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New data on the Late Mousterian in Mediterranean France: First radiocarbon (AMS) dates at Saint-Marcel Cave (Ardèche)

Nouvelles données sur le Moustérien final de la France méditerranéenne : premières datations radiocarbone (SMA) à la Grotte de Saint-Marcel (Ardèche)

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ABSTRACT

This article presents new accelerator mass spectrometry (AMS) radiocarbon dates of cut-marked ungulate remains from one of the uppermost archaeological layers (f) at the Grotte de Saint-Marcel, Ardèche, France. This site is situated in a key location regarding population dispersal and potential interaction between Neanderthals and modern humans, as it lies at the crossroads of two main routes of passage. Attributing the upper sequence of this site to a precise chronological period within the Mousterian was difficult until now. Previous conventional ^{14}C analyses done on bulk samples over twenty years ago were considered too young (23,000–30,000 BP). Our new AMS radiocarbon results give two statistically identical dates of 37,850 ± 550 BP and 37,850 ± 600 BP, thus confirming the Late Mousterian attribution of the upper levels of this site. A third date overlaps them at two standard deviations. These are among the very few chronometric dates available for the Mousterian (especially its late phases) in Mediterranean France. The Late Mousterian of this zone, a key region in recent debates about late Neanderthal behaviour, is discussed in light of these results.

RÉSUMÉ

Cet article présente de nouvelles datations radiocarbone par spéctrométrie de masse par accélérateur (SMA) effectuées sur des ossements présentant des stries de découpe provenant du niveau f (ensemble supérieur) de la grotte de Saint-Marcel (Ardèche, France). Ce site est localisé à un endroit clé – carrefour géographique – pour aborder les mouvements de population et les relations éventuelles entre Néanderthal et *Homo sapiens*. L'âge précis de la séquence supérieure de ce site moustérien n'est pas connu. Des datations effectuées par ^{14}C (méthode conventionnelle) il y a une vingtaine d'années sur des échantillons d'os et de charbons de bois provenant des couches e et g ont été considérées comme trop jeunes (23 000 à 30 000 BP). Nos datations radiocarbone par SMA donnent deux dates identiques de 37 850 ± 550 BP et 37 850 ± 600 BP, confirmant ainsi l'attribution de la partie supérieure de la séquence à un Moustérien final. Une troisième date les recouvre à deux écarts-types.

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Celles-ci sont parmi les très rares datations radiométriques du Moustérien (surtout de ses phases terminales) de la France méditerranéenne. Le Moustérien final de cette région et de fait le débat sur les comportements des derniers Néandertaliens sont ainsi discutés à la lumière de ces nouveaux résultats.

1. Introduction

The end of the Mousterian (Middle Palaeolithic) is a critical time to examine in the study of the Palaeolithic. Debate regarding until what date Neanderthals survived, how much overlap there existed, if any, with *Homo sapiens*, the extent and nature of cultural contact with the latter and the possible causes of the demise of the Neanderthals, are only some of the key issues at the forefront of current research (Camps and Szmidt, 2009; d'Errico and Sánchez Goñi, 2003; Finlayson et al., 2006; Jöris and Street, 2008; Mellars, 2004; Pettitt, 1999; Roebroeks, 2008; Zilhão, 2006; Zilhão and d'Errico, 2003; Zubrow, 1989).

The study of the archaeological manifestations of these last Neanderthals, in all its aspects (lithic, osseous, ornaments, subsistence, raw material), as well as the comparison with those of the Aurignacian and transitional technocomplexes, is of critical importance and relevance in addressing these issues, as well as in discussions about cognitive capabilities of these various Upper Pleistocene hominins. Another aspect which is fundamental to the assessment of these issues is the dating of sites to establish their chronological position reliably.

Mediterranean France is a key region to examine the Middle Palaeolithic period. There are numerous sites, thus permitting large-scale regional and chronological perspectives on Neanderthal behaviour (Boyle, 2000; Daujeard, 2008; Daujeard and Moncel, 2010; Moncel, 2003; Szmidt, 2000; Szmidt, 2003; Szmidt, 2009). The proximity of Mediterranean France to southwestern France and their broadly similar palaeoenvironments make them relevant for comparaison. It also makes the former a good testing ground for the models developed within the latter. Due to its relatively mild climate, cul-de-sac geography, abundant limestone caves and good archaeological preservation, Mediterranean France shows continual occupation during the Last Glacial and earlier, even during marine isotope stage (MIS) 4. This enables evaluation of long-term chronological change within sites or micro-regions. Also, Mediterranean France lies right along one of the two main hypothesised dispersal routes of *Homo sapiens* (Bar-Yosef, 1998; Kozłowski, 1992; Mellars, 2004). The potential for interaction and exchange between species in this region as a whole is thus high (Camps and Szmidt, 2009; Szmidt, 2009), an assessment for which chronology plays a vital role.

Saint-Marcel Cave is located in this region (Fig. 1) (Gilles, 1986; Moncel, 1998; Moncel et al., 2004). In particular, it is situated just adjacent to (10 km) the Rhone Valley, one of the key passageways linking northern and southern Europe and constituting an important migration route for animals. The site is thus next to the crossroads of two key routes of passage, the Mediterranean one and the Rhone Valley one.

Based on sedimentological, faunal and floral analyses, its upper levels were suspected of being of Late Mousterian age (Daujeard, 2004, 2008; Debard, 1988; Moncel, 1998; Moncel et al., 2004). Given the issues outlined above and the recent discoveries and current discussions on the Late Mousterian of this region specifically ((Slimak, 2007; Slimak, 2008), and see Discussion section below), it was of importance to verify this Late Mousterian attribution. This fits within our larger project of re-analysing the entire collection from this site. After a brief presentation of the site and its faunal and lithic characteristics, we present three new accelerator mass spectrometry (AMS) radiocarbon dates on layer f, one of the uppermost Mousterian layers of the sequence, and discuss how these results fit within current debates about the Late Mousterian.

