuable in the collection); they were usually broken or difficult to identify, e.g. phalanges or vertebrae. In such cases it is highly probable that a single sample contained the bones of several individuals, or even species. Wherever possible, dating was performed on identified bones belonging to one species, which was noted in the dating results. A closer determination of the location of the bones being dated in the cross and long profiles of the deposits was impossible owing to the lack of this type of data in the studies devoted to the particular caves. Hence the information about the location of the dated remains is only limited to the layer in the deposits, without any details of depth or location relative to the cave entrance. This is certainly a serious drawback hampering any suppositions as to e.g. the redeposition of the remains. Another deficiency is undoubtedly the lack of data on the species membership of some of the dated bones. A confirmed presence of a specified species in the given place and time can be valuable information about the paleoenvironment and the paleoclimate.

The chronostratigraphy of the Vistulian adopted in the present research is that put forward by KOZARSKI & NOWACZYK (1999) (Fig. 2). It is an elaboration on the stratigraphic diagram proposed

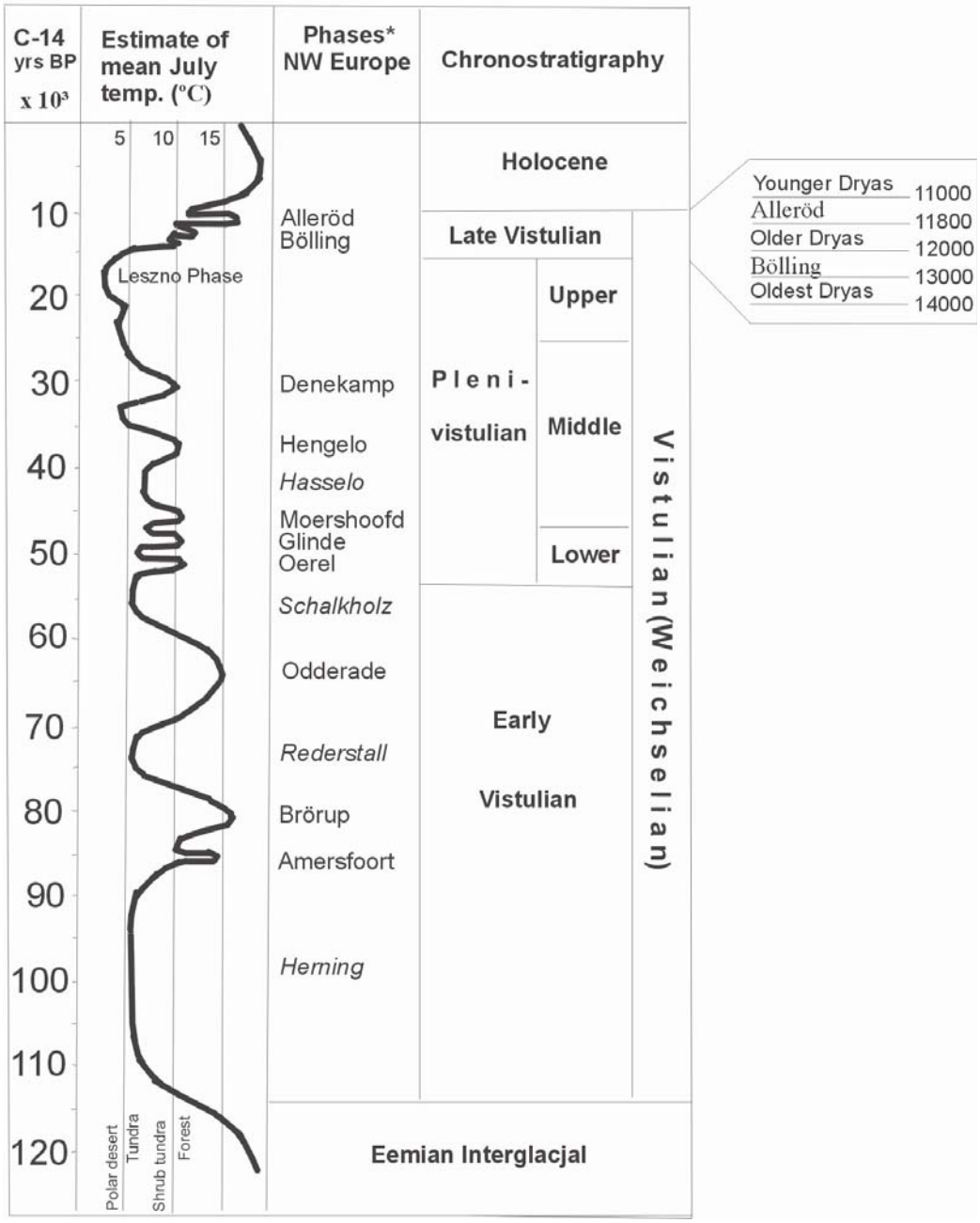

Fig. 2. Chronostratigraphy with climatic curve of the Vistulian (Weichselian) used in the study (after KOZARSKI & NOWACZYK 1999). * – cold phases (cursive writing) after BEHRE (1989), Hasselo Phase after RUN & HUISSTEDEN (1990 in: HUILZER & VANDENBERGHE 1998).

by KOZARSKI (1980, 1981), which follows the most precise divisions of the Vistulian worked out for north-western Europe (e.g. BEHRE 1989). The time scale in the adopted chronostratigraphic division, expressed in C-14 years BP, provides reference for the radiocarbon dates discussed in the article.

III. RESULTS OF RADIOCARBON STUDIES

The dating results are listed in Table I. The numbering of layers from which the dated bones derive is presented in accordance with the one adopted in the quoted works on the individual sites (the successive layers are not always numbered from bottom to top of the profile). The obtained ages of bones are presented against the accepted stratigraphy of layers from which they derive.

Deszczowa Cave

Location: Częstochowa Upland, Popielowa Mountain near Kroczyce (Fig. 1A). The long profile of the Deszczowa Cave deposits and their short lithological characteristics are given in Fig. 3. The stratigraphy of the layers in question, after CYREK et al. (2000), is presented below and in Table I.

Excavations were made both in the cave interior and near its entrance. 11 layers were distinguished in the deposit profile. Layers with corresponding numbers in both exposures are of the same ages. The letter "a" denotes layers from the cave interior.

