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The Magdalenian upper horizon of Goyet and the late Upper Palaeolithic recolonisation of the Belgian Ardennes

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Abstract

Three bones of muskox, horse and cave hyaena of the first, Magdalenian horizon from the cave of Goyet (Belgium) were dated by Accelerator Mass Spectrometry (AMS); the ones of the first two species show traces of human manipulation. The bones belong to the Dupont collections, curated at the royal Belgian Institute for Natural Sciences. The AMS results on the bones of horse and muskox suggest that the Magdalenian occupations at Goyet (horizon 1) date from the very end of the Pleniglacial or the beginning of the Late Glacial (Oldest Dryas). The cave hyaena bone is much older. The dates and faunal assemblage are compared with those from other Belgian Magdalenian sites. The main Magdalenian colonisation of the region can be dated between *ca* 15200 cal yr BP and *ca* 14800 cal yr BP.

Key-words: Dupont collections, Late Glacial, mammals, Belgium, AMS dates

Résumé

Trois ossements de boeuf musqué, cheval et hyène des cavernes de la première couche magdalénienne de Goyet (Belgique) ont été datées par la méthode "Accelerator Mass Spectrometry" (AMS); les os des deux premières espèces ont des traces de manipulation humaine. Les ossements appartiennent aux collections de Dupont, conservées à l'Institut royal des Sciences Naturelles de Belgique. Les resultats AMS des ossements de cheval et boeuf musqué suggèrent que les occupations magdaléniennes datent de la fin du Pléniglaciaire ou du début du Tardiglaciaire (Dryas le plus ancien). L'os de l'hyène des cavernes est beaucoup plus ancien. Les dates et l'assemblage faunistique sont comparés avec ceux d'autres sites magdaléniens belges. La colonisation magdalénienne la plus importante peut être datée entre *ca* 15200 cal yr BP et *ca* 14800 cal yr BP.

Mots-clefs: collections de Dupont, Tardiglaciaire, mammifères, Belgique, datations AMS

Introduction

The village of Goyet (Namur Province, Belgium) is situated at the confluence of two small rivers: the Samson and the Strud. Three km downstream, the Samson joins the river Meuse. The Carboniferous limestone cliff at Goyet on the right bank of the Samson harbours a series of caves, which were excavated by DUPONT in 1868 and 1869 (DUPONT, 1869a, b, 1873a; VAN DEN BROECK *et al.*, 1910). Later, more excavations were carried out by scientists of different institutions and laymen (OTTE, 1979), but only the material collected by Dupont will be treated here. The third cave, as named by Dupont, was the most important one, from the archaeological as well as from the palaeontological point of view. Its entrance is located 15 m above the Samson. The cave runs very deep and is connected with the other caves by transverse galleries (DUPONT, 1873a; RAHIR, 1908; ULRIX-CLOSSET, 1975). DUPONT (*ibid.*) describes three parts: chamber A, B and C (Fig. 1). Chamber A is about 25 m deep and 5 m wide, chamber B is connected to A by a small gallery situated deeper and has a depth of circa 10 m, C is much further down from the cave entrance. DUPONT (*ibid.*) gives a list of mammals present; in his unpublished notes of 1905 muskox is one of the species added. Since this arctic animal has strict ecological requirements and was clearly utilised by prehistoric people, one bone with cut marks was dated in order to better place the mammal assemblage in the late glacial chronology. Muskox occurs in other late glacial Belgian cave sites as well, and the dates and the faunal assemblages from these and other Magdalenian sites are compared. An extensive historic overview of the research at the Goyet caves is given in ULRIX-CLOSSET (1975), OTTE (1979) and DEWEZ (1987).

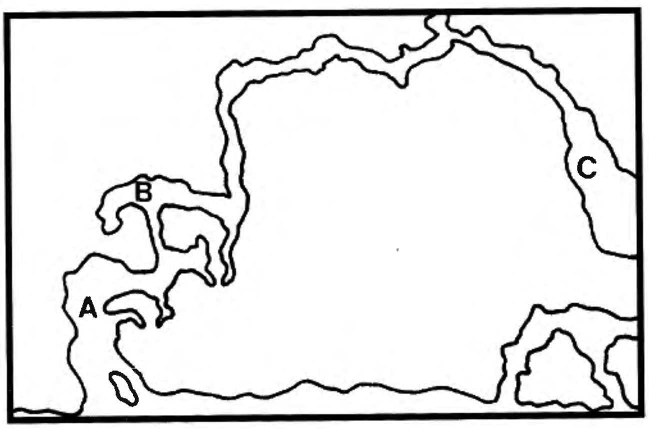

Fig. 1 — Map of chambers A, B and C of the third cave of Goyet, redrawn from DUPONT (1873a, fig. 12)

Stratigraphy and archaeology

DUPONT (1873a) describes five successive bone containing horizons (''niveaux ossifères'') inside the third cave of Goyet. The bones occur in clayey-sandy loam which he calls ''limon fluvial''. DUPONT (1873b) also mentions the presence of successive stalagmite floors in the loam. According to DUPONT (1873a) the bone horizons are separated by sterile ''alluvial'' sediments. Since the bones are in the same state of preservation, Dupont excludes a remixing of the material: ''Ils (=the bones) ont tous le même degré de conservation; ce qui entraîne une semblable quantité de gélatine, par conséquent leur introduction dans le même état et l'evidence qu'aucun, n'étant d'une époque plus ancienne que les autres dans le même niveau ossifère, n'a pas été amené dans la caverne par un remaniement quelconque.'' (DUPONT 1873c, 222-223). All bone horizons in the third cave correspond to the ''Age du Mammouth'' (DUPONT, 1873a), characterised by the presence of woolly mammoth, woolly rhinoceros, cave bear, cave hyaena and cave lion. DUPONT (*ibid.*) distinguishes three types of bone accumulations inside the cave. The first category concerns carnivores such as lion, bear and hyaena which used the cave as den and all their skeletal remains are well represented in the darker parts of the cave, sometimes in anatomical connection. The second type is caused by hyaenas, which introduced body parts of their prey, mostly herbivores, in the cave; the bones of these animals are often gnawed. Finally, a lot of broken bones are often associated with bone and stone artefacts and would belong to animals butchered elsewhere and partly brought to the cave by prehistoric people. They are found in the better illuminated part of the cave. The bones often carry traces of human manipulation (DUPONT, *ibid.*).

Most of the remains left by prehistoric man of horizon 1 (''premier niveau ossifère'') were recovered in chamber A (DUPONT, 1873a). All the typical ''Age du mammouth'' mammals were found with the exception of cave lion and DUPONT (*ibid.*) as well as RUTOT (1910) place the horizon in the ''Age du Mammouth''. They consider this bone bearing deposit to be older than the Magdalenian ones of Chaleux and Furfooz, which date from the ''Age du Renne'' and are characterised by the absence of woolly rhinoceros, cave bear, cave hyaena and cave lion.

According to DEWEZ (1987), the first (upper) bone horizon at Goyet contains in general archaeological material dating from the late Upper Palaeolithic and represents one or several Magdalenian occupations. There are fewer borers present than at Chaleux, but rectilinear backed bladelets occur in fairly high number. Some are very typical for Goyet and can probably be assigned to the same occupation. The relative high frequency of bone needles in several stages of production and bone needle production wastes point to the importance of the Magdalenian occupations. The famous bone harpoon (DUPONT, 1873a) was discovered in this horizon. Other spectacular finds include a necklace composed of 26 teeth and two bone fragments, a necklace composed of 180 fossil moulds of *Turitella* shells, a ''bâton de commandement'', several notched bones, ivory pendants and fragments of ochre (DUPONT, *ibid.*; VAN WETTER, 1920; DEWEZ, 1987).

The second bone level at Goyet contains artefacts also attributed to the Magdelenian (DEWEZ, *ibid.*). TWIESSELMANN (1951) and DELPORTE (1956) assign the artefacts from the third level to the Mousterian and the Aurignacian. According to OTTE (1979) mixing of the archaeological material of several horizons occurred and each horizon could contain material from several successive occupations.

