



RADIOCARBON CHRONOLOGY OF REPRESENTATIVE UPPER PALAEOOLITHIC SITES IN THE CENTRAL EUROPEAN PLAIN : A CONTRIBUTION TO THE SC-004 PROJECT

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1. INTRODUCTION

The main objective of the radiocarbon datings is to contribute to the establishment of the most precise possible chronological framework for the climatic events recorded in the loessic deposits of Central Europe. With regard to the numerous interpretation problems posed by the ^{14}C datings already available for Central Europe, one of the main goals of the Sc-004 project was to perform new datings from a solid stratigraphic basis with the highest degree of reliability and accuracy. The results achieved provide a set of partly new and partly published data (DAMBLON *et al.* 1996, HAESAERTS *et al.* 1996, 1997, OTTE *et al.* 1996), the whole of which gives new precisions on the chronology of the human occupations and of the climatic oscillations during the Upper Pleistocene.

The selection of the sites of Willendorf II, Schwallenbach and Grubgraben in Lower Austria, Dolni Vestonice, Pavlov, Stranska Skala in Czechia, Mitoc Malu Galben in Romania and Cosautsi in Moldavia (Fig. 1) was made on the basis of their common importance for climatic reconstructions. All of these are key-sites for the understanding of human industries, cultures and migrations. They are characterized by important loess sequences with paleosols, both containing good organic material for radiometric datings and palaeoenvironmental reconstructions.

2. DATING STRATEGY AND METHODOLOGY

The reliability of a ^{14}C date depends mostly on two factors : the precise

stratigraphic origin of the sample and the degree of purity of the material to be dated. Besides, the accuracy of the result depends on the quantity of material to be dated, which affects the reproducibility of the measurements in the laboratory. Yet in the loessic field, these conditions are very often far from being satisfactory for the distortion causes are multiple: inaccuracy of the field sampling, collecting of objects contaminated by humates or rootlets, collecting of materiel reworked by run-off or bioturbations, collecting of insufficient quantities of material for dating. In order to overcome these drawbacks, the dating strategy has been focused on the permanent control of the stratigraphic origin of the samples, on the choice of satisfactory quality material submitted to the dating (mostly charcoal, and dense bone fragments), on the selection of uncontaminated material and finally, on the anthracological identification.

2.1. Stratigraphic origin of the sample and spatial distribution of the material inside the stratigraphic unit

The starting point was a detailed study of the site's stratigraphy and the precise positioning of the samples in the stratigraphic units. A permanent control of sampling was achieved along cleaned section walls or pits whilst sampling from large surfaces of excavation in loess was avoided to keep off any mixing up between successive sedimentation units or archaeological layers. In some critical situations, like in Willendorf II, Mitoc or Cosautsi, small steps were burrowed into the loess wall in order to obtain a maximal carbon mass for dating and to verify continuously the homogeneity of the sample.

The distribution of the fossil material inside the stratigraphic unit or in the

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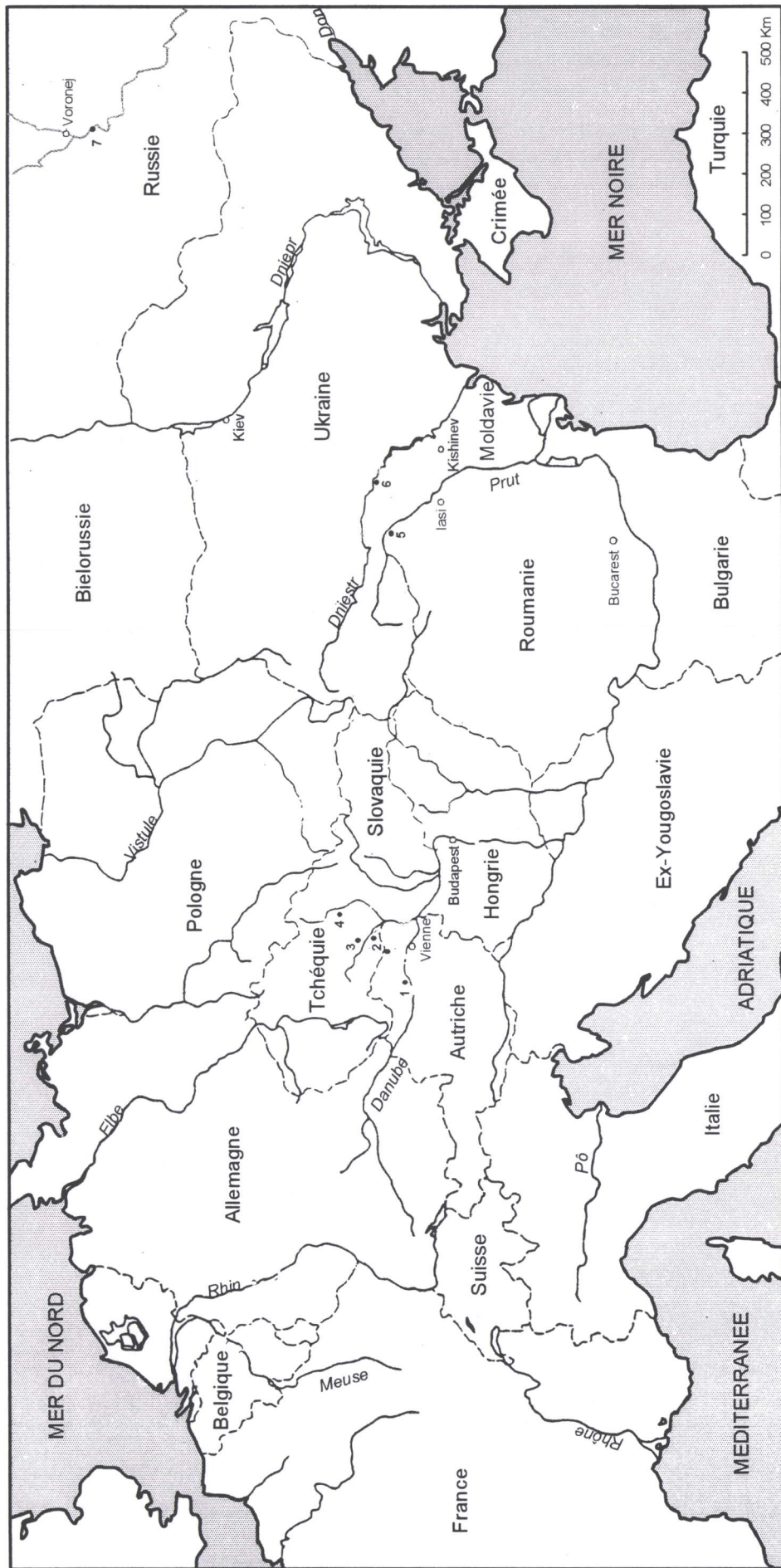


Figure 1 : Location map of the investigated sites in Central Europe. 1: Willendorf II & Schwallenbach, 2: Dolni Vestonice & Pavlov, 3: Bohunice & Stranska Skala, 4: Predmost, 5: Mitoc Malu Galben, 6: Cosautsi, 6: Cosautsi, (7: Kostenki).

archaeological layer can affect the accuracy and the quality of the datings. It was considered *a priori* that charcoal or bone concentrations provide more reliable results than fossil groups scattered inside the same sedimentary unit (BOWMAN 1990). Likewise the charcoal pieces from a hearth inside an archaeological layer are considered to be in close association with one or more successive human occupations. However, this does not necessarily guarantee that the material to be dated will not be contaminated. Nevertheless, results in good keeping with the data provided by the general stratigraphy and chronology of the site were obtained when the fossil material was scattered in the sedimentary unit, like in Willendorf II, Schwallenbach, Mitoc and Cosautsi.

2.2. The material for dating

Charcoal was systematically traced as most reliable material for dating (WATERBOLK 1971, 1983, OGDEN 1977, MOOK & WATERBOLK 1985, SOFFER 1985, LANTING & VAN DER PLICHT 1994, BOWMAN 1990, KUZMIN & TANKERSLEY 1996), notably because of its high inert carbon content and the least risks of chemical contamination it implies. Datings were performed on bone collagen each time charcoal and bone association occurred, notably in Willendorf and Cosautsi (HAESAERTS *et al.* 1996, OTTE *et al.* 1996).

2.3. Laboratory treatment

Charcoal fragments were first of all collected by water dispersion of the sediment with or without sodium pyrophosphate, then by sifting through successive 1 mm, 0.5 mm and 0.25 mm meshes. If the effects of contamination on charcoal and bone are well-known (WATERBOLK 1971, 1983, MOOK & WATERBOLK 1985, GOWLETT & HEDGES 1987, BOWMAN 1990), it has to be said that the precautions and manipulations necessary to reduce or eliminate it are far from being systematically applied by the dating demanders. Within the framework of the present project, the material to be dated was very carefully examined in the laboratory to select the pieces with the highest quality possible. In such a context, charcoal fragments were sorted out and identified piece per piece after removal of rootlet remains under

binocular glass. The fragments crossed by rootlets or supposedly contaminated by other vectors (mycelium, secondary carbonates or root traces) were discarded. Finally, charcoal pieces whose structures were obliterated by silicate or carbonate recrystallizations were undamagedly treated by HF and HCl, then rinsed in distilled water and dried in the oven. This procedure is presented in details in DAMBLON *et al.* (1996).