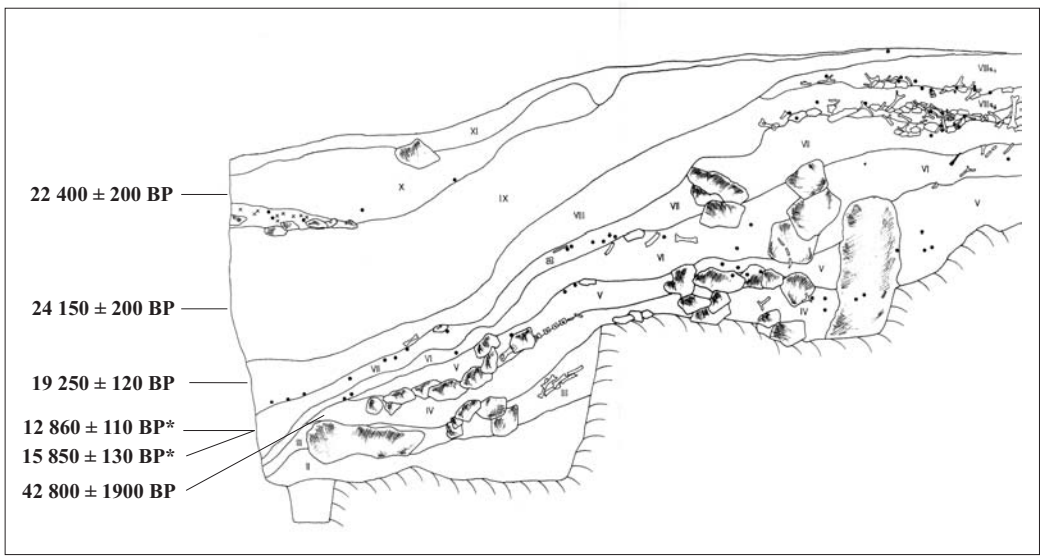

Fig. 3. Longitudal profile of sediments at the entrance and central part of Deszczowa Cave (after CYREK et al. 2000) and the results of the radiocarbon dating. * – dates probably false (it may also refer to the date from layer IV); : – flint artifacts; x – charcoals. Simplified description of the sediments (after CYREK et al. 2000): **I** – grey sand with limestone rubble, preserved in a narrow fissure of the cave bottom at the entrance, **II** – yellow fine and medium grained sand with silt intercalations, almost horizontally laminated. The lamination shows that the sand was transported by water with feeble flow, **III** – silty sand with chemically weathered limestone rubble, **IV** – silty-sandy loam with scare, fine limestone clasts strongly chemically weathered. High amount of organic carbon, iron compounds and phosphate, **V** – silty sand and sandy silt with corroded, chemically weathered limestone clasts, **VI** – laminated sand, fine or very fine at places. It is well segregated, washed with small admixture of sharp-edged, fine limestone rubble, **VII** – fine and medium grained, well sorted sand. Scarce limestone blocks and rubble is present. The lamination is clearly visible near the entrance, **VIII** – loess which passes into slightly laminated sand silts inside the cave. There, the differentiation into darker lower part and lighter upper part is clearly visible. The uppermost part is loose, with disturbed primary structure, enriched in fine limestone rubble, **IX** – laminated fine and medium grained sands. Outside the cave they lie on a slope formed by the eroded layer VIII, **X** – fine and medium grained sand without lamination, **XI** – recent humus.

Table I

The results of the radiocarbon dating of bones from cave and rockshelter sediments (abbreviations used: C. – cave, Rs. – rosksheltер). „**!**"– bone ages which do not agree with the stratigraphy given in the literature for layers from which they come; „?"– bones of unidentified taxonomy; [1] – more accurate identification of bones (see footnote 3); [2] – age probably inaccurate (see footnotes 1 and 2); [3] – second dating of the sample number 1134 (see footnote 4)

Cave/layer	Stratigraphy of the layers (on the basis of data cited in the text)	C-14 age of the dated bones	Age of the dated bones (acc. to the used chronostratigraphy)	Dated bones	Laboratory number of the dated samples
Deszczowa C.					
layer X	Late Vistulian / Holocene	22,400 ± 200 BP	Upper Plenivistulian !	big mammal bones[1]	Poz-3757
layer IXa	Late Vistulian / Holocene	24,150 ± 200 BP	Upper Plenivistulian !	big mammal bones[1]	Poz-3755
layer VIII	Upper Plenivistulian	19,250 ± 120 BP	Upper Plenivistulian	*Lagopus lagopus*	Poz-3751
layer VIIa	younger Middle Plenivistulian	12,860 ± 110 BP[2] 15,850 ± 130 BP[2]	Late Vistulian ! Upper Plenivistulian !	*Tetrao urogallus* *Tetrao tetrix*	Poz-3750 Poz-5195
layer IV	Early Vistulian	42,800 ± 1,900 BP[2]	Middle Plenivistulian !	*Tetrao tetrix* + goose sp.	Poz-3749
Rs. a. the Deszczowa C.					
layer IX/X	Late Vistulian / Holocene	>46,000 BP	? !	*L. lagopus/mutus*	Poz-3756
layer IX	Late Vistulian / Holocene	44,700 ± 2,400 BP	Middle Plenivistulian / Lower Plenivistulian !	*L. lagopus/mutus*	Poz-3753
layer VIII	Upper Plenivistulian	30,100 ± 400 BP	Denekamp !	*Corvus monedula*	Poz-3752
Dziadowa Skała C.					
layer 8	Late Vistulian and Upper Plenivistulian	10,280 ± 60 BP	Younger Dryas	*Tetrao urogallus*	Poz-3745
layer 7	Upper Plenivistulian	11,360 ± 60 BP 12,190 ± 60 BP	Alleröd ! Bölling !	*L. lagopus/mutus* *Tetrao urogallus*	Poz-3743 Poz-1149
Sąspowska Zach. C.					
layer 3	Upper Plenivistulian/ Late Vistulian	10,280 ± 50 BP	Younger Dryas	?	Poz-1167
Mamutowa C.					
layer 1	Early Holocene	11,910 ± 60 BP	Older Dryas !	?	Poz-1150
layer 2 top layer 2 floor	Upper Plenivistulian Upper Plenivistulian	11,820 ± 60 BP 12,000 ± 60 BP	Older Dryas /Alleröd ! Bölling/ Older Dryas !	?	Poz-1152 Poz-1151
layer 2g	Upper Plenivistulian	29,800 ± 400 BP 31,300 ± 500 BP	Denekamp ! Denekamp !	*L. lagopus/mutus* *Tetrao tetrix*	Poz-3746 Poz-3747
layer 3	Denekamp	30,300 ± 350 BP	Denekamp	?	Poz-1153
Obłazowa C.					
layer II	Late Vistulian	11,260 ± 60 BP	Alleröd	?	Poz-1132
layer IV	Late Vistulian	12,740 ± 70 BP	Bölling	*L. lagopus/mutus*	Poz-3742
layer V	Late Vistulian	14,580 ± 80 BP 24,120 ± 200 BP	Upper Plenivistulian ! Upper Plenivistulian !	*Lagopus lagopus* ?	Poz-3740 Poz-1133
layer VII bis[3] layer VII	Upper Plenivistulian	13,800 ± 70 BP 12,940 ± 70 BP 12,830 ± 70 BP	Oldest Dryas ! Bölling ! Bölling !	? ? *L. lagopus/mutus*	Poz-1134 Poz-1437 Poz-3741
layer XI	Middle Plenivistulian	36,400 ± 700 BP	Hengelo	?	Poz-1135

The ages of layers I to IV are correlative with the Early Vistulian. Sedimentological properties of layer IV show it to represent a period of a marked amelioration of the climate, much warmer than the conditions under which the other layers in the cave accumulated. It may come from the Brörup oscillation, but the faunal data do not preclude layers I to IV to be much older, even pre-Eemian.

The age of layer V was correlated, on the basis of sedimentological data, with the Lower Plenivistulian. In its lower part Middle Paleolithic tools were found, which indicates that it must be older than 35,000 years. It should be added here that a bone was also found in this layer that was AMS dated to about 12,000 years BP (NADACHOWSKI, written information). It shows that it accumulated in the Late Vistulian and was redeposited from the overlying layers.

Layers VI and VII are taken to derive from the Middle Plenivistulian. Middle Paleolithic tools coming from layer VI show its age to exceed 35,000 years. This is corroborated by the AMS dating of bones from layer VI: two samples from it were dated to about 43,000 BP and 44,000 BP, respectively. The age of a bone from layer VII was established at about 26,200 BP (NADACHOWSKI et al. 2006).

The accumulation of layer VIII is correlated with the close of the Upper Plenivistulian. The sedimentological and faunal data that suggest it are corroborated by radiocarbon dates. A reindeer antler coming from layer VIII was dated to 17,480±150 BP, and a reindeer bone, probably from layer VIIIa, to 16,150±280 BP (CYREK et al. 2000).

The sedimentation of layers IX do XI is placed in the Late Vistulian and/or Holocene. This age may be indicated by artefacts found in them that come from the Late Paleolithic or Early Mesolithic. However, faunal data do not preclude the origin of layer IX from the Upper Plenivistulian because, like layer VIII, it features a typical steppe-tundra assemblage of species. According to NADACHOWSKI (written information), those layers may be partly mixed, which makes their age determination difficult.

In the light of the above data, the dating results obtained look as follows:

Layer IV: the age of the dated bones does not agree with the proposed age of the layer. The bones come from the Plenivistulian (probably from the older part of the Middle Plenivistulian), while the formation of layer IV is correlated with the Early Vistulian. It should be kept in mind, however, that the obtained bone age may be imprecise[1]. As has been mentioned, bones of a similar age were found in the overlying layer VI. It is probable, therefore, that the bones extracted from layer IV were redeposited from layer VI. Thus, the determination of ages of bones from layers IV and V is difficult. It is highly probable that the remains found in them drifted down from the overlying deposits.