The fourth and fifth horizon contain bone assemblages, dominated by carnivore remains; artefacts are lacking. The fourth horizon was found at the back of chamber A, in chamber B and was the only horizon present in chamber C. The fifth horizon is only well developed in chamber B (DUPONT, 1873a).

The Dupont collections

The material from Goyet, stored since its excavation by Dupont in the Royal Belgian Institute for Natural Sciences, was subdivided in an archaeological-anthropological and a palaeontological collection, which were curated respectively in the Section of Prehistory-Anthropology and the Section of Fossil Vertebrates. The palaeontological collections were organised in museum trays at the beginning of the century and displayed in the then newly opened museum hall (the so called Iguanodon hall or Janlet I hall). The texts accompanying these trays are signed by Dupont. These unpublished notes contain more detailed information than his publications on the Goyet caves, which are more than thirty years older. According to RUTOT (1910), Dupont completely reviewed his excavations from the Belgian cave sites for the display in the new museum hall.

Each museum tray carries a different number, each bone in the tray has the same number written in red ink and a label with the identification of the bone as to species and skeletal element. Sometimes there is also a second label referring to the cave and horizon. The text of each tray gives the provenance (cave and horizon), notes on the material, the number labelled on the bones, the date and the initials of Dupont. The note details the material present and points out whether butchering or carnivore traces are present. It is not clear if the numbering of the trays corresponds with a grouping by species, excavation date, distribution, or is arbitrary, but in general, the trays are sorted by species. Duponts identifications are very accurate. At a later date, the display trays were removed to the store rooms of the Section of Fossil Vertebrates. Not all the material collected by Dupont was put on display. Unidentified fragments and what Dupont called ''collections d'étude'' were preserved in boxes. These bones generally do not have a number, but a label indicating the cave and bone horizon.

Since the work of Dupont, the palaeontological collections from Goyet have never been studied. They are relatively complete: Dupont and his team not only gathered and curated well preserved complete bones, but the broken unidentified specimens as well. The palaeontological collections look, apart from a small percentage of intrusive, Holocene material, homogeneous and contrary to the published opinion that "aucun enseignement valable ne peut donc être tiré de l'étude des restes osseux récoltés à Goyet" (ULRIX-CLOSSET, 1975, p. 74) deserve study. The association of mammalian species as mentioned by DUPONT (1873a), which according to DEWEZ (1987) and ULRIX-CLOSSET (1975) are abnormal, are perfectly compatible with the late glacial context, if we disregard the few intrusive elements.

The history of the archaeological collections is a very different one. Initially, the archaeological material was also put on exhibit. Later, the archaeological specimens were removed from the display trays and apparently reorganised. Most bone elements from this collection have numbers written in red or black ink, the ones in black ink are according to the technician P. Cornand, working in Section of Prehistory-Anthropology, written by his predecessor P. Timperman. Some bones carry two different numbers, one in red and one in black ink. The numbers in red ink are the original ones also seen in the palaeontological collections. Hand-written attributions to bone level in black ink also are indicated on the worked bones; sometimes, the number of the level was later corrected. Some numbers are associated with two bone levels. All this gives the impression that the archaeological collections of Goyet have been partly mixed. The archaeological studies undertaken so far are essentially typological analyses (ULRIX-CLOSSET, 1975; OTTE, 1979; DEWEZ, 1987).

First bone horizon: fauna

Bones from horizon 1 were found mostly in chamber A (DUPONT, 1873a). This horizon yielded not only remains from herbivores and carnivores, but also a few human bones. In his note of July 1905 on this collection, Dupont lists some species, not mentioned in his previous publications, namely muskox, arctic hare, bison and roe deer.

Table 1 gives the Number of Identified SPecimens (NISP) per species, the estimated Minimum Number of Individuals (MNI) per species, the Number of Unidentified SPecimens (NUSP) and the MNI given by DUPONT (1873a). In general, the MNI calculated by DUPONT (*ibid.*) and the newly established ones are very comparable, indicating similar computing techniques and that few material is missing. The number of fragments of unidentified specimens is also presented in Table 1 as well as the remains that are considered to derive from domesticated and/or Holocene mammals (GERMONPRE, 1996, in prep.).

The identifiable component of the Dupont collection of the first bone horizon amounts to about 1264 bones (63%) of the total collection found back. The three better represented species are the horse *Equus arcelini*, the reindeer *Rangifer tarandus* and the cave bear *Ursus spelaeus* (Table 1). According to EISENMANN (1990), Pleistocene European horses younger than 15 000 y BP belong to the *Equus arcelini* group. This horse is characterised by relative big teeth with long protocones especially on the premolars. The teeth of the Magdalenian horse from

Table 1 — Late Pleistocene mammals and Holocene intrusives of horizon 1 from Goyet, cave 3 (NISP: Number Identified Specimens, MNI: Minimum Number of Individuals, NUSP: Number of Unidentified Specimens, indet: indeterminata)

Goyet 3, horizon 1	NISP	MNI	DUPONT (1873) MNI
Lagomorpha			
Lepus timidus / L. capensis	3	1	2
Carnivora			
Canis lupus	18	2	2
Alopex lagopus	9	3	2
Vulpes vulpes	11	3	3
Alopex/Vulpes	28	4	
Ursus arctos	5	1	1
Ursus spelaeus	193	14	9
Mustela putorius	1	1	1
Meles meles	7	2	2
Crocuta crocuta spelaea	42	5	5
Proboscidea			
Mammuthus primigenius	40	2	3
Perissodactyla			
Equus arcelini	533	13	14
Coelodonta antiquitatis	43	3	2
Artiodactyla			
Cervus elaphus	13	2	1
Capreolus capreolus	6	2	
Rangifer tarandus	250	39	11
Bison priscus / Bos primigenius	33	2	2
Ovibos moschatus	4	1	
Rupicapra rupicapra	3	1	1
Capra ibex	9	2	
Bovidae	13		
Total NISP / MNI	1264	103	61
	NUSP		
indet	727		
TOTAL NISP+ NUSP	1991		
Holocene intrusives	**NISP**	**MNI**	
Oryctolagus cuniculus	1	1	
Bos primigenius f. taurus *	1	1	
Ovis ammon f. aries / *Capra hircus* f. aegragus **	8	1	
Sus scrofa f. domestica ***	18	3	2

*: 1 NISP: subadult
**: 3 NISP: juveniles or subadults
***: 14 NISP: juveniles or subadults

Table 2 — AMS dates from Goyet, cave 3, horizon 1

Lab code	Site	Material	Species	Element	Human manipulation	AMS date (y BP)	cal (1σ) y BP
GrA-3238	Goyet 3, horizon 1	single bone	*Ovibos moschatus*	phalanx	cut marks	12620 +/- 90	15030 - 14620
GrA-3237	Goyet 3, horizon 1	single bone	*Equus arcelini*	vertebra	cut marks and ochre	12770 +/- 90	15270 - 14850
GrA-3239	Goyet 3, horizon 1	single bone	*Crocuta crocuta*	calcaneum	without	27230 +/- 260	-

Goyet compare well with those of *Equus arcelini* from Le Quéroy (EISENMANN, ibid. table 2). Unfortunately, no complete metapodials were recovered. The few measurements available give an estimate of a mean metacarpus length of about 220 mm, which points to a withers height of 135 cm.

The mammals present indicate an open steppe-like environment, the so-called steppe-tundra (GITERMAN *et al.*, 1982; HIBBERT, 1982) or Mammoth Steppe (GUTHRIE 1982, 1990). According to VERESHCHAGIN & BARYSHNIKOV (1991) the "mammoth fauna" existed in a continental dry climate having cold winters and short, hot summers in open steppe, meadow-steppe and tundra-steppe landscapes. Leaf-bearing and coniferous gallery forests might be found along river valleys. Ibex and chamois, while occurring in small numbers, reflect the hilly character of the region. Muskox points out the dry climate.