As for the bone fragments, the selection work consisted in choosing the dense pieces, non spongy if possible, in freeing them carefully from their potential mineral crust and, if necessary, in cutting the bone to extract the denser central part susceptible of a less humate contamination. Despite all these precautions, a total eradication of the contaminants is clearly deluding. It is however possible to reduce them very significantly by a progressive and selective extraction of collagen in the ^{14}C laboratory (STREURMAN in DAMBLON *et al.* 1996).

The homogeneity of a sample for dating must be controlled as a potential mixing up of taxa resulting from charcoal intrusion could induce a completely distorted date. As a rule, we selected charcoal pieces exclusively from conifers, essentially spruce and pine, considering the Upper Pleistocene environmental context in order to lower the probability of possible mixing up with intrusive Holocene taxa.

The dating procedure was chosen according to the quantities of charcoal gathered from the samples. The preference was given to conventional dating with the hope of diluting the potential pollutions to which the AMS measurements are very sensitive (LANTING & VAN DER PLICHT 1994). Of course, AMS measurements were performed on the small samples while trying to work on masses superior to 100 mg.

All datings on charcoal and bone fragments were exclusively carried out in the Groningen ^{14}C laboratory to work systematically in the same pretreatment and measurement conditions. For Cosautsi, a series of AMS datings on bone has been achieved in the Oxford laboratory (OTTE *et al.* 1996) parallel to the datings on charcoal carried out in Groningen (DAMBLON *et al.* 1996, HAESAERTS *et al.* 1997).

All ^{14}C ages are given in BP years, including the corrections made for the ^{13}C isotopic fractionation. The results are not calibrated. In fact, the dendrochronological calibration curves (STUIVER, LONG & KRA 1993) do not encompass the Upper Pleistocene, and the calibration curves based on the lake varves or on the marine laminations are not yet completed. In the present state of the work, the use of BP dates enables easier comparisons between the published data. Concerning the published data and mainly those of questionable reliability, their calibration would only add to the general confusion. This question will be dealt with in a further publication.

3. RESULTS : THE ^{14}C DATES AND THE RADIOCARBON CHRONOLOGY OF THE SITES

3.1. Lower Austria

3.1.1. Willendorf II and Schwallenbach

3.1.1.1. Presentation of the data

The interest of the site of Willendorf II lies first of all in the sedimentary sequence containing a paleosol (D), 3 humic horizons (C8, C4, C2), 2 tundra gleys (C6, top of C1) and a stabilization surface (B2) interbedded within a loessic type sedimentation (C9, C7, C5, C3, C1 p.p., B3, B1). It further lies in the succession of 9 Upper Palaeolithic (Aurignacian and Gravettian) cultural layers among which 4 (CL3, CL4, CL5, CL8) were rediscovered in the 1993 section.

The stratigraphy of the site and the distribution of the dates in the sequence are illustrated in Haesaerts *et al.*, 1996 and Damblon *et al.*, 1996. The sequence is divided

into 4 main sedimentary units A, B, C and D, which are themselves divided into subunits (C1, C2, ...). The position of the cultural layers is given in parallel. Considering the regional stratigraphic context, units D and C are ascribed to the Interpleniglacial, while unit B corresponds to the Upper Pleniglacial (HAESAERTS 1990a).

In total, 36 ^{14}C datings are available, among which 26 were performed within the framework of the present project (DAMBLON *et al.* 1996, HAESAERTS *et al.* 1996); three of them were discarded for they were obviously erroneous or unreliable.

Amongst the 33 dates retained (Fig. 2), 27 were made on charcoal. Nevertheless, 2 dates on bone have allowed an excellent cross-dating with the charcoal fragments extracted from cultural layer 8. Finally, 4 dates were made on bone fragments taken out of cultural layer 9 and preserved in the Naturhistorisches Museum Wien.

The Willendorf II sequence is directly comparable with that of Schwallenbach at 1 km upstream, which presents an equivalent stratigraphic succession (Fig. 3), suggesting a lateral continuity of the marker horizons over several km. Moreover, at Schwallenbach, the humic horizons do not contain any artifacts, which strengthens the climatic character of the dated events thanks to the charcoal pieces generally found scattered or in small monospecific clusters within the sediments. Table 1 indicates the ^{14}C dates achieved for Schwallenbach. The validity and significance of the Willendorf II and Schwallenbach dates will be discussed jointly.

Sedim. unit	n° date	^{14}C age (BP)	Charcoal
III-1	GrA-5219	29,530 +880 -800	Picea
IV-1	GrA-6899	31,680 ±290	Picea
IV-4	GrA-5221	39,000 +3,300 -2,300	Picea
V-1	GrA-5222	37,400 +2,600 -2,000	Picea
V-2	GrN-21801	39,920 +1,300 -1,100	Picea

Table 1: Schwallenbach; ^{14}C dates from the main sedimentary units

Willendorf II : chronostratigraphy and chronology

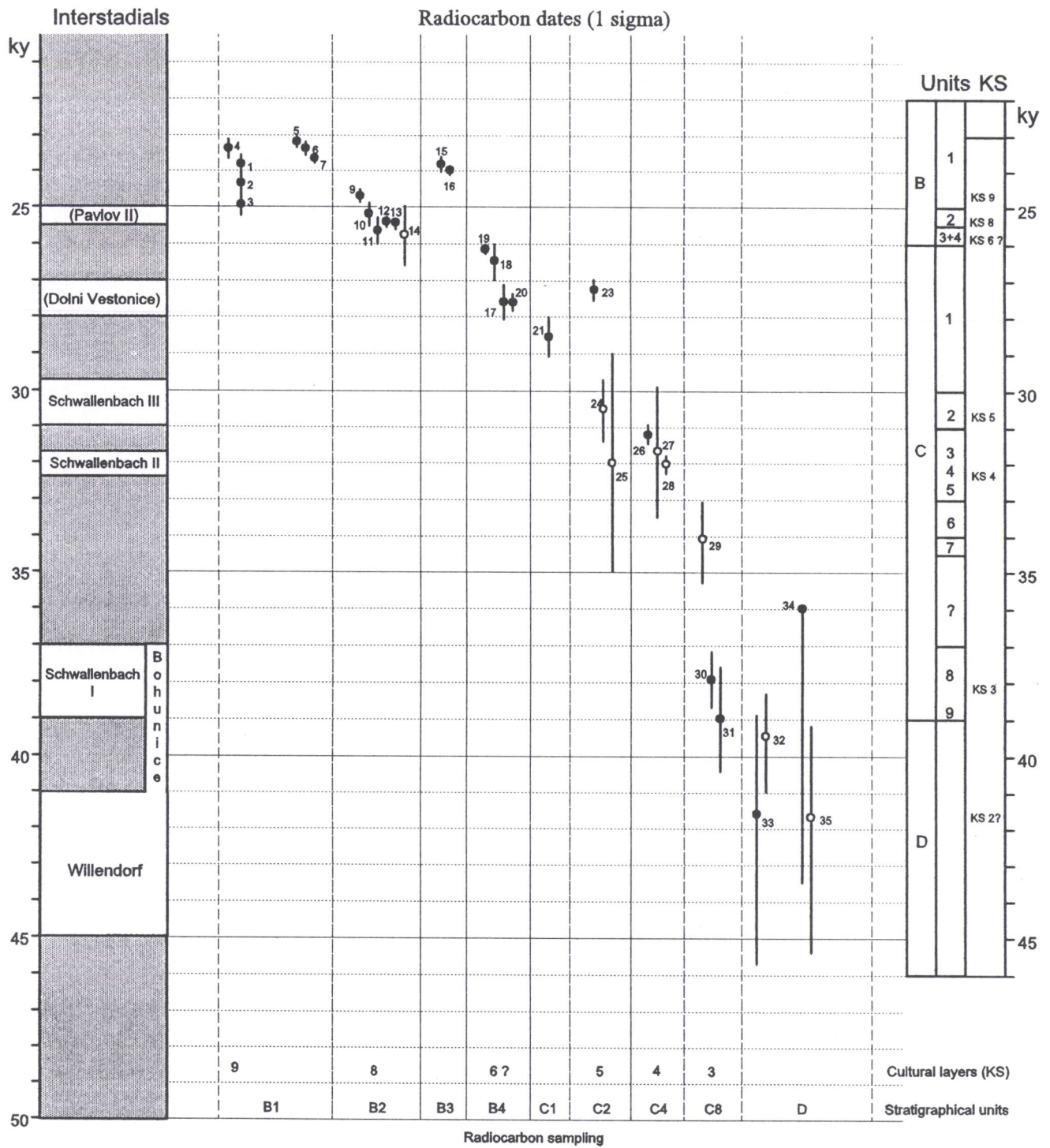


Figure 2 : Willendorf II. Chronostratigraphy and chronology of the site. The central column gives the chronological distribution of the ^{14}C dates by stratigraphical unit and by cultural layer. Symbols: black: Sc-004/GrN & GrA dates; white: other previous dates. Right column: local chronostratigraphy; left column: chronostratigraphy for Central Europe. Both left and right subdivisions are interpretative.

