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Radiocarbon ages of bones from Vistulian (Weichselian) cave deposits in Poland and their stratigraphy

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ABSTRACT:

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Twenty-six bone samples from cave sediments mainly of Vistulian (Weichselian) age were radiocarbon (AMS) dated. The material comes from seven localities in the Kraków-Częstochowa Upland and in Podhale (southern Poland). These are: the Komarowa Cave, the Deszczowa Cave, the Upper Rock Shelter of the Deszczowa Cave, the cave in Dziadowa Skała, the Sąspowska Zachodnia Cave, the Mamutowa Cave and the Obłazowa Cave. The obtained radiocarbon ages of most of the samples differs from their stratigraphy as formerly proposed. The reasons for this discrepancy are discussed. Also examined were the radiocarbon ages of bones from other caves in the study area. Most of the dated bones are shown to have come from relatively short time periods. The existing data on radiocarbon age of bones from Vistulian cave deposits of the Kraków-Częstochowa Upland and Podhale are summarized.

Key words: Radiocarbon (C-14) dating of bones; Vistulian (Weichselian); Chronostratigraphy; Cave deposits/sediments; Redeposition.

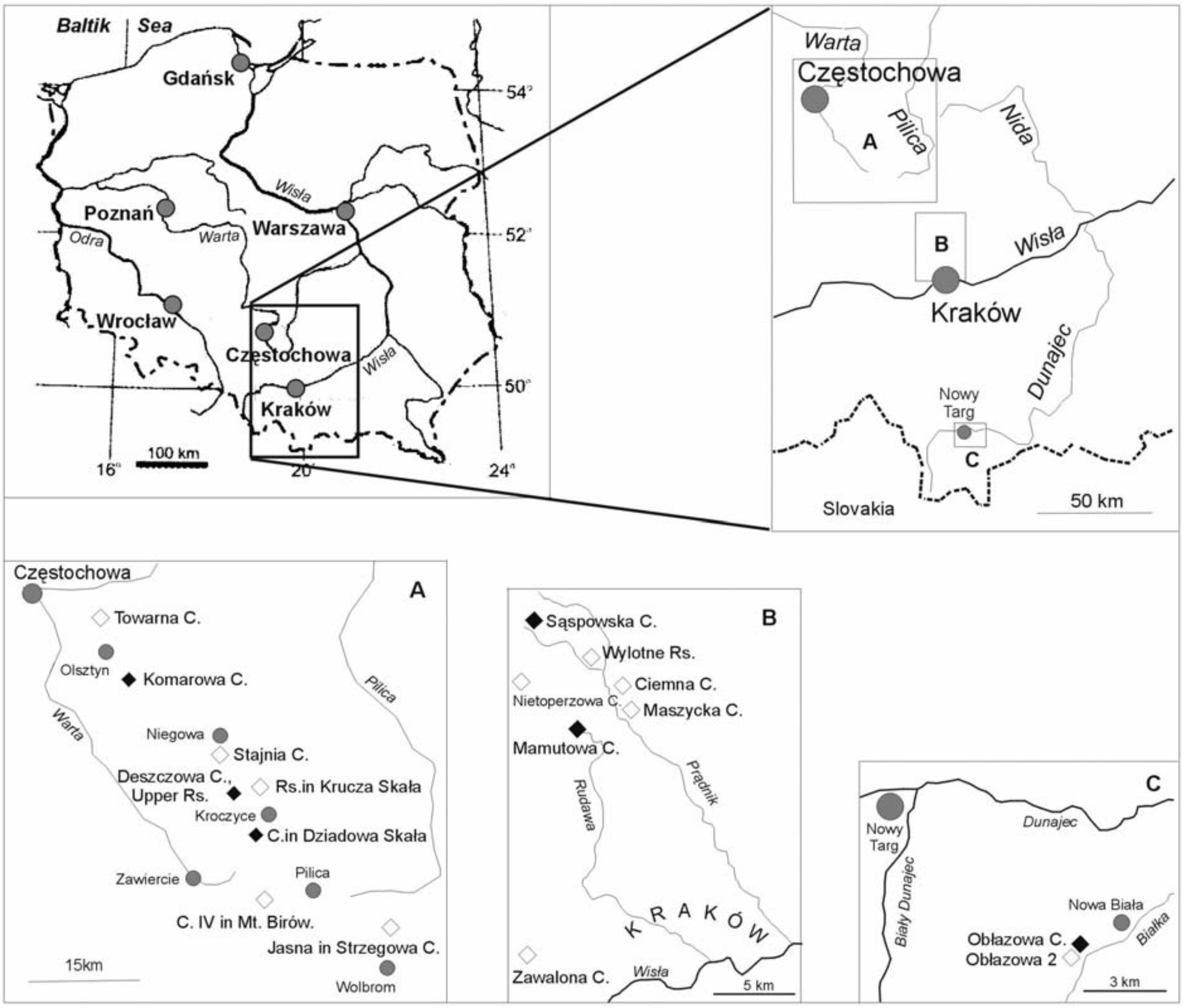
INTRODUCTION

An analysis of the species composition of bone assemblages from the Vistulian cave deposits in Poland has often been used in studies of the evolution of the climate and environment. However, radiometric data on those bones are still incomplete. The stratigraphy of cave deposits, and hence the age of the bones yielded, is usually based on sedimentological and lithostratigraphical premises, supplemented sometimes by biostratigraphic analysis of the bone assemblages themselves. Analysis of the radiocarbon ages of bones from Vistulian cave deposits (Lorenc 2006a) produced surprising results. Out of twenty-six bone samples, collected from five localities in the Kraków-Częstochowa Upland and one in the Podhale region (the Deszczowa Cave, the Upper Rock Shelter of the Deszczowa Cave, the cave in Dziadowa Skała, the Sąspowska Zachodnia Cave, the Mamutowa Cave and the Obłazowa Cave), the radiocarbon ages of the majority (sixteen) did not correspond to the stratigraphic dates of their source deposits. Such discrepancies were recorded at each of the above sites, especially in deposits from the Late Plenivistulian, in which the bones were usually found to be younger (Late Vistulian) and/or older (Middle Plenivistulian), while there were often no bones from the Late Plenivistulian itself. The obtained results revealed great age differences among bones within individual layers. To investigate this further, an additional twenty-six bone samples from the above-mentioned sites, as well as from the Komarowa Cave (Text-fig. 1) were radiocarbon dated for the present study. Half of the dated bone samples came from layers of undoubtedly Late Plenivistulian age (thirteen samples). The remaining samples are from layers dated as Middle Plenivistulian, Late Vistulian and/or Holocene. Together with the dates from the earlier studies (Lorenc 2006a), fifty-three radiocarbon dates from the above-listed localities were obtained (one sample dated twice). In combination with forty-seven radiocarbon dates of other authors, this gave a total of one hundred radiocarbon dates for the localities studied herein. The obtained results allowed a more accurate determination of the extent of the differences in the ages of bones in the deposits analysed. An explanation is put forward to interpret the discrepancies between the radiocarbon ages of the bones and the stratigraphy of their source deposits. The results demonstrate that great caution is necessary when interpreting the palaeoclimate and palaeoenvironment based on bone assemblages from cave deposits.

It is also shown that changes in the climatic and environmental conditions may have affected the amount of bones accumulated in the cave deposits. For this purpose, a summary of literature data on the radiocarbon ages of twenty-eight bone samples from twelve other caves of the Kraków-Częstochowa Upland and Podhale was added (Text-fig. 1), thus providing a total of one hundred and twenty-eight radiocarbon dates for the present study.

MATERIALS AND METHODS

The radiocarbon ages of twenty-six bone samples from the Vistulian deposits of seven caves (the Deszczowa Cave, the Upper Rock Shelter of the Deszczowa Cave, the cave in Dziadowa Skała, the Sąspowska Zachodnia Cave, the Mamutowa Cave, the Komarowa



Text-fig. 1. Location of the caves and rock shelters which yielded the bones dated by the present author (♦) and of the remaining sites for which the radiocarbon ages of bones from Vistulian deposits are known (◇)

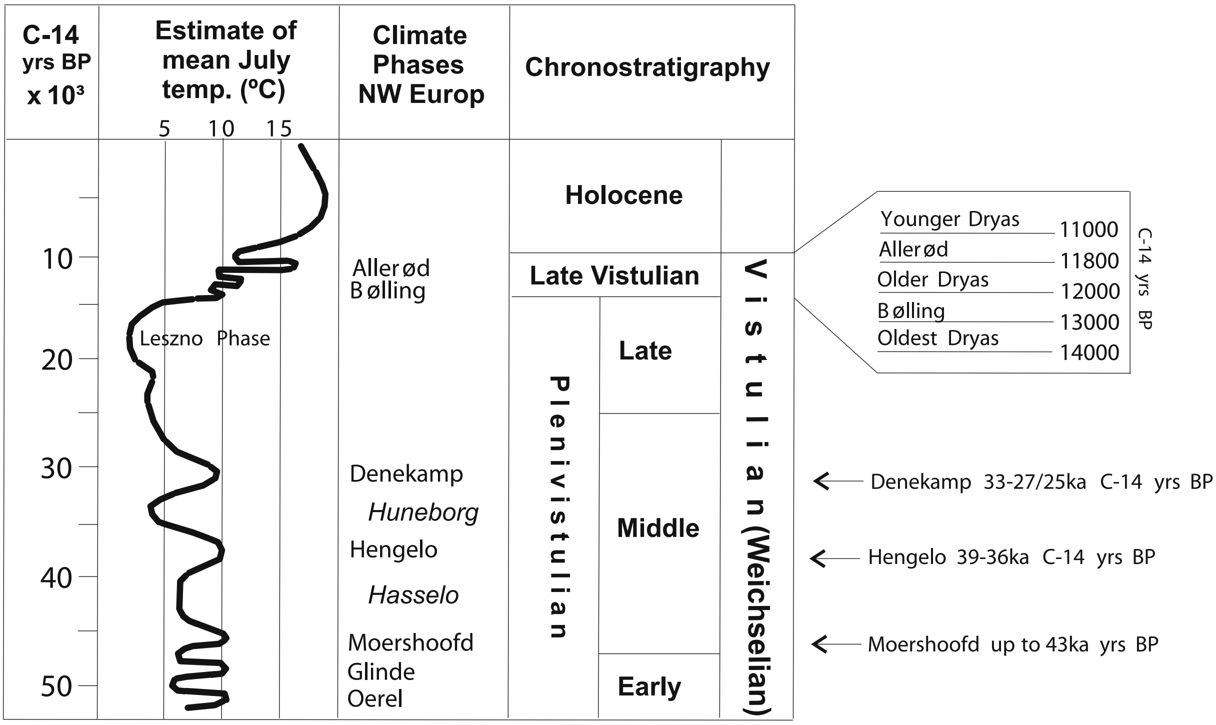


Table 1. Chronostratigraphy with climatic curve of the Vistulian (Weichselian) used in the study (after Kozarski and Nowaczyk 1999). Cold phases (cursive writing) after Run and Huissteden (1990 in: Huijzer and Vandenberghe 1998)

Cave and the Obłazowa Cave) were determined (Text-fig. 1). The bones were identified to species level. Each of the dated samples was a fragment of a single bone; samples consisting of several bones were not dated. The bones studied are primarily those of birds, used by the present author in reconstructions of the Vistulian palaeotemperatures (Lorenc 2007, 2008). In the absence of suitable bird material, bones of mammals were collected[1]. Half of the dated samples (thirteen) come from layers of Late Plenivistulian age; the remaining samples represent layers of the Middle Plenivistulian, Late Vistulian and/or Holocene. The location of the dated remains is usually limited to the number of the layer in the succession, without precise depth or position relative to the cave entrance. This lack of accuracy hampers any inferences relating to the deposition of the bones, particularly the possibility of redeposition.

All of 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 or paper envelopes, usually several per bag/envelope. The dated mammalian bones were kept in polystyrene bags, usually one per bag. All of the bones were kept without the use of any preservatives, glues, varnishes, etc. that might have affected the dating.