Layer VIIa: the age of the dated bones does not agree with the alleged age of the layer. The dating shows them to come from the close of the Upper Plenivistulian and the Late Vistulian, while the formation of layer VIIa is correlated with the Middle Plenivistulian. However, the probability that the obtained dates of the samples are wrong is very high[2].

Layer VIII: the age of the dated bones shows them to come from the Upper Plenivistulian. This agrees with the age of the layer proposed in the literature. Another corroboration is the age of the two reindeer bones found in it.

Layers IXa and X: the age of the dated bones[3] does not agree with the purported age of the layer. The dating shows them to come from the Upper Plenivistulian, while the layers are believed to have accumulated in the Late Vistulian and/or Holocene. Moreover, the bones from layer IXa are almost 2,000 years older than those from the overlying layer X. At the same time, the bones from

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[1] From the dated bones a small amount of collagen was extracted (mg of collagen per 1 g of bones), which may undermine the reliability of the age obtained (GOSLAR, written information).

[2] In the case of sample no. Poz-3750, during collagen extraction about 5 milligrams of the material were obtained, but it had an uncharacteristic look and when burned yielded a mere 0.3 milligrams of carbon. Similar reservations apply to sample no. Poz-5195 (GOSLAR, written information).

[3] Sample no. Poz-3755 was identified as a fragment of the shaft of a long bone of a deer/reindeer/bear. Sample no. Poz-3757 was identified as a fragment of the shaft of a long bone of a large ungulate, an aurochs/horse (WOJTAL, written information).

layers IXa and X are older than those from the underlying layer VIII. The former come from before the glacial maximum of the Leszno Phase, while the latter were deposited shortly after it. The obtained results indicate that there has been a mixing of the bone remains from layers VIII-X. It is hard to explain why it should have taken place. Assuming, after CYREK et al. (2000), the formation of layers IXa and X in the Late Vistulian or even Holocene, it should be presumed that the Upper Plenivistulian bones found in them come from the lower-lying deposits of layers VIII and/or VIIIa. This requires the assumption that there may be bones even from the early Upper Plenivistulian in layers VIII and/or VIIIa. It cannot be ruled out, however. The shift of bones from older layers lying lower in the profile to younger ones lying higher (against gravitation) usually raises some doubts. Such redeposition requires an especially strong disturbance of deposits. It seems, however, that in Deszczowa Cave no such strong disturbances were necessary - the layers in question show no indication of general mixing. It follows from the long profile of the Deszczowa Cave deposits (Fig. 3) that inside the cave deposits of layer VIII, and especially VIIIa, lie fairly high and the thickness of their overlay (layers IX and partly XI) is very small. Ultimately, layers XI and then IX disappear and layer VIIIa forms the top of the deposits in the cave. The thickness of layer VIIIa is considerable and it contains numerous bone remains. Perhaps the Upper Plenivistulian bones found in layers IXa and X come largely from the deeper part of the cave, primarily from layer VIIIa. During the sedimentation of layer IX (as well as IXa) the top of layer VIIIa could have been exposed, which facilitated the transport of bones from this layer to the younger deposits accumulating in the lower part of the cave. It may have happened through the agency of water, the more so as the deposits of layer VIII in the cave interior pass into fine sands (CYREK et al. 2000) which usually yield themselves easily to washout or gravity movement. Another cause of the shift of the bone material from layer VIII/VIIIa to the younger deposits may have been man's activity in the cave in the Late Vistulian and/or Holocene, as indicated by artefacts found in layers IX and X. The amount of bones redeposited from layer VIII/VIIIa was probably substantial. This is indicated by the mentioned high proportion in layer IX of the remains of steppe-tundra species characteristic of the Upper Plenivistulian.

Upper Rock Shelter of the Deszczowa Cave

Location: the shelter lies a few metres above Deszczowa Cave. The layer numbers in the shelter correspond to those in Deszczowa Cave and are given after CYREK et al. (2000); layers with corresponding numbers at both sites are of the same age (Table I).

With the above data as background, the dating results obtained look as follows:

Layer VIII: the age of the dated bones does not agree with the purported age of the layer. The remains come from the Middle Plenivistulian, while the time of formation of the layer is believed to be the Upper Plenivistulian.

Layers IX and IX/X: the age of the dated bones is highly surprising. Not only are the bones much older than those from the underlying layer VIII, but there is also a radical mismatch between their age and that suggested for those layers in the literature. Their age is identified as the Late Vistulian/Holocene while the dated remains are much older, coming at least from the Middle Plenivistulian. They are the oldest bones of all those dated under the present research.

As in the case of Deszczowa Cave, the dating results indicate a considerable mixing of the remains (deposits?) of layers VIII-X. It is likely that the same holds for the older layers, which is mainly suggested by the age of sample from layer IX/X. It is hard to give another explanation for the occurrence in younger layers lying higher in the profile of bones much older than in the layers lying under them, in the lower part of the profile. It is hard to ascertain precise causes for such a considerable mixing of the bone material on the basis of the existing body of data. It seems that, as in the case of Deszczowa Cave, one cannot rule out the agency of man, whose presence at this site is documented with artefacts coming from the Late Vistulian and/or Holocene. In the light of the above data, it is also impossible to make any age correlations between the remains from layers with corresponding numbers in Deszczowa Cave and the Upper Rock Shelter.

Dziadowa Skała Cave

Location: Częstochowa Upland, near Podlesice (Fig. 1A). The long profile of deposits in the cave interior and their short lithological characteristics are given in Fig. 4. Eleven layers have been distinguished in the profile. Their lithology and stratigraphy are presented in DYLIK et al. (1954) and CHMIELEWSKI (1958). The ages of the layers presented in those works raise much doubt, often connected with a much poorer knowledge of the Vistulian stratigraphy at the time of their publication. The stratigraphy of deposits from this cave is also given by BOCHEŃSKI jun. (1990). It follows from it that only layers 7 and 8 come from the Vistulian; the underlying layers accumulated in the Eemian while the overlying layers 9-11, in the Holocene. Since this is the latest work on the site in question, the stratigraphy it proposes has been adopted in the present study (Table I).

With the above data as background, the dating results obtained look as follows:

Layer 7: the age of the dated bones does not agree with the proposed age of the layer. None of the two samples comes from the Upper Plenivistulian. Assuming that layer 7 did accumulate in the Upper Plenivistulian, the dated bones found in it must be of secondary origin. Their age does not indicate in an unambiguous way their derivation from the overlying layer 8, although this cannot be ruled out. The bones could also have been deposited before layer 8 had accumulated. This apart, the penetration of younger remains into deposits of layer 7 may have been facilitated by the presence of limestone rubble. Water and secondary disturbances affecting this layer could also have been of significance (Fig. 4).

Layer 8: the age of the dated bones conforms to the age of the layer given in the literature, although the remains are slightly younger than expected (they come from the Late Vistulian/Holocene boundary).