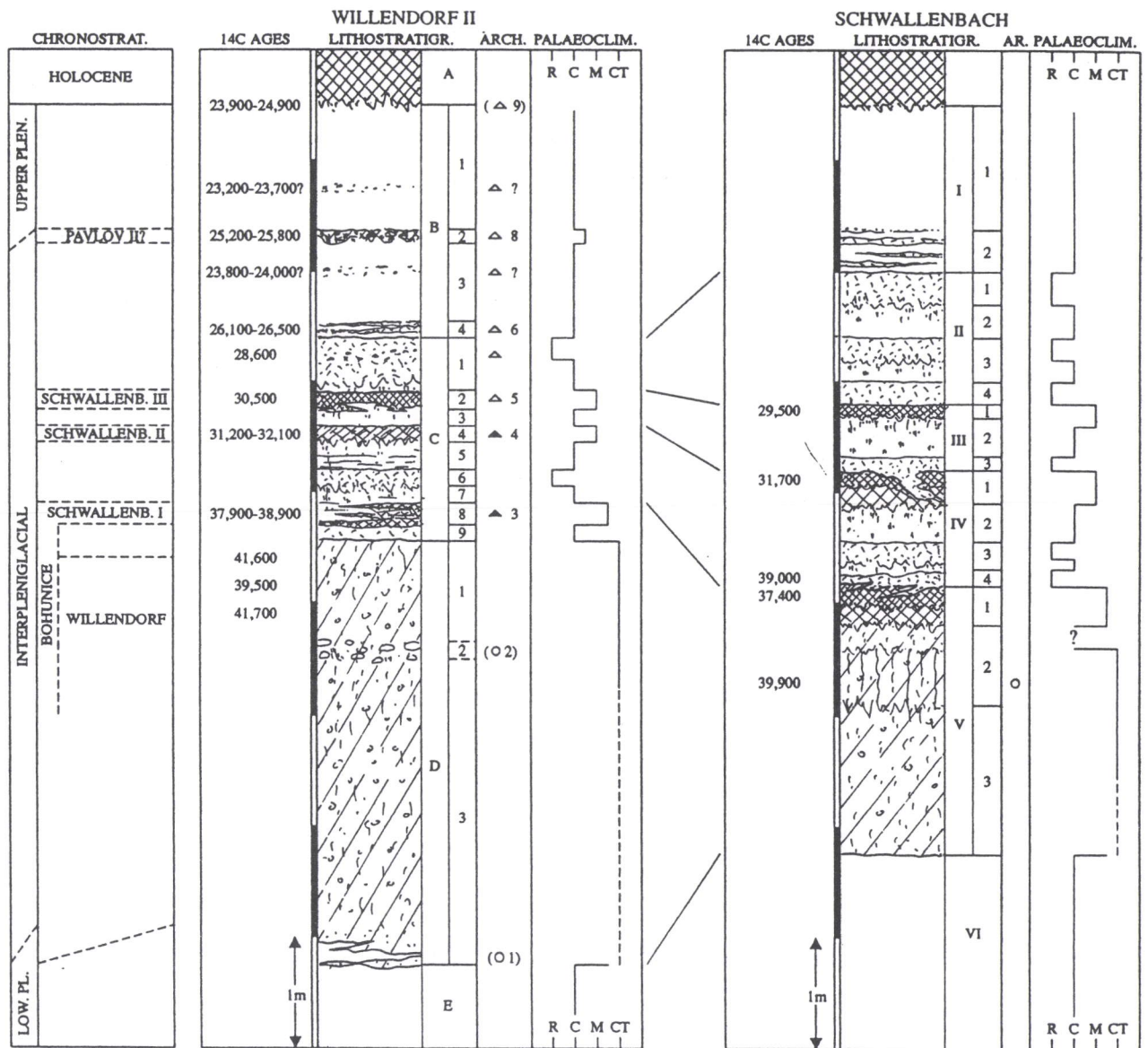


Figure 3: Willendorf II and Schwallenbach. Compared stratigraphy and chronology.
 Palaeoclimate: R: rigorous; C: cold; M: cold medium; CT: cold temperate.

3.1.1.2. Interpretation

As a rule, the chronological distribution of the 33 dates retained for Willendorf II (Fig. 2) draw a coherent evolution curve in comparison with the great stratigraphic units D-C-B- and within these units.

Unit D (first half of the Interpleniglacial)

Concerning unit D, 3 useful dates are retained (32, 33, 35), which define a period comprised between $\pm 42,000$ and 39,500 BP, the fourth date (34) not contrasting with this time range. The period enlightened corresponds in the upper part of unit D to the "Willendorf Interstadial" record recognized by its palaeopedological characters and the malacological evidences (FRANK & RABEDER 1994) found in Schwallenbach and Willendorf II. Thus, the age 39,920 obtained for subunit V-2 in Schwallenbach seems coherent with the dates of unit D in Willendorf. Therefore the date 36,700 achieved by BRANDTNER (in HAESAERTS 1990b) in the same deposit appears too young by contamination. Finally, the ^{14}C ages corresponding to the "Willendorf Interstadial" are concentrated over the period from 42,000 up to 40,000 BP, the lower limit impossibly being fixed here. At Willendorf II, cultural layer 2 is considered as included into sedimentary subunit D2, but the ^{14}C dates are based on charcoal pieces scattered through subunit D1 (Fig. 2). This suggests a quick sedimentation of subunit D1 and we propose an age around 42,000 BP for cultural layer 2.

Unit C (second half of the Interpleniglacial)

The solifluated humic horizon C8 contained, in the left part of the profile, charcoal concentrated in a position identical to that of a hearth belonging to the first Aurignacian cultural layer 3 mentioned by BAYER (in FELGENHAUER 1956-59). From a stratigraphic point of view, the horizon C8 is directly comparable with the V-1 horizon of the Schwallenbach sequence (Fig. 3). The ^{14}C ages obtained in the neighbouring two sequences, between 38,900 and 37,400, confirm that these horizons belong to the same oscillation characterized by equivalent malacological assemblages (FRANK pers. com.) indicative of a medium dry and cool climate. This oscillation is named "Schwallenbach I Interstadial". Let us note

that the solifluction disturbing subunit C8 in Willendorf II does not seem to have affected the ^{14}C age of this horizon. Besides, the charcoal remains of the first Aurignacian layer (cultural layer 3) being included in humic horizon C8, one can infer that the age 38,900 corresponds best to the first Aurignacian occupation in Willendorf II; previous date 34,000 obtained for this layer is clearly too young for contamination reasons.

Horizon C4 corresponds to a root of *in situ* humic horizon that contained slightly concentrated charcoal. Considering the dates achieved on old samples (32,060 and 31,7000) and the AMS date on scattered material that seems too young (DAMBLON *et al.* 1996), it has to be admitted that the second Aurignacian occupation occurred around 32,000 BP. In the Schwallenbach sequence, humic horizon IV-1, dated 31,680 \pm 290 (GrA-6899) with no human occupation traces, lies in a stratigraphic position identical to that of horizon C4 in Willendorf. This lateral expansion of a paleosol demonstrates the climatic significance of the positive oscillation named "Schwallenbach II Interstadial" (HAESAERTS *et al.* 1996), having the same age as the second Aurignacian occupation in Willendorf II.

Contrary to the preceding horizon, humic horizon C2, which contains evidences of the first Gravettian occupation (cultural layer 5), clearly appears as solifluated, which could possibly explain the difference between the dates n° 24 and 25, whose large reliability margins broadly cover one another. A contamination of the charcoal by means of rootlet traces can explain the updating n° 23 by AMS. The date n° 24 (GrN-11193 : 30,500 + 900/-800) is considered to be the most reliable one for it comes from an important cluster preserved with pellets of reddened loam in association with artifacts from cultural layer 5 (HAESAERTS 1990a).

In the Schwallenbach sequence, an equivalent humic horizon (III-1) without artifacts lies in the same stratigraphic position. It was dated 29,530 (GrA-5219), which demonstrates the climatic dimension of the humic horizon preserved in both sites. This horizon results therefore from a climatic improvement named "Schwallenbach III Interstadial" which can be ascribed to the period between 30,500 and 29,500.

A small charcoal cluster associated with secondary concentrations of artifacts within subunit C1 appeared well-integrated into the sedimentation of the loess that deposited subsequently to the solifluction in C2. Its ¹⁴C age (date 21 : GrN-17804 : 28,560 ± 520) slots perfectly into the preceding chronological sequence.

Unit B (Upper Pleniglacial)

The base of this unit (B4) is complex for it consists of a superimposition of light-shaded yellow loam with grey solifluted loamy lobes reworked in the upper part of subunit C1. A charcoal concentration collected in the grey loam provided 4 dates distributed into 2 age classes around 27,500 and 26,500. The oldest ages relate probably to charcoal pieces from unit C1, which are integrated into the solifluction lobes at the bottom of unit B. On the other hand, the youngest ages would result from a different pollution by rootlets. Consequently, the deferrification that affects the top of C1 would be subsequent to 27,500 BP. The direct association between subunit B4 and cultural layer 6, mentioned in this position by FELGENHAUER (1956-59), could not be observed on the 1993 section.

Within the middle part of the B loess unit, the thin *in situ* humic horizon B2 contained a major concentration of charcoal

preserved in a hearth-like structure corresponding to cultural layer 8. The radiometric results form a very coherent system of cross-datings obtained both on charcoal (n° 9, 10, 11, 14) and on high quality bone (n° 12 and 13), which are concentrated between 25,800 and 25,200 BP. A slight updating affects the AMS date n°9, undoubtedly by contamination. Consequently, the Gravettian occupation (cultural layer 8) and the thin humiferous horizon (B2) belong to the same time period.