2. Site description

The site of Saint-Marcel is situated at the end of the Ardèche Gorge. The cave's natural entrance is located along a rather abrupt section of the north side of the gorge, approximately two hundred metres back from the Ardèche River. The deposits lie under the cave's overhang, in a very large, sub-horizontal, south-facing section of 12.5 m wide, 7 m depth and 3 m height.

Excavation of the Mousterian layers was carried out by R. Gilles from 1974 to 1988, during which a surface area of 30 m^2 was exposed, under the overhang, down to nearly 7 m in depth. Two main stratigraphic units were defined. It is the upper one (u to c), which contains the Mousterian levels (Figs. 2 and 3). Based on stratigraphical, palaeontological and archaeological data, this upper stratigraphic unit has been divided into four occupation phases. From bottom to top these are: layer u, which is attributed to the Eemian period (cf. below); the lower layers (k to t); Unit 7 (g to j) and the upper layers (e and f) (Figs. 2 and 3; (Crégut-Bonnoure, 2002; Crégut-Bonnoure and Guérin, 1986; Crégut-Bonnoure et al., 2008; Daujeard, 2008; Debard, 1988; Defleur et al., 2001; Gilles, 1986; Moncel, 1998)). There is no Upper Palaeolithic occupation at this site.

2.1. Subsistence characteristics

This site is unique in a number of ways. It is one of the rare Mousterian sites of the Ardèche (among a few others like Baume Néron or Abri du Maras for upper levels, and more generally of the period) to exhibit a clear specialisation in hunting (Daujeard, 2004; Daujeard, 2008; Defleur et al., 1994b; Moncel et al., 2004). In addi-