Dating of the first bone horizon

Table 2 gives the uncalibrated Accelerator Mass Spectrometry (AMS) dates on three bones from horizon 1 and, for the two youngest dates, their calibrated ranges with one standard deviation, calculated with the OxCal 2.18 programme (BRONK RAMSEY, 1994, 1995). Other dates from Belgian Magdalenian sites can be compared in Tables 3 and 4, calibration was made with the same programme.

The dates of the humanly modified bones of muskox (12620 +/- 90 yr BP) and horse (12770 +/- 90 yr BP) from Goyet (horizon 1) fit very well with the Upper Magdalenian age of the human occupations of this level. Muskox was found in other Belgian cave sites (Chaleux, Bois Laiterie, Trou Reuviau) (Fig. 2) and it is also known from the late Magdalenian levels of the site of Burghöhle (Germany) attributed to the Older Dryas. During the climatic warming of the Late Glacial the range of this arctic mammal retreated north-eastwards. It survived in northern Siberia at least until *ca* 2900 yr BP (STUART, 1991). Remains of horse, the dominant species in most Magdalenian assemblages of the Ardennes, have been dated at several sites (Table 3). Horse is recorded in Britain until about 10000 years ago (HOUSLEY,1991). CLASON (1986) mentions the presence of a wild horse at the site of Swifterbant, the Netherlands, dated at *ca* 5400 yr BP. Also at Spiennes (Belgium) Holocene wild horse remains were recovered. The site belongs to the Michelsberg culture and was dated 5420 +/-170 BP (charcoal) (GAUTIER & BIONDI, 1993). An AMS date of a cut phalanx of woolly rhinoceros from Goyet is currently underway. DUPONT (1873a) does not mention this animal in other late glacial settlements of the Ardennes, but it is also present at Verlaine (DESTINEZ & MOREELS, 1887-1888; CHARLES, 1994). Late glacial AMS dates for this mammal are lacking in Britain (HOUSLEY, *ibid.*). According to STUART (*ibid.*) woolly rhino survived until at least *ca* 12500 yr BP in western Europe and apparently had gone by *ca* 12000 yr BP. However, it was relatively scarce during the Late Glacial and probably its population density was reduced prior to extinction (STUART, *ibid.*).

The origin of the cave hyaena calcaneum (27230 +/- 260 yr BP) must be different from the two other dated bones that are much younger. It is possible that is was found further back in the cave, maybe in chamber B, and does not belong to horizon 1 of chamber A, or maybe some mixing of the bones occurred in the course of the taphonomic history of the cave, during the excavation or while curating the material. At Creswell Crags (England) remains of spotted hyaena have an AMS date of 24000 +/- 260 yr BP (HEDGES *et al.*, 1996). STUART (*ibid.*) mentions its presence in Magdalenian horizons of south-western France. Late glacial AMS dates for hyaena are, however, lacking (HOUSLEY, 1991).

Subdivision of the Late Glacial

The late glacial subdivisions based on plant remains from bog deposits in Denmark were established by JESSEN (1935). He distinguishes three zones: zone I: Older Dryas period, zone II: Alleröd period, zone III: Younger Dryas period. IVERSEN (1942, 1954) recognises five periods of development of the late glacial vegetation of Denmark: the two latter zones of JESSEN and the first zone which he further subdivides in zone Ia: Oldest Dryas (treeless tundra), zone Ib: Bölling (park-tundra with tree birches), zone Ic: Older Dryas (treeless tundra). VAN DER HAMMEN (1952) considers the rise of *Artemisia* to be a more or less synchronous event in north-western Europe indicating the first clear rise in temperature and demonstrating the beginning of the Late Glacial in north-western Europe. The zone between this rise and the immigration of the first large birches corresponds to the Oldest Dryas (Ia), when the vegetation is still treeless. The Bölling environment consists of a park landscape with birches (*Betula*) but without pines (*Pinus*). Later, VAN DER HAMMEN (1957) extends the Bölling period downwards to the beginning of the *Artemisia* rise and introduced the term Bölling *sensu lato* for this extended unit. The lower part of the Bölling s.l. corresponds to the pre-Bölling s.s. (or Earliest Dryas). The Bölling s.s. starts at 12400 +/- 100 yr BP. As to the limit between the Pleniglacial and the

Table 3 — AMS dates from Belgian Magdalenian cave sites (dates on intrusive, Holocene material are not included)

Lab code	Site	Material	Species *	Element	Human manipulation	AMS date (yr BP)	cal (1σ) yr BP	Reference
OxA-4199	Trou da Somme	single antler	cervid	antler	artefact (sagaie)	12240 +/- 130	14520 - 14080	HEDGES *et al*. (1994)
OxA-4195	Furfooz: Trou des Nutons	single bone	*Equus ferus*	phalanx	cut marks	12630 +/- 140	15100 - 14550	HEDGES *et al*. (1994)
GX-204331	Bois Laiterie					12625 +/- 117	15070 - 14600	OTTE *et al*. (1995)
OxA-4198	Bois Laiterie	single antler	cervid	antler	artefact (sagaie)	12660 +/- 140	15150 - 14600	HEDGES *et al.* (1994)
GX-204341	Bois Laiterie					12665 +/- 96	15110 - 14680	OTTE *et al*. (1995)
OxA-3632	Trou de Chaleux	single bone	*Equus ferus*	cuneiform	cut marks	12790 +/- 100	15310 - 14870	HEDGES *et al*. (1993)
OxA-4192	Trou de Chaleux	single bone	*Ovibos moschatus*	phalanx	cut marks	12860 +/- 140	15500 - 14900	HEDGES *et al*. (1994)
OxA-3633	Trou de Chaleux	single bone	*Equus ferus*	cuneiform	cut marks	12880 +/- 100	15450 - 15020	HEDGES *et al*. (1993)
OxA-4197	Furfooz, Trou du Frontal	single bone	*Equus ferus*	metacarpus	cut marks	12800 +/- 130	15360 - 14850	HEDGES *et al*. (1994)
OxA-4014	Verlaine,Trou des Nutons	single bone	*Equus ferus*	pisiform	cut marks	12870 +/- 110	15450 - 14990	HEDGES *et al.* (1994)
OxA-3635	Bomal, Grotte du Coléoptère	single bone	*Equus ferus*	phalanx	cut marks	12870 +/- 95	15430 - 15010	HEDGES *et al*. (1993)
OxA-4200	Vaucelles, Trou des Blaireaux	single bone	*Equus ferus*	ulna	cut marks?	13330 +/- 160	16200 - 15650	HEDGES *et al*. (1994)

* species identification as in the reference

Table 4 — Conventional ^{14}C dates from Belgian Magdalenian cave sites (dates on intrusive, Holocene material are not included)

Lab code	Site	Material	Species *	Element	Human manipulation	^{14}C date (yr BP)	cal (1σ) yr BP	Reference
Lv-686	Bomal, Grotte du Coléoptère	single bone	-	-	-	12150 +/- 150	14420 - 13950	GILOT (1984)
Lv-717	Bomal, Grotte du Coléoptère	single bone	*Rangifer tarandus*	-	-	12400 +/- 110	14730 - 14310	GILOT (1984)
Lv-1568	Trou de Chaleux	bone splinters	-	-	-	12370 +/- 170	14750 - 14200	OTTE & TEHEUX (1986)
Lv-1136	Trou de Chaleux	bone splinters	-	-	cut marks	12710 +/- 150	15250 - 14650	GILOT (1984)
Lv-1569	Trou de Chaleux	bone splinters	-	-	-	12990 +/- 140	15700 - 15150	OTTE & TEHEUX (1986)
Lv-1434D	Vaucelles, Trou des Blaireaux	bone splinters**	-	-	-	13730 +/- 400	17050 - 15850	BELLIER & CATTELAIN (1986)
Lv-1314	Vaucelles, Trou des Blaireaux	single antler	*Rangifer tarandus*	antler	-	13790 +/- 150	16750 - 16320	GILOT (1984)
Lv-1309D	Vaucelles, Trou des Blaireaux	single antler	*Rangifer tarandus*	antler	-	13850 +/- 335	17050 - 16150	GILOT (1984)
Lv-1749	Furfooz, Trou du Frontal			-		12950 +/- 170	15650 - 15000	LEOTARD (1993)
Lv-1750	Furfooz, Trou du Frontal			-		13130 +/- 170	15950 - 15300	LEOTARD (1993)
Lv-1582	Trou Walou	bone splinters	-	-	-	13030 +/- 140	15750 - 15200	DEWEZ (1992)
Lv-1593	Trou Walou	bone splinters	-	-	-	13120 +/- 190	15950 - 15250	DEWEZ (1992)
Lv-690	Verlaine, Trou des Nutons	bone splinters	-	-	-	13780 +/- 220	16850 - 16200	GILOT (1984)