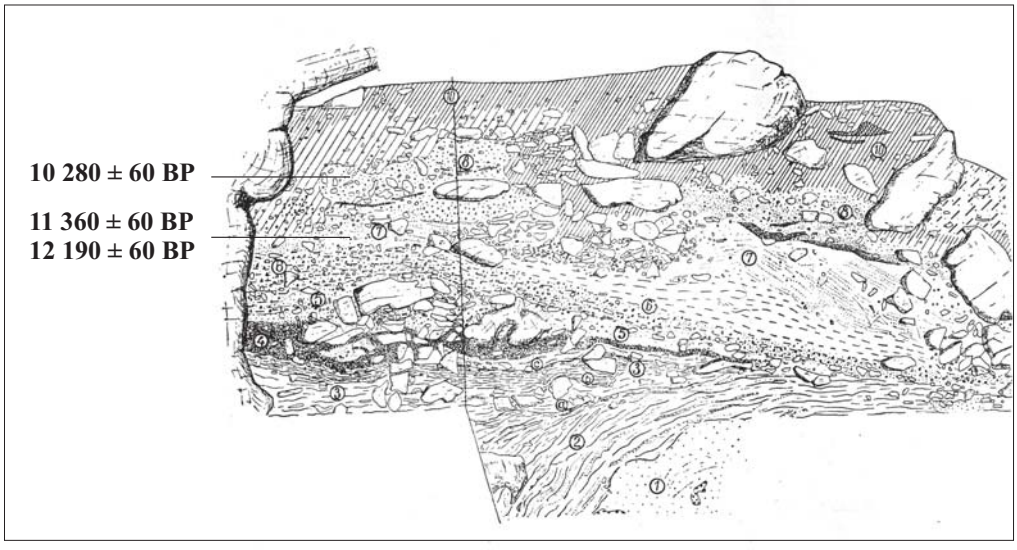

Fig. 4. Longitudal profile of sediments at the inner part of Dziadowa Skała Cave (after CHMIELEWSKI 1958) and the results of the radiocarbon dating. Simplified description of the sediments (after DYLIK et al. 1954 and CHMIELEWSKI 1958): **1** – fine quartz sand, **2** – sandy clay, **3** – series of clay with admixture of sand and limestone rubble, **4** – fine quartz sand, **5** – medium grained quartz sand with limestone rubble at the top, **6** – laminated loess, **7** – quartz sand. The sand is not segregated, with no structure at the deepest part of the cave and fine, laminated, washed with layers of loess in the middle and at the entrance of the cave. Limestone rubble of different sizes is present as well as small fissures and faults, **8** – not segregated sand with no lamination. Limestone rubble of different sizes is present. **9** – subsoil, **10** – soil.

Cave Sąspowska Zachodnia

Location: the Cracow Upland, Sąspowska Valley (Fig. 1B). The long profile of deposits in the cave entrance and their brief lithological characteristics are given in Fig. 5. Their stratigraphy after MADEYSKA (1981, 1988) is presented below and in Table I.

Six layers are distinguished in the profile. The sedimentation of layers 1 and 2 occurred in the time interval between the Early Vistulian and Plenivistulian. Layer 3 accumulated as a result of a collapse of the cave ceiling at the close of the Upper Plenivistulian or in the Late Vistulian. The overlying layers 4-6 are of a cultural character.

The dating shows the presence in layer 3 of bones coming from the close of the Late Vistulian. The age of the bones agrees with that given in the literature for layer 3. MADEYSKA (1981, 1988), however, points out that the bone material from layer 3 is secondary to it, younger. It follows from the genesis of layer 3 as well as its lithology and structure. Therefore it is highly probable that the layer contains both older and younger remains than those dated.

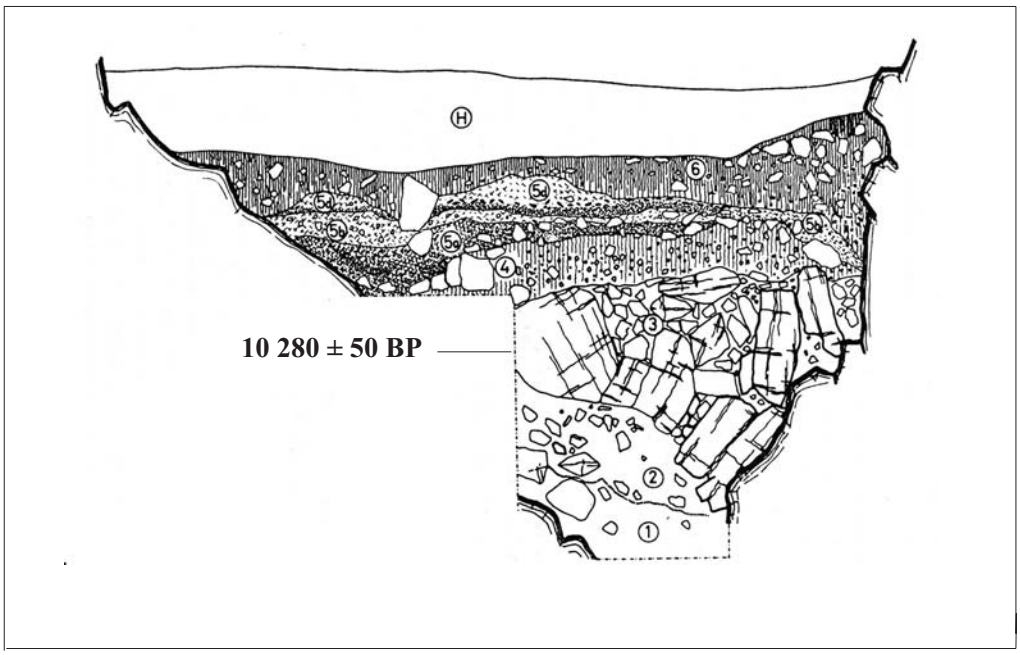

Fig. 5. Section of sediments at the entrance of Sąspowska Zachodnia Cave (after MADEYSKA 1988) and the results of the radiocarbon dating. Simplified description of the sediments (after MADEYSKA 1988): **1** – dusty clay, **2** – dusty clay with limestone rubble, **3** – limestone blocks and sharp-edged rubble coming from the cave ceiling (thickness up to 1m.). The binding material is almost absent at the entrance (the limestone material is loose). The bones and artefacts present in this layer are younger then the sediments, **4** – limestone rubble binded with dusty clay, **5** – cultural layer (density of hachure indicates the level of intensity of black tinge), **6** – humus, **H** – heap from the old trench.

Mamutowa Cave

Location: the Cracow Upland, the village of Wierzchowie (Fig. 1B). Four excavations were made in the cave at various distances from its entrance. The dated bones come from exposure I on the cave threshold. The profile of the deposits where they were found and their brief lithological characteristics are given in Fig. 6. Their stratigraphy after BOCHEŃSKI (1974, 1989), NADACHOWSKI (1976) and MADEYSKA (1981, 1992) is given below and in Table I.

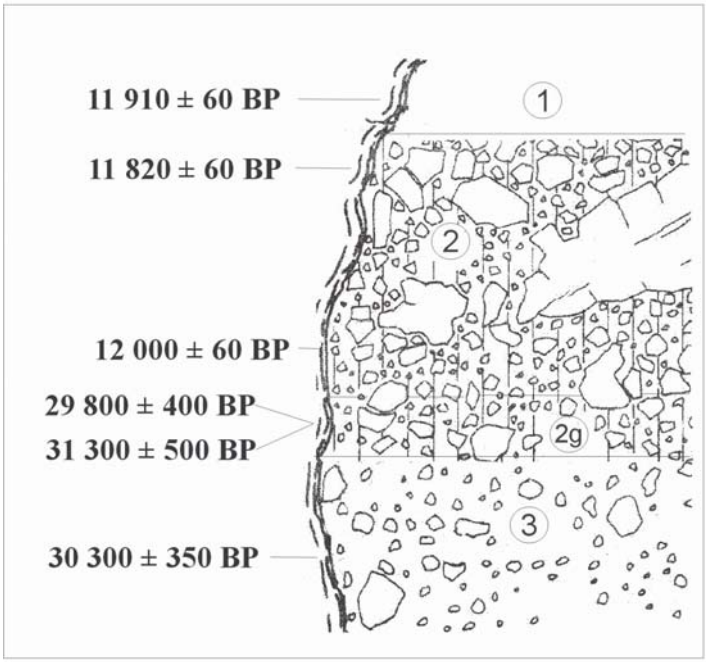

Fig. 6. Section of sediments in the front part of Mamutowa Cave, and the results of the radiocarbon dating. Section prepared on the basis of the lithological description by NADACHOWSKI (1976) and MADEYSKA (1981, 1992). Simplified description of the sediments: **3** – grayish-brown, dusty loess-like clay containing rounded limestone rubble, **2g** – loess with a large quantity of limestone sand (thickness up to 40 cm.), **2** – loess containing angular limestone rubble and big limestone blocks. The entire layer bears signs of water redeposition down the slope, saved as small layers of fine limestone gravel and washed loess. The top of this layer contains less binding material and traces of soil forming processes, resulting from a contact with layer 1, **1** – Holocene humus, divided into the older part, saved only fragmentary, and the younger, present part.