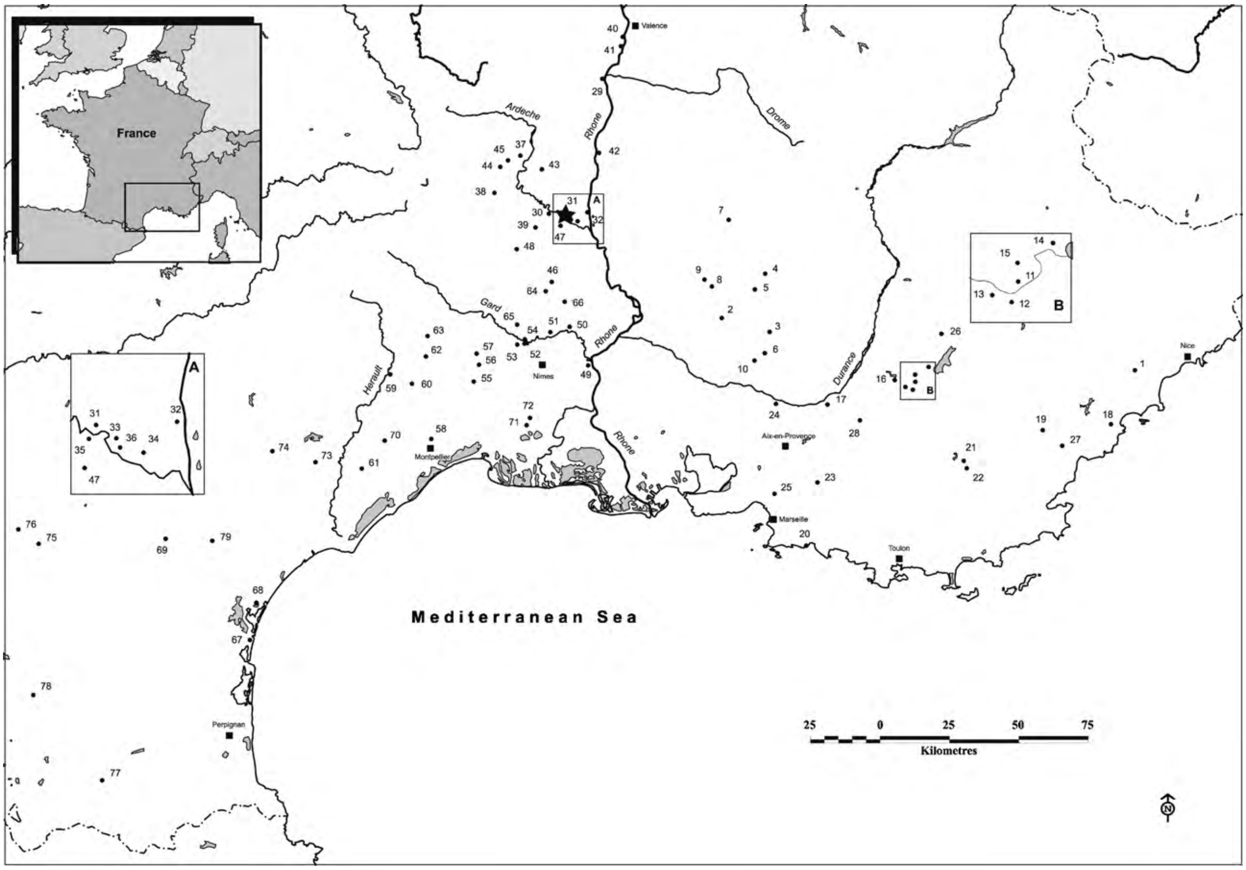

Fig. 1. Map of southern France showing the location of sites mentioned in the text. 1. Pié-Lombard, 2. Bérigoule, 3. Trécassats, 4. Pied de Sault, 5. Aubésier, 6. Peyrards, 7. Bas-Guillotte, 8. Sablons, 9. Coquillade, 10. Combette, 11. Bonne, 12. Breuil, 13. Sainte-Maxime, 14. Murée, 15. Plaine de Sirène, 16. Sauzade, 17. Adaouste, 18. Barral, 19. Rainaude I, 20. Trémie, 21. Saint-Loup, 22. Les Michelles, 23. Tonneau, 24. Gardure, 25. Station des Peyrards, 26. Ségriès, 27. Colle Rousse, 28. Rigabe, 29. Payre, 30. Oullins, 31. Saint-Marcel, 32. Serre Pluma, 33. Ranc Pointu 2, 34. Maras, 35. Baou-de-la-Sello, 36. Figuier, 37. Balazuc, 38. Pêcheurs, 39. Flandin, 40. Moula, 41. Néron, 42. Mandrin, 43. Ranc de l'Arc, 44. Haut Gabernard, 45. Bois du Tallon, 46. Fontarèches, 47. Les Pradas, 48. Cros de Peyrolles, 49. Ioton, 50. Balauzière, 51. St Vérédème, 52. Les Charlots, 53. Calmette, 54. Esquicho-Grapaou, 55. Bézal de Souvignargues, 56. Mas d'Espanet, 57. Verrerie de Macassargues, 58. Bourgade, 59. Cayla, 60. Hortus, 61. Baumasse d'Antonègue, 62. Salpêtre de Pompignan, 63. Roquette II, 64. Brugas, 65. Foissaguet, 66. Rouziganet, 67. Ramandils, 68. Crouzade, 69. Poteries, 70. St-Paul-et-Valmalle 2, 71. Vallat des Marchands, 72. Jean Thomas I, 73. Rothschild, 74. Cadenas, 75. Cennes Monestiés, 76. Ermitage, 77. Mitg, 78. Belvis, 79. Tournal. The site of Saint-Marcel is identified by a star. The larger boxes A and B magnify the regions contained within the small squares A and B. (Basemap ©Bartholomew Ltd. 2000 Reproduced by Kind Permission of HarperCollins Publishers www.bartholomewmaps.com).

Fig. 1. Carte du Sud de la France avec les sites mentionnés dans le texte (voir numéros). Le site de Saint-Marcel est identifié par une étoile. Les grands carrés A et B agrandissent les régions représentées dans les petits carrés A et B. (Basemap© Bartholomew Ltd. 2000 Reproduction avec la permission d'HarperCollins Publishers www.bartholomewmaps.com).

tion, the high proportion of bone retouchers ($n = 303$, representing nearly 7% of the number of total remains (NTR) greater than 5 cm) also makes this site distinctive (Daujeard, 2004; Daujeard, 2007; Daujeard, 2008). The degree of specialisation of Neanderthal subsistence practices, with all the cognitive and cooperative implications that this might entail is contested and often contrasted with that of anatomically modern humans (Chase, 1987; Chase, 1988; d'Errico, 2003; Gaudzinski, 1997; Gaudzinski and Roebroeks, 2000; Grayson and Delpech, 2002; Marean, 1998; Mellars, 1996; Mellars, 1999; Mellars, 2004; Shea, 1998; Stiner, 1991; Stiner, 1994). At Saint-Marcel, in the upper layers and in Unit 7 (layers g to j), red deer dominate at greater than 80% of the ungulate number of identified specimens (NISP) and in the lower layers at 62%. The Neanderthals who occupied the site practised selective hunting of prime-aged adult deer. Carcass butchery was particularly intensive and extensive. Butchery marks are represented on just over half the identified specimens in the faunal assemblage and more than 70% bear evidence of green-bone fractures (Daujeard, 2004; Daujeard, 2008; Moncel et al., 2004). The carcasses brought back to the site were entirely defleshed, even the bones bearing little meat (scraping of metapodials) and some carcasses were skinned, eviscerated and cut up into sections. Marrow extraction was systematically practised on the long bones, phalanges and mandibles of all herbivores. The extreme rarity of cancellous bones, be it from epiphyses or axial skeletal elements, has led us to hypothesise that these were boiled to extract their grease and/or burned for fuel (for details see (Daujeard, 2004; Daujeard, 2008)).