Concerning the famous Upper Gravettian layer 9 which was no more present on top of the 1993 section, two large bones from this layer preserved in the Naturhistorisches Museum Wien were submitted by us to dating and provided consistent ¹⁴C ages close to 25,000 BP (DAMBLON *et al.* 1996, HAESAERTS *et al.* 1996). As BAYER (1930) clearly situated the position of the Venus in the B1 loess, its age should be intermediate between 25,500 and 25,000 BP.

Consequently, the isolated charcoal fragments collected by us in the same position in B1 appear clearly updated by contamination (AMS 5, 6, 7), as it is also the case for the small pieces of charcoal taken in B3 below cultural layer 8 and AMS dated around 23,990 BP.

Pedology	Schwallenbach Sediment subunits	Willendorf II Sediment subunits	Willendorf II Cult. layers	Willendorf II Industry	Probable time limits	Interstadials
loess	I-1	B1	KS9	Gravettian	24,900 - 24,370	-
humiferous horizon	I-1	B2	KS8	Gravettian	25,800 - 25,200	(Pavlov II)
loess	I-2	B4	KS6 ?	Gravettian	26,500 - 26,100	(Dolni Vestonice)
bleached loess	II-1	C1	-	-	± 28,600	-
humiferous horizon	III-1	C2	KS5	Gravettian	30,500 - 29,500	Schwallenbach III
humiferous horizon	IV-1	C4	KS4	Aurignacian	32,100 - 31,200	Schwallenbach II
humiferous horizon	V-1	C8	KS3	Aurignacian	38,900 - 37,900	Schwallenbach I
brownish loam	V	D	-	-	± 42,000	Willendorf

Table 2: Possible time range concerning the human occupations or some climatic oscillations recorded at Willendorf II and Schwallenbach.

As a conclusion, the combined sequence of Willendorf II and Schwallenbach allows us to recognize an exceptional succession of climatic episodes including no less than 5 interstadial phases, whose chronological ranges are proposed in Table 2.

3.1.2. Grubgraben

The site of Grubgraben to the north-east of Krems is particularly interesting as the local loessic sequence (Fig. P.H. report), comprising 5 successive Epigravettian occupation layers (AL5-AL1), prolongs upwards the Willendorf II and Schwallenbach sequences thanks to the Stratzing deposits. It represents one of the rare loessic accumulations of the second half of the Upper Pleniglacial in Central Europe (HAESAERTS 1990c).

In the absence of charcoal, 8 radiocarbon datings were performed on bones extracted from 4 occupation layers (AL4-AL1) that successively encompass the period between 19,000 and 16,800 BP (HAESAERTS 1990c, DAMBLON *et al.* 1996). Given the variability of the ages for layer AL4, a new dating was realized on a large horse bone that provided the age $19,270 \pm 80$ (GrN-21790) for the internal collagen extract (DAMBLON *et al.* 1996).

The whole AL4-AL1 archaeological complex is included in a pack of loessic sediments (LP1 to LP3) enclosing several humic horizons (HH1, HH2) or of surface stabilization (bottom of LP2, top of LP2). The humic HH1-HH2 complex corresponds to at least one climatic improvement, enabling the development of a herbaceous vegetation preceding the maximal glacial deterioration (HAESAERTS 1990c).

3.2. Czechia

3.2.1. The Upper Palaeolithic sites : Dolni Vestonice, Pavlov and Stranska Skala

The site of Dolni Vestonice, just like those of Pavlov and Milovice which are the continuation of the first one, extends over several kilometres at the bottom of Mount Pavlov on the right bank of the River Dije in the south-eastern part of the Czech Republic. They rank among the most prestigious Upper Palaeolithic settlements in all Central Europe. In Dolni Vestonice, the multiple

stations are gathered in two main concentrations named Dolni Vestonice I and II respectively, distributed midway between the villages of Pavlov and Dolni Vestonice. The first concentration comprehending stations A to D is the most famous one and was excavated by B. Klima in the fifties (KLIMA 1963), while the Dolni Vestonice II concentration located just above the brickyard near the village was excavated from 1985 on following the construction of a dam on the River Dije (SVOBODA 1991, KLIMA 1995).

At Dolni Vestonice and Pavlov all the archaeological layers, the W 2/3 Soil and the Upper Pleniglacial loessic cover are included into the complex of solifluated loams affected by G1 Gley (KLIMA 1963).

All the dates published for Dolni Vestonice and related sites are presented, discussed and selected in DAMBLON *et al.* (1996). The dates can be divided into three groups according to their stratigraphic position. The first set of dates comes from the main cultural layer which is distributed into several sites (Dolni Vestonice I, II, III and also Pavlov I). The second set of dates comes from the samples taken in the loess deposit below the cultural layer but not connected to the archaeological finds. The last group of dates relates to the so-called W 2/3 brown paleosol (Fig. 4).

The first group of dates

The main cultural layer provided some 35 dates among which 18 dates from Dolni Vestonice II and I and 6 dates from Pavlov I can be kept in for a safe chronological setting of the main occupation between 27,500 and 25,500 BP. The other dates are discarded for various reasons (DAMBLON *et al.* 1996).

At Dolni Vestonice II, the datings can be gathered into two groups : the first set of dates between $\pm 27,600$ and $\pm 26,500$ corresponds to occupations associated with a slightly humic horizon ascribable to a climatic improvement named "**Dolni Vestonice Interstadial**". The triple burial is situated just in the middle of the occupation phase (Fig. 4 n° 12, GrN-14831 : $26,640 \pm 110$) (KLIMA 1995).

The second set between $\pm 26,500$ and $\pm 25,500$ seems to be associated with occupation layers within the solifluated loess, as it is

CZECHIA: Chronostratigraphy and chronology

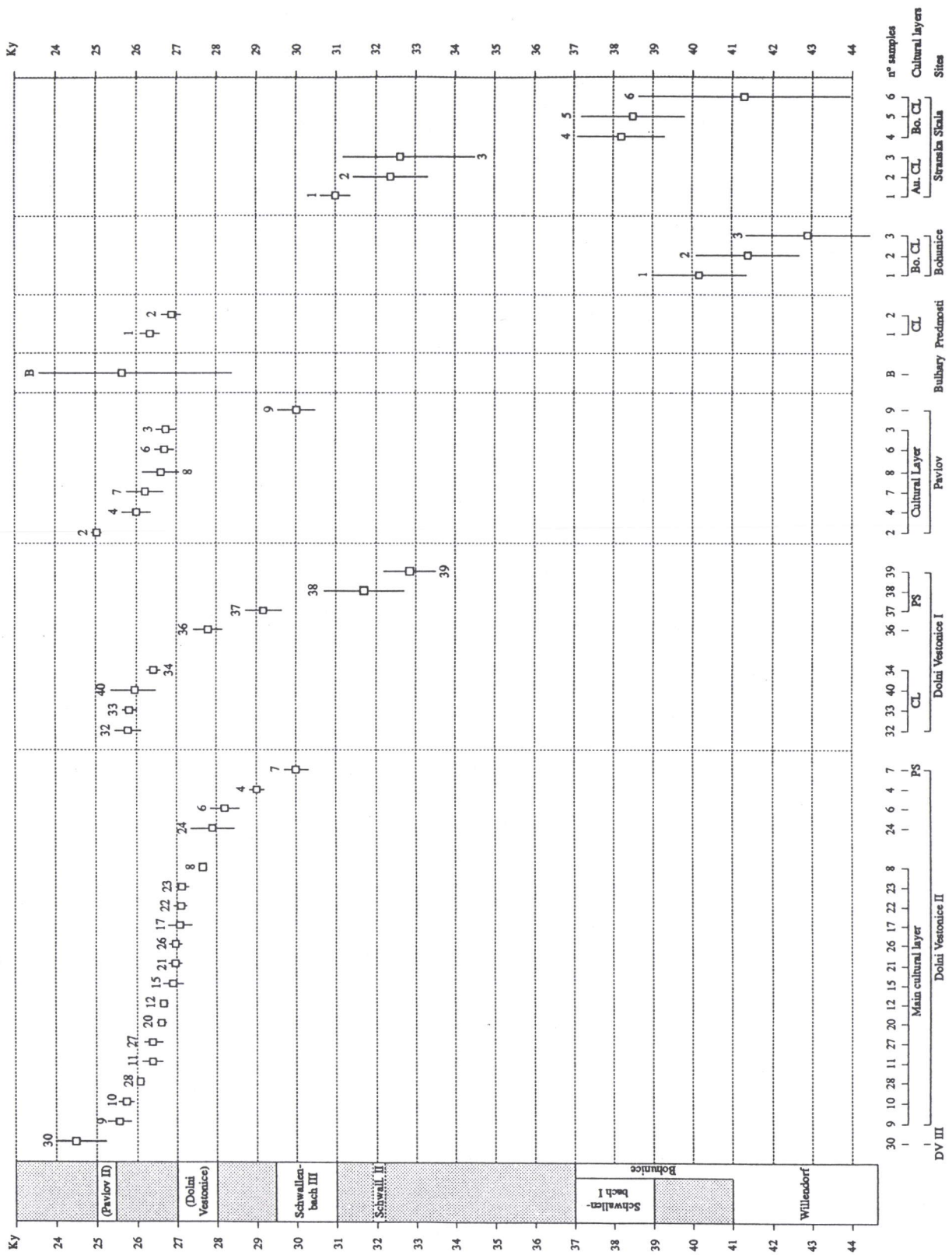


Figure 4: Czechia. Chronostratigraphy and chronology of selected sites. Legend: see fig. 2; PS: palaeosol, CL: cultural layer, Bo: Bohunician, Au: Aurignacian, Gr: Gravettian.

the case for the high-position Gravettian occupations (concentrations C and D) of Dolni Vestonice I and Pavlov I, also dated between 26,500 and 25,500.