Seven layers have been distinguished in the near-entrance part of the cave. The youngest, layer 1, is humus which formed in the Holocene. Within it a younger, contemporary part was separated as well as an older one preserved only partially. The archeological and paleontological materials found in the underlying layers 2, 2g and 3 allowed them to be correlated with the Vistulian. Layer 2g was identified on the basis of an admixture of fine limestone rubble and sand as the bottom part of a thick loess layer 2 (BOCHEŃSKI 1974; NADACHOWSKI 1976; MADEYSKA 1981). According to MADEYSKA (1981), layers 2 and 2g should be correlated with the Upper Plenivistulian. BOCHEŃSKI (1974) associates the formation of layer 2g with the Leszno Phase and considers layer 2 to be younger, formed after the climax of this phase, but in the Upper Plenivistulian. In turn, NADACHOWSKI (1976) is of the opinion that both layers (2 and 2g) represent the climatic minimum period of the Leszno Phase. Related with those layers are four radiocarbon dates obtained for bones of large mammals in an Oxford laboratory. Three samples from layer 2 have been dated to about 20,659 BP, 27,040 BP and 35,460 BP, respectively, while the bone from layer 2g has been estimated at about 26,010 BP (DAVIES - written information). The first of the above dates indicates the presence in layer 2 of bones from the Leszno Phase, which is in agreement with the stratigraphic interpretation offered by NADACHOWSKI (1976). However, the two other dates show there to be also older bones, from the Middle Plenivistulian, in the layer. The dating of the bone from layer 2g, in turn, places it at the start of the Upper Plenivistulian or even the end of the Middle Plenivistulian, not in the Leszno Phase. Moreover, the bone from layer 2g is much younger than the oldest bone found in the overlying layer 2. The above dates suggest some discrepancy between the stratigraphy of the layers presented in the literature and the age of bones found in them. The sedimentation of layer 3 is thought to have taken place in the Middle Plenivistulian. The underlying loamy layers do not contain bird bones and are considered to be much older.

With the above data as background, the dating results obtained look as follows:

Layer 1: the bones from this layer were dated because of the possibility of their pre-Holocene derivation (BOCHEŃSKI, oral information). The age of the dated sample corroborates this supposition. It does not agree with the purported age of this layer. The sample comes from the Late Vistulian while the formation of layer 1 is correlated with the Holocene.

Layers 2 and 2g: the age of the bone remains from layers 2 and 2g differs radically from the stratigraphy of those layers given in the literature. No dated sample found in them, and there were as many as four, comes from the Upper Plenivistulian. The samples from layer 2g are too old (the Denekamp), and those from layer 2 are too young (the Late Vistulian). As has been mentioned, layer 2g was identified as the bottom part of layer 2, but the age of the remains coming from it is clearly similar to that of the remains from the underlying layer 3, not 2. The bones from layer 2 are of the same age as those from layer 1. They were deposited in the Late Vistulian, in the Bölling-Alleröd time interval. It cannot be ruled out that the bones from layer 2 derive from the Older Dryas, as do the bones from layer 1.

Layer 3: the age of the dated bones agrees with the age proposed for this layer in the literature (the Denekamp).

In sum, the bird bones found in the layers of deposits under study come exclusively from the Late Vistulian (layers 1 and 2) and the Denekamp (layers 2g and 3). There are definitely no bones from the Upper Plenivistulian in which layers 2 and 2g are presumed to have accumulated. In the light of the above data, however, one can hardly refuse to regard the Late Vistulian remains in Mamutowa Cave as a new, but strongly substantiated fact. If layer 2 is correlative with the Upper Plenivistulian, it must be assumed that the Late Vistulian bird remains which it contains are of secondary origin. But where might they have come from? No Late Vistulian layer has been distinguished in this cave from which the bones might have been redeposited (although there are layers identified as coming from the Upper Plenivistulian and Holocene). There seem to be two possibilities. One is the accumulation of Late Vistulian bones on the surface of layer 2 after the completion of its sedimentation but before the formation of layer 1. In this situation one should assume that the amount of bones and perhaps also of deposits accumulating over that time was too small to form a distinct layer in the profile that might be correlated with the Late Vistulian. One cannot also preclude the possibility that such a (thin) layer actually developed, but then underwent erosion. Still, the bones gathering on the surface of layer 2 may have penetrated inside it. This may have been facilitated by the presence in it of coarse clastic material and boulders as well as a smaller amount of binding material at the top (Fig. 6). It still does not account for the presence of Late Vistulian bones in layer 1. The other hypothesis does. It assumes the formation of the older part of layer 1 in the Late Vistulian, in the Bölling-Alleröd time interval. Then the bones of this age from layer 1 can be considered autochthonous. Radiocarbon dating of the soil material from the bottom of layer 1 would perhaps help to bear out or rule out this possibility. Still, in both cases the Late Vistulian bones in layer 2 should be considered younger than its deposits, i.e. redeposited. What is surprising, however, is that remains of this age can be found both at the top and bottom of this very thick layer, and what makes it even more astonishing is the fact that it is a layer of loess. Gravity movement of bones in this layer down to a depth of tens of centimetres seems difficult, despite the presence of limestone rubble and boulders. A significant clue may be the traces of downslope movement of the deposit from layer 2 as a result of flow (NADACHOWSKI 1976, MADEYSKA 1981). In effect, the Late Vistulian bird bones that had accumulated at the top of layer 2 (the first possibility) or at the bottom of the remnant (!) of layer 1 (the other possibility) could have penetrated into layer 2, even down to its bottom. The flow of deposits of the entire layer 2 (hence also its bottom part designated 2g) can perhaps also be taken to account for the presence in this layer of bones of large mammals from the Middle Plenivistulian, and even more so of bird bones of this age in layer 2g. The deposit flowing down the slope could have scoured some amount of bone remains from the top of underlying layer 3 and caused them to shift to layers 2 and 2g. The accumulation of layer 3 is correlated in the literature with the Middle Plenivistulian. The dated bird bones from this layer come from this time interval.

What is more, they are of the same age as the bird bones from layer 2g. The age is also similar to that of two older mammal bones from layer 2. There is no mention in the literature of the mixing of those layers, but worth noting is the information about layer 3 passing into layer 2 without a distinct boundary (NADACHOWSKI 1976, MADEYSKA 1981). Whether the above interpretations are correct or not, the bone material of layer 2 (including 2g) must be regarded as being of various ages, heavily mixed, and coming from the Middle Plenivistulian, Upper Plenivistulian (mostly the Leszno Phase?) and Late Vistulian. Bones from the Middle Plenivistulian can come from layer 3, those from the Upper Plenivistulian (Leszno Phase) should be considered autochthonous, and those from the Late Vistulian can derive from the surface of the top of layer 2 or the bottom of layer 1. What one should regard as the cause of such heavy mixing (perhaps not the sole one but principal) is the downslope flow of deposits of layer 2 (including 2g). Without doubt, the results of radiometric studies obtained for Mamutowa Cave are particularly perplexing.

Obłazowa Cave

Location: Podhale, the Białka valley near the village of Nowa Biała (Fig. 1C). This is the best-examined cave site of all those considered in the present study. The results of a wide-ranging research carried out in this cave have been published in a monograph (VALDE-NOWAK et al. 2003). The profile of the Obłazowa Cave deposits and their short lithological characteristics are given in Fig. 7. The layer stratigraphy, after MADEYSKA (2003), is presented below and in Table I.

21 layers in the form of six series (from A to F) have been distinguished in the deposits filling the cave. Each series consists of one or more layers that have accumulated in similar climatic conditions. Series A (layers XXI and XX) is correlated with the Early Vistulian, the first period of cooling, 100-105 ka BP. Also the formation of series B (layers XIX-XIII) occurred in the Early Vistulian, probably in the Brörup. Series C (layer XII) is correlated with the Lower Plenivistulian, and series D (layers IX-VIII) with the Middle Plenivistulian. The ages of the AMS-dated bones from layer VIII are 32,400±650 BP, 31,000±550 BP and 30,600±550 BP (VALDE-NOWAK et al. 1995, HOUSLEY 2003). Series E (layer VII) is correlated with the Upper Plenivistulian, and series F (VI-I) with the Late Vistulian and Holocene. Deposits of layers XXI to IX are cut abruptly near the cave entrance (which is not visible in Fig. 7). The cutting was probably initiated by the river, but is largely due to human activity. The space below the cutting, i.e. near the entrance of the cave and in front of it, is filled by material redeposited from the cave interior. It was designated layer XXII and explored too.