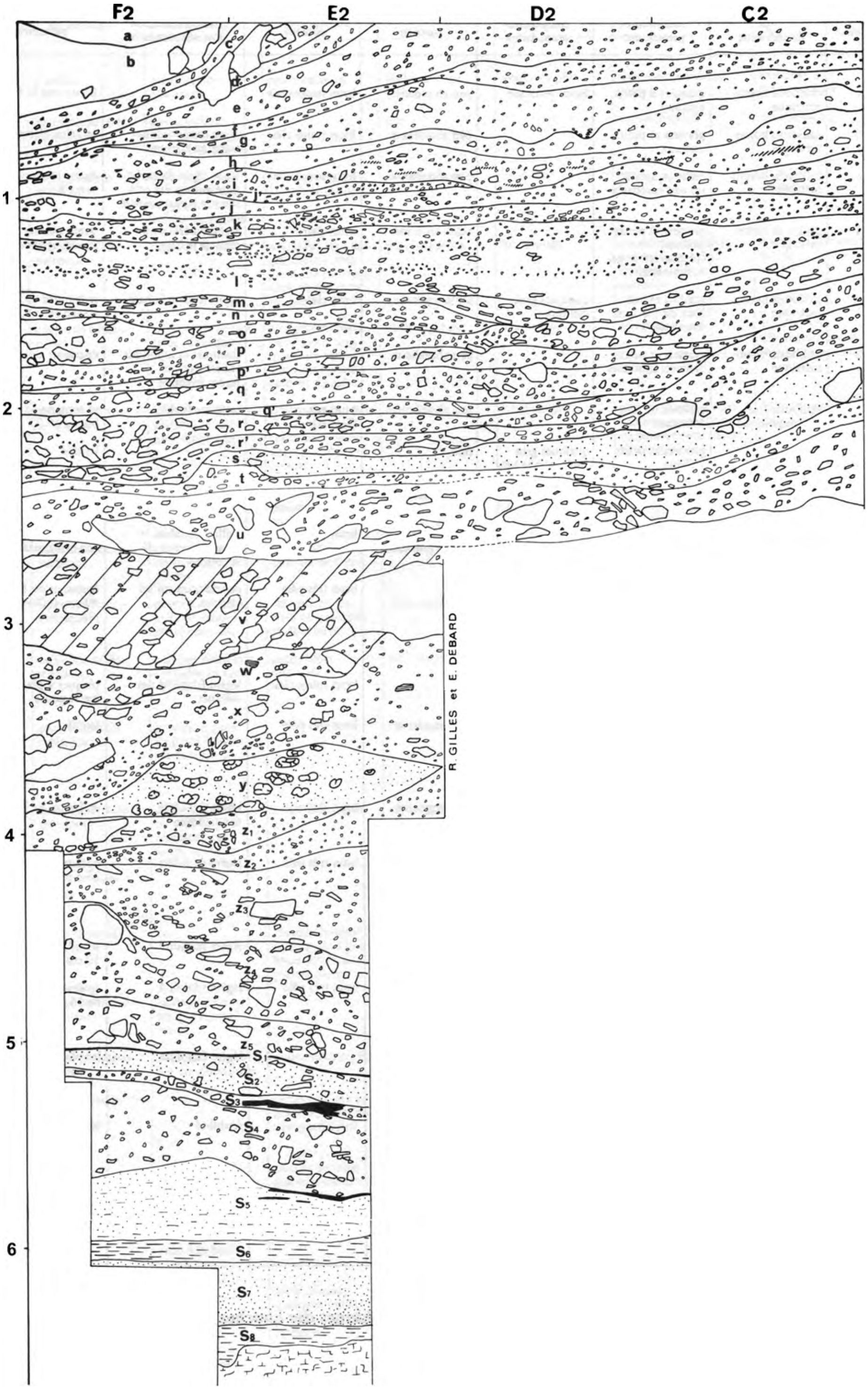

Fig. 2. Stratigraphy of Saint-Marcel Cave, France. Northern section (according to Gilles and Debard, 1988).
Fig. 2. Stratigraphie du gisement de Saint-Marcel, France. Section nord (d'après Gilles et Debard, 1988).

In all the layers above layer u, the Neanderthals practised similar susbistence habits, namely, the preferential hunting of prime-aged adult red deer. Layer u differs somewhat from the other layers in that fallow deer are dominant (64% of the NISP) and old-aged adults form the majority. This, in conjunction with a large proportion of juveniles, is indicative of a more opportunistic hunting strategy in this layer, which may also have incorporated some scavenging.

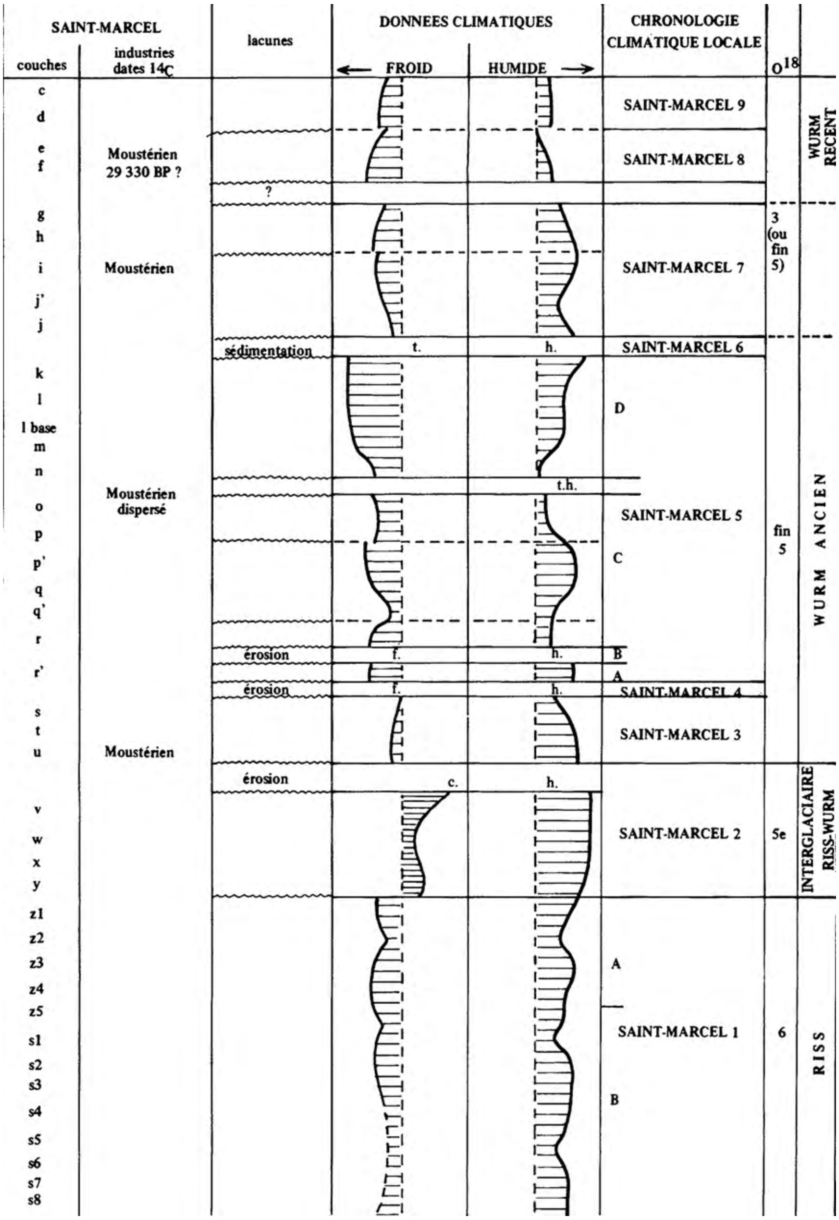

Fig. 3. Palaeoclimatic and stratigraphical overview of Saint-Marcel Cave, France (according to Debard, 1988).