The second group of dates

Three dates around 28,000 BP are related to samples (Fig. 4 : n° 6 & 24 at DV II, n° 36 at DV I) collected below the main cultural layers in Dolni Vestonice II and Dolni Vestonice I but not connected to archaeological finds.

Finally, the association of the main cultural layer with a humic horizon at Dolni Vestonice II and the distribution of the ^{14}C ages strongly suggest that the Gravettians settled during an interstadial (named here **Dolni Vestonice Interstadial** between $\pm 28,000$ and $\pm 27,000$ BP) and subsisted through the next stadial up to about 25,500 BP (burial DV XVI) as proposed by SVOBODA (1991).

The third group of dates

The W 2/3 brown paleosol has given various more or less coherent dates comprised between 23,850 and 29,000 BP (n° 7 & 4 at DV II; n° 39, 38, 37 at DV I; n° 9 at Pavlov I where the date $30,010 \pm 460$ BP (KN-286? : 28,060 BC) was obtained from the brown soil below the cultural layer). This suggests that paleosol W 2/3 could result from the superimposition effect of two climatic improvements corresponding to the Schwallenbach II and III Interstadials.

A similar brown humiferous paleosol containing Aurignacian layers is also recorded at Stranska Skala with three dates between $32,600 +1700/-1400$ (GrN-16918, n° 3) and $30,980 \pm 360$ (GrN-12605, n° 1). The dating of this paleosol leads to make once again the correspondence with the successive Schwallenbach II and III Interstadials. The correlation with the subunits C2 (cultural layer 5) and C4 (cultural layer 4) of Willendorf II seems obvious.

3.2.2. The archaic Upper Palaeolithic sites : Bohunice and Stranska Skala

In these two sites, located in the suburbs of Brno, some industries called Bohunician occur underneath and within a brown paleosol with carbonated horizon named "Bohunice Soil". At Bohunice, the

charcoal associated with the industry present underneath the soil was dated between $\pm 43,000$ and $40,000$. The same case occurs at Stranska Skala IIIa-4 which provided the date 41,300. On the other hand, the Bohunician occupation in the upper part of the soil was dated between 38,500 and 38,200. This soil lies under the humiferous horizon, dated 32,600 and 30,980 respectively.

Consequently, the Bohunician industry appears to cross the Willendorf Interstadial up to the Schwallenbach I Interstadial between $\pm 43,000$ and $38,000$ BP, but new datings are needed to increase the accuracy of the results. As for the Bohunician Soil, it seems rather contemporaneous of 38,000 BP and thus corresponds to the Schwallenbach I Interstadial.

In conclusion, despite the remarkable archaeological interest of the Pavlovian sites, the chronology of the Moravian loess deposits is hampered by the absence of a continuous sequence safely datable by ^{14}C . Nevertheless a set of 3 paleosols could be dated. The dating of the W 2/3 paleosol between $\pm 33,000$ and $30,000$ BP could be the result of a double palaeopedogenesis during the Schwallenbach II and III Interstadials successively, just like the dating of the Bohunice Soil could represent a superimposition of two successive pedogeneses during the Willendorf and Schwallenbach I Interstadials.

Finally, in the present state of the question, the loess sequences of Moravia give evidence for 1) a humiferous horizon dated around 27,000 BP at Dolni Vestonice resulting from an interstadial named "Dolni Vestonice Interstadial"; 2) the Würm 2/3 Soil which is dated between 32,600 and 29,900 BP and should correspond to the Schwallenbach II and Schwallenbach III Interstadials; 3) the Bohunice soil posterior to 42,000 should be ascribed to the successive Willendorf and Schwallenbach I Interstadials.

3.3. The Prut Basin in Romania and the site of Mitoc Malu Galben

The Upper Palaeolithic site of Mitoc Malu Galben (CHIRICA 1984, 1989), located on the west bank of the River Prut (north-east of Romania) is made of an impressive loess deposit on the Prut second terrace. It contains a large number of Aurignacian and Gravettian

occupation layers excavated by V. Chirica (Archaeology Institute of Iasi) and by the University of Liège team. The collaboration with the present authors has led to a new approach of the site.

A succession of 13 sedimentary cycles was recognized in a 14 m cover, each one of them being made of a loess accumulation phase followed by a stabilization stage with incipient soil formation.

In the lower half of the sequence (cycles 13 to 8), the incipient soils at the end of each cycle are mainly brown humic horizons related to short warmings while in the upper half of the sequence, most of them are of tundra-gley type associated with permafrost.

In this connection, the positioning of the various archaeological and palaeontological occurrences was reconstructed in the new stratigraphic sequence. It was therefore possible to identify some seven preferential occupation levels with three Aurignacian levels linked to the sedimentary cycles 12 to 8 and four Gravettian levels within the cycles 7 to 2.

Presently, 60 radiocarbon dates are available for Mitoc Malu Galben among which 14 dates were performed as part of the Sc-004 project. For various reasons, such as doubtful stratigraphic attribution and bad quality of the charcoal samples, some 21 dates were discarded (DAMBLON *et al.* 1996).

Fig. 5 sets out the 39 dates of normal quality for which no negative argument was found concerning their origin. The results are presented by sedimentary cycle after restitution in the general stratigraphy. However, some dates are still unacceptable because of their position clearly outside the chronological trend of sedimentation. This is the case for the isolated date n°10 from cycle 5a that is separated from the upper group of dates for unknown reasons and must be rejected. The date n° 9 might be a little older too. In contrast, and regarding dates n° 42 and 47, the sample n° 54 is updated, especially if we consider that n° 55 was obtained from the same Gravettian charcoal accumulation. The most probable cause is a contamination underscored by the AMS measurement. On the other hand, dates n° 29 (perhaps 28) and 32 appear much too old with regard to the trend of the other dates in the same sedimentary

cycles. Some mistakes in the stratigraphic attributions are suspected. Finally, we can discard dates n° 34, 35 and 37 which are clearly too young in such a context of sedimentation. These samples clearly appear updated by contamination. Thus, at the term of our selection, only 31 dates over 60 are held as reasonably reliable.

Given what precedes, the radiocarbon dates retained present a coherent distribution within the whole sequence from $\pm 33,000$ up to $\pm 20,000$ BP and allow us to precise the chronology of the recorded pedostratigraphic events (Fig. 5). More particularly, the humic horizons of the sequence are assimilated to positive climatic oscillations referred by the MG label (Malu Galben) followed by the number of the corresponding cycle. These horizons occur preferably in the lower half of the sequence and can be positioned respectively around 32,000 (MG 12), 30,000 (MG 10) and 28-27,000 (MG 9 and 8). A last humic horizon is present higher in the sequence, in the upper part of cycle 4, probably around 23,500 BP. As for the tundra gleys, associated with permafrost episodes, they are also distributed in the upper half of the sequence, between 26,000 and 20,000 BP.

If one realizes that the Mitoc Malu Galben site, with its large number of more or less individualized layers, was almost continuously occupied by Aurignacian and Gravettian populations, an attempt to define the occupation time limits appears to be very vain - as suggested by HONEA (1993, 1994) and by OTTE *et al.* (1996). Nevertheless, the distribution of the accurate dates with regard to stratigraphy leads to put in evidence three main ensembles of workshop phases. The first one of Aurignacian culture (cycles 12a - 9) would have lasted from about 33,000 up to 29,500 BP. Around 27,500 BP (cycle 8b) began the last Aurignacian occupation directly relayed by the Gravettian settlement in cycle 7b or maybe 8b already. This long exploitation phase could have lasted up to about 23,000 BP (cycle 4a) but we should distinguish a subdivision between a former period from around 26,500 up to 25,000 (cycles 7b-6b) and a later one from 24,000 up to 23,000 (cycles 5b-4).