The bone samples were dated using the technique of accelerator mass spectrometry (AMS) in the Poznań Radiocarbon Laboratory of the Adam Mickiewicz University Foundation. For each sample a collagen preservation test was performed by measuring its content of nitrogen and carbon. All the results are given in radiocarbon years. This follows from the Vistulian chronostratigraphy employed (based on the time scale expressed in radiocarbon years) and the cited literature where the age of bones, discussed in the present article, is always given in radiocarbon years. This use of radiocarbon years and the Vistulian chronostratigraphy facilitates comparison with earlier published data on the ages of bones from Vistulian sediments.

The chronostratigraphy of the Vistulian is adopted after Kozarski (1980, 1981), and Kozarski and Nowaczyk (1999) (Table 1). The presented stratigraphic diagram is based on palaeobotanical data supported by C-14 dating, as well as on litho- and morphostratigraphic and periglacial data from the Wielkopolska region (western Poland), and follows the most precise subdivision of the Vistulian as currently available for north-western Europe (e.g. Behre 1989; Vandenberghe *et al*. 1998; Guiter *et al*. 2003). Short-term climatic oscillations of the Middle

[1]The shortage of suitable bird bones resulted from their weight being too small to meet the requirements of the dating method employed.

Plenivistulian and Late Vistulian are ranked as phases and interphases.

DESCRIPTION OF THE ANALYSED CAVES, DEPOSITS AND RESULTS OF THE STUDY

Komarowa Cave

Location and earlier study: Częstochowa Upland, Sokole Mountains, northern slope of the Puchacz Hill, near Olsztyn, c. 10 km SE of Częstochowa (Text-fig. 1A), 340 m a.s.l., 20–30 m above a dry valley bottom. It is a small cave, consisting of a single horizontal corridor, c. 20 m long. The entrance faces NE (Nadachowski *et al.* 2009).

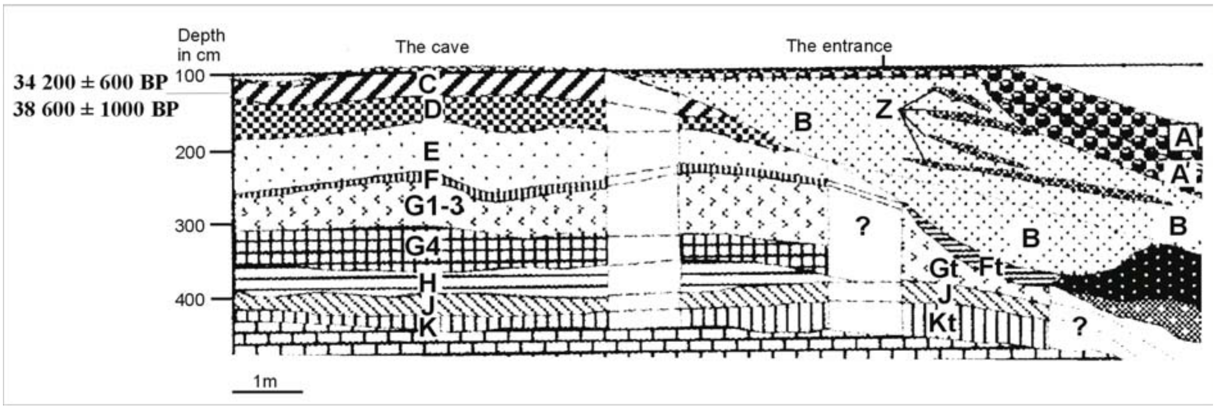
The cave was examined in the years 1997–2002. Preliminary data on its deposits, bones and archaeological material were presented by Gierliński *et al*. (1998). A preliminary study of fossil bats (Chiroptera) was published by Ochman (2003); a detailed description of fossil birds by Tomek and Bocheński (2005); insectivores by Rzebik-Kowalska (2006); and a taphonomic analysis of the megafauna by Wojtal (2007). This interdisciplinary study was summarised in Nadachowski *et al*. (2009).

Stratigraphy: Excavations were made both inside the cave and on the terrace in front of its entrance. Ten layers were distinguished in the succession inside the cave (from K to A). The longitudinal profile of the deposits is shown in Text-fig. 2. The dated bones come from layer C.

Based on lithostratigraphy, Gierliński *et al*. (1998) suggested that layer C represents the early Leszno Phase (30-22 ka BP). This time interval embraces also the latest Middle Plenivistulian (Denekamp). Subsequent studies, including radiocarbon dates, suggest that layer C is of late Middle Plenivistulian or early Late Plenivistulian age. Layers F–D are of Middle Plenivistulian (Grudziądz Interstadial) age. The overlying layer B is of Late Plenivistulian and Late Vistulian age. Layer A is of Holocene age (Nadachowski *et al*. 2009). Based on radiocarbon ages of bones, Tomek and Bocheński (2005) correlate layer C with the early Late Plenivistulian, layer D with the latest Huneborg Phase and the Denekamp Interphase and layer E with the Hengelo Interphase (Table 2).

Radiocarbon ages: Two samples from layer C were dated (Poz-22676, Poz-22677). Also available are: (1) the age of sample Poz-339 from layer C; (2) the ages of bone samples from layers D and E; and (3) the ages of samples from deposits on the terrace in front of the cave (Table 2; Text-fig. 2).

Discussion: The radiocarbon age of sample Poz-22676 from layer C indicates its derivation from the Huneborg Phase. It is c. 10,000 years older than Poz-339, from the same layer, and is closest to the age of sample Gd-15029 from layer D. This suggests the derivation of Poz-22676 from layer D. Both these samples, however, are markedly older (Huneborg) than the three remaining samples from layer D (Denekamp). It is therefore possible that sedimentation of layer D started during the Huneborg Phase. One cannot exclude the presence in layer C of bones coming from layer E. This possibility is suggested by the age of sample Poz-22677 from layer C, which is closest to that of Poz-323 from layer E. Both come from the Hengelo Interphase or the Hasselo Phase. Consequently,



Text-fig. 2. Cross-section of sediments in the Komarowa Cave (Nadachowski *et al*. 2009); the ^{14}C dates from the present study. The succession is as follows (after Nadachowski *et al*. 2009): F – grey-brown loam with limestone rubble (c. 20 cm thick, reduced due to slope processes). E – brown-grey loam with a considerable amount of limestone rubble (ca. 60 cm thick). D – brown-grey loam with occasional limestone rubble (35–45 cm thick). C – pale brown loam with limestone rubble (40–50 cm thick). In a deeper part of the cave the entire surface of the layer is covered by recent humus. The above layers are cut off at the entrance part of the cave and covered by aeolian sand (layer B). B – fine pale yellow sands, rather roughly sorted, laminated in the middle and bottom part (up to 2.5 m thick). Z – loams washed from layers E and D among sands of layer B (from a few to ca. 20 cm thick). A', A – mainly rusty-brown sands with a high content of humus and limestone rubble

Layer	Stratigraphy of the layers (on the basis of literature cited in the text)	C-14 age of the dated samples	Laboratory number of the dated samples	Dated bones	Source of data
Layers inside the cave					
C	Late Middle Plenivistulian / early Late Plenivistulian	24 550 ± 220 BP **34 200 ± 600 BP** **38 600 ± 1000 BP**	Poz-339 Poz-22676 Poz-22677	*Ursus spelaeus* *Tetrao urogallus* *Crocuta crocuta*	Wojtal (2007); Nadachowski *et al.* (2009) **New date** **New date**
D	Middle Plenivistulian (Grudziądz Interstadial / Denekamp)	28 500 ± 500 BP 31 100 ± 400 BP 31 400 BP 35 500 BP	GdA-94 Poz-313 Gd-13097 Gd-15029	*Ursus spelaeus* ? ? *Rangifer tarandus*	Wojtal (2007); Nadachowski *et al.* (2009) Wojtal (2007); Nadachowski *et al.* (2009) Wojtal (2007); Nadachowski *et al.* (2009) Wojtal (2007); Nadachowski *et al.* (2009)
E	Middle Plenivistulian (Grudziądz Interstadial / Hengelo)	39 900 ± 1200 BP	Poz-323	?	Wojtal (2007); Nadachowski *et al.* (2009)
Layers on the terrace in front of the cave					
A, A′	Holocene	41 700 ± 1100 BP [1] 42 200 ± 800 BP 46 100 ± 900 BP	OxA-11161 OxA-11158 OxA-11062	*Crocuta spelaea* *Crocuta spelaea* *Crocuta spelaea*	Wojtal (2007); Nadachowski *et al.* (2009) Wojtal (2007); Nadachowski *et al.* (2009) Wojtal (2007); Nadachowski *et al.* (2009)
B	Late Plenivistulian / Late Vistulian	12 260 ± 60 BP	Poz-6621	*Ursus arctos*	Wojt al (2007); Nadachowski *et al.* (2009)
Z	Middle Plenivistulian	37 500 ± 450 BP 43 900 ± 1000 BP	OxA-11098 OxA-11097	*Megaloceros giganteus* *Megaloceros giganteus*	Wojtal (2007); Nadachowski *et al.* (2009) Wojtal (2007); Nadachowski *et al.* (2009)

[1] Sample no. OxA-11161 comes from layer A′

Table 2. Radiocarbon ages of bones from the sediments of the Komarowa Cave (in each layer according to the age of the samples). The new dates from the present study are given in boldface

only sample Poz-339 can be considered autochthonous to layer C. Its derivation from layers D or B is scarcely possible. Layer D yielded much older samples, and the sedimentation of layer B is correlated with a later period. This indicates that layer C accumulated during the early Late Plenivistulian, and its sedimentation may have even started at the close of the Middle Plenivistulian.

Redeposition of bones from layers D and E to layer C also seems possible in the light of the results of palaeozoological and archaeological studies. The bones of capercaillie (*Tetrao urogallus*), and especially of cave hyena (*Crocuta spelaea*), from the dated samples from layer C, have been found in abundance in layers D and E (Tomek and Bocheński 2005; Wojtal 2007; Nadachowski *et al*. 2009). Moreover, during the sedimentation of layers E to C the Komarowa Cave was regularly inhabited by many large animals, such as cave bears and cave hyenas, as well as by Palaeolithic hunters (Wojtal 2007). These animals could have caused mixing of the deposits of the above layers and redeposition of bones. Redeposition is also supported by a study of the bird bone remains. Tomek and Bocheński (2005) reported that the composition of bird species in layer C is not typical, because of the mixing of arctic species living exclusively in the tundra with those characteristic of the taiga. Moreover, the proportion of forest species among all those found is much higher in layer C than in D and E, which formed under a milder climate than layer C. Hence, some of the bones of the forest species, more thermophilic, found in layer C may have come from layers D and E.

Also known is the age of bones from terrace deposits in front of the cave. Outstanding among those deposits is sample OxA-11097 from layer Z. Layer Z formed as a result of the flow of loam from layers E and D (Nadachowski *et al*. 2009) (Text-fig. 2). The age of this sample indicates its derivation from layer E, because the bones associated with layer D are much younger. This, however, would mean that the sedimentation of layer E (correlated with the Hengelo Interphase) started already in the Moershoofd Interphase. The age of bones from layer A and A' indicates their origin from layer E or even F (age of sample OxA-11062).

Deszczowa Cave

Location and earlier study: Częstochowa Upland, Kroczyce Rocks, northern slope of the Popielowa Hill, c. 10 km NE of Zawiercie (Text-fig. 1A), c. 340 m a.s.l. and 15 m above a dry valley bottom. The cave consists of a corridor splitting into three branches. It is 32 m long and 2 m wide. Its entrance faces NE (Cyrek *et al*. 2000; Nadachowski *et al*. 2009).

Excavations in the Deszczowa Cave were conducted from 1989 to 1997; preliminary results were presented by Cyrek (1996) and the final results by Cyrek *et al*. (2000) and Nadachowski *et al*. (2009). A taphonomic analysis of the megafauna was provided by Wojtal (2007).