Fig. 3. Synthèse paléoclimatique et stratigraphique du gisement de Saint-Marcel, France (d'après Debard, 1988).

Once the animals were transported to the site, however, the *chaîne opératoire* of carcass exploitation was the same for both cervids, although there is a slightly lower proportion of cutmarked bones in layer u. Despite the evolution observed along the sequence, topographical and zooarchaeological data allow us to associate all of the levels of Saint-Marcel with long-term, large-scale occupations.

Aside from eight cave bear remains in layer u, no other carnivore remains have been found in the site. Furthermore, carnivore surface marks do not exceed 4% of the faunal assemblages (NTR). In the upper layers (c to f) there are nine such bones. This is the only evidence for the presence of carnivores at this site.

In layer f, there were two refits on green-bone fractures and in layers e and f there were respectively one and two refits on dry-bone fractures within levels. These are indicative of some horizontal movement within layers e and f (trampling, solifluxion). There were no refits between levels. The site plans of the excavation do not reveal a particular orientation to the long bones. Less than ten percent of bones display short, superficial and haphazard striations on their surfaces.

These observations allow us to reject the possibility of major accumulations by means of violent transport or by carnivores. On the other hand, it attests mainly to recurrent human accumulations (Lyman, 1994).

2.2. Lithic characteristics

The lithic assemblages show a great deal of homogeneity throughout the stratigraphic sequence in the technical choices made. They are all Middle Palaeolithic or Mousterian. Flint, which was collected in various forms (as pebbles, nodules, flakes and tablets) was the main raw material used, indicating procurement from a variety of sectors (in the Barremian-Bedoulian from the plateau to the north, from the Orgnac plateau to the south and in the Rhone Valley to the east), as is typical for the region (Moncel, 2003). Most of the flint processing occurred at the site. The entire *chaîne opératoire* is represented on nodules, pebbles and partially on flakes for the main type of flint. On the other hand, there are also some already extracted flakes made from various flint types, which were brought inside the site from diverse outcrops.

The lithic assemblage of each of the layers consists mainly of debitage products, especially flakes. These are small in size, ranging from 30 to 50 mm in length on average. The flakes are short, sometimes with a back, and have thick and wide platforms. These can be attributed largely to a discoid debitage (centripetal, unipolar or bipolar method), which was carried out especially on the ventral surface of flakes. In some cases they struck along a third plane, perpendicularly to the regular oblique planes of flake detachment, enabling the extraction of thick flakes of triangular cross-section ("crested flake") (Moncel, 1998).

There are very few retouched tools on this site (approximately 5%), consisting primarily of scrapers, in addition to some convergent pieces. Retouch is light and barely modifies the blank, although some thinning is present. Layer f, although poor in material, does not differ in technical or metrical attributes from the rest of the assemblages (Fig. 4).

Overall, the lithic characteristics remain the same over time, from the base to the top of the sequence. Regarding subsistence practices, aside from the differences noted above in age-profiles and species' dominance between layer u and all other layers, there is little variation through the sequence in carcass processing and in the type of occupation.

3. Radiocarbon dating

3.1. Previous dating at the site

Attributing this site to a precise chronological period, in particular the upper part of its sequence, was difficult until now. The lower layers (k to u) were attributed to isotope stage 5 based on the sedimentological analysis (Debard, 1988). The paleontological analysis of the faunal remains, carried out by É. Cregut-Bonnoure in 1982, clearly sets apart layer u from all the others, given the abundance of fallow deer in this layer. In addition, a re-examination in 1989 of the fauna from this layer revealed the presence of remains of a tahr, *Hemitragus cedrensis*. Both of these point to an Eemian date of occupation for layer u, thus making it also contemporaneous with the interglacial period layers of Abri Moula (layers XV and XVI) (Crégut-Bonnoure, 2002; Crégut-Bonnoure and Guérin, 1986; Crégut-Bonnoure et al., 2008; Defleur et al., 2001). Furthermore, paleontological, environmental and sedimentological analyses allow us to ascribe Unit 7 ('Ensemble 7') (layers j to g) to a warm episode, either stage 3 or the end of stage 5 (Crégut-Bonnoure, 2002; Daujeard, 2008; Debard, 1988; Moncel et al., 2004). Given the hiatus in sedimentation between layers k and j, it is more likely that the upper part of the sequence dates to stage 3 (Debard, 1988). In addition, radiocarbon dates done in the 1980s gave a very recent date for layer e (see below). There seems to be no hiatus in sedimentation between layers j and g, nor between g and f. The faunal, anthracological, as well as sedimentological analyses point instead to continuity (Daujeard, 2008; Debard, 1988). It was thus not clear whether the uppermost layers (e and f) were genuinely younger than the underlying layers j to g. Given the evidence, it seemed more likely that they all dated to the same period and that instead it was the radiometric dates which were incorrect.