3.4. The Dniester Basin in Moldavia and the site of Cosautsi

Cosautsi is an Upper Palaeolithic multilayered site on the west

MITOC MALU GALBEN : chronostratigraphy and chronology

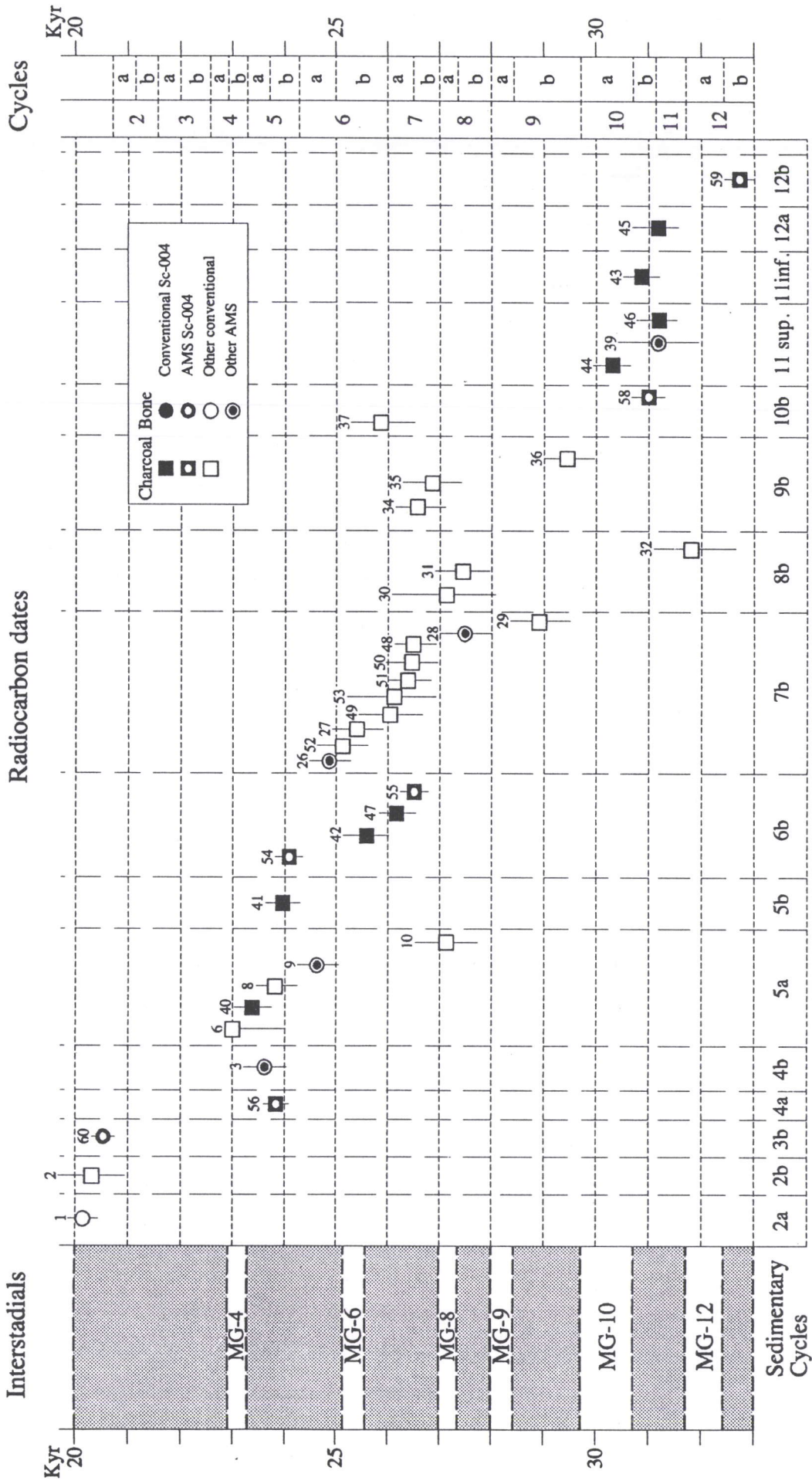


Figure 5 : Mitoc Malu Galben. Chronostratigraphy and chronology of the site. The central column gives the chronological distribution of the ¹⁴C dates by sedimentary cycle and by cultural layer. Symbols: black: Sc-004/GrN & GrA dates; white: other previous dates. Right column: local chronostratigraphy; left column: chronostratigraphy for Central Europe. Both left and right subdivisions are interpretative.

bank of the Dniester in north-eastern Moldavia. Its main interest lies firstly in a \pm 18 m loess sequence encompassing the whole Upper Pleniglacial and the Lateglacial periods. Secondly, it lies in some 21 occupation layers found in the loess sequence with numerous Upper Palaeolithic encampments remarkably documented with abundant stone and bone industry, mostly associated with multiple hearths rich in charcoal. All the 21 occupation layers have been precisely located in the stratigraphy

(Fig. 6).

Some 31 new Sc-004 datings on charcoal and on bone were presented and discussed by DAMBLON *et al.* (1996), by OTTE *et al.* (1996) and by HAESAERTS *et al.* (1997). The following three results can be added for cultural layer 5 at the top of sedimentary subcycle VI-1 and for the upper sedimentary subcycles III-3 and III-2 (Tab. 3).

n°	Sedim. cycle/ (cult. layer)	n° date	¹⁴ C age	Material
49	III-2	GrA-9565	13,380 \pm 80	Picea charcoal
48	III-3	GrN-23582	13,660 \pm 140	horse bone
47	(5)	GrN-23581	18,150 \pm 100	Picea charcoal

Table 3 : Cosautsi new ¹⁴C dates.

The stratigraphic distribution of the dates on charcoal is given in Fig. 6. Together with the 15 previous datings (SVEZHENTSEV 1993, SVEZHENTSEV & POPOV 1993), some 46 ¹⁴C dates are presently available to frame 17 cultural layers and 18 sedimentary subcycles. Altogether, and contrary to the previous dates, the distribution of the new Sc-004 datings on charcoal and bone is drawing up an evolution in agreement with stratigraphy between sedimentary subcycles VI-4 (GrN-21795 : 19,410 \pm 100) and III-2 (GrA-9565 : 13,380 \pm 80).

As pointed out in a previous paper (HAESAERTS *et al.* 1997), the distribution line of the Oxford dates on bones and the trend of the Groningen dates on charcoal from layer 9 up to layer 2c show an evident parallelism (Fig. 7). For instance, the new dating of cultural layer 5 has given GrN-23581 : 18,150 \pm 100 on charcoal and OxA-5247 : 18,140 \pm 200 on bone. However, the distribution of the dates on bones appears a little more flattened while the dates on charcoal are more spread out, especially near the top and the bottom layers. Moreover, the datings on charcoal have given some older results than on bone, as observed in the same layer 5 where the AMS dating on charcoal provided GrA-5218 : 18,260 \pm 210. The younger

OxA-5247 date on bone is probably due to interactions between collagen and humics while traces of rootlets could have induced a slight updating of GrN-23581.

The most salient feature from the data is the evidence of two sets of dates, the former being associated with the lower layers 9 to 6b between 19,400 and 19,200 BP and the latter linked to layers 5 to 1b between 18,260 and 17,620 both indicating a high sedimentation rate. On the contrary, a break appears between layers 5 and 6b, suggesting a slowing down of the sedimentation rate at the top of the sedimentary cycle VI-2 which resulted in the development of the humiferous horizon. On the other hand, the chalky layers do not appear as important time lags but rather as very sudden flow injections coming from next hill.

Altogether, the distribution of the dates frames a relatively short period of *ca.* 3300 years for accumulation of >6 m of loess, loam and sand, but evidently with a varying deposition rate. Thus, the 2390 yr. difference between subcycles IV-1 and III-3 also points to a sedimentation break at the turn of the Upper Pleniglacial and the Lateglacial.

The new succession of dates from the loessic sequence at Cosautsi allows the chronological establishment of two main