Species-rich assemblages of bird remains from the Vistulian were found to occur in four series of deposits: A, D, E and F. Because the age of bones from series A exceeded the range of the radiocarbon method, only those from the other three series were dated.

With the above data as background, the dating results obtained look as follows:

Layer XI: the dated bones come from the Middle Plenivistulian, from the younger part (end) of the Hengelo Oscillation. Thus, their age agrees with that given for this layer in the literature. It also agrees with the dates obtained for the remains from the overlying layer VIII.

Layer VII: the ages of the two dated samples are very similar and show them to come from the Late Vistulian (Bölling)[4]. Thus, the bones are younger than the age proposed for this layer (Upper Plenivistulian).

Layer V: the dated bones are older than the age of this layer given in the literature. They come from the Upper Plenivistulian, while the sedimentation of layer V is placed in the Late Vistulian. Significantly, according to the stratigraphy cited, the age of the remains from layer V corresponds to

[4]Sample Poz-1134 was dated twice. The more probable age is that obtained from the second dating, i.e. 12,940+70 BP (GOSLAR, written information). It is also corroborated by the dating result for sample Poz-3741 from this layer.

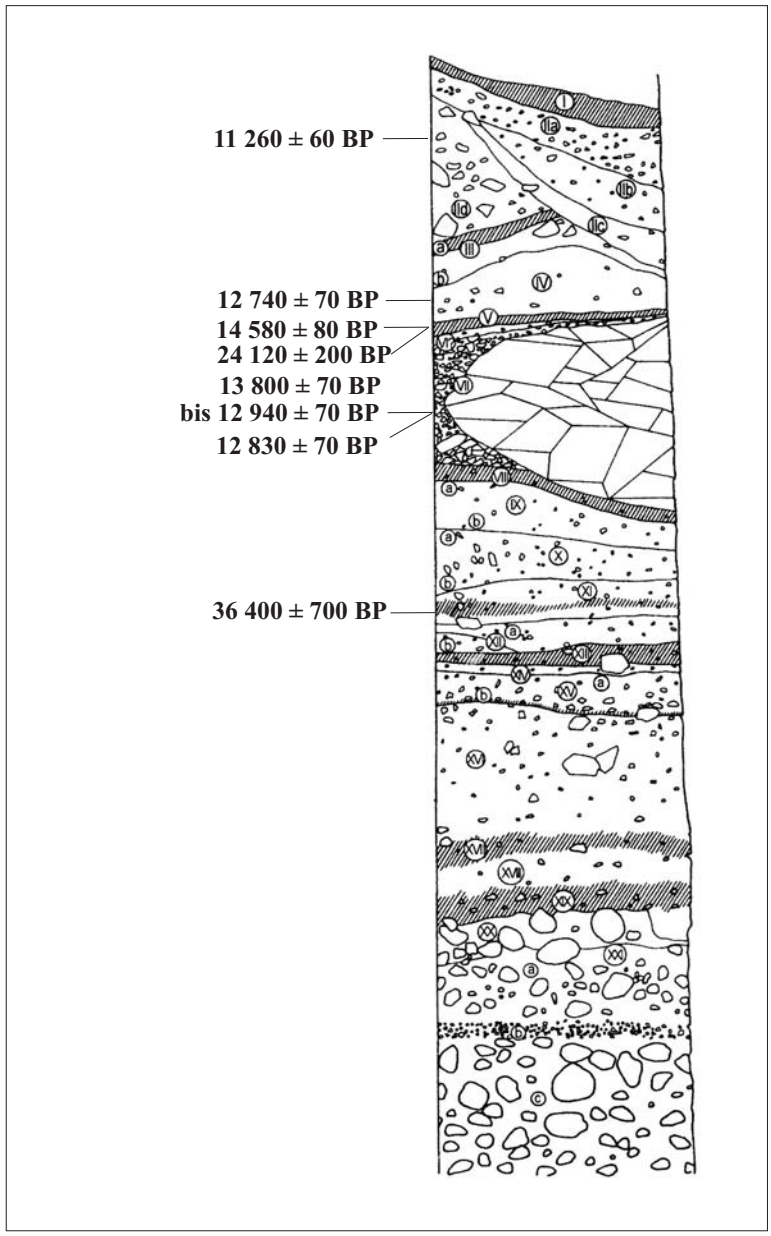

Fig.7. Section of sediments in Obłazowa Cave (after MADEYSKA 2003) and the results of the radiocarbon dating. Main cultural horizons (Mousterian, Szeletian and Pavlovian) are marked with cross-hatching. Simplified description of the layers XII-I (series F to C) (after MADEYSKA & VALDE-NOWAK 2003): **XII** – grey-brown sandy loam with fine rubble, **XI** – red-brown sandy loam with smoothed rubble, **X** – greenish-grey sandy loam with small pebbles from outside of the cave, **IX** – yellow-brown sandy loam with a small amount of limestone rubble, **VIII** – grey-brown cultural layer of loam with rubble of different sizes, **VII** – sharp-edged rubble with particles of different sizes, with small admixture of loam. Large limestone block (1,5 m in diameter), visible on the section, **VI** – thin (5 cm in thickness) layer of loam with slightly smoothed rubble, only present in the inner part of the cave, **V** – dark brown loam with humus and slightly smoothed limestone rubble. The layer gently grades into the lower lying sediments and becomes thinner towards the cave entrance, **IV** – light brown loam with small amount of fine limestone rubble, gradually grading into layer III, **III** – bipartite layer of ashen-brown loam with smoothed limestone rubble, **II** – series of four loamy-rubble taluses. Some limestone pieces transported from the back part of the cave, **I** – dark grey-brown loam with rubble.

layer VII, while that of the remains from layer VII corresponds to layer V. The presence in layer VII of younger remains, secondary to it, can be accounted for by the loose structure of its deposits. The bones may have penetrated among its many boulders and sharp-edged pieces of limestone rubble long after their deposition. The bones from layer VII are of the same age as those from layer IV. They are also only slightly younger than one of the samples from layer V. This corroborates the possibility of the bones from layer VII deriving from the overlying deposits. With respect to layer V, worth noting is the big age difference between the two dated samples: about 10,000 years. The older sample (24,120±200 BP) comes from before the period of the maximum cooling of the climate, while the younger one (14,580±80 BP) from the end of the Upper Plenivistulian. Taking into consideration the very small thickness of layer V (about 5 cm at places), it is doubtful whether the two samples are autochthonous to this layer. Still, it is hard to indicate in an unequivocal way which of the two samples has been redeposited. It cannot also be ruled out that they are both secondary to layer V. According to the stratigraphy given in the literature, the formation of layer V took place in the Late Vistulian, which would point to the younger sample as the autochthonous one. However, one cannot rule out that it derives from the bottom of layer IV. The older sample, in turn, may come from layer VII, although it would be difficult to explain the mechanism of its redeposition in layer V, but on the other hand it cannot be ruled out that this is the sample autochthonous to layer V. There is indirect archeological evidence suggesting this. Layer V has supplied finds that are probably associated with the Aurignacian culture. Artefacts of this culture have also been found in the mentioned layer XXII, in which they occurred in a secondary bed. It is highly probable, however, that those artefacts come from layers V and/or III (VALDE-NOWAK 2003). The date obtained for them is 23,430±380 BP (HOUSLEY 2003), which is very similar to the age of the older bone sample from layer V (24,120±200 BP). This may indicate that the Upper Plenivistulian bone material in layer V is autochthonous to this layer. Assuming this possibility, the bird bones from the Late Vistulian (Bölling) found in layer VII should be regarded as deriving from layer IV, in which bones of this age have also been found. On this interpretation, also the younger bone from layer V should be considered redeposited from layer IV (or rather from its bottom). It should be added that in a preliminary work on bird remains from the Obłazowa Cave deposits (TOMEK & BOCHEŃSKI 1995), layer V is thought to correlate not with the Late Vistulian but Upper Plenivistulian, i.e. in agreement with the dating of bones from this layer and the above interpretation which accommodates the archeological data. However, the interpretation cannot be regarded as correct beyond any doubt.

Layers II and IV: the dated bones come from the warm climatic oscillations of the Late Vistulian (Bölling and Alleröd). Their age agrees with that given in the literature for those layers.