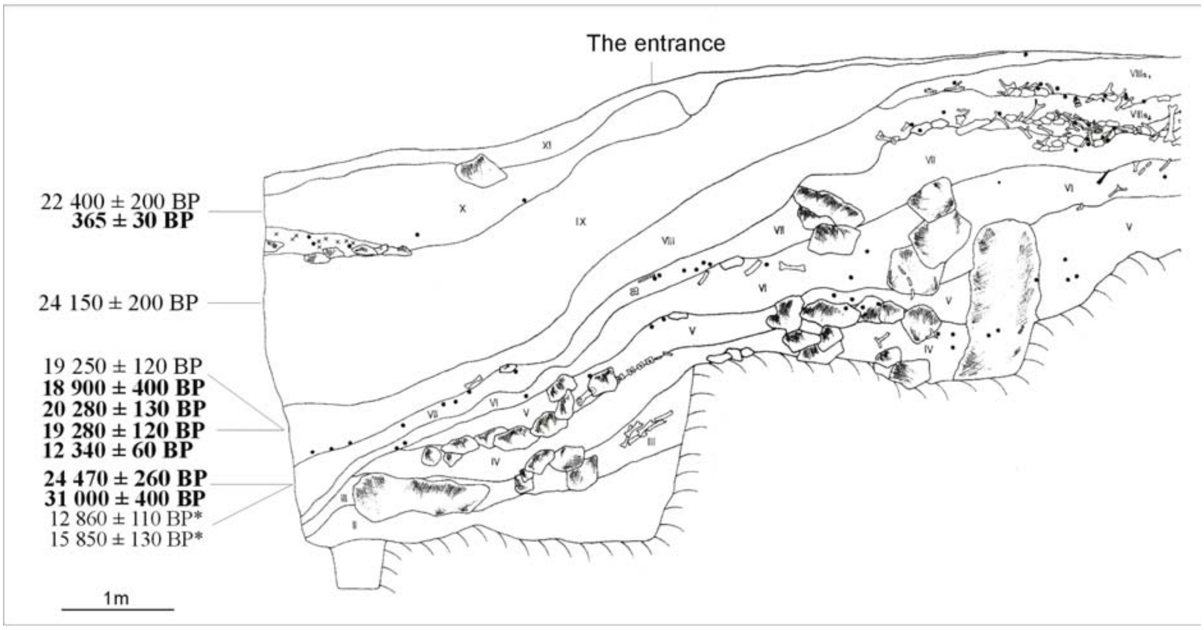
Excavations made both in the cave and at its entrance revealed a c. 4 m thick sediment series, composed of 11 layers (I to XI). Layers with corresponding numbers in the cave and at its entrance are of the same age. The subdivision of the sediment by Cyrek *et al*. (2000) into those inside the cave (marked by the letter "a") and those outside (without the letter "a") is followed herein. The longitudinal profile of the deposits is shown in Text-fig. 3. The dated bones come from layers VIIa, VIIIa, VIII and X.

Stratigraphy: Cyrek *et al*. (2000) suggested that layer VII/VIIa represents the Middle Plenivistulian. Nadachowski *et al*. (2009) indicated the Grudziądz Interstadial and the earliest Late Plenivistulian. Layer VIII/VIIIa is of Late Plenivistulian age, layers IX/IXa and X/Xa are probably of Late Vistulian or Late Vistulian–Holocene age, and layer XI is of Holocene age (Table 3).

Radiocarbon ages: Seven samples, from beds VIIa, VIIIa, VIII and X, were dated (Table 3). Also available are an additional seventeen radiocarbon ages from the same layers, as well from layers IV, V and VI (Table 3; Text-fig. 3).

Discussion: **Layer VII/VIIa:** The radiocarbon ages of the two dated samples differ, although they basically agree with the stratigraphy of the layer. Sample Poz-23772 is from the Middle Plenivistulian (Denekamp) and sample Poz-23437 is from the early Late Plenivistulian / late Middle Plenivistulian. Samples Poz-26126 and Poz-314 from layer VII are of similar ages. Consequently, layer VII/VIIa is dated as Denekamp Interphase through to Late Plenivistulian. The radiocarbon age of 6,080 BP from layer VIIa suggests redeposition from younger deposits. The ages of samples Poz-3750 and Poz-5195 are most probably wrong (Table 3).

Layer VIII/VIIIa: The radiocarbon ages of three dated samples (Poz-22666, Poz-22668 and Poz-22669) and of three other samples (Poz-3751, Poz-25169 and OxA-11060) indicate a Late Plenivistulian (Leszno Phase) age, which is in agreement with the stratigraphy of the layer. There are, however, other bones that are either older (Poz-25075, Poz-28284) or younger than these (Gd-9464, Gd-10212), which means that the sedimen-



Text-fig. 3. Cross-section of sediments at the entrance and in the central part of the Deszczowa Cave (after Cyrek *et al*. 2000); ^{14}C dates after Lorenc (2006a) and the present study (the latter are in boldface). The succession is as follows (after Cyrek *et al*. 2000; Nadachowski *et al*. 2009): VII – fine- and medium-grained, well-sorted sand (c. 30–60 cm thick in the inner part and c. 10 cm outside the cave entrance); scarce limestone blocks and sharp-edged rubble present; lamination clearly visible outside the cave. VIII – pale brown loess, passing into weakly laminated sandy silts inside the cave, where it is clearly differentiated into a darker lower and a paler upper part; the uppermost part loose, with disturbed primary structure, enriched with fine limestone rubble. IX – laminated, fine- and medium-grained yellowish-brown sands (more than 1 m thick in front of the cave and 10 to 50 cm thick within the cave); lamination occurs both in front of and inside the cave (the layer continues up to 5 m into the cave). X – fine- and medium-grained yellowish-brown sand without lamination (c. 20–60 cm thick), limited to the front of the cave. XI – lithologically the same as layers IX–X but with a high content of recent humus; it is the surface layer in front of the cave and c. 3 m within it

tation of layer VIII/VIIIa was not restricted exclusively to the Leszno Phase. Moreover, there are bones which are distinctly younger or older (Poz-25324 and Poz-22667), and are interpreted as redeposited from overlying (most probably layer VII/VIIa) or underlying deposits (layer IXa). Sample Poz-22667 is, so far, the only bone known from the Deszczowa Cave of Late Vistulian age.

Layers IX/IXa and X/Xa: Of the five samples dated, four (Poz-3755, Poz-3757, Poz-25163 and Poz-25170) are of Late Plenivistulian age. Sample Poz-3755 agrees in age with the ages of samples Poz-23437 and Poz-26126 from layer VIIa and Poz-28284 from layer VIIIa, which suggests its derivation from one of these layers. The remaining three samples agree in age with most of the samples from layer VIII/VIIIa (Late Plenivistulian) and are probably from this layer.

The redeposition of bones from underlying layers is usually connected with secondary transport, e.g., by water current, and/or from human activity. In the Deszczowa Cave the bone-rich layer VIII, and especially VIIIa, lie higher than much of layer IX/IXa (Text-fig. 3). In addition, layer IXa is very thin, and it wedges out completely, downlapping onto the top of layer VIIIa. Consequently, during the sedimentation of layer IX/IXa the deposits of layer VIIIa may have been widely exposed. The redeposition could have resulted from water flow over the surface of the deposits, as indicated by the finely laminated sands of layer VIII and of layer IX (Text-fig. 3). Redeposition by the activity of Palaeolithic people and predators is equally possible, their presence in the cave during the sedimentation of layers VII/VIIa to X/Xa being well documented (Cyrek *et al*. 2000; Wojtal 2007; Nadachowski *et al*. 2009). Redeposition is also suggested by the fact that the bone assemblages in layers IX/IXa, X/Xa represent various ecological groups in unnatural proportions. It seems that layer IX/IXa may come from the Bølling Interphase, according to the radiocarbon age of sample Poz-22667, from layer VIIIa.

Layer X also yielded sample Poz-23438, which represents almost contemporaneous material (Text-fig. 3), redeposited probably from layer XI. At the same time, the layer provided no bone of Late Vistulian age with which its sedimentation is correlated.

Upper Rock Shelter of Deszczowa Cave

Location and earlier study: 5 m to NE from the Deszczowa Cave, a few m above it (Text-fig.1A). The rock

Layer	Stratigraphy of the layers (on the basis of literature cited in the text)	C-14 age of the dated samples	Laboratory number of the dated samples	Dated bones	Source of data
X	Late Vistulian / Late Vistulian and Holocene	**365 ± 30 BP** 22 400 ± 200 BP	Poz-23438 Poz-3757	*Capreolus capreolus* Large mammal bone [1]	**New date** Lorenc (2006a)
Xa	Late Vistulian / Late Vistulian and Holocene	19 310 ± 130 BP	Poz-25170	*Saiga tatarica*	Nadachowski *et al.* (2009)
IXa	Late Vistulian / Late Vistulian and Holocene	19 680 ± 140 BP 24 150 ± 200 BP	Poz-25163 Poz-3755	*Gulo gulo* Large mammal bone [1]	Nadachowski *et al.* (2009) Lorenc (2006a)
VIII	Late Plenivistulian	17 480 ± 150 BP **18 900 ± 400 BP** 19 250 ± 120 BP 20 800 ± 150 BP	Gd-10212 Poz-22668 Poz-3751 OxA-11060	*Rangifer tarandus* *Rangifer tarandus* *Lagopus lagopus* *Coelodonta antiquitatis*	Cyrek *et al.* (2000) **New date** Lorenc (2006a) Wojtal (2007); Nadachowski *et al.* (2009)
VIIIa	Late Plenivistulian	**12 340 ± 60 BP** 16 150 ± 280 BP [2] **19 280 ± 120 BP** 19 530 ± 130 BP **20 280 ± 130 BP** 22 530 ± 160 BP 24 580 ± 200 BP 28 600 ± 400 BP	Poz-22667 Gd-9464 Poz-22669 Poz-25169 Poz-22666 Poz-25075 Poz-28284 Poz-25324	*Lagopus lagopus* *Rangifer tarandus* *Rangifer tarandus* *Saiga tatarica* *Vulpes vulpes* *Alopex lagopus* *Ursus spelaeus* *Ursus spelaeus*	**New date** Cyrek *et al.* (2000) **New date** Nadachowski *et al.* (2009) **New date** Nadachowski *et al.* (2009) Nadachowski *et al.* (2009) Nadachowski *et al.* (2009)
VII	Middle Plenivistulian / Grudziądz Interstadial - beginning of the Late Plenivistulian	26 200 ± 300 BP	Poz-314	?	Wojtal (2007); Nadachowski *et al.* (2009)
VIIa	Middle Plenivistulian / Grudziądz Interstadial - beginning of the Late Plenivistulian	6080 BP 12 860 ± 110 BP [4] 15 850 ± 130 BP [4] **24 470 ± 260 BP** 24 620 ± 200 BP **31 000 ± 400 BP**	- [3] Poz-3750 Poz-5195 Poz-23437 Poz-26126 Poz-23772	*Felis silvestris* *Tetrao urogallus* *Tetrao tetrix* *Vulpes vulpes* *Alopex lagopus* *Coelodonta antiquitatis*	Nadachowski, Wojtal (written information) Lorenc (2006a) Lorenc (2006a) **New date** Nadachowski *et al.* (2009) **New date**
VI	Middle Plenivistulian (Grudziądz Interstadial)	43 000 BP 44 000 ± 2000 BP	Poz-330 Poz-373	? ?	Wojtal (2007); Nadachowski *et al.* (2009) Wojtal (2007); Nadachowski *et al.* (2009)
V	Early or the beginning of Lower Plenivistulian	11 840 ± 55 BP 12 050 ± 60 BP [5]	Poz-317 Poz-371	?	Nadachowski *et al.* (2009) Wojtal (2007); Nadachowski *et al.* (2009)
IV	Early Vistulian or pre-Vistulian	42 800 ± 1900 BP [6]	Poz-3749	*Tetrao tetrix* + goose sp.	Lorenc (2006a)

Layer	Stratigraphy of the layers (on the basis of literature cited in the text)	C-14 age of the dated samples	Laboratory number of the dated samples	Dated bones	Source of data
IX/X	Late Vistulian / Late Vistulian and Holocene	> 46 000 BP	Poz-3756	*Lagopus lagopus/mutus*	Lorenc (2006a)
IX	Late Vistulian / Late Vistulian and Holocene	44 700 ± 2400 BP	Poz-3753	*Lagopus lagopus/mutus*	Lorenc (2006a)
VIII	Late Plenivistulian	**28 200 ± 300 BP** 30 100 ± 400 BP	Poz-22665 Poz-3752	*Rangifer tarandus* *Corvus monedula*	**New date** Lorenc (2006a)
VII	Middle Plenivistulian	32 500 ± 700 BP	Poz-24205	*Mammuthus primigenius*	Nadachowski *et al* (2011)

Table 4. Radiocarbon ages of bones from the sediments of the Upper Rock Shelter of the Deszczowa Cave. The new date from the present study is given in boldface

shelter has developed along a fissure and is 10 m long. Excavations of sediments in the shelter and in the Deszczowa Cave were performed at the same time (Cyrek *et al*. 2000). 11 layers were distinguished (from I to XI). Technical difficulties (a very narrow cutting) made it impossible to prepare the cross-section (Cyrek, written information). The dated bones come from layers VIII, IX and IX/X.