* species identification as in reference
** pers.com. Cattelain

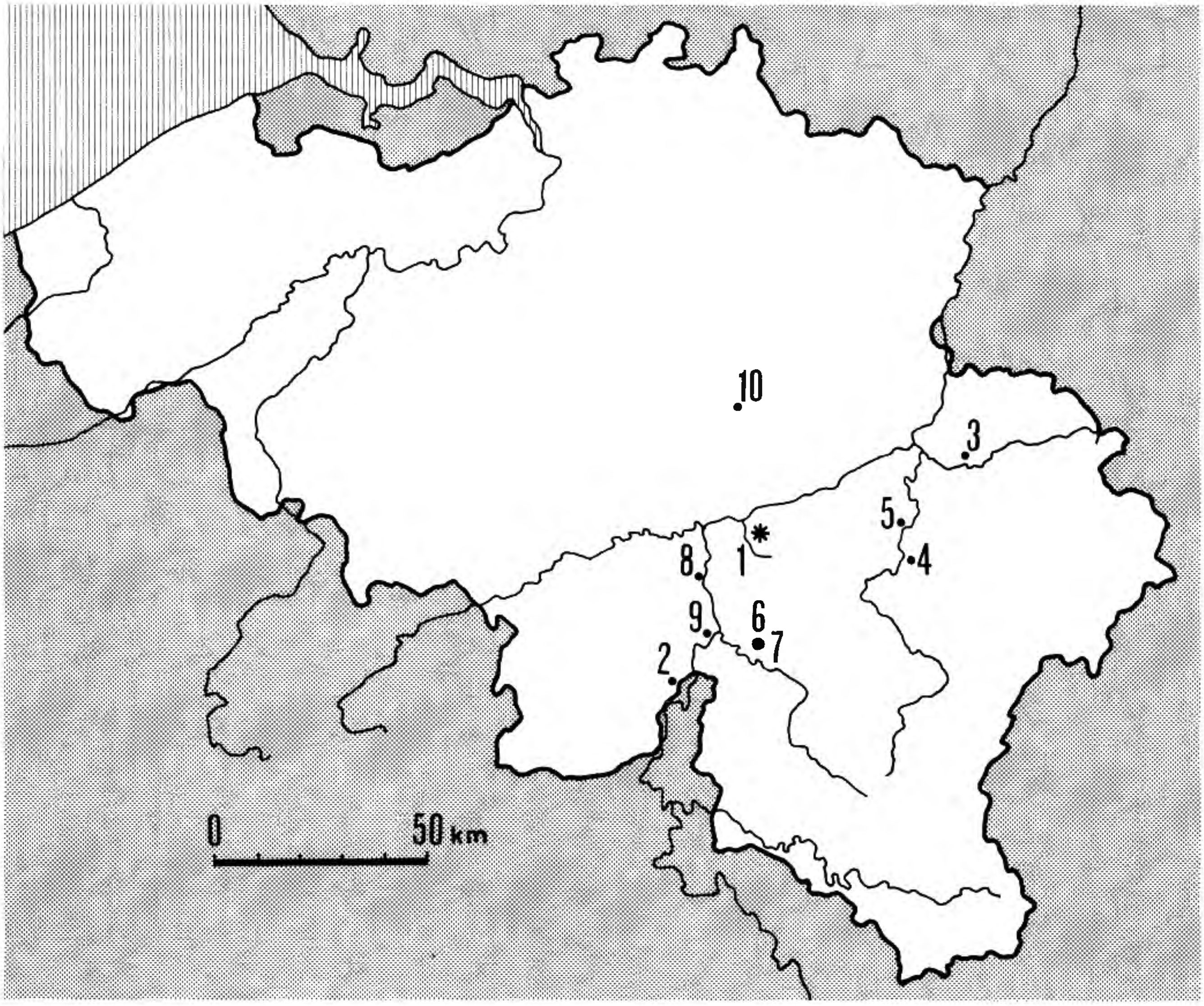

Fig. 2 — Location of the Belgian Magdalenian sites discussed in the text: 1: Goyet, 2: Vaucelles, 3: Trou Walou, 4: Bomal, grotte du Coléoptère, 5: Verlaine, 6 & 7: Furfooz and Chaleux, 8: Bois Laiterie, 9: Trou da Somme, 10: Orp

Bölling s.l., it would be dated shortly after 12900 yr BP (Van Geel *et al.*, 1989). According to Mangerud *et al.* (1974), the Bölling Chronozone comprises the Oldest Dryas and the Bölling. These authors propose 13000 yr BP for the lower boundary of the Bölling Chronozone, which is also the lower limit of the Late Glacial. They place the limit between the Oldest Dryas and the Bölling at 12300 yr BP. Lang (1994) subdivides the Late Glacial and the Holocene in simple chronostratigraphic units with a general time span of 1000 or 500 years. His age attribution is for the time being based on uncalibrated ^{14}C dates; the rounded conventional years can in the future be replaced by calibrated dates. The beginning of the Late Glacial (and of the Oldest Dryas) is placed at 15000 yr BP, the Oldest Dryas - Bölling boundary at 13000 yr BP (Table 5).

The Greenland ice core records show an increase in global atmospheric methane concentrations at about 16000 calendar years BP (cal yr BP) pointing to an early beginning of environmental change in the tropics. The first abrupt warming event over the North Atlantic occurred 14500 +/- 150 calendar years ago, at the Bölling transition. This event also affected the monsoonal climate as recorded in deep-sea sediments from the Arabian Sea (Sirocko *et al.*, 1996). According to Stuiver *et al.* (1995), the major pollen zone boundaries in Europe can be equated with $\delta^{18}O$ changes in the Greenland ice cores. They consider that the major Greenlandic and European climatic events have a zero time lag and that northwestern Europe, the North Atlantic and Greenland have climatic interdependence. The Oldest Dryas - Bölling boundary, based on ice layer counts of the Greenland Ice Sheet Projects 2 (GISP2) ice core, is placed at *ca.* 14670 cal yr BP, when a first clear signal in the ice core isotopic records would indicate that the climate over Greenland had shifted out of its glacial mode. The glacial branched jet stream system is at the beginning of the