IV. DISCUSSION OF THE RESULTS

Out of the 26 bone samples dated, the age of 19 does not correspond with the stratigraphy, as given in the literature, of layers from which they come. Three of them can be disregarded as probably dated incorrectly owing to the poor condition of the bones. These are samples from Deszczowa Cave (footnotes 2 and 3). However, the dating of the remaining 16 samples raises no doubts laboratory-wise. The causes of those discrepancies were proposed when presenting the dating results for bones from the individual caves (chapter III). This allows the following discussion.

(a) Layers correlated in the literature exclusively with the Upper Plenivistulian

Out of the 16 samples in question, 9 come from layers correlated in the literature exclusively with the Upper Plenivistulian. These are: layer VIII in the Upper Rock Shelter of the Deszczowa Cave, layer 7 in Dziadowa Skała Cave, layer 2 and 2g in Mamutowa Cave, and layer VII in Obłazowa Cave. Of those 9 samples, 6 derive from the Late Vistulian (the Bölling-Alleröd time interval), and 3 from the Middle Plenivistulian (Denekamp). Thus, the bird bones from layers correlated with the Upper Plenivistulian are usually of a different age, usually Late Vistulian. Only once

did bird bones found in a layer from the Upper Plenivistulian turn out to be of the same age: layer VIII in Deszczowa Cave (Table I).

The occurrence of Late Vistulian bones in the layers in question is largely accounted for by their lithology and secondary disturbances of those deposits. Bones of this age were found in layer 7 of Dziadowa Skała Cave, layer 2 of Mamutowa Cave, and layer VII of Obłazowa Cave. In all those layers limestone rubble was found to occur (usually in the form of sharp-edged clasts of varying sizes) as well as large boulders (Figs 4, 6, 7). The presence of coarse material, especially large boulders, facilitates downward migration of bones (especially small ones) in the deposits. The bones that kept accumulating in the Late Vistulian could have penetrated inside them gravitationally immediately on deposition or somewhat later as a result of a secondary movement of the deposits, also through the agency of water. Secondary disturbances could have been of special importance in the case of layer 7 in Dziadowa Skała Cave and layer 2 in Mamutowa Cave.

The presence of bones from the Denekamp in layers correlated in the literature exclusively with the Upper Plenivistulian is more puzzling. This concerns layer VIII in the Upper Rock Shelter of the Deszczowa Cave and layer 2g in Mamutowa Cave. The bird bones from the Denekamp found in those layers had probably been redeposited from the older underlying layers, i.e. against gravitation. As has been mentioned, in the case of layer VIII in the Upper Rock Shelter of the Deszczowa Cave, it is difficult to identify definite causes of such redeposition, the more so as even older, evidently redeposited bones were discovered in the overlying younger layers IX and IX/X. This is indicative of a general mixing of the bone remains (deposits?) of this cave. One cannot rule out that this may have been due to man's presence in this place as shown by artefacts coming from the Late Vistulian and/or Holocene that have been found in layers IX and X of Deszczowa Cave.

In the case of layer 2g in Mamutowa Cave, the Denekamp bones may come from the underlying layer 3. The entire layer 2 in this cave shows traces of downslope movement involving water. It was suggested that such a movement of the deposit could have scoured some amount of bone remains from the top of layer 3 and redeposited them in layer 2, including 2g.

(b) The remaining layers

The remaining 7 dates were obtained for samples from layers correlated in the literature with the Late Vistulian (layer V of Obłazowa Cave), Late Vistulian or Holocene (layers IXa and X of Deszczowa Cave and IX and IX/X of the Upper Rock Shelter of the Deszczowa Cave), and Holocene (layer 1 of Mamutowa Cave). In each case the obtained age was older than that proposed for the individual layers.

The age of 4 samples shows them to derive from the Upper Plenivistulian. These are samples from layers IXa and X of Deszczowa Cave and layer V of Obłazowa Cave. In the case of Deszczowa Cave it is suggested that the dated bones come from layer VIII/VIIIa. It developed in the Upper Plenivistulian, which is corroborated by the dating of bones from those deposits. In the deeper part of the cave the deposits of layer VIII, and especially VIIIa, lie high enough to justify the hypothesis that the bones deriving from them were redeposited in younger sediment lying in the lower part of the cave, especially as in many places the top of layer VIIIa has no overlay of younger deposits (Fig. 3). In the case of layer V in Obłazowa Cave, an unequivocal interpretation of the origin of the dated bones is difficult. At least one of the dated samples, if not both, is secondary to layer V. If it is the younger one (14,580±80 BP) then it must be regarded as redeposited from layer IV (or rather from its bottom). If it is the older sample (24,120±200 BP), it is hard to explain the mechanism of its redeposition, hence the suggestion that it may be autochthonous to layer V. Also archeological data do not rule this possibility out. However, it undermines the stratigraphy of this layer given in the literature because it is thought to have accumulated in the Late Vistulian. What one should note, however, is that layer V lies at the bottom of series F, which is composed of deposits correlated with the Late Vistulian and Holocene.

The age of the next 2 samples coming from layers IX and IX/X of the Upper Rock Shelter of the Deszczowa Cave shows them to derive from the Middle Plenivistulian or an even earlier period.

The bone age suggests heavy mixing of its deposits. It may be due to man's activity, whose presence at this place is documented with artefacts from the Late Vistulian and/or Holocene.

The age of one sample shows it to derive from the Late Vistulian (Older Dryas). The sample comes from layer 1 of Mamutowa Cave. Two explanations have been offered for its presence there. One is that the bones originated at the top of layer 2 and were then redeposited at the bottom of layer 1. The other alternative is that the older, bottom part of layer 1 (preserved only partially) accumulated in the Late Vistulian, during the climatic amelioration of the Bölling-Alleröd time interval. In this approach, the dated bones can be considered autochthonous to the bottom of layer 1.

The issue that may need expanding on is that of the layers correlated in the literature exclusively with the Upper Plenivistulian and dealt with in subsection (a). They have been proved to contain bird bones of a different age, occurring widely and deriving from periods of a much milder climate than that obtaining in the Upper Plenivistulian. It is hard to determine the proportion of those remains among the ones supposedly coming from the Upper Plenivistulian. It may be considerable, which is indicated, indirectly, by the following clues:

(a) The co-occurrence in those layers of the remains of typically Arctic species, today nesting in the tundra, and those indicating a much milder climate (e.g. temperate) and decidedly different environmental conditions (e.g. the presence of forests). Thus, with reference to layer 2 from Mamutowa Cave, BOCHEŃSKI (1974) states that "from the climatic point of view, it contains evidently cold-loving, Arctic elements together with species of the temperate zones whose northern limits run between the July isotherms of 15°C and 17°C". Side by side with typically forest species, tundra species can be found in the layer, although they constitute a minority (!). There are only a few species known from layer 2g, but even among those remains one can find both, typical forest and tundra species (BOCHEŃSKI 1974, 1981). There is a similar diversity among the bird remains from layer VIII of the Upper Rock Shelter of the Deszczowa Cave (CYREK et al. 2000). It is hard to imagine a simultaneous occurrence in the same place of species with so dissimilar environmental and climatic requirements; species whose ranges do not coincide today, and are often widely apart. Even more puzzling are the assemblages of birds from layer 7 of Dziadowa Skała Cave (BOCHEŃSKI jun. 1990) and layer VII of Obłazowa Cave (TOMEK et al. 2003). They can hardly be treated as characteristic of the Upper Plenivistulian if Arctic species are only an admixture (according to VOOUS 1962, BOCHEŃSKI 2000) and the remaining majority of species are typical of the temperate zone. In the case of those layers the proportion of allochthonous remains may be exceptionally high.