Stratigraphy: The layer numbers in the shelter correspond to those in the cave and, based on purely lithostratigraphic correlation, are regarded as of the same age (Cyrek *et al*. 2000). Consequently, layer VIII is regarded as of Late Plenivistulian age, and layers IX and X of Late Vistulian, or Late Vistulian–Holocene age (Cyrek *et al*. 2000; Cyrek, written information) (Table 4).

Radiocarbon ages: A single sample was dated (Poz-22665 from layer VIII). Also available are single ages from layer VII, VIII, IX and IX/X (Table 4).

Discussion: **Layer VIII:** Both radiocarbon ages from this layer are similar and indicate the Middle Plenivistulian (Denekamp). This does not match the age of layer VIII, based on lithostratigraphic correlation. The dated bones are most probably redeposited from layer VII, as is also indicated by the age of sample Poz-24205 from the latter layer. The age relationships resemble the situation in layer VIIIa of the Deszczowa Cave, where bones of Denekamp age were also found, redeposited from the underlying layer (Table 3).

Layers IX and IX/X: The radiocarbon ages of samples Poz-3753 from layer IX and Poz-3756 from layer IX/X are much older than those from the underlying layer VIII, and even VII. Moreover, the sample from layer IX/X is older than that from the underlying layer IX. They are certainly redeposited, probably from layer VI. These are the oldest samples studied herein.

Table 3. Radiocarbon ages of bones from the sediments of Deszczowa Cave (in each layer according to the age of the samples). The new dates from the present study are given in boldface

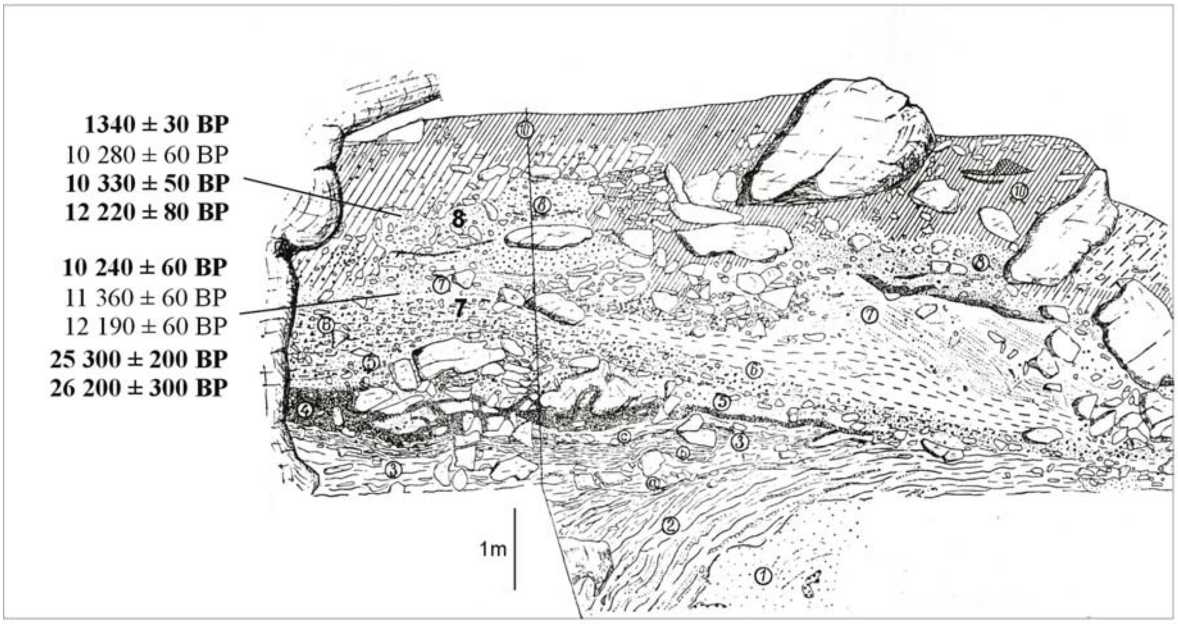
[1] Sample no. Poz-3755 was identified as a fragment of the shaft of a long bone of a deer/reindeer/bear. Sample no. Poz-3757 was identified as a fragment of the shaft of a long bone of a large ungulate, an aurochs/horse (Wojtal, written information).

[2] It is not entirely certain whether the bone belongs to the layer VIIIa. The bone comes from the cave front, from the layer which slid down the slope (Cyrek *et al.* 2000).

[3] As mentioned earlier, in the case of the previously unpublished dates now made available to the author, no laboratory sample number or measuring error are given.

[4] 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. It undermines the reliability of the ages obtained (GOSLAR, written information).

[5] Repeated date from the sample no. Poz-317. The obtained date is questionable due to the very small amount of extracted collagen (Goslar, written information).From the dated bones a small amount of collagen was extracted (<5 mg of collagen per 1g of bones), which may undermine the reliability of the age obtained (Goslar, written information).



Text-fig. 4. Cross-section of sediments in the inner part of the Dziadowa Skała Cave (after Chmielewski 1958); ^{14}C dates after Lorenc (2006a) and the present study (the latter are in boldface). The succession is composed of (after Dylik *et al*. 1954 and Chmielewski 1958): 6 – laminated loess. 7 – white-yellow quartz sand, not segregated, structureless in the deepest part of the cave, and fine-grained, laminated and washed with layers of loess in its middle part and at the entrance; limestone rubble of different sizes is present as well as rock blocks, small fissures and faults. 8 – non-segregated sand with no lamination. Limestone, sharp-edged rubble of different sizes is present. 9 – subsoil. 10 – soil

As in the Deszczowa Cave, it seems that the redeposition of bones may have been due to the activity of Palaeolithic people, whose presence in layers VII/VIIa to X/Xa of the Deszczowa Cave, is well documented (Cyrek *et al*. 2000; Wojtal 2007; Nadachowski *et al*. 2009). The bones coming from stratigraphically equivalent layers of the Deszczowa Cave and of the rock shelter, represent different time spans.

Dziadowa Skała Cave

Location and earlier study: Small cave, 9 m long and 2–3 m wide; Chmielewski (1958), on the Częstochowa Upland, Podlesickie Rocks, near Skarżyce village, NE of Zawiercie (Text-fig. 1A), c. 365 m a.s.l.

The studies in the Dziadowa Skała Cave were conducted in 1952-1954. Descriptions of the succession

Layer	Stratigraphy of the layers (on the basis of literature cited in the text)	C-14 age of the dated samples	Laboratory number of the dated samples	Dated bones	Source of data
8	Late Plenivistulian / Late Vistulian	**1340 ± 30 BP** 10 280 ± 60 BP **10 330 ± 50 BP** 11 780 BP **12 220 ± 80 BP**	Poz-22673 Poz-3745 Poz-35251 - Poz-22671	*Strix aluco* *Tetrao urogallus* *Tetrao urogallus* *Ursus arctos* *Tetrao urogallus*	**New date** Lorenc (2006a) **New date** Nadachowski, Wojtal (written information) **New date**
7	Late Plenivistulian	**10 240 ± 60 BP** 11 360 ± 60 BP 12 190 ± 60 BP **25 300 ± 200 BP** **26 200 ± 300 BP**	Poz-22672 Poz-1149 Poz-3743 Poz-23894 Poz-22675	*Corvus monedula* *Tetrao urogallus* *L. lagopus/mutus* *Equus sp.* *Rangifer tarandus*	**New date** Lorenc (2006a) Lorenc (2006a) **New date** **New date**

Table 5. Radiocarbon ages of bones from the sediments of the Dziadowa Skała Cave (in each layer according to the age of the samples). The new dates from the present study are given in boldface

and of the archaeological finds were given by Dylik *et al*. (1954), Chmielewski (1958) and Madeyska (1981). The small mammals were described by Kowalski (1958). Bocheński Jr. (1990) gave a summary on the bird bones and Wojtal (2007) a taphonomic analysis of the megafauna.

Excavations were made in the cave interior, at the entrance, and in front of the entrance. Eleven layers were distinguished in the succession (from 1 to 11). The cross-section of the sediments in the inner part of the Dziadowa Skała Cave is shown in Text-fig. 4. The dated bones come from layers 7 and 8.

Stratigraphy: Layer 7 represents the Late Plenivistulian and layer 8 the Late Plenivistulian–Late Vistulian (Madeyska 1981; Bocheński Jr. 1990); layer 6 is of Middle Plenivistulian age and layers 9–11 are of Holocene age (Table 5).

Radiocarbon ages: Six samples were dated: three from layer 7 and three from layer 8. Also known are the ages of two other samples from each of the above layers (Table 5; Text-fig. 4).

Discussion: **Layer 7:** The radiocarbon ages of sample Poz-22672 dated herein and of the two samples dated earlier (Poz-1149 and Poz-3743) show them to come from the Late Vistulian and possibly from the earliest Holocene (Poz-22672). The two other samples (Poz-22675, Poz-23894) come from the late Middle Plenivistulian. It is noteworthy that the dated bones of birds are of Late Vistulian age, and those of mammals are of Middle Plenivistulian age. The radiocarbon ages of all of the samples do not accord with the chronostratigraphy of the layer; none of the bones dated is of Late Plenivistulian age. This suggests that they are all redeposited. The Middle Plenivistulian mammalian bones may come from the underlying layer 6, correlated with that period (Madeyska 1981), while the Late Vistulian bird bones probably originate from layer 8. The redeposition could have been due to the activity of Palaeolithic hunters or predators, whose presence in the cave during that time is well documented (Wojtal 2007). Chmielewski (1958) mentioned that "the top of layer 6 has been sheared by flowing water, which is marked by lack of conformity and the occurrence of fine limestone rubble in the bottom of the overlying layer". This information would be significant if the dated bones came from the bottom of layer 7; one might then infer that those are bones washed out from layer 6 by the flowing water and accumulated on its surface among the limestone rubble treated as the bottom of layer 7. However, there is no exact information about the location of the dated bones of layer 7.

Layer 8: With the exception of sample Poz-22673, all the other samples come from a variety of Late Vistulian climatic phases. The radiocarbon ages of those samples correspond to the chronostratigraphy of the layer in question.

With the exception of a sample with a radiocarbon age of 11,780 BP, all are bird bones and come exclusively from periods of relatively mild climatic conditions; Bølling (Poz-22671, Poz-1149), Allerød (the sample with a radiocarbon age of c. 11,780 BP, Poz-3743) and the close of the Youngest Dryas/start of the Holocene (Poz-35251, Poz-3745, Poz-22672).

Sample Poz-22673 proves that there are also much younger bones in layer 8, redeposited from the overlying Holocene deposits.