Table 5 — Comparison of late glacial subdivisions

	VAN DER HAMMEN *et al.* (1967)	MANGERUD *et al.* (1974)	VAN GEEL *et al.* (1989)	LANG (1994)	JOHNSEN *et al.* (1992)	STUIVER *et al.* (1995)
Holocene						
	10000 yr BP	10000 yr BP	10150 +/- 50 yr BP	10000 yr BP	11550 cal yr BP	11650 cal yr BP
Late Glacial	Late Dryas	Younger Dryas Chronozone	Late Dryas	Younger Dryas Chronozone	Younger Dryas	Younger Dryas
	11000 yr BP	11000 yr BP	10950 +/- 50 yr BP	11000 yr BP	12700 cal yr BP	12890 cal yr BP
	Alleröd	Alleröd Chronozone	Alleröd	Alleröd Chronozone	Alleröd	Alleröd
	11800 yr BP	11800 yr BP	11900 +/- 50 yr BP	12000 yr BP		14010 cal yr BP
	Early Dryas	Older Dryas Chronozone	Earlier Dryas	Bölling Chronozone (including Older Dryas)		Older Dryas
	12000 yr BP	12000 yr BP	12150 +/- 100 yr BP			14090 cal yr BP
	Bölling s.s.	Bölling Chronozone / Bölling	Bölling s.l. / Bölling s.s.		Bölling	Bölling
	12400 yr BP	12300 yr BP	12400 +/- 100 yr BP	13000 yr BP	14450 cal yr BP	14670 cal yr BP
		Oldest Dryas	Earliest Dryas (=Pre-Bölling s.s.)	Oldest Dryas Chronozone		Oldest Dryas
		13000 yr BP	12930 +/- 210 yr BP	15000 yr BP		15070 cal yr BP
Pleniglacial						

Bölling replaced in a mere 10 years by a warmer circulation mode. JOHNSEN *et al.* (1992) give an age of 14450 cal yr BP for the lower Bölling boundary, based on a multiparameter analysis of the Summit ice core (Table 5). According to these authors, the interstadials begin abruptly but they terminate gradually or in a stepwise fashion.

How fast the environment in the Ardennes was reacting to the changes at the beginning of the Late Glacial is not well known. Few incontestable pollen diagrams and macrobotanical remains were analysed from the pleni - late glacial transition in this region.

Recently, new excavations were made on the terrace in front of the cave of Chaleux where remains of a Magdalenian occupation were found (OTTE, 1994). However, the archaeological level was perturbated by a partial land slide, plant root actions and clandestine excavations. Macrobotanical samples from a hearth, found on the terrace, were analysed by SCHOCH (1994). They contain temperate taxons such as *Prunus* sp. , *Clematis vitalba* and *Corylus avellana.* According to SCHOCH (*ibid.*), this assemblage cannot be correlated with the Bölling or even the Palaeolithic, but it should result from a contamination with much younger material dating from a warmer period (from Boreal to Recent).

Palynological assemblages were sampled from several levels. The level attributed to the end of the Oldest Dryas, occurring below the Magdalenian horizon, is characterised by a steppic landscape with many Cyperaceae. However, a few pollen indicating a *Quercetum mixtum* with *Quercus, Carpinus, Fraxinus, Corylus* and *Alnus* are explained by NOIREL-SCHUTZ (1994) as indicating refugia near the cave. The palynological assemblages contemporaneous with the Magdalenian industry are, according to NOIREL-SCHUTZ (*ibid.*), distinguished by relative high levels of *Juniperus* and an expansion of thermophilous plants (*Primula, Rosaceae, Geranium t. sanguinem, ...*). The tree vegetation confirms the climatic amelioration and the vegetation cover approaches the ''forest'' stage with a domination of trees of the *Quercetum mixtum* group (*Quercus, Carpinus, Ulmus, Tilia*, etc.). Also according to LEROI-GOURHAN (1992) refugia of thermophilous species forming forest-galleries existed during the Bölling and/or Alleröd in northern France, Belgium and the Rhineland.

It is difficult to accept that typical cold-adapted mammals such as muskox and reindeer in the faunal assemblages go together with the development of a *Quercetum mixtum* at Chaleux. The faunal assemblages must be older, the refugia areas had a very limited extension or the remains of the *Quercetum mixtum* are intrusive, as was proposed by SCHOCH (1994).

The pollen diagrams of Opgrimbie, a site located approximately 80 km north of Goyet, were analysed by PAULISSEN & MUNAUT (1969). Deposits attributed to the Oldest Dryas and Bölling were found. During the Oldest Dryas, the vegetation cover was essentially composed of Gramineae, Cyperaceae, *Salix* and *Betula.* The willows were dwarf or scrub forms. The Bölling is characterised by an expansion of *Betula* and, less well marked, *Pinus.* The abundance of heliophilous species and the moderate AP/T ratio points, just as in the adjacent regions, to a rather open landscape with a range of species already present in the Oldest Dryas, but in which *Betula* becomes established combined with a discrete expansion of *Pinus;* the latter would be due to long distant transport from more southern regions.

The analysis of the Winge valley, a tributary of the Dyle (Brabant Province), revealed that during the Oldest Dryas, the steppic landscape was dominated by Poaceae (67.3%) with some steppic plants as *Artemisia* and *Helianthemum.* In the beginning of the Bölling, *Betula* invades the steppe, this corresponds with the first tree migration at the beginning of this interstadial (MUNAUT, 1993).

BASTIN (1980) studied the pollen record at Hinkelsmaar in the Eifel, Germany. The vegetation of the Oldest Dryas is an open one, dominated by Gramineae (48%), Cypereaceae (11%) and *Artemisia* (6%). Among the trees, *Betula* (7.6%) and *Salix* (5.2%) prevail. A large number of heliophilous species is also present as well as xerophilous taxons. The climate can be described as very cold and dry. The Bölling is distinguished by an increase in *Betula* (17.6%) and *Salix* (16.9%), and a decrease in the Gramineae (32%) and Cyperaceae (4.5%). However, *Artemisia* continues its expansion. The vegetation cover remains very open.

The late glacial section at Usselo, the Netherlands, provides many palaeobotanical and palaeozoological data. In the deposits dating from the Earliest Dryas period (=pre-Bölling s.s.) pollen of herbs, mainly of Poaceae and Cyperaceae, are dominant. Pollen of *Artemisia, Salix* and *Helianthemum* are present with a few percentages. The climate is already relatively warm with a mean July temperature similar to the Bölling s.s., but the vegetational development is inhibited by poor soil maturation. The Bölling s.s. is characterised by a rise of the pollen curve of *Betula* and *Juniperus* indicating a more dense vegetation cover than in the preceding period. The shrubby to arborescent birches form an important component of the vegetation (VAN GEEL *et al.*, 1989).

In the Central Massif (France), the discrete presence of *Juniperus* in the open vegetation indicates the end of the Oldest Dryas. In the clear lakes of the Oldest Dryas *Ranunculus* were abundant. At the beginning of the Bölling, the temperature rose and the increase in precipitation amplified sheet flood action, causing turbulences in the lakes which were fatal for the *Ranunculus* (de BEAULIEU *et al.*, 1988).

Not only pollen remains give indications of the palaeoenvironmental changes, but fossil beetles are useful as well. COOPE (1977) describes the Coleoptera present in the late glacial interstadial sediments of Windermere, England. This interstadial corresponds, according to ANDERSEN & BORNS (1994), with the Bölling, Older Dryas and Alleröd. Even at the base of these deposits, a temperate beetle assemblage is already present, which suggest that the initial climatic amelioration must have been sudden and intense. The fauna of these early stages of the Windermere interstadial is associated with herb-dominated pollen assemblages with Gramineae, Cyperaceae and *Rumex* the main groups present. The absence of thermophilous trees at that moment is probably related to the inability of these species to reach the region in the time available. When the forest arrived, the "climatic optimum" had already passed, so only a birch woodland became established (COOPE *et al.*, 1971).

Hydrographical data can also be considered as many small river basins in the lowlands of Belgium and the Netherlands underwent river adjustments at the Oldest Dryas - Bölling transition as an adaptation to increases in water and sediment discharges. The increased discharges are consistent with an improvement of the climate linked with the presence of a non-adapted vegetation, due to the delay of tree migration (CLEVERINGA *et al.,* 1988). High water levels during the Bölling were according to VERBRUGGEN *et al.* (1996) caused by relative low temperatures and increased precipitation.

The micromammals from the cave sites of the Meuse basin in Belgium confirm the foregoing environmental reconstructions. In assemblages of the late Oldest Dryas, arctic lemming prevail. No woodland rodents or insectivores occur. The climate is very cold. The Bölling is characterised by a rapid reduction of lemming and a clear increase in the insectivores as a proof of the relative warming. However, the environment consisted mainly of open biotopes with steppes and grassland (CORDY, 1991).