(b) The lithological features of those layers are indicative of a more severe climate than the bird assemblages found in them. The deposits of layer VII in Obłazowa Cave indicate that it accumulated in the coldest climate of all the layers in this cave. It is correlated with the culmination of cold in the Upper Plenivistulian. It follows from the data quoted by MADEYSKA (2003) that the predominant type of vegetation in its area at that time was the treeless tundra. Also the deposits of layer VIII from Deszczowa Cave are indicative of a cold and dry climate corroborated by the sedimentation of loess. The same holds for layers 2 and 2g from Mamutowa Cave, built mainly of loess and sharp-edged limestone rubble (MADEYSKA 1981, 1992), and layer 7 from Dziadowa Skała Cave (CHMIELEWSKI 1958). In the climatic conditions implied by the lithological characteristics of those layers, the occurrence of forests, or even a low-shrub tundra, seems doubtful. This extends to forest birds and in general to species associated at present with the temperate climate, and corroborates the claim that their remains are probably allochthonous to those layers.

Taking into consideration the well-tested and probably substantial presence of allochthonous bird remains (from the Late Vistulian and Denekamp) in layers correlated with the Upper Plenivistulian, one cannot but be critical about any attempts at inference concerning the paleoenvironment or paleoclimate of the Upper Plenivistulian on the basis of the bird assemblages from those layers. Such attempts have often been made, e.g. BOCHEŃSKI (1974) on the basis of bird bones from layers 2 and 2g in Mamutowa Cave, BOCHEŃSKI jun. (1990) on the basis of bird bones from layer 7 in Dziadowa Skała Cave, TOMEK & BOCHEŃSKI (1995) and TOMEK et al. (2003) on the basis of bird bones from layer VII in Obłazowa Cave, and CYREK et al. (2000) on the basis of bird bones from layer

VIII in Deszczowa Cave and its Upper Rock Shelter. Naturally, the picture of the paleoenvironment obtained on the basis of those bird assemblages is highly diversified. It usually includes the simultaneous presence near the caves of such widely differing types of environment as the tundra and forests, offering the relief as an explanation. Forests are supposed to have grown on south-facing slopes even during the maximum cold of the Upper Plenivistulian, i.e. the Leszno Phase (BOCHEŃSKI 1974, BOCHEŃSKI jun. 1990). While such a possibility cannot be ruled out, it should be emphasised that to some extent those conclusions rest on bird remains from the Late Vistulian (the Bölling-Alleröd interval) and the Denekamp, i.e. warmer periods during which the presence of forests in Poland has been proved, mainly on the basis of palynological data, e.g. KOPEROWA (1958), MAMAKOWA (1968), ŚRODOŃ (1968, 1972), HARMATA (1995), MADEYSKA (1995, 1998), MADEYSKA & KOZŁOWSKI (1995). The remains of the woodland species of Black Grouse *Tetrao tetrix* found in layer 2g of Mamutowa Cave come from the Denekamp. The remains of another such species, the Capercaillie *Tetrao urogallus*, from layer 7 of Dziadowa Skała Cave, have been dated to the Late Vistulian. Also from the Denekamp come the bones of a Jackdaw *Corvus monedula* found in layer VIII of the Upper Rock Shelter of the Deszczowa Cave, which suggests at least the presence of trees. It is on the basis of those species, among others, that forests have been deduced near the caves in the Upper Plenivistulian. These conclusions seem to need revision, which makes it necessary to perform further dating of still other bones. In the case of bird bones, especially valuable would be the knowledge of the age of remains of those species which do not occur in the Arctic zone at present (e.g. typical forest species).

The material collected cannot be used to invalidate the stratigraphic assignment of the deposits from the particular sites, and it has not been meant to do so. Still, it leaves no doubt that the bone remains (probably not only of birds) found in the cave deposits under study have been mixed to some indeterminate extent. As has been mentioned, in the case of small bones lying in coarse clastic material (e.g. rubble), their redeposition need not mean the redeposition of the sediment itself. But in the case of layers built of fine material (e.g. loess), one can hardly imagine a major shift of the bones without the movement of the deposit in which they lie. Hence, traces of transport of the deposits and the location of the collected bones in relation to them should be carefully documented during field studies. In many situations a precise location of the remains in the profile (both horizontal and vertical) may be the only clue to an explanation of the discrepancies between the age of the bones and that of the deposit from which they come.

The presented results of radiometric studies have also some universal significance not only for the sites and layers of cave deposits examined during the present research. They suggest that:

(a) It is necessary to approach the question of the age of bones from cave deposits very carefully. The age of a deposit may differ considerably from that of the bones found in it. As has been proved, the discrepancies can be really wide, and this is not a rare occurrence. It is therefore necessary to discriminate between two issues, viz. the age of the deposit and the age of the bones in it.

(b) It is necessary to be equally careful about any reconstruction of the paleoclimate or paleoenvironment made on the basis of insufficient knowledge of the age of animal (not only bird) remains from the cave deposits. This may especially concern the bone material from layers correlated with the Upper Plenivistulian (mostly of coarse clasts). If the bones are to provide a basis for conclusions about the paleoclimate or paleoenvironment, their age must be identified much better than has been done to date.

It should be emphasised that there is ample justification for a wide-ranging research on the absolute age of the bone material from the cave deposits. Its results may help to improve the accuracy of the present stratigraphy of layers of those deposits, which is largely based on low-precision, relative dating methods. They may also throw some light on the scale of possible movement of bone remains of varying ages within the individual layers. There is no doubt that such data will be of value not only to paleobiologists, but also to paleoclimatologists, geologists and archeologists using cave material in their studies.

V. SUMMING UP

1. 26 bone samples, almost exclusively of birds, were dated obtaining 27 dates (one sample was dated twice). The method employed was radiocarbon (AMS) dating. The bones came from cave deposits correlated mainly with the Vistulian (Weichselian), from six sites in southern Poland (Fig. 1).

2. A decided majority of the dated samples, as many as 19, do not agree in age with the stratigraphy given in the literature for layers from which they come (Table I). Three of them can be disregarded as probably dated incorrectly owing to the poor condition of the bones. The dating of the remaining 16 samples raises no doubts laboratory-wise.

3. Most of the 16 samples (9) come from layers correlated in the literature with the Upper Plenivistulian. However, their age shows them to derive not from the Upper Plenivistulian, but from the Late Vistulian (the Bölling-Alleröd interval) (6 samples), and from the Middle Plenivistulian (Denekamp) (3 samples). Only once did bird bones found in a layer correlated with the Upper Plenivistulian turn out to be of the same age: it was layer VIII in Deszczowa Cave. The presence of bones from the Late Vistulian (Bölling-Alleröd) in layers accumulated in the Upper Plenivistulian can be explained by their redeposition from overlying deposits. The redeposition was facilitated by the lithology of the Upper Plenivistulian layers (the presence of sharp-edged limestone rubble and boulders), their often loose structure, and secondary disturbances of those deposits. It is harder to give a neat explanation of the presence of bones from the Middle Plenivistulian (Denekamp) in layers formed in the Upper Plenivistulian. It was suggested that there had been a mixing of deposits from the Upper Plenivistulian with the underlying ones from the Middle Plenivistulian.

4. The remaining discrepancies (7 samples) between the stratigraphy of the deposits and the age of the dated bones concern layers correlated in the literature with the Late Vistulian, Late Vistulian or Holocene, and Holocene. In each case the obtained age was older than that proposed for the individual layers. Causes of the redeposition of older bones in younger deposits were suggested, and in two cases a possibly autochthonous character of the dated bones was acknowledged and a different stratigraphy of the layers was proposed.

5. The obtained results of radiometric studies make it clear that a distinction should be drawn between two issues, namely the age of a deposit and the age of the bones found in it. They also show that there is a high probability of the co-occurrence of bone material of varying ages within the same layer of cave deposits.

6. The probability of the occurrence of bones of widely differing ages in layers deriving from the Upper Plenivistulian is considered especially high. The bones may come from a variety of climatic periods. Therefore extra care is suggested when dealing with any reconstruction of the paleoclimate and paleoenvironment of the Upper Plenivistulian that has been made on the basis of faunal assemblages coming from layers of this age.

7. It is deemed highly justified to launch a wide-ranging research on the absolute age of bones from the cave deposits. Given the above conclusions, particularly interesting will be the dating results obtained for bones from Upper Plenivistulian layers, especially those of species not living in the tundra today.

8. The conclusions concerning the relations between the genesis and age of the cave deposits in question and the age of the bones found in them may also apply to many other caves that have not been examined in the present research. Hence, they may be of value to scholars of many specialities who rely in their work on broadly understood cave material.

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