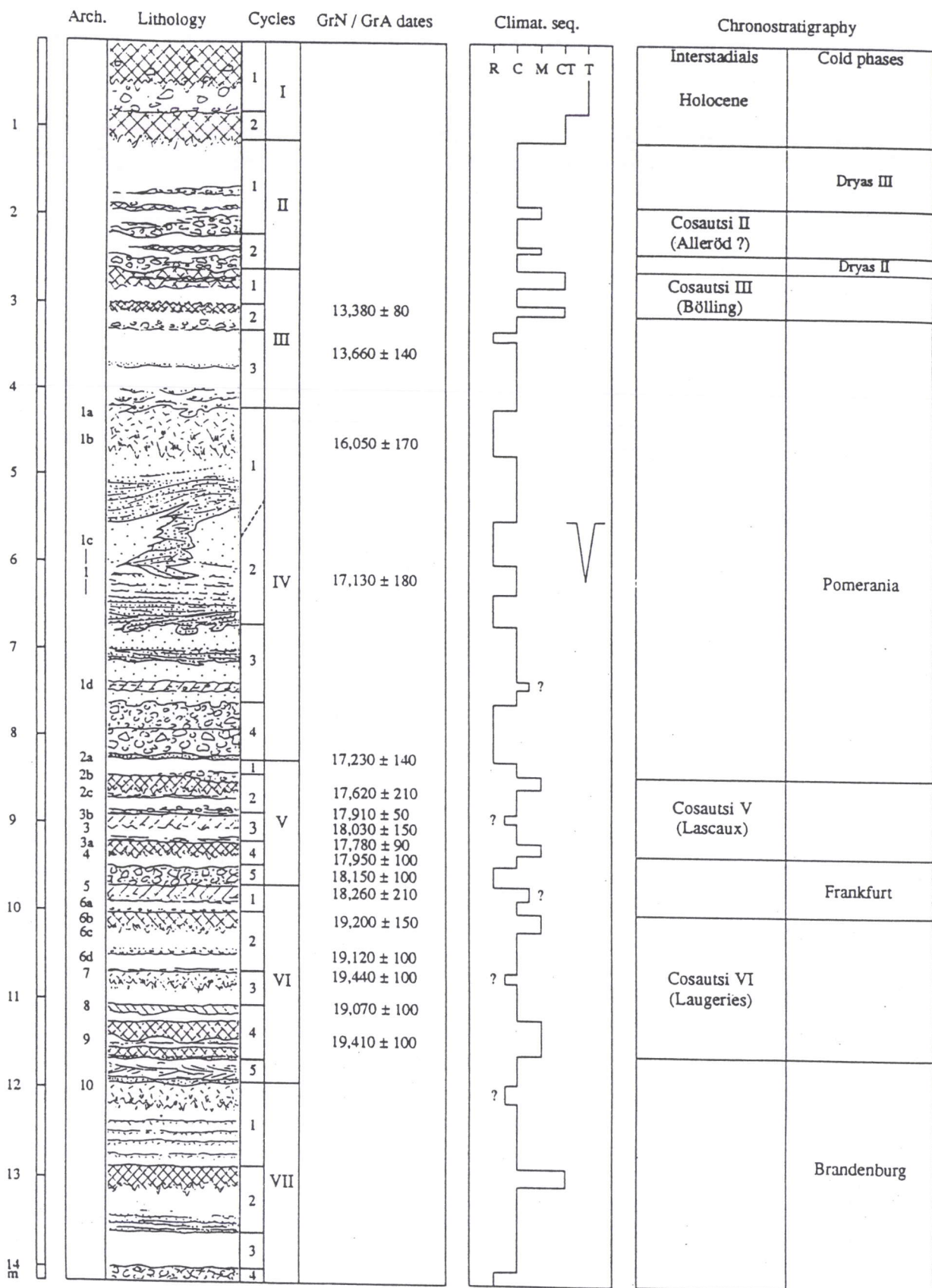


Figure 6 : Cosautsi. Stratigraphic column, radiocarbon dates and palaeoclimatic interpretation (R : rigorous; C : cold; M : cold medium; CT : cold temperate; T : temperate).

COSAUTSI : Chronostratigraphy

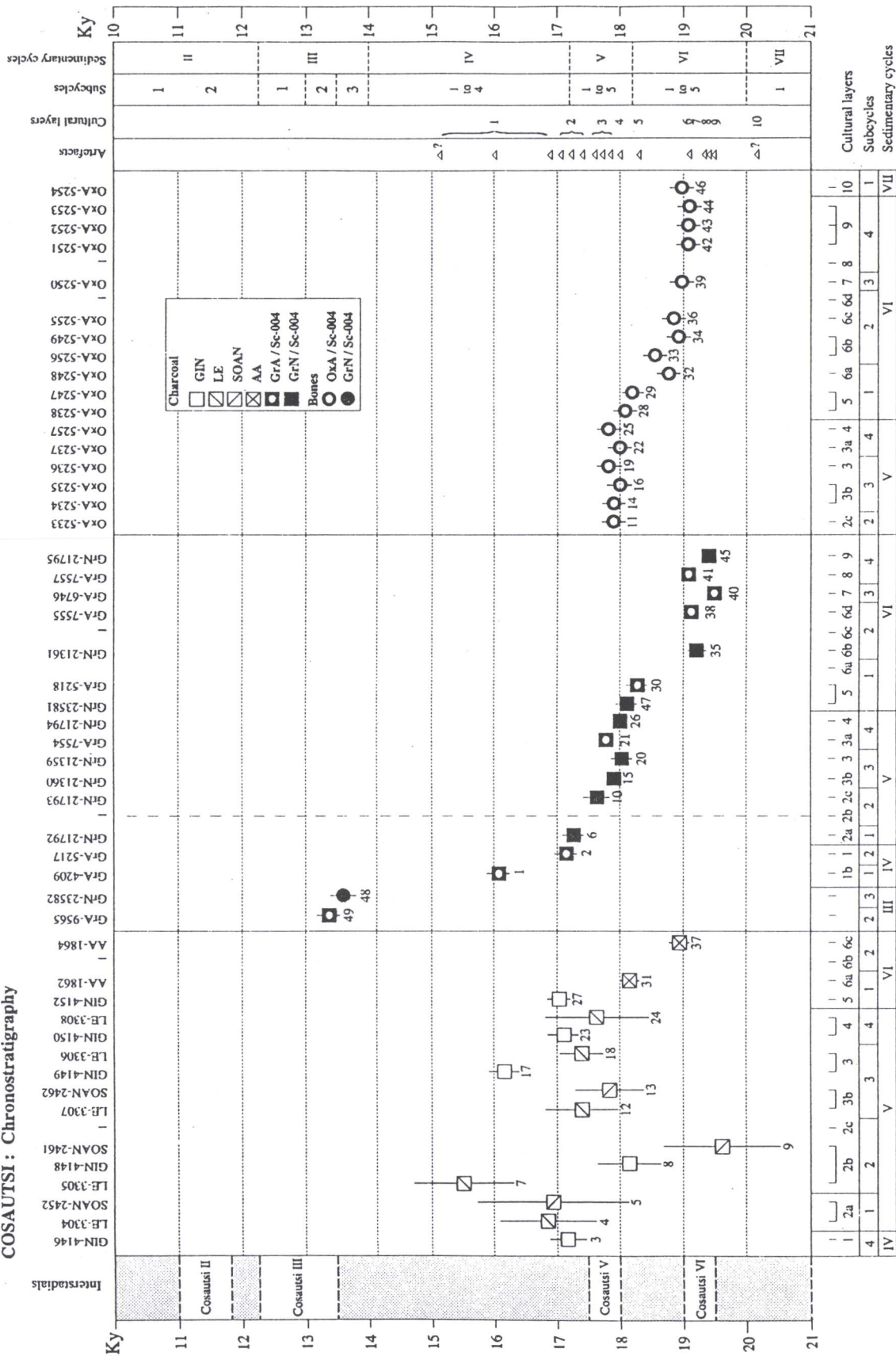


Figure 7 : Cosautsi. Chronostratigraphy and chronology of the site. The central columns give the chronological distribution of the ¹⁴C dates by sedimentary cycle and by cultural layer. Symbols: black: Sc-004/GrN and OxA dates; white: other previous dates. Right column: local chronostratigraphy; left column: chronostratigraphy for Central Europe. Both left and right subdivisions are interpretative.

climatic improvements indicated by sets of humic horizons. The first set is dated from *ca.* 19,500 up to 19,000 BP. This episode is named here "**Cosautsi VI Interstadial**". The second is limited from 18,000 up to *ca.* 17,500 BP and is named "**Cosautsi V Interstadial**". Most likely this pair of positive climatic variations is similar to the Laugerie and Lascaux Interstadials recognized by LEROI-GOURHAN (1968) in south-western France and is recorded by palynology in the sequence of Maisières-Canal in central Belgium (HAESAERTS & BASTIN 1977, HAESAERTS & DE HEINZELIN 1979).

The new radiocarbon dates also provide information on the last Upper Pleniglacial sedimentation phase, which seems to have begun *ca.* 17,200-17,100 BP. Nearly 4 m of sandy loess was deposited during cycle IV and between 17,200 and 16,000 BP. The evidence for active permafrost in this part of the sequence points to very cold climatic conditions that form a sharp contrast with the uppermost loess series, including at least 4 humus-bearing horizons ascribed to the Lateglacial. Moreover, the ^{14}C age of $13,660 \pm 140$ (GrN-23582) on a bone collected just underneath the upper humus-bearing complex strongly suggests that these horizons should be ascribed to the Lateglacial period. That is confirmed by the date GrA-9565: $13,380 \pm 80$ on *Picea* charcoal extracted from this humic horizon III-2. Therefore this last horizon is related to a climatic improvement named locally "**Cosautsi III Interstadial**" which should correspond to the Bølling oscillation.

The double series of dates also gives crucial information on human occupations in Cosautsi, which was frequented by hunters during >3000 yr., from *ca.* 19,500 up to 16,000. The strategic position of the site, certainly facing a ford at the outlet of a lateral valley and near a spring, may explain the recurrence of the Upper Gravettian settlements at Cosautsi.

4. DISCUSSION

The radiometric data achieved as part of the Sc-004 project, aiming to reconstruct a chronology of the loess deposits in Central Europe, point up the importance of the care taken while working on the field and

in the laboratory in order to get reliable dates. The method consisted systematically into 1) seeking the most complete possible loessic sequences containing enough palaeontological evidences for dating, 2) carrying out the detailed stratigraphic study of each sequence (see P.H., this vol.), 3) controlling the precise stratigraphic origin of the samples, 4) giving the preference to charcoal and if needed to dense bone fragments as material to be dated, 5) identifying the taxa in order to control the homogeneity of the material for dating, discarding the material considered to be intrusive and selecting certain taxa, 6) eradicating the contaminant rootlets, 7) cleaning, sorting out and selecting the best pieces for the radiometric measurements, and also 8) performing cross-datings on charcoal and bone as often as possible (Willendorf II cultural layer 8, Mitoc Malu Galben, Cosautsi).

Despite all the precautions taken, it is clear that a total eradication of all the contaminants cannot be guaranteed each time. Eventually, the accuracy of the radiometric dates is checked on the basis of the coherence of the successive sets of dates within an undisturbed stratigraphic sequence. The graphic presentation of the distribution of the dates in the stratigraphic sequence allows a better study of the trends and the spotting out of the anomalies, generally downdatings of various origins. Most often rootlet intrusions into charcoal fragments are responsible of younger dates, but the fixing of recent humates or carbonates also occurs frequently, as it seems to be the case in the upper part of the Mitoc sequence.