From the foregoing it is clear that the palaeoenvironment of the Oldest Dryas in the studied regions was an open, steppic landscape with a relative cold and dry climate. Due to the delayed development of wooded vegetation, the environment of the Bölling, although warmer and more humid, remains relatively open with many herbaceous plants.

The presence of real cold-adapted animals at Goyet like the (dated) muskox, reindeer, arctic fox, woolly mammoth and woolly rhinoceros indicates a cold, steppic landscape. Especially muskox has strict ecological requirements. Today, it lives in the arctic tundra where snowfall is limited or where winds blow the vegetation free (BANFIELD, 1974; BOHLKEN, 1986). In the summer the herds live in river valleys, at lake shores and in meadows; during winter time they prefer hilltops, slopes and plateaus. Muskox is very sensitive to a damp environment. Very humid winters with heavy snowfall, rain and ice-cover are catastrophic: ice formation and thick snow cover prevent the muskox to reach its winterfood and the animals can easily catch pneumonia (VIBE, 1967). Its main food consists of grasses, sedges and willows. During the Last Glacial, its occurrence in Belgium is very

Table 6 — Late Pleistocene mammals and Holocene intrusives from Belgian Magdalenian cave sites

	Vaucelles *1*	Bomal *2*	Verlaine *2*	Furfooz Trou du Frontal 2	Chaleux *3*	Goyet *4*	Bois Laiterie *5*	Furfooz Trou des Nutons 2
Rodentia								
Marmotta marmotta	+ ?							
Castor fiber			+	+	+			
Lagomorpha								
Oryctolagus cuniculus			+	+		+	+	
Lepus timidus / L. capensis	+	+	+	+	+	+	+	+
Carnivora								
Canis lupus			+	+	+	+	+	+
Alopex/Vulpes	+	+	+	+	+	+	+	+
Ursus arctos	+		+	+	+	+		+
Ursus spelaeus	+					+	+	
Mustela erminea							+	
Mustela nivalis							+	
Mustela putorius						+	+	
Mustela foina								+
Mustela sp.	+		+	+	+			+
Gulo gulo					+			+
Meles meles	+		+	+	+	+	+	+
Crocuta crocuta spelaea			+		+	+	+	
Felis silvestris							+	
Felis silvestris f. domestica							+	
Felis sp.			+	+	+			+
Lynx lynx							+	
Proboscidea								
Mammuthus primigenius		+	+		+	+		
Perissodactyla								
Equus arcelini/ferus/germanicus	+	+	+	+	+	+	+	+
Equus hydruntinus					+			
Coelodonta antiquitatis			+			+		
Artiodactyla								
Sus scrofa / *Sus scrofa* f. domestica			+	+	+	+	+	+
Cervus elaphus	+	+	+	+	+	+	+	+
Capreolus capreolus				+	+	+		+
Alces alces							+	
Rangifer tarandus	+	+	+	+	+	+	+	+
Bison priscus /Bos primigenius	+					+	+	
Bos primigenius f. taurus						+	+	
Bos sp.			+	+	+			+
Saiga tatarica					+			
Ovibos moschatus					+	+	+	
Rupicapra rupicapra	+ ?				+	+	+	
Capra ibex					+	+	+	
Capra sp.		+			+			
Ovis ammon f. aries / *Capra hircus* f. aegragus			+	+	+	+		+

1: Cattelain (pers. com.)
2: CHARLES (1994)
3: CHARLES (1994), PATOU-MATHIS (1994), own observations
4: own observations
5: Gautier (pers. com.)

rare. Few remains were recovered from the Belgian lowland (GAUTIER, 1976; VANLERBERGHE & GAUTIER, 1980; GERMONPRE, 1993). Several settlements (Goyet, Chaleux, Bois Laiterie, Furfooz: Trou Reuviau) in the Ardennes delivered some muskox material (Table 6), the species ranges from 0.3% NISP (Goyet, horizon 1) to 4% NISP (Chaleux) of the faunal assemblages. At Chaleux, it is even the third best represented species based on MNI, after horse and fox. These figures are higher than in the study of CHARLES (1994: table 3.2) because they also include material from the Dupont collections which was rediscovered recently. Goyet (horizon 1), Chaleux and Bois Laiterie have more or less the same age (Table 1, 2). The latter cave was excavated under the direction of M. Otte and L. Straus. Trou Reuviau is considered by DUPONT (1873) to date from the "Age du Renne", although OTTE (1979), distinguishes three palaeolithic industries (Mousterian, Aurignacian and Perigordian or Magdalenian) in the assemblage. Probably, during the Oldest Dryas the climate was very suitable for muskox. During the Bölling interstadial, although the vegetation was still rather open and included numerous herbaceous plants, humidity and temperature attained higher levels which may have been too high for this arctic mammal.

The Magdalenian in the Ardennes

As known, Palaeolithic people abandoned Northern Europe during the Last Glacial Maximum. According to OTTE (1989), the Magdalenian arrived in Belgium as an established culture at the end of the Oldest Dryas. The typology, technology and raw material of the artefacts point to an affinity with the sites of the Paris Basin. OTTE *et al.* (1994) suggest that a first period of "exploration" happens around 14000 yr BP or even as early as 16000 yr BP (Vaucelles). Later on, several Magdalenian sites (Chaleux, Bois laiterie, ...) were formed during the Bölling and Dryas II (erroneously called Dryas III by the authors). STRAUS (1995) argues that Belgium was sporadically visited *ca* 16000 years ago and permanently reoccupied *ca* 13000 years ago. However, STRAUS & OTTE (1995) consider that the latter occupations date from the Bölling. According to CHARLES (1994) Magdalenian groups occupied the Paris Basin and the Neuwied Basin at the very end of the Oldest Dryas, the Belgian Ardennes were colonised at the Oldest Dryas - Bölling transition and the British caves later into the Bölling. Unfortunately, the authors do not clearly explain the ecostratigraphical concepts they use; it is not always clear if they refer to calibrated dates or not. Many uncalibrated dates attest the human presence in Britain from *ca* 12600 to 12000 yr BP with *ca* 12500 - 12300 yr BP especially well represented (HOUSLEY, 1991).

In Figure 3 the AMS dates from the Belgian Magdalenian cave sites are compared. This figure was realised with the OxCal 2.18 programme (BRONK RAMSEY, 1994; 1995). It includes single AMS dates, but for the multiple dates of Bois Laiterie, Goyet and Chaleux probability distributions by summing were combined; this generates a "probability distribution which is a best estimate for the chronological distribution of the items dated. The effect of this form of combination is to average the distributions and not to decrease the error margins as with other forms of combination." (BRONK RAMSEY, 1994; 1995). The faunal assemblages are summarised in Table 6. In what follows, little attention will be given to the archaeological characteristics of the Magdalenian recovered at these sites. More detailed information concerning that matter can be found in DEWEZ (1987) and CHARLES (1994).

In Figure 3 three age groups can be distinguished. The oldest group contains only the multi-layered site of Vaucelles. Several bone assemblages were recovered but there are few indications of human presence. Magdalenian artefacts are associated with "couche III". Horse, reindeer, fox, cave bear, brown bear and red deer are some of the species present (BELLIER & CATTELAIN, 1986; CATTELAIN, pers. comm.). An ulna of horse with presumed cut marks from this level was used for AMS dating. The date indicates the presence of Magdalenian people around 16000 cal yr BP, at the end of the Pleniglacial. However, CHARLES (1994) considers the cut marks on this bone doubtful.