Sąspowska Zachodnia Cave

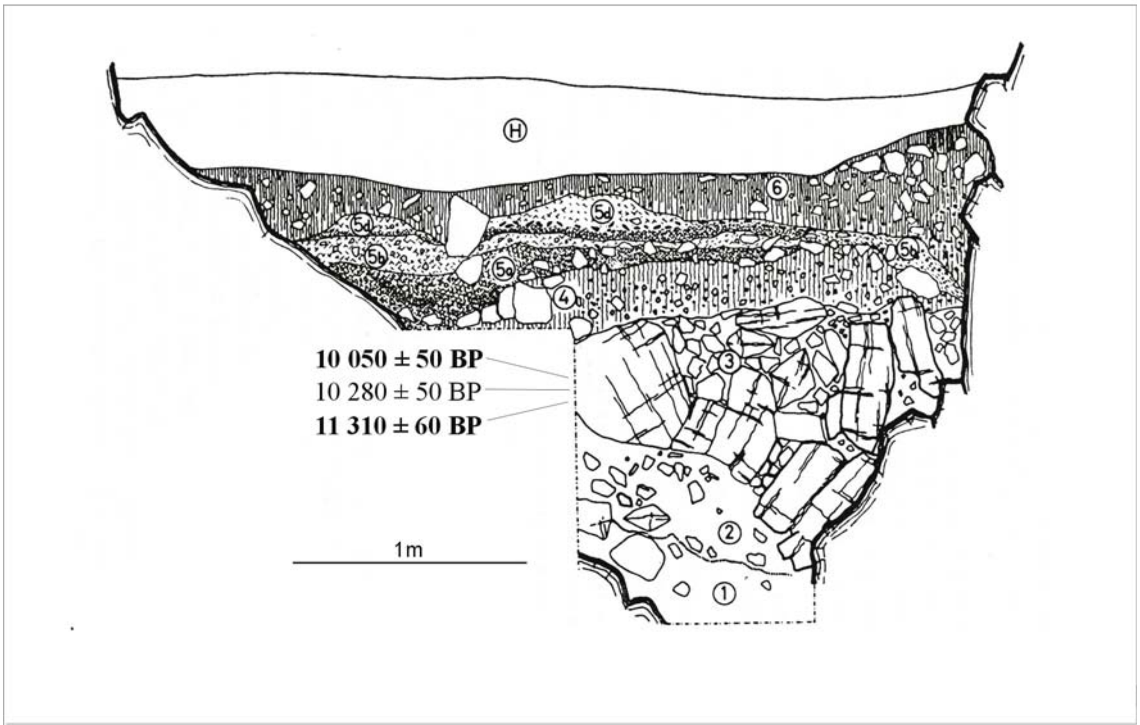
Location and earlier study: Cracow Upland, Sąspów village in the Sąspowska Valley (Text-fig. 1B), 430 m a.s.l., and 19 m above the valley bottom. The cave is 16 m long and 4 m to 1.5 m wide. It ends in two chambers, 4 x 4 m and 6 x 6 m respectively. The entrance faces south (Madeyska 1981, 1988).

Excavations in the cave were conducted already in the 19th century and then in the 1970s. Preliminary results were published by Madeyska (1981), and more detailed results by Chmielewski (1988). Six layers were distinguished in the succession. The succession at the entrance is shown in Text-fig. 5. The dated bones come from layer 3.

Stratigraphy: Layers 1–3 are of Vistulian age, determined by analogy with the deposits of neighbouring caves. Layer 3 is correlated with the latest Plenivistulian or Late Vistulian. It resulted from the weathering of rocks of the cave ceiling under a cold or even arctic climate. The overlying deposits (layers 4–6) are of Holocene age (Madeyska 1981, 1988) (Table 6).

Radiocarbon ages: Two samples from layer 3 were dated, one other sample is available (Table 6; Text-fig. 5).

Discussion: The bones from layer 3 are younger than the layer itself, and vary in age. This is indicated not only by the radiocarbon age of the dated samples but also by the ecological characteristics of the fauna from layer 3, especially the predominance of forest and eurytopic species and the scarcity of tundra species, clearly visible among the birds (Bocheński 1988) and mammals (Madeyska 1981, 1988; Nadachowski 1988). Penetration of bones into layer 3 was facilitated by its porous structure, due to the



Text-fig. 5. Sediment succession at the entrance of the Sąspowska Zachodnia Cave (after Madeyska 1988); ^{14}C dates after (Lorenc 2006a) and the present study (the latter are in boldface). The succession is composed of (after Madeyska 1981, 1988): 1 – dusty clay without bones. 2 – dusty clay with limestone rubble, redeposited, sporadic bones coming from both warm and cold periods. 3 – limestone blocks and sharp-edged rubble coming from the cave ceiling (thickness up to 1 metre). Binding material almost absent from the entrance area (limestone material is loose). Bones and artefacts present, mainly between limestone blocks. 4 – limestone rubble bound with dusty clay. 5 – cultural layer (density of hachure indicates the intensity of its black tinge). 6 – humus. H – spoil heap from old diggings

Layer	**Stratigraphy of the layers** (on the basis of literature cited in the text)	**C-14 age of the dated samples**	**Laboratory number of the dated samples**	**Dated bones**	**Source of data**
3	Plenivistulian / Late Vistulian	**10 050 ± 50 BP** 10 280 ± 50 BP **11310 ± 60 BP**	Poz-35216 Poz-1167 Poz-35217	*Buteo buteo* Bird bone *Tetrao tetrix*	**New date** Lorenc (2006a) **New date**

Table 6. Radiocarbon ages of bones from the sediments of Sąspowska Zachodnia Cave (according to the age of the samples). The new dates from the present study are given in boldface

presence of rock blocks and sharp-edged rock fragments (Text-fig. 5).

The oldest of the radiocarbon dated samples (Poz-35217) comes from the Allerød period of the Late Vistulian. The two remaining samples are younger, representing the latest Late Vistulian (Poz-1167) and the earliest Holocene (Poz-35216). Because the layer developed under the conditions of a cold or even arctic climate (Madeyska 1981, 1988), it can be assumed that this took place before the Alleröd, probably in the Oldest Dryas or Late Plenivistulian. The occurrence of bones pre-dating the Allerød is therefore almost certain, and the radiocarbon dating of further samples is likely to confirm this. It is also suggested by the above-mentioned presence of bones of tundra species.

Mamutowa Cave

Location and earlier study: Kraków Upland, Kluczwoda valley, the village of Wierzchowie (Text-fig. 1C), 370 m a.s.l., c. 20 m above the valley bottom. The entrance opens to the SW. The cave has the form of a chamber 8 m wide and 12 m high, with two corridors (Madeyska 1981; Wojtal 2007).

Excavations in the cave were conducted already in the years 1873–1881. As a result, the Mamutowa Cave became the first Polish Palaeolithic site, and the one recognised in the European literature. The next investigation took place in 1913. Interdisciplinary research was carried out, with breaks, in the years 1957–1974 (e.g. Kowalski 2006). Descriptions of the deposits, together with the results of archaeological studies were presented by Kowalski (1967, 1969), Kozłowski and Kozłowski (1977), Nadachowski (1976) and Madeyska (1981, 1992). The bird bone remains were studied by Bocheński (1974, 1981), (see summary in Lorenc 2007). Mustelid remains were studied by Wójcik (1974), amphibian and mammal remains by Nadachowski (1976), palaeoenvironmental interpretation of the faunal assemblages by Madeyska (1981), and a taphonomic analysis of the megafauna by Wojtal (2007).

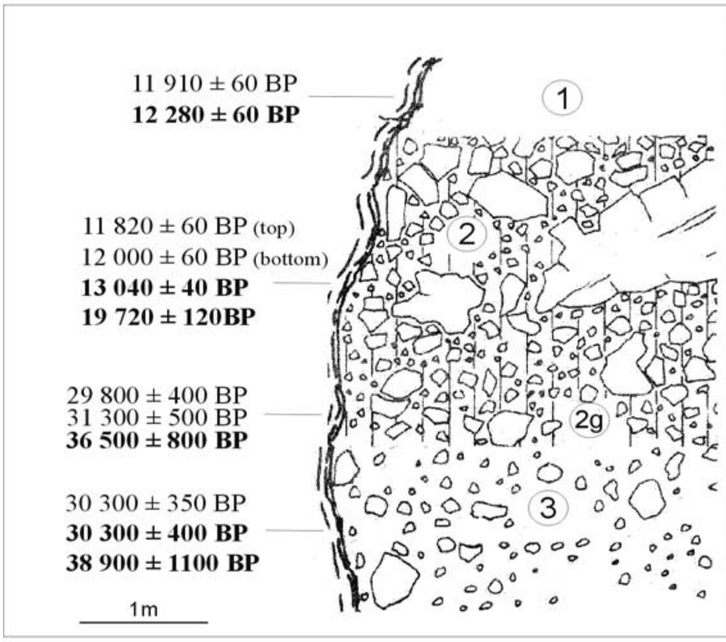
Excavations were made both in the cave interior and at its entrance. Ten layers were distinguished in the interior succession (layers I–X) and seven layers at its entrance (layers 7–1). It was not possible to correlate deposits from both parts of the cave. The section of sediments at the entrance to the cave is shown in Text-fig. 6). The dated bones come from layers 1 to 3.

Stratigraphy: Layer 3 is of Middle Plenivistulian age (Madeyska 1981, 1992), from the Denekamp Interphase (Bocheński 1974, 1981; Nadachowski 1976). Layers 2 and 2g are of Late Plenivistulian age. Layer 2g (of Kowalski 1967), at the base of the thick loess layer 2, was distinguished by its admixture of fine limestone rubble. Madeyska (1981, 1992) interprets both layers as of Late Plenivistulian age. Bocheński (1974, 1981) correlated layer 2g with the Leszno Phase of the Vistulian Glaciation and layer 2 with the younger phase of the Late Plenivistulian. According to Nadachowski (1976), both layers are from the Leszno Phase.

Layer 1 is of Holocene age. It yielded numerous Neolithic to modern archaeological artefacts (Kowalski 1967) (Table 7).

Radiocarbon ages:Six samples were dated from layers 1–3; the radiocarbon ages of ten additional samples from these layers are also available. The radiocarbon ages of eight bones from the deposits in the cave interior are also known (Table 7, Text-fig. 6).

Discussion: **Layer 3:** The radiocarbon ages of two samples (Poz-1153, Poz-22679) are identical and date them to the Denekamp Interphase, which corresponds to the chronostratigraphic dating by Bocheński (1974, 1981) and Nadachowski (1976). The third sample (Poz-22682)



Text-fig. 6. Simplified fragment of the sediment succession in the front part of the Mamutowa Cave; ^{14}C dates after Lorenc (2006a) and the present study (the latter are in boldface). The succession is composed of (after Kowalski 1967; Nadachowski 1976; and Madeyska 1981, 1992): 3 – greyish-brown, dusty loess-like clay with an admixture of rounded limestone rubble. The layer passes gradually into layer 2. 2g – loess with a high content of sharp-edged limestone rubble and limestone sand (up to 40 cm thick). 2 – loess with angular limestone rubble and big limestone blocks (up to 250 cm thick). The entire layer bears signs of downslope redeposition by water, saved as small layers of fine limestone gravel and washed loess. The top of the layer (up to 40–50 cm) contains less binding material and traces of soil-forming processes resulting from contact with layer 1. 1 – Holocene humus (10-15 cm thick), subdivided into an older part, only partially preserved, and a younger, Recent one