Bioturbations could also be another source of contamination inducing updatings as possibly in Willendorf II unit C2 (cultural layer 5) or in Mitoc sed. cycle 10b. An accidental supply of charcoal from younger Pleistocene horizons is most probable whilst updatings engendered by the intrusion of Holocene material would certainly have resulted in much younger dates than those observed. Such contaminations are also suspected where root castings and krotovinas are present. Still, the intrusive phenomenon should not be overestimated when the results appear accurate and coherent.

Besides, some downdatings could theoretically have been caused by the residuality of old bone pieces potentially

preserved in the loess and brought to light by run-off, deflation and solifluction processes as suggested by SOFFER (1985). However such processes could never be demonstrated for the sites under study.

In the present state of the work, the AMS results are somewhat younger than conventional ones. This is exemplified in the Willendorf sequence where repeated datings have given younger AMS (sed. units C8 - cultural layer 3 : n° 26 and 27; B4 - c.l. 6 : n° 20a and 20b; B2 - c.l. 8 : n° 15 and 16), exactly as in the Pavlov I NW site (VAN DER PLICHT 1997). As clearly shown in the Gravettian accumulation of burnt material in square M5 (sed. cycle 6b) at Mitoc Malu Galben, a pair of AMS datings has produced two very different results (n° 54 and 55) of which the latter appears in better concordance with two conventional dates at least. The only explanation for such a distortion could be the extreme sensitivity of the AMS to the least contamination especially for low ^{14}C content material.

Moreover some discrepancies between conventional and AMS results seem linked more to geological and biological factors than to laboratory handling and measurements. This was observed for example in layer CL8 of Willendorf II. On the contrary, discordances in both conventional and AMS from different laboratories are clearly suggested for some sites like Mitoc and Cosautsi. For various reasons some ancient dates from Russian laboratories do not show a high degree of accuracy and precision. In the absence of systematic cross-datings and interdatations on the same material, we cannot estimate the real role taken by sampling, laboratory handling, chemical treatment and ^{14}C measurements in the distortion of the results.

5. CONCLUSIONS

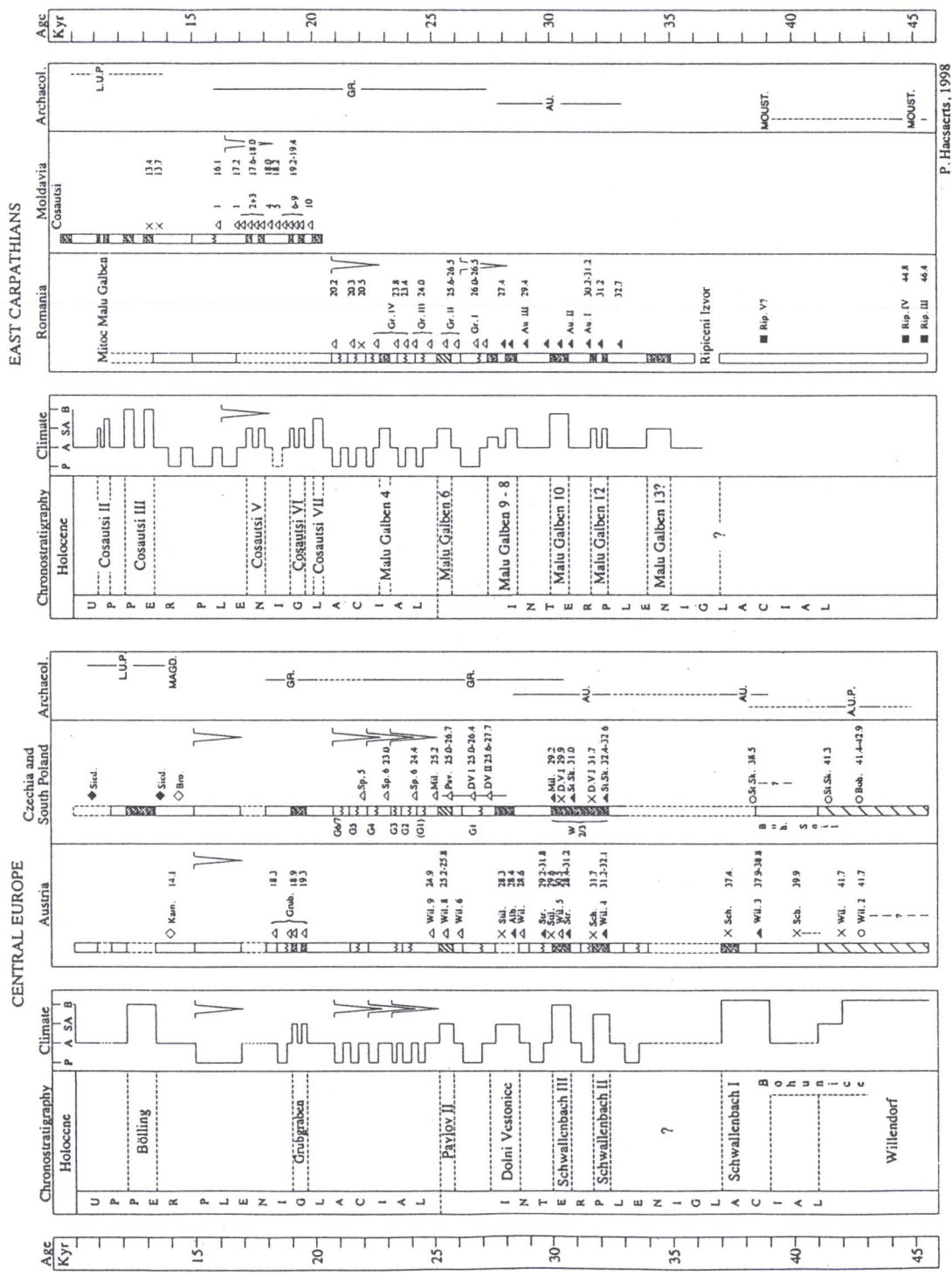
It has to be stressed that the basis of the site's chronology rests on the stratigraphy of the loessic accumulations and paleosols to which a climatic significance is ascribed. It is the succession of these recorded climatic events within a same sequence that grants value to the ^{14}C dates obtained from different sedimentary layers. Principally, the link with archaeological layers is not always considered as obvious and must be permanently controlled.

Some problems remain open, notably concerning the factors inducing up- or down datings. It seems that we have reached the limits of charcoal cleaning and purification. The contamination factor appears as the main obstacle to achieve better AMS datings and only chemical treatments to remove all traces of soft tissues could improve the accuracy of the results. The datings on bones have given satisfactory results even if some doubt may subsist about the possible use of old bones by the Palaeolithics. Of course it is necessary to insist on the importance of having a permanent control of the accuracy and precision of the dates useful for chronostratigraphy because each result only takes sense in coherent sequences and cannot be used roughly for archaeological treatments.

The comparison of safe radiometric results with stratigraphic, palaeopedological and palaeobotanical data leads to a better understanding of the environment's and the human behaviour's evolution during the transitional period between the Neandertal and Modern Man. In particular, the new radiometric results have revealed interesting points about the chronological position of some climatic oscillations between 40,000 and 15,000 BP and Pleniglacial periods. In this way a succession of interstadial phases characterized by humiferous horizons and named Willendorf, Schwallenbach I, Schwallenbach II, Schwallenbach III is recognized in Central Europe, the last one being equivalent to the so-called Stillfried B Interstadial.

Concerning the Upper Pleniglacial, the period between 25,000 and 20,000 BP appears to have been characterized by a succession of cold to very cold phases with permafrost and ice-wedges. On the contrary, two sets of poorly expressed interstadial episodes (Cosautsi VI and Cosautsi V) seem to have occurred around 19,000 and 17,000 BP while the Lateglacial seems to be expressed in a humic complex formed around 13,000 BP (Cosautsi III).

In the present state of the work, more detailed conclusions on the chronology of the loess deposits and human occupations in the Great European Plain would be premature. Nonetheless the amount of new data allows original perspectives on the chronostratigraphy of the area (Fig. 8), on the



P. Haesaerts, 1998

Fig. 8 : Distribution of the palaeolithic assemblages and 14C dates (Groningen dates) with regard to the chronostratigraphic sequences of Central Europe. Shortenings. Climatic environment. P: permafrost; A: arctic; SA: subarctic; B: boreal. Sites: Austria: Kam: Kamegg; Grub.: Grubgraben; Will.: Willendorf; Stil.: Stillfried; Alb.: Albernorf; Str.: Stratzing; Sch.: Schwallenbach; Poland: Sied.: Siedlnica; Bro.: Brozkvinia; Sp.: Spadzista; Czechia: Mil.: Milovice; Pav.: Pavlov; D.V.: Dolni Vestonice; St. Sk.: Stranska Skala; Boh.: Bohunice. Archaeology: LUP: Late Upper Palaeolithic; MAGD.: Magdalenian; GR.: Gravettian; AU: Aurignacian; AUP: Archaic Upper Palaeolithic; MOUST: Moustesian.

palaeoenvironment of Upper Palaeolithic populations and on the climatic evolution having affected the continent. More particularly, chronological data obtained from material dated in loess deposits will help us to put forward correlations between continental, oceanic and polar ice records.

Together with the available published data and some 30 other new Sc-004 datings from other sites, these data will contribute to establish a firm data base on which the chronology of loess deposits, of climatic variations and of human occupations from Western Europe to Central Asia should be worked out.

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