Chronometric dating had been attempted on levels e and g, through conventional ^{14}C analysis on bulk samples (Evin et al., 1985). The samples dated and the results obtained are presented in Table 1. Those of layer g were considered to be too young. Even those of layer e were younger than expected. Layer e is essentially the uppermost Palaeolithic layer in the sequence (aside from two flakes in layer c), so bones from it may be too superficially placed and subject to contamination

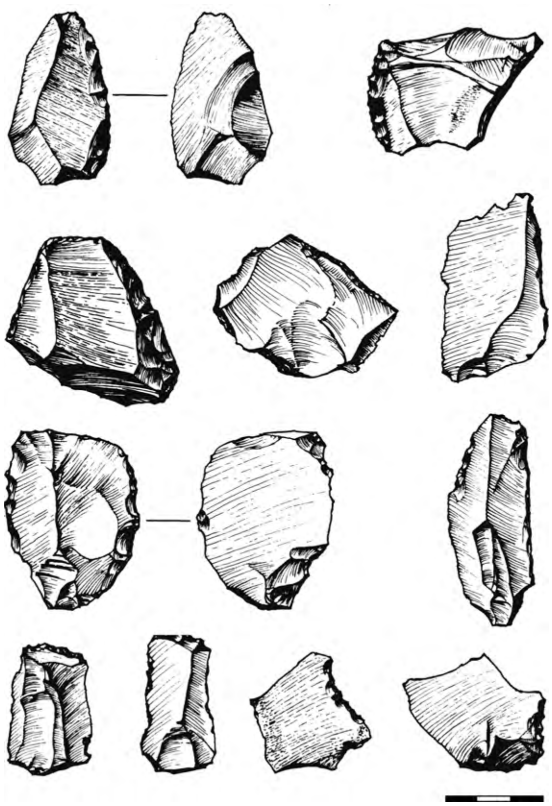

Fig. 4. Flint artefacts from layer f, Saint-Marcel Cave, France (drawings by Gilles, unpublished).

Fig. 4. Matériel lithique en silex du niveau f, Saint-Marcel, France (dessins par Gilles, non publiés).

Table 1
Results of radiocarbon dating (conventional method) done in the 1980s at Saint-Marcel Cave, France.
Tableau 1
Résultats des datations radiocarbone (méthode conventionnelle) effectuées dans les années 1980 à Saint-Marcel, France.

Site	Layer	Provenience	Material dated	Date (radiocarbon years BP); conventional analysis	Laboratory Number	Comments
Saint-Marcel	e	ca. 2.3 m depth	Bones	29,330 ± 650	Ly-2276	Considered younger than expected (Evin et al., 1985)
Saint-Marcel	g	ca. 2.5 m depth	Bones	23,260 ± 370	Ly-2861	Considered much too young for associated industry (Evin et al., 1985)
Saint-Marcel	g		Charcoal	≥ 25,000	Ly-2901	Considered too diluted to be conclusive (Evin et al., 1985)

Table 2
Provenience, taxonomic and human modification information of the AMS ^{14}C-dated bones of layer f, Saint-Marcel Cave, France.
Tableau 2
Provenance, détermination et types de modifications humaines des ossements datés par ^{14}C (SMA) du niveau f, Saint-Marcel, France.

Site	Layer	Square	Number	Species	Anatomical part	Cutmarks	Laboratory number
Saint-Marcel	f	F2	46	Red deer (*Cervus elaphus*)	Femur	Yes	OxA-19623
Saint-Marcel	f	F2	49	Red deer (*Cervus elaphus*)	Tibia	Yes	OxA-19624
Saint-Marcel	f	C2	68	Red deer (*Cervus elaphus*)	Humerus	Yes	OxA-19625

(Debard, 1988; Moncel et al., 2004). The date thus remains questionable.

It became clear that only new radiometric dating could resolve this discrepancy and place the site in a more precise chrono-cultural framework. We thus dated layer f to help us determine the absolute date of the top of the Saint-Marcel sequence and confirm or not its Late Mousterian attribution.

3.2. New AMS ^{14}C dating

3.2.1. Sample selection criteria

The dating of this site is part of a larger project, directed by one of us, to date the Middle to Upper Palaeolithic transition, mostly in the larger southern France region (Mediterranean, Pyrenean and southwestern regions) (Szmidt et al., 2010). Rigourous sample selection and analysis criteria have been used in this project. These include the selection of individual samples rather than groups (‘single entity dating’); the zooarchaeological identification of remains in order to select appropriately and avoid bears/carnivores; the preferential selection of remains bearing direct, clear evidence of human involvement (for example cutmarks).

Despite the fact that carnivore presence is minimal at Saint-Marcel, we chose to date only those ungulate remains displaying cutmarks. In addition, we focused only on long-bone fragments which were well preserved and whose cortical bone was thick. The three samples we chose from layer f are listed in Table 2. They come from the R. Gilles collection housed at the Musée de Préhistoire d’Orgnac (Orgnac l’Aven, France). Taphonomic aspects also played an important role in the choice of samples. Those chosen bear no evidence of concretions, root etching, dissolution or flaking. Weathering is at stage 0 or 1. Cracking is either absent or very discreet. The edges of the bones are not rounded and there are no carnivore marks on the fragments.

3.2.2. Radiocarbon analysis

The three bones were submitted to the Oxford Radiocarbon Accelerator Unit (ORAU) for radiocarbon analysis by AMS. Pre-treatment followed standard methods currently employed in this laboratory, including an ultrafiltration step. This added step, as it was initially developed (Brown et al., 1988) and subsequently modified and adapted by the ORAU has been amply described in a number of publications, as has the rest of the pre-treatment method used (Brock et al., 2007; Bronk Ramsey et al., 2004a). Given the very old age of the bones (near the limit of the radiocarbon method), it was particularly important to ensure, as far as possible, that any potential exogenous carbon was eliminated. Based on a number of analyses carried out on Palaeolithic samples at ORAU, ultrafiltration seems to be one of the best methods currently available to achieve this. Including an ultrafiltration step has often resulted in older dates than ones obtained on the same sample without ultrafiltration (Higham et al., 2006; Jacobi et al., 2006). The laboratory attributes this difference in age to the more thorough elimination of contaminants with ultrafiltration. Combustion, graphitization and measurement were done according to the standard methods used at this laboratory (Bronk Ramsey et al., 2002; Bronk Ramsey et al., 2004b). The artefacts had not been coated with preservatives or consolidants. In addition, no cast had been made of these bones. Photographs were taken before submission.