Layer	Stratigraphy of the layers (on the basis of literature cited in the text)	C-14 age of the dated samples	Laboratory number of the dated samples	Dated bones	Source of data
Layers in the entrance of the cave					
1	Holocene	11 910 ± 60 BP **12 280 ± 60 BP**	Poz-1150 Poz-22683	Bird bone *Lagopus lagopus*	Lorenc (2006a) **New date**
2	Late Plenivistulian	11 820 ± 60 BP [1] 12 000 ± 60 BP [1] **13 040 ± 40 BP** 19 530 BP **19 720 ± 120 BP** 20 650 ± 100 BP 35 460 ± 260 BP	Poz-1152 Poz-1151 Poz-22685 - Poz-22680 OxA-14409 OxA-14410	Bird bone Bird bone *Rangifer tarandus* *Saiga tatarica* *Ursus* cf. *arctos* *Rangifer tarandus* *Bos/Bison*	Lorenc (2006a) Lorenc (2006a) **New date** Nadachowski, Wojtal (written information) **New date** Wojtal (2007) Wojtal (2007)
2g	Late Plenivistulian	26 010 ± 150 BP 29 800 ± 400 BP 31 300 ± 500 BP **36 500 ± 800 BP**	OxA-14406 Poz-3746 Poz-3747 Poz-22681	*Ursus spelaeus* *Lagopus* sp. *Tetrao tetrix* *Ursus* cf. *arctos*	Wojtal (2007) Lorenc (2006a) Lorenc (2006a) **New date**
3	Middle Plenivistulian	30 300 ± 350 BP **30 300 ± 400 BP** **38 900 ± 1100 BP**	Poz-1153 Poz-22679 Poz-22682	Bird bone *Tetrao tetrix* *Ursus spelaeus*	Lorenc (2006a) **New date** **New date**
Layers in the mid and rear parts of the cave					
IX	Late Plenivistulian	37 550 ± 450 BP 38 500 BP	OxA-14408 OxA-14475	*Rangifer tarandus* *Ursus spelaeus*	Wojtal (2007) Wojtal (2007)
VIII	Upper/Middle Plenivistulian [2]	38 250 ± 550 BP 46 400 ± 1200 BP	OxA-14404 OxA-14405	*Rangifer tarandus* *Rangifer tarandus*	Wojtal (2007) Wojtal (2007)
VII	Late/Middle Plenivistulian [2]	40 700 ± 800 BP	OxA-14407	*Ursus spelaeus*	Wojtal (2007)
VI	Middle Plenivistulian	42 400 BP	OxA-14474	*Ursus spelaeus*	Wojtal (2007)
?	Sediments without stratigraphy	32 280 ± 220 BP 33 640 ± 250 BP	OxA-14434 OxA-14436	Ivory Mladeč blades	Wojtal (2007)

[1] Sample no. Poz-1152 comes from the top, and Poz-1151 from the bottom of the layer
[2] Layer VII and VIII come from the Late Plenivistulian (Nadachowski 1976) or from the Middle Plenivistulian (Madeyska 1992)

Table 7. Radiocarbon ages of bones from the sediments of Mamutowa Cave (in each layer according to the age of the samples). The new dates from the present study are given in boldface

reveals the presence of older bones, of middle Middle Plenivistulian (Hengelo?) age.

Layer 2g: Three samples (Poz-3746, Poz-3747 and OxA-14406) are of Denekamp Interphase age; the fourth (Poz-22681) is of middle Middle Plenivistulian (Huneborg?) age. The radiocarbon ages of all of the samples do not agree with the chronostratigraphy of layer 2g and indicate redeposition of bones from the underlying deposits.

Layer 2: The three youngest samples (Poz-1152, Poz-1151, Poz-22685) are of Late Vistulian age, from the latest Oldest Dryas/beginning of the Bølling (Poz-22685) and the close of the Older Dryas/start of the Allerød (Poz-1152), respectively. The other three samples (Poz-22680, OxA-14409 and one aged 19,530 BP) are of Late Plenivistulian age, the Leszno Phase. The oldest sample (OxA-14410) is of middle Middle Plenivistulian (Huneborg?) age. It is noteworthy that sample Poz-22681 from layer 2g has a similar age. Only the Late Plenivistulian-age samples correspond to the chronostratigraphic position of layer 2.

Layer 1: The two dated samples are of Late Vistulian age: Bølling (Poz-22683), and Older Dryas (Poz-1150). This does not agree with the chronostratigraphy of layer 1 and suggests redeposition of bones from the underlying sediments.

The Mamutowa Cave has a relatively high number of radiocarbon dates available. Their most important characteristics are:

– the presence of Late Vistulian bones in layers 2 and 1, with four samples (Poz-1150, Poz-1151, Poz-1152, Poz-22683) representing a very short, <500 years, time interval, and
– the presence in layer 2g of bones exclusively of Middle Plenivistulian age; their age is similar to that of the bones from layer 3 (especially samples Poz-3746, Poz-3747 and Poz-1153, Poz- 22679).

The presence of Late Vistulian bones in layers 2 and 1 is very important as no Late Vistulian-age layer was distinguished in the Mamutowa Cave (see discussion in Lorenc 2006a, 2007). Two explanations are proposed:

(a) (see also Lorenc 2006a) The bones are a residuum of a once-existing sediment, formed during the Late Vistulian [at least from the latest Oldest Dryas/begining of the Bølling (Poz-22685) until the latest Older Dryas/begining of the Allerød (Poz-1152)] at the top of the existing layer 2; the bones were then transported into the cave bottom, facilitated by the porous structure of layer 2 (due to the presence of large, sharp-edged rock fragments coming from rockfalls from the cave ceiling) (Text-fig. 6). In this scenario, the Late Vistulian bones found in layer 2 should be considered allochthonous.

(b) The sedimentation of the top of layer 2 extended into the Late Vistulian, at least until the close of the Older Dryas/begining of the Allerød (the age of sample Poz-1152). The physical weathering of the cave walls and ceiling, especially in the Oldest and Older Dryas (the age of most of the samples can be correlated with those climatic phases) led to a further accumulation of limestone rubble on the cave bottom (as in the Late Plenivistulian). That the sedimentation of the top part of layer 2 continued into the Late Vistulian is also shown indirectly by the bipartite structure of this layer: there is less binding material in its top part, while it bears traces of soil-forming processes (to a depth of 40–50 cm) (Nadachowski 1976) (Text-fig. 6). Moreover, the top of layer 2 clearly differs in faunistic terms from the remaining part: the proportion of tundra species declines while that of forest ones increases. Nadachowski (1976) therefore suggested that during the sedimentation of the top of layer 2 the climate was somewhat warmer and more humid than during the sedimentation of the rest of the layer. The sedimentation of the top part of layer 2 proposed by the present author as Late Vistulian does not agree with the stratigraphy of the layer, but in the light of the above data seems justified. In this scenario, the Late Vistulian bones occurring in layer 2 should be considered autochthonous, like those from the Late Plenivistulian.

However, Late Vistulian bones were found not only in the top of layer 2 (Poz-1152), but also in its bottom (Poz-1151), and this is a layer of considerable thickness (Table 7; Text-fig. 6). The process responsible for such a deep penetration of Late Vistulian bones into layer 2 is probably downslope flow of this layer (Text-fig. 6). The flow of layer 2 could also cause the penetration into it (mostly to its bottom – layer 2g) of the Middle Plenivistulian bones from layer 3 and the blurring of the boundary between those layers (between layers 2g and 3) (Text-fig. 6).

The presence of Late Vistulian bones in layer 1 can be explained by human activity in the cave, including former excavations. The considerable mixing of the upper part of the cave deposits as a result of earlier investigations has been pointed out by Kowalski (1967, 2006) and Nadachowski (1976).

The radiocarbon age of bones from layer IX from inside the cave is also worth noting. The formation of this layer is correlated with the Late Plenivistulian, as is that of layer 2g. However, in neither layer were bones from the Late Plenivistulian found, but only bones from the Middle Plenivistulian. Here, too, bones of this age may have come from the underlying deposits, mostly layer VIII, as indicated by the age of the sample OxA-14404. The age of the second sample from layer VIII (OxA-14405) suggests its redeposition from older deposits.

Obłazowa Cave

Location and earlier study: Podhale, the Białka River valley near the village of Nowa Biała (Text-fig. 1C). The cave is situated in the SW part of the Obłazowa Rock, 670 m a.s.l., c. 7 m above the Białka River level. The cave had the form of a chamber, 9 m long, 5 m wide and 3 m high before the excavations (Valde-Nowak *et al*. 1995, 2003).

Interdisciplinary studies of the cave were conducted in the years 1985–1992, and then in 1995 (e.g. Valde-Nowak *et al*. 1987, 1995; Valde-Nowak 1991; Madeyska 1991; Wołoszyn 1995; Tomek, Bocheński 1995; Madeyska *et al*. 2002; Valde-Nowak *et al*. 2003).

Excavations were made in the cave interior, at its entrance, and in front of the entrance. Twenty-one layers (series A to F) were distinguished. Each series consists of one or more layers that accumulated under similar climatic conditions (Madeyska *et al.* 2002; Madeyska 2003). A cross-section is shown in Text-fig. 7. The dated bones come from series E (layer VII) and F (layers VI–I).

Stratigraphy: Series E (layer VII) represents the Late Plenivistulian. The underlying series D (layers XI–VIII) is of Middle Plenivistulian age, and the overlying series F (layers VI–I) is of Late Vistulian–Holocene age (Madeyska *et al*. 2002; Madeyska 2003). Layers VI and V were also correlated with the Late Plenivistulian (Madeyska 1991; Wołoszyn 1995; Tomek and Bocheński 1995) (Table 8).

Radiocarbon ages: Two samples (Poz-22686, Poz-22687) from layer VII were dated herein; also available are ages of two other samples from layer VII, and a number of ages from layers XI, VIII, V, IV, and II (Table 8; Text-fig. 7).

Discussion: **Layers XI–VIII (series D):** The sample from layer XI is of Hengelo Interphase age, and samples from layer VIII are of Denekamp Interphase age. An exception is sample OxA-3694, evidently redeposited from younger sediments. The sedimentation of series D lasted thus from the Hengelo Interphase through to the Denekamp Interphase. These new data add precision to previously published data on the stratigraphy of this series of deposits.

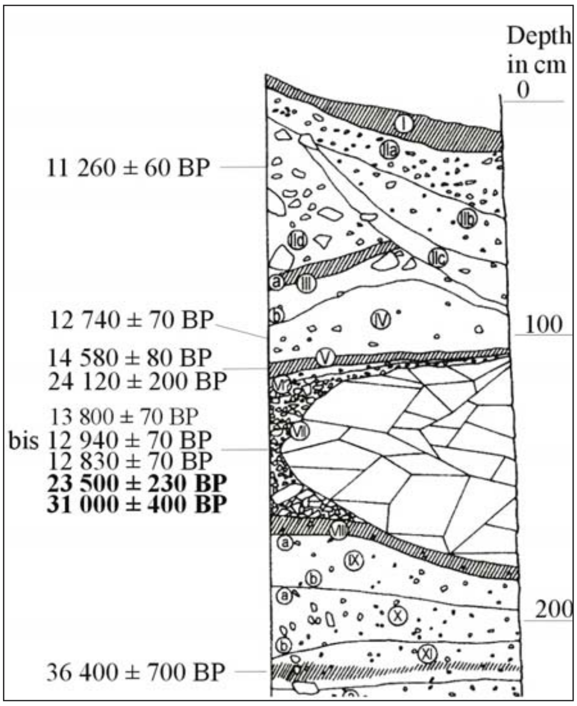
Layer VII (series E): Sample Poz-22686 is of Late Plenivistulian age, and Poz-22687 of Middle Plenivistulian age (Denekamp Interphase). They are accompanied by bones of Late Vistulian (Bølling) age (Poz-1437, Poz-3741). The Late Plenivistulian sample is considered autochthonous; older and younger samples are therefore redeposited. The bones of Middle Plenivistulian (Denekamp Interphase) age are redeposited from layer VIII, as indicated by the age of sample Poz-22687, which agrees with that of the samples from layer VIII. The presence of Late Vistulian bones in the limestone rubble of layer VII can be explained by their redeposition from the overlying sediments. Their penetration into layer VII was facilitated by its porous structure (Text-fig. 7). Nevertheless, there is some evidence to indicate that the Late Vistulian bones of layer VII come not from layer V (as suggested by the sequence of sediments and stratigraphy of layer V) but from layer IV. Determination of the age of the very thin layer V is not straightforward. The two dated samples (Poz-3740 and Poz-1133) from this layer are both of Late Plenivistulian age, albeit with quite an age difference (c. 10,000 years) between them. It seems neither probable that both samples are autochthonous to layer V, nor it can be assumed that both were redeposited from the underlying bed (layer VII). The characters of layers V and VII do not suggest their long sedimentation for a minimum of 10,000 years (Text-fig. 7). Consequently, it seems that the most logical explanation is that the younger sample (Poz-3740) is autochthonous, whereas the older sample (Poz-1133) is redeposited from layer VII. From layer VII comes a sample of similar age (Poz-22686). The redeposition of bones from layer VII to layer V could have either taken place due to sedimentological processes or may have been caused by the activity of Palaeolithic people, who used the cave during the formation of layer V (Valde-Nowak 2003). This means that the sedimentation of layer V took place at the close of the Late Plenivistulian, perhaps also extending into the Oldest Dryas. The Late Plenivistulian age of layer V is also supported by other arguments:

(a) The results of geological studies.