The second and also the richest group of sites can be attributed to the very end of the Pleniglacial and/or the Oldest Dryas. Furthermore, it seems that this group can be further subdivided: Bomal, Verlaine, Trou du Frontal (Furfooz) and Chaleux could be slightly older than the contemporaneous sites of Goyet, Bois Laiterie and Trou des Nutons (Furfooz). The faunal composition of these sites is very comparable (Table 6). Horse is, in general, the main species present. At Verlaine, woolly rhino, woolly mammoth and cave hyaena (bones, coproliths, etched bones) have been found (DESTINEZ & MOREELS, 1887-1888; CHARLES, 1994). At Bomal (Trou du Coléoptère), reindeer is the best represented animal in NISP but this is mainly due to the large number of antler fragments. This discrepancy between antler and postcranial representation is also observed in other cave sites (Goyet, Vaucelles, etc.). Mammoth ivory is also present, as in Chaleux where cave hyaena, muskox and saiga antelope were discovered as well (PATOU-MATHIS, 1994; CHARLES, *ibid.*). The presence of mammoth is further testified by an engraving on a bone disc (BELLIER *et al., in press*). Trou du Frontal (Furfooz) yielded only a small collection of Pleistocene mammals mixed with a large quantity of remains from domesticated animals (CHARLES, *ibid.*). According to HOUSLEY (cited in CHARLES, 1994) AMS dates OxA-3632, OxA-3633, OxA-4014 and OxA-3635 from Chaleux, Verlaine and Bomal are so close as to be statistically indistinguishable. At Bois Laiterie, muskox and elk are present, the assemblage is dominated by horse (GAUTIER, pers.com.). The collections of Trou des Nutons (Furfooz) contains a lot of domesticates. In NISP reindeer is the main Pleistocene species, once more because of the large number of antler fragments (CHARLES, 1994).

The third group contains only the site of Trou da

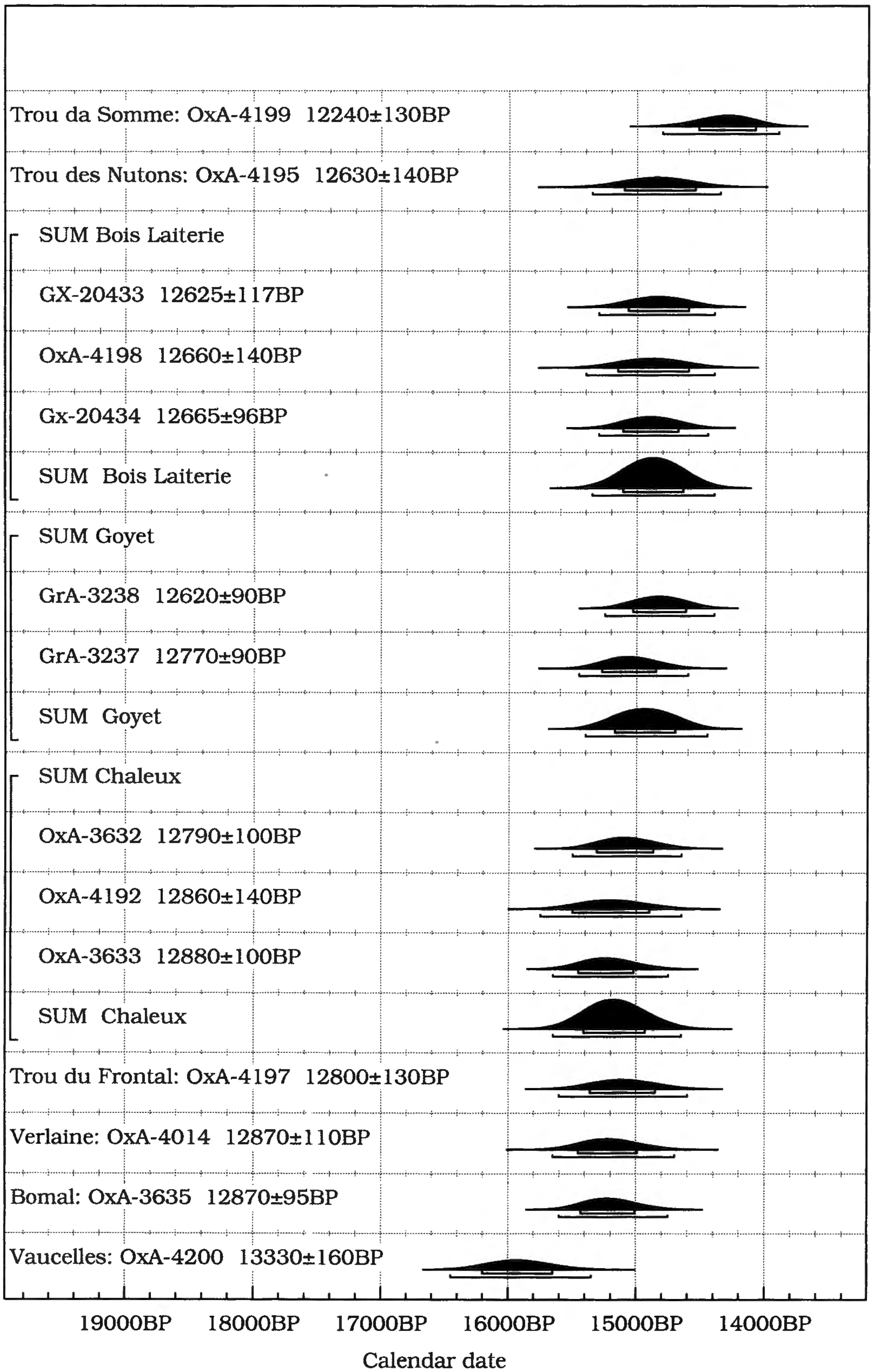

Fig. 3 — Calibrated AMS dates of Belgian Magdalenian cave sites realised with the OxCal 2.18 programme (BRONK RAMSEY, 1994, 1995; STUIVER *et al.*, 1993)

Somme. The AMS date is clearly the youngest and corresponds to the Bölling s.s. Unfortunately, this site has not yet been published in detail. It would be very interesting to verify if the faunal assemblage is different from those dating from the Oldest Dryas, although it is also dominated by horse (LEOTARD, 1988)