3.2.3. Results

Results are quoted in radiocarbon years before present (BP) using the Libby ^{14}C half-life and have been corrected for natural isotopic fractionation. The collagen yield, as well as the elemental and isotopic values (C:N, δ^{13}C, δ^{15}N) of the three bones are within normal parameters (Table 3) (Burleigh et al., 1984; DeNiro, 1985; Hedges and van Klinken, 1992; van Klinken, 1999).

Table 3
Radiocarbon, isotopic and elemental measurements on bones from layer f, Saint-Marcel Cave, France.
Tableau 3
Ensemble des mesures radiocarbone et isotopiques des ossements datés du niveau f, Saint-Marcel, France.

Site	Layer	Square	Number	Bone powder mass (mg)	Collagen mass (mg)	Collagen yield (%)	Atomic C:N	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	% C	Date (radiocarbon years BP)	^{14}C Calibrated date using OxCal 4.1.5 (68.2% probability) in cal BP	Laboratory Number
Saint-Marcel	f	F2	46	560	15.1	2.7	3.4	−19.73	3.8	45.6	37,850 ± 550	42,041–42,826	OxA-19623
Saint-Marcel	f	F2	49	630	6.56	1	3.4	−19.96	3.9	44.6	41,300 ± 1700	43,491–46,512	OxA-19624
Saint-Marcel	f	C2	68	620	13.3	2.1	3.4	−19.99	3.1	44.9	37,850 ± 600	42,011–42,864	OxA-19625

Stable isotope ratios are expressed in ‰ relative to the VPDB standard for carbon and the AIR standard for nitrogen. The radiocarbon calibrated dates were obtained using the OxCal 4.1.5 calibration curve (Bronk Ramsey, 2001; Bronk Ramsey, 2009), which is based on the IntCal09 dataset (Reimer et al., 2009).

Two of the three dates are statistically identical to each other: 37,850 ± 550 BP and 37,850 ± 600 BP. The third, 41,300 ± 1700 BP, has a large standard deviation, so is hard to compare. It does, however, overlap them at two standard deviations. These results indicate that layer f of Saint-Marcel does indeed date to the Late Mousterian. The date of 29,330 ± 650 BP (Ly-2276) obtained on layer e by decay counting radiocarbon method more than twenty years ago is, however, very likely too young, perhaps due to a residual, younger contaminant, which was not entirely removed. Significant progress in dating (in particular the AMS method) and in pre-treatment could explain this difference.

4. Discussion

These new results indicate that Saint-Marcel can thus contribute to discussions concerning the Late Mousterian and the final Neanderthals. In addition to the general problems of collagen preservation faced in all bone/antler samples in radiocarbon dating, it is particularly rare to be able to date Middle Palaeolithic and early Upper Palaeolithic sites by this method because the amount of ^{14}C still remaining at that age is low. As a result, even slight contamination by more recent extraneous carbon can be quite problematic. Importantly as well, sites of these periods are often occupied alternatively by hominins and carnivores. Thus, in addition to luck in preservation conditions, dating sites of these periods with reliability requires both archaeological rigour in sampling and technical rigour in cleaning.

These aspects have rarely been applied (sometimes because it was not feasible or available), in the dating of Mousterian sites in this region and elsewhere. The results presented here regarding the Mousterian site of Saint-Marcel are an attempt to reverse this trend. Through the careful selection of artefacts (well preserved, species-identified, cutmarked bones from a reliable stratigraphic/sedimentary context), the use of one of the most thorough cleaning methods known at this time (ultrafiltration) and good preservation conditions, we have aimed to improve dating reliability as much as possible.

It is difficult to know with which sites to compare Saint-Marcel f as so few Mediterranean France Mousterian sites are chronometrically dated. In addition, calibrating dates in this period to be able to compare them to TL, uranium series or ESR dates has been fraught with controversy and difficulty until now, due to the lack of agreement between different records used to make such a radiocarbon calibration (Bronk Ramsey et al., 2006; van der Plicht et al., 2004; Weninger and Jöris, 2008). The recent release of IntCal09 (Reimer et al., 2009) has now made this more feasible, however. Using the recently updated OxCal calibration curve (OxCal 4.1.5) (Bronk Ramsey, 2001; Bronk Ramsey, 2009), which is based on the IntCal09 dataset, two of the Saint-Marcel dates are on the order of 42–42.8 ka cal BP (68.2% probability), and the third on the order of 43.5–46.5 ka cal BP (68.2% probability) (Table 3). At 95.4% probability, two of the dates are on the order of 41.6–43.3 ka cal BP and the other on the order of 42.8–49.1 ka cal BP.

The few sites in Mediterranean France which have been dated and which seem to be broadly contemporaneous with the upper levels from Saint-Marcel are listed in Table 4. These should be taken with a level of caution, however. It is difficult, for instance, to evaluate the accuracy of the ^{14}C-dated assemblages listed in Table 4 as no pre-treatment information was published for most and no isotopic, elemental or yield values for any, often because this was the standard practice at the time. They include conventional and AMS radiocarbon dates, identified (genus/species) and non-identified samples. Some, however, have been corroborated by other chronometric methods, although these often have extremely large error limits, making them difficult to interpret.

If we tentatively take all of these results at face value for now until further dating is done, the late part of the Mousterian across Mediterranean France would be represented by the following assemblages, in addition to Saint-Marcel: Grotte Mandrin layers 6, 5, 4, 3 and 2, Baume Néron layers I, II and III, Baume d'Oullins Ra/Rb, Ranc-de l'Arc layers 4 and 5; Ioton Ag, Grotte Tournal layer H and possibly some of the layers of Abri des Pêcheurs (see notes of Table 4).