Layer V is very similar lithologically to the Late Plenivistulian layer VII. The similarity is so striking that during the excavations they were not separated over a considerable area of the cave (Madeyska 2003). This strong lithological similarity between layers V and VII shows them to have formed under similar climatic conditions and at a similar time.

(b) The results of palaeozoological studies.

In a preliminary study of the bone material from Obłazowa Cave (Valde-Nowak *et al*. 1995), and in its monographic treatment (Valde-Nowak 2003), attention is drawn to the fact that a marked transformation in the composition of animal species indicating environmental changes can be observed no earlier than in layers IV and III. The faunal assemblage of layer V is still similar to that from the underlying deposits.



Text-fig. 7. The sediment succession in the Obłazowa Cave (after Madeyska 2003); ^{14}C dates after Lorenc (2006a) and present study (new dates are in boldface); main cultural horizons (Szeletian and Pavlovian) marked with cross-hatching. The succession is composed of (after Madeyska and Valde-Nowak 2003): XI – red-brown sandy loam with smoothed rubble; X – greenish-grey sandy loam with small pebbles from outside 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 a small admixture of loam. Large limestone block (1.5 m in diameter), visible in the section; VI – thin (c. 5 cm thick) 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 grades gently into the underlying sediments and becomes thinner towards the cave entrance; IV – pale brown loam with a 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 (a–d) loamy-rubble taluses. Some limestone pieces transported from the back part of the cave; I – loam with an admixture of limestone rubble

As has been mentioned, in the earlier palaeozoological studies the sedimentation of layer V was correlated with the Late Plenivistulian and it was only layer IV that was considered Late Vistulian (Madeyska 1991; Wołoszyn 1995; Tomek and Bocheński 1995). The Late Plenivistulian age of layer V indicates the Late Vistulian (Bølling) age bones found in layer VII do not originate from layer V but from layer IV. Finally, the Bølling age of the sample from layer IV prove this interpretation to be correct.

Layers IV–II (series F): The sedimentation of layer V in the Late Plenivistulian means that layer IV can be the oldest layer formed in the Late Vistulian. The sedimentation of layer II probably occurred in the Allerød Interphase.

TIME INTERVALS OF BONE ACCUMULATION

It is possible to indicate some short time intervals favourable for the accumulation of bones in the cave deposits analysed herein.

Late Vistulian: The following intervals are represented by bone samples of Late Vistulian radiocarbon ages:

- 14–13 ka BP (Oldest Dryas): 1 sample (Table 7)
- 13–12 ka BP (Bølling): 9 samples (Tables 2, 3, 5, 7, 8)
- 12–11.8 ka BP (Older Dryas): 3 samples (Tables 3, 7)
- 11.8–11 ka BP (Allerød): 4 samples (Tables 5, 6, 8)
- 11–10.2 ka BP (Younger Dryas): 4 samples (Tables 5, 6)

Of the twenty-one samples, nine come from between 13 ka BP and 12 ka BP. There is a virtual absence of bones from periods with especially unfavourable climatic conditions. The only sample from the Oldest Dryas represents the close of the phase, i.e. a period of advancing amelioration. Similarly, the 4 samples from the Younger Dryas are from the close of this phase, a period of distinct warming. Three samples come from the Older Dryas, which can hardly be considered a time of much worse climatic conditions[2] and four samples are from the Allerød Interphase. There is no doubt that the climatic and environmental conditions of the Bølling–Allerød interval and the late Younger Dryas were more favourable to the appearance of fauna (including Palaeolithic people) than during the culmina-

The Older Dryas cooling is thought to have been short and only slight. The drop in its mean July temperatures in comparison with the Bølling is usually estimated at 1–2˚C, and some research results do not record Older Dryas cooling at all. The abundance of data in this field has been summarised in Lorenc (2007). The Bølling–Allerød time interval is often treated as a single chronostratigraphic unit called the Late Glacial Interphase. The maximum warming in many places fell at its start – the Bølling(!) (e.g. Lowe *et al*. 1994).

tion of the Oldest and Younger Dryas periods. They were also favourable to the eagle owls (*Bubo bubo*). As has been shown earlier (Lorenc 2006b), bird bones found in the cave deposits (making seventeen of the above twenty-one samples) are mostly the remains of prey of these owls.

The same conclusions could have been drawn from the radiocarbon ages revealed by bone samples from other caves of the Kraków-Częstochowa Upland. As in the case of the samples studied herein, these additional samples revealed a high proportion of bones from the Bølling and Allerød interphases .

Middle Plenivistulian: The following intervals are represented by bone samples of this interval:
– 50–43 ka BP (Moershoofd): 6-7 samples (Tables 2, 3, 4, 7)
– 43–39 ka BP (Hasselo): 5-6 samples (Tables 2, 7)
– 39–36 ka BP (Hengelo): 7-8 samples (Tables 2, 7, 8)
– 36–33 ka BP (Huneborg): 4 samples (Tables 2, 7)
– 33–30 ka BP (Denekamp): 15 samples (Tables 2, 3, 4, 7, 8)
– 30–25 ka BP (Denekamp): 7 samples (Tables 2, 3, 4, 5, 7), 4 coming from the close of the Denekamp (27–25 ka BP).

Layer	**Stratigraphy of the layers** (on the basis of literature cited in the text)	**C-14 age of the dated samples**	**Laboratory number of the dated samples**	**Dated bones**	**Source of data**
II	Late Vistulian	11 260 ± 60 BP	Poz-1132	Bird bone	Lorenc (2006a)
IV	Late Vistulian	12 740 ± 70 BP	Poz-3742	*Lagopus lagopus/mutus*	Lorenc (2006a)
V	Late Vistulian	14 580 ± 80 BP 24 120 ± 200 BP	Poz-3740 Poz-1133	*Lagopus lagopus* Bird bone	Lorenc (2006a) Lorenc (2006a)
VII	Late Plenivistulian	13 800 ± 70 BP 12 940 ± 70 BP[1] 12 830 ± 70 BP **23 500 ± 230 BP** **31 000 ± 400 BP**	Poz-1134 Poz-1437 Poz-3741 Poz-22686 Poz-22687	Bird bone Bird bone *Lagopus lagopus/mutus* *Vulpes vulpes* *Rangifer tarandus*	Lorenc (2006a) Lorenc (2006a) Lorenc (2006a) **New date** **New date**
VIII	Middle Plenivistulian	18 160 ± 260 BP 30 600 ± 550 BP 31 000 ± 550 BP 32 400 ± 650 BP 32 400 ± 1700 BP	OxA-3694 OxA-4585 OxA-4586 OxA-4584 Gd-2555	Mammoth tusk boomerang Bone perforator Human bone *Cervus elaphus* Group of tiny bones	Housley (2003) Housley (2003) Housley (2003) Housley (2003) Housley (2003)
XI	Middle Plenivistulian	36 400 ± 700 BP	Poz-1135	Bird bone	Lorenc (2006a)
XV/XVI	Early Vistulian	25 900 ± 1700 BP[2]	Gd-4532	Bone fragment	Housley (2003)
Pit XXII	Sediments without stratigraphy	23 420 ± 380 BP[2]	OxA-3695	Antler	Housley (2003)

[1] Second dating of the sample no. Poz-1134. The more probable age is that obtained from the sample Poz-1437 (Goslar, written information). It is also corroborated by the dating result for sample no. Poz-3741 from this layer.
[2] Low quality of the dated samples undermines the reliability of the ages obtained Housley (2003).

Table 8. Radiocarbon ages of bones from the sediments of Obłazowa Cave (in each layer according to the age of the samples). The new dates from the present study are given in boldface

Cave (Test-fig. 1)	**C-14 age of the samples**	**Laboratory number of the dated samples**	**Dated bones**	**Source of data**
Rs. in Krucza Skała	12 970 ± 60 BP 12 520 ± 70 BP 12 480 ± 60 BP 11 980 ± 70 BP 11 450 ± 200 BP 11 210 ± 80 BP[1]	Poz-27245 Poz-1138 Poz-27261 Poz-1139 Lod-407 Poz-1141	*Alopex lagopus* ? ? ? ? ?	Nadachowski *et al.* (2009) Nadachowski *et al.* (2009) Nadachowski *et al.* (2009) Nadachowski *et al.* (2009) Cyrek (1994) Nadachowski *et al.* (2009)
Jasna in Strzegowa C.	13 630 ± 70 BP	-	?	Stefaniak *et al.* (2009)
Cave IV in Mt. Birów	12 590 ± 60 BP	Poz-27244	*Alopex lagopus*	Muzolf *et al.* (2009)

[1] Late Vistulian sediments of Rock-shelter in Krucza Skał a produced also the date 2 240 ± 35 BP (Poz-1140), indicating the secondary admixture of sediments (Nadachowski *et al*. 2009) .

Table 9. Radiocarbon age of Late Vistulian bones from caves not covered by the radiocarbon study of the author

Cave (Test-fig. 1)	**C-14 age of the samples**	**Laboratory number of the dated samples**	**Dated bones**	**Source of data**
Maszycka Cave	32 900 ± 500 BP 35 500 ± 450 BP 29 700 ± 450 BP	Gd-8003 Gd-8004 Gd-8005	? ? ?	Allain *et al.* (1985); Kozłowski *et al.* (1993)
Towarna (Niedźwiedzia) C.	>52 000 BP	Poz-24205	*Ursus spelaeus*	Stefaniak *et al.* (2009)
Cave IV in Mt. Birów	27 980 ± 220 BP	Poz-27279	*Vulpes vulpes*	Muzolf *et al.* (2009)
Stajnia C.	>49 000 BP	Poz-28892	*Ursus spelaeus*	Urbanowski *et al.* (2010)
Obłazowa 2	33 430 ± 1230 BP	OxA-3696	Fox	Nadachowski *et al.* (1993); Housley (2003)
Nietoperzowa C.	33 000 BP 33 200 BP 45 000 BP	- - -	*Ursus spelaeus* *Ursus spelaeus* *Ursus spelaeus*	Nadachowski, Wojtal (written information)[1]
Ciemna C.	37 800 BP 42 000 BP	- -	*Ursus spelaeus* *Ursus spelaeus*	
Zawalona C.	37 300 BP	-	*Ursus spelaeus*	
Wylotne Rs.	>45 000 BP	-	*Ursus spelaeus*	

[1] The dates the Nietoperzowa, Ciemna and Zawalona caves and the Wylotne Rock shelter, obtained from bones of the cave bear (*Ursus spelaeus*) (Nadachowski, Wojtal – written information), come from current research on the history of this species in the territory of Poland (Nadachowski *et al.* 2008a-c)

Table 10. Radiocarbon age of Middle Plenivistulian bones from caves not covered by the radiocarbon study of the author

Of the forty-five samples coming from this interval fifteen are from between 33 ka BP and 30 ka BP. This is the period of maximum climate warming of the Denekamp Interphase. Together with the seven remaining Denekamp samples, the number of samples associated with this interphase amounts to half of all those dated as Middle Plenivistulian. Similarly, there is also a higher number of bones from the remaining interphases (Moershoofd, Hengelo) than from the periods of climatic cooling (Hasselo, Huneborg). The same characteristics are also shown by the Middle Plenivistulian radiocarbon-dated bones from nine other sites not studied herein (Table 10): a higher proportion of samples (six to seven samples out of the fifteen dated) come from the Denekamp Interphase, while only

Cave (Text-fig. 1)	C-14 age of the samples	Laboratory number of the dated samples	Dated bones	Source of data
Maszynka C.	15 490 ± 310 BP 14 520 ± 240 BP	Ly-2454 Ly-2453	*Rangifer tarands* Horse	Allain *et al*. (1985); Kozłowski *et al*. (1993)
Zawalona C.	15 380 ± 340 BP 14 060 ± 340 BP[1]	- -	? ?	Alexandrowicz *et al*. (1992)
Jasna in Strzegowa C.	14 400 ± 80 BP	-	?	Stefaniak *et al*. (2009)
Borsuka C.[3]	24 850 ± 200 BP[2]	Poz-26124	*Mammuthus primigenius*	Nadachowski *et al.* (2011)

[1] The sample may come from the oldest Dryas
[2] The sample may come from the Middle Plenivistulian
[3] The Borsuka Cave, not shown on the map, is located in the Szklarka river valley, constituting the southern part of the Kraków-Częstochowa Upland, about 20 km north-west of Kraków.