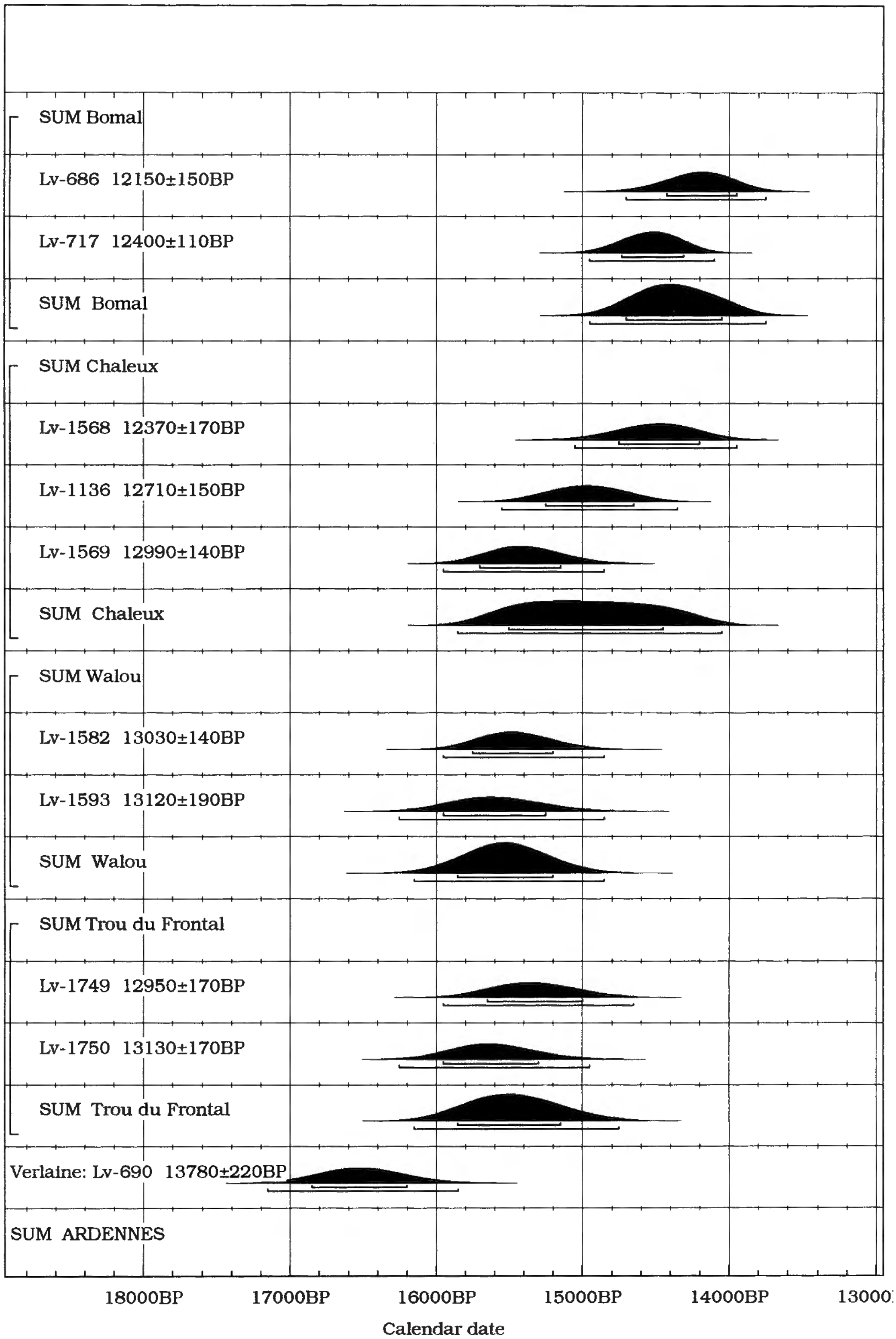

Fig. 4 — Calibrated conventional ^{14}C dates of Belgian Magdalenian cave sites realised with the OxCal 2.18 programme (BRONK RAMSEY,, 1994, 1995; STUIVER *et al.*, 1993)

The conventional radiocarbon dates from the above discussed sites do not, however, always confirm the results of the AMS dates. Figure 4 gives the conventional dates for the Belgian Magdalenian cave sites; it was also realised with the OxCal 2.18 programme (BRONK RAMSEY 1994, 1995). Most dates are on bone splinters. According to CHARLES (1994) the nature of the contextual relationship between these bone samples and the Magdalenian archaeology is unclear; the date gives merely an average age of a mixture of bone fragments of uncertain origin, while the AMS dates on the cut bones can be directly linked with the human activity on the settlement. Out of the three conventional dates of Chaleux, only the one from the Dupont collection on bone fragments with cut marks (Lv-1136) falls completely in the range of the AMS dates. Two of the dates of Vaucelles have a very large standard deviation (Lv-1434D, Lv-1309D), the remaining conventional date on reindeer antler is slightly older than the AMS date (Tables 3 & 4). Also at Furfooz (Trou du Frontal) and Verlaine (Trou des Nutons), the conventional dates on bone splinters are older than the AMS dates on single cut bones. On the other hand, the two conventional dates from Bomal, grotte du Coléoptère, are much younger than the AMS date. For Trou Walou only conventional dates on bone splinters exists.

According to Housley (1991) bone samples which display clear evidence of human modification should be dated rather than unidentified specimens found together with tool assemblages. One of the most important advantages of the AMS technique is that only small amounts are needed so that single, modified bones can be dated. The conventional radiocarbon dates from the Belgian Magdalenian sites are mostly on bulk samples without traces of human manipulation. In this light, the new AMS dates should be preferred as the base for the Magdalenian prehistory in Belgium.

According to Street *et al.* (1994) the comparison between the calibrated ages of Magdalenian settlements in Northern France, Belgium and the Rhineland and that of the late glacial climatic phases recorded in the Greenland ice cores shows that the Magdalenian was already established in north-western Europe before the Late Glacial (Bölling) climatic amelioration and is not limited to the Bölling as has been widely accepted (*e.g.* Brunnacker, 1978). The calibrated ages for the Magdalenian sites of Gönnersdorf and Andernach-Martinsberg fall in a stadial phase preceding the Bölling interstadial. The engravings of woolly mammoth and woolly rhinoceros recovered at these sites would according to Street *et al.* (*ibid.*) point in the same direction.

Two open air Magdalenian settlements were excavated at Orp, located on the Brabant loess plateau. Unfortunately, faunal remains were not preserved. The sites were dated by thermoluminescence (TL), which gave as results 13300 +/-1100 yr BP and 12200 +/- 800 yr BP. Comparison with the Belgian cave sites is difficult since no TL dates exists for these (Vermeersch, 1991).

The composition of the faunal assemblage from the Magdalenian horizon 1 at Goyet requires a dry, open landscape, like the continental environment of the Oldest Dryas. This is in agreement with the range of the dates, which corresponds better with the Oldest Dryas, if the age of the Oldest Dryas - Bölling transition found in the Greenland ice cores can be accepted for Western Europe. The ^{14}C date of this boundary (mean calibrated age *ca* 14500 cal yr BP) found in the Usselo deposits compares well with the ice core age (14450 cal yr BP, Johnsen *et al.* 1992; 14670 cal yr BP, Stuiver *et al.* 1995). The ^{14}C date of the Pleniglacial - Late Glacial limit at Usselo is somewhat older (mean calibrated age about 15300 yr BP) than the ice core age (15070 cal yr BP, Stuiver *et al.*, 1995). The new AMS dates from Goyet confirm the age attribution given by Street *et al.* (1994) for the Belgian Magdalenian sites.

The dates of Vaucelles and Trou Walou could indicate that the Magdalenians already came sporadically to the Ardennes between *ca* 16500 and 15500 cal yr BP, at the end of the Pleniglacial. However, it must be noted that this time range is mainly based on conventional dates on bones without marks of human manipulation. The cluster of dates from *ca* 15200 cal yr BP to *ca* 14800 cal yr BP points to a more permanent colonisation of the region at the closing of the Pleniglacial and/or during the Oldest Dryas. In mean uncalibrated AMS dates this ranges from *ca* 12850 yr BP to *ca* 12650 yr BP. How and if the Magdalenians passed the Oldest Dryas - Bölling s.s. boundary can at the moment not be decided since only one site (Trou da Somme) dates from the Bölling s.s. The question remains if Trou da Somme bears witness of a continuation of the Magdalenian presence from the Oldest Dryas into the Bölling s.s. or was revisited after the region had been abandoned at the end of the Oldest Dryas.

The dates of the more recent Belgian Creswellian, Tjongerian and Ahrensbourgian sites are not considered here, but are reviewed in Charles (1994).

Conclusion

The radiocarbon dates from the Belgian cave sites point to a sporadic presence of Magdalenian hunters at the end of the Pleniglacial, between *ca* 16500 cal yr BP and 15500 cal yr BP. At the closing of the Pleniglacial and/or during the Oldest Dryas, the Magdalenian occupation was more permanent with a concentration of dates from different settlements between *ca* 15200 cal yr BP and *ca* 14800 cal yr BP. This is in agreement with the faunal composition of the sites that is characterised by cold-adapted species (reindeer, muskox, etc.) requiring a dry, open landscape. The youngest dated Magdalenian site so far would be Trou da Somme, which is the only Magdalenian settlement that can be firmly placed in the Bölling s.s.

The faunal analysis and the AMS dating of the bone assemblage associated with the Magdalenian artefacts from horizon 1 at Goyet proves once more that the Dupont collections are of inestimable value for unravelling the Magdalenian prehistory of Belgium. Furthermore, in the future, findings of new major sites will be rare and the information contained in the Dupont collections can no longer be neglected.

Finally, it can be hoped that a further extension of the tree ring chronology and the Uranium-Thorium date series will lead to more precise calendar ages for the Late Glacial, and that the problem of the peopling of north-western Europe can in the future be better correlated with the climatic and ecological changes at the end of the Pleistocene.

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