Table 11. Radiocarbon age of Late Plenivistulian bones from caves not covered by the radiocarbon study of the author

a few (three to four samples) come from the cold climatic phases (Hasselo, Huneborg).

Late Plenivistulian: Unlike in the Middle Plenivistulian and Late Vistulian, no predominance of bones from any strictly defined intervals is revealed. From each of almost all of the Late Plenivistulian millennia come at most two samples. An exception is the start of the Late Plenivistulian, the period of the maximum extent of the ice sheet in the Leszno Phase, contributing a few more samples, as follows:

– 25–24 ka BP: 5 samples (Tables 2, 3, 8)
– 21–19 ka BP: 10 samples (Tables 3, 7), with 7 from the period 20–19 ka BP.

The majority of the twenty-four Late Plenivistulian samples (fifteen) come from the Deszczowa Cave (Table 3).

Among radiocarbon-dated bones from four other sites not studied herein (Table 11) samples from the close of the Late Plenivistulian dominate.

CONCLUSIONS

Based on twenty-six bone samples from seven caves dated herein (Text-fig. 1), twenty-seven former radiocarbon dates (Lorenc 2006a), and forty-seven radiocarbon dates from other published and unpublished

Cave	New dates (this paper)	Lorenc (2006a)	Other published dates	Unpublished dates	Together
Komarowa C.	2	-	12	-	**14**
Deszczowa C.	7	6	14	1	**28**
Rs. a. the Deszczowa C.	1	3	-	1	**5**
Dziadowa Skała C.	6	3	-	1	**10**
Sąspowska Zach. C.	2	1	-	-	**3**
Mamutowa C.	6	6	10	1	**23**
Obłazowa C.	2	8	7	-	**17**
Together	**26**	**27**	**43**	**4**	**100**

Table 12. Number of radiocarbon dates obtained for the bone samples from the discussed caves (by source of data)

Cave and layer	**C-14 age of the dated samples**	**Laboratory number of the dated samples**	**Cave and layer**	**C-14 age of the dated samples**	**Laboratory number of the dated samples**
Komarowa C.			**Dziadowa Skała C.**		
layer B	12 260 ± 60 BP	Poz-6621	layer 8	**1340 ± 30 BP**	Poz-22673
				10 280 ± 60 BP	Poz-3745
				10 330 ± 50 BP	Poz-35251
Deszczowa C.				~ 11 800 BP	-
				12 220 ± 80 BP	Poz-22671
layer X	**365 ± 30 BP**	Poz-23438			
	22 400 ± 200 BP	Poz-3757			
			Sąspowska Zach. C.		
layer Xa	**~ 19 700 BP**	-			
			layer 3	**10 050 ± 50 BP**	Poz-35216
layer XIa	**24 150 ± 200 BP**	Poz-3755		10 280 ± 50 BP	Poz-1167
				11 310 ± 60 BP	Poz-35217
Rs. a. the Deszczowa C.					
			Obłazowa C.		
layer XI/X	**> 46 000 BP**	Poz-3756			
			layer II	11 260 ± 60 BP	Poz-1132
layer IX	**44 700 ± 2400 BP**	Poz-3753			
			layer IV	12 740 ± 70 BP	Poz-3742
			layer V	**14 580 ± 80 BP**	Poz-3740
				24 120 ± 200 BP	Poz-1133

Table 13. Radiocarbon ages of bones from layers correlated with the Late Vistulian (in each layer according to the age of the samples). The ages of samples which do not agree with the stratigraphy of the layers from which they originate are given in boldface

Cave and layer	**C-14 age of the dated samples**	**Laboratory number of the dated samples**	**Cave and layer**	**C-14 age of the dated samples**	**Laboratory number of the dated samples**
Deszczowa C.			**Mamutowa C.**		
layer VIII	17 480 ± 150 BP	Gd-10212	layer 2	**11 820 ± 60 BP**	Poz-1152
	18 900 ± 400 BP	Poz-22668		**12 000 ± 60 BP**	Poz-1151
	19 250 ± 120 BP	Poz-3751		**13 040 ± 40 BP**	Poz-22685
	20 800 ± 150 BP	OxA-11060		~ 19 500 BP	-
				19 720 ± 120 BP	Poz-22680
layer VIIIa	**12 340 ± 60 BP**	Poz-22667		20 650 ± 100 BP	OxA-14409
	19 280 ± 120 BP	Poz-22669		**35 460 ± 260 BP**	OxA-14410
	~ 19 500 BP	-			
	20 280 ± 130 BP	Poz-22666	layer 2g	**26 010 ± 150 BP**	OxA-14406
	~ 22 500 BP	-		**29 800 ± 400 BP**	Poz-3746
				31 300 ± 500 BP	Poz-3747
				36 500 ± 800 BP	Poz-22681
Rs. a. the Deszczowa C.					
			layer IX	**37 550 ± 450 BP**	OxA-14408
layer VIII	**28 200± 300 BP**	Poz-22665		**38 500 BP**	OxA-14475
	30 100± 400 BP	Poz-3752			
			Obłazowa C.		
Dziadowa Skała C.					
			layer VII	**12 830 ± 70 BP**	Poz-3741
layer 7	**10 240 ± 60 BP**	Poz-22672		**13 800 ± 70 BP**	Poz-1134
	11 360 ± 60 BP	Poz-1149		**12 940 ± 70 BP**[1]	Poz-1437
	12 190 ± 60 BP	Poz-3743		23 500 ± 230 BP	Poz-22686
	25 300 ± 200 BP	Poz-23894		**31 000 ± 400 BP**	Poz-22687
	26 200 ± 300 BP	Poz-22675			

[1] Second dating of the sample no. Poz-1134. The more probable age is that obtained from the sample Poz-1437 (GOSLAR, written information). It is also corroborated by the dating result for sample no. Poz-3741 from this layer.

Table 14. Radiocarbon ages of bones from layers correlated with the Late Plenivistulian (in each layer according to the age of the samples). The ages of samples which do not agree with the stratigraphy of the layers from which they originate are given in boldface

Cave and layer	C-14 age of the dated samples	Laboratory number of the dated samples	Cave and layer	C-14 age of the dated samples	Laboratory number of the dated samples
Komarowa C.			**Rs. a. the Deszczowa C.**		
layer C	24 550 ± 220 BP	Poz-339	layer VI I	32 500 ± 700 BP	Poz-24205
	34 200 ± 600 BP	Poz-22676			
	38 600 ± 1000 BP	Poz-22677			
			Mamutowa C.		
layer D	28 500 ± 500 BP	GdA-94			
	31 100 ± 400 BP	Poz-313	layer 3	30 300 ± 350 BP	Poz-1153
	31 400 BP	Gd-13097		30 300 ± 400 BP	Poz-22679
	35 500BP	Gd-15029		38 900 ± 1100 BP	Poz-22682
layer E	39 900 ± 1200 BP	Poz-323	layer VIII	38 250 ± 550 BP	OxA-14404
				46 400 ± 1200 BP	OxA-14405
layer Z	37 500 ± 450 BP	OxA-11098			
	43 900 ± 1000 BP	OxA-11097	layer VII	40 700 ± 800 BP	OxA-14407
			layer VI	42 400 BP	OxA-14474
Deszczowa C.					
layer VII	26 200 ± 300 BP	Poz-314	**Obłazowa C.**		
layer VIIa	**~ 6100 BP**	-	layer VIII	**18 160 ± 260 BP**	OxA-3694
	24 470 ± 260 BP	Poz-23437		30 600 ± 550 BP	OxA-4585
	24 620 ± 200 BP	Poz-26126		31 000 ± 550 BP	OxA-4586
	31 000 ± 400 BP	Poz-23772		32 400 ± 650 BP	OxA-4584
				32 400 ± 1700 BP	Gd-2555
layer VI					
	43 000 BP	Poz-330	layer XI	36 400 ± 700 BP	Poz-1135
	44 000 ± 2000 BP	Poz-373			

Table 15. Radiocarbon ages of bones from layers correlated with the Middle Plenivistulian (in each layer according to the age of the samples). The ages of samples which do not agree with the stratigraphy of the layers from which they originate are given in boldface

sources (Table 12), the following conclusions are reached:

1. Radiocarbon ages of a substantial proportion of the bone samples do not match the chronostratigraphic position of their source rocks. This is particularly common in Late Vistulian and Late Plenivistulian layers, and less distinctly in Middle Plenivistulian samples. The details are as follows:

- Late Vistulian deposits: The samples are from eleven layers of six sites (Table 13). In six layers Late Vistulian bones were not found (!), instead they yielded bone samples of Middle Plenivistulian and Late Plenivistulian age. Late Vistulian bones were found in five layers; two of them also contained Holocene bones.
- Late Plenivistulian deposits: The samples derive from a total of five sites and eight layers. In four layers no bones of Late Plenivistulian age were found (!); those dated come from the Middle Plenivistulian and/or Late Vistulian. In the next three layers, Late Plenivistulian bones were accompanied by bones from the Late Vistulian or from both the Late Vistulian and Middle Plenivistulian. In only a single layer did the bones come exclusively from the Late Plenivistulian.
- Middle Plenivistulian deposits: The samples derive from a total of five sites and fourteen layers. In only two layers were samples found that did not come from that period. The above data show that bones of this age predominate in the Middle Plenivistulian layers of the sites under study. This, however, does not preclude the presence of redeposited bones in those layers, as indicated in earlier discussions.
- Holocene deposits also contain redeposited bones of widely varying ages (Table 2, 7).

2. Redeposition of bones results mainly from:
- The porous structure of the majority of the layers, due to the presence of sharp-edged limestone rubble and even rock blocks (Text-figs 3–7).
- The presence of water in the caves. Traces of washing by water were found in at least three sites (Text-figs 3, 4, 6).
- The presence of large mammals and humans (mostly Palaeolithic) in the caves during the deposition of a substantial part of the layers in question. Such traces were found in all of the sites discussed.

3. Sedimentation of bones was more intensive during warm climatic phases. Those are: the Bølling–Allerød time interval (mainly between 13 ka BP and 12 ka BP) for the Late Vistulian and the Denekamp Interphase (mainly between 33 ka BP and 30 ka BP) for the Middle Plenivistulian. Undoubtedly, the climatic and environmental conditions of warm climatic phases were more favourable to the appearance of a higher diversity fauna (including Palaeolithic people) than during calm climatic phases.

4. Bone assemblages (mostly mammalian and bird) from Vistulian cave deposits are often employed in the reconstruction of the palaeoenvironment and the palaeoclimate of the period. These reconstructions relate to the period with which the sedimentation of the layer from which the bone assemblages derive is correlated. The key issue, however, is not so much the age of the deposits, but rather the age of the bones that they contain. The present study has shown that the bones found in the Vistulian cave deposits are often of widely varying radiocarbon ages, indicating that at least some of the bones have been redeposited. Inferences concerning the palaeoclimate and the palaeoenvironment based on heavily mixed bone assemblages might therefore be open to question. It must be emphasised that the radiocarbon ages of bone assemblages used for this purpose should be determined as accurately as possible. Moreover, the present study has shown that precise determination of the location of bones within individual layers, in both their vertical and horizontal profiles, is necessary in order to interpret the direction and causes of their possible redeposition. It is also essential to provide documentation of all evidence of redeposition of the sediments themselves.

The results obtained from this investigation may prove valuable to researchers of many different disciplines who rely on material from caves in their studies.

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