These assemblages (as well as neighbouring others which are not directly/reliably radiometrically dated but often considered of Late Mousterian age, such as Le Figuier layer 1', Abri du Maras layers 1 and 1' and Abri Moula layer IV) are varied in their technical traits. Setting aside the fact that some assemblages are larger than others, this could be interpreted as the result of there being distinct facies and/or as due to the differing needs of diverse activities. For instance, the top of the Middle Palaeolithic sequence at the Abri des Pêcheurs, (which lies underneath an Aurignacian layer), contains, such as at Saint-Marcel, a discoid assemblage with a very low retouched tool frequency. In this case, this could likely be linked both to the brief nature of the occupations and to the main use of quartz (Daujeard and Moncel, 2010; Moncel et al., 2008b).

Assemblages in this region display the use of Levallois or discoid methods, on raw materials, which are sometimes of small size (e.g. at Baume d'Oullins, Ranc de l'Arc). At the latter two sites, as well as at Grotte Tournal and Ioton, blanks are rarely laminar and points are equally rare. By contrast, in level 1' of Le Figuier, elongated flakes are more frequent. Overall, side-scrapers are the dominant tool-type, with very few Upper Palaeolithic types and denticulates, except at Grotte Tournal and Baume Néron.

In Abri Moula layer IV, the number of lithics is too small (28 artefacts) to be interpretable as a specific point-facies (Defleur, 2000). Elongated blanks and points are better represented at Baume Néron, Abri du Maras and Grotte Mandrin level 6, the latter two within a Levallois context (Defleur et al., 1994b; Moncel, 2001a; Slimak, 2007). At the top of the Grotte Mandrin sequence, underneath the Protoaurignacian layer, are layers (1–4) with assemblages consisting of large-sized flakes and side-scrapers, which differ from the layers below them (layers 5 and 6).

4.1. *Examining the Late Mousterian in Mediterranean France*

The Late Mousterian in Mediterranean France has often been characterised as having a high percentage of end-scrapers, borers and denticulates, as well as a high blade index (blade = length > twice width) (Ambert, 1994; Blaize, 1986; Combier, 1967; Combier, 1990; de Lumley, 1969; Rolland, 1988; Tavoso, 1987). Very few of the over 75 Mousterian sites in this region have been dated chronometrically, however, (see Table 4 and (Szmidt, 2003)), so that this assertion often becomes circular. When only chronometrically-dated (non-radiocarbon) assemblages are examined, the pattern does not hold (Szmidt, 2003).

The new radiocarbon dates at Saint-Marcel indicate a Late Mousterian occupation of the upper levels of this site. These do not, however, have high blade index, high frequencies of denticulates or high percentage of Upper Palaeolithic types, thus further confirming the fact that these traits should not be used as markers of the Late Mousterian in this region. In fact, as in northern Europe, some of these traits, such as blade production or production of elongated products, may instead have existed already much earlier in Mediterranean France, made by various methods (Gagnepain et al., 2004; Moncel, 2001a; Moncel, 2005; Moncel et al., 2008b; Slimak, 1999; Tavoso, 1988).

More recently, regarding the Late Mousterian, a new facies called the *Néronien* (Slimak, 2007; Slimak, 2008) has been defined in a very circumscribed region of the Middle Rhone Valley. This is the very region in which is located Saint-Marcel. According to these studies, it is thought to be this region's equivalent of the Châtelperronian, this region having been devoid of the latter as well as of Mousterian of Acheulian Tradition (MTA) assemblages. Already over forty years ago, and then more recently, this was pointed out by Combier (Combier, 1967; Combier, 1990). He described the unusual aspects of some Mousterian assemblages in this region (e.g. high proportion of blades and Upper Palaeolithic types, ventrally retouched elongated Levallois points: *pointes Soyons*) and suggested that this might have resulted from either one group's adaptation or acculturation.

The Neronian is found in five assemblages, one in each of five sites: Le Figuier layer 1', Grotte Mandrin layer 6, Abri du Maras layers 1-1', Abri Moula layer IV and Baume Néron layer I. Its attribution to the Late Mousterian has been argued on its being at the top of a Mousterian sequence in four of the five sites. At the fifth site, there is an AMS ^{14}C date of 33 300 ± 230 BP (Ly 2755 OxA) on the Neronian level (Grotte Mandrin, layer 6). There are TL dates (weighted averages) on heated flints from Mousterian levels (non-Neronian) below and above Grotte Mandrin layer 6, spanning 52,000 ± 3350 (layer 7) to 35,000 ± 1600 (layer 2/bottom of 1) (Slimak, 2007; Slimak, 2008). The new dates from Saint-Marcel are older than the one chronometrically-dated Neronian level, Mandrin 6. Saint-Marcel may still be broadly contemporaneous with this facies, but more dates on the Neronian are needed to confirm or refute this.

The layer at Grotte Mandrin, which is defined as Neronian (layer 6) is radically different from the Mousterian layers of Saint-Marcel, Abri des Pêcheurs, Ranc de l'Arc, Baume d'Oullins, Grotte Tournal and Ioton, all attributed to the Late Mousterian by direct dating (albeit some with caution, as mentioned above). The assemblages from Grotte Mandrin 6 and Saint-Marcel contrast each other in that

Table 4
Mousterian sites in Mediterranean France chronometrically-dated to the Late Mousterian.
Tableau 4
Sites moustériens tardifs de la France méditerranéenne, datés par des méthodes radiométriques.

Site	Layer or Depth	Dating Method(s)	Material Dated	Age	^{14}C Calibrated Date using OxCal 4.1.5 (68.2% probability) in cal BP	Industry	Laboratory Number	References	Notes
Ioton	Ag	TL	Flint	48,000 ± 3000		Quina Mousterian	Gif, no number given	(Valladas et al., 1987)	Date is average of seven samples
Mandrin	B (base of layer 1 and top of layer 2)	TL	Flint	35,000 ± 1600		Post-Neronian II	Gif, no number given	(Slimak, 2007; Slimak, 2008)	Date is average of five samples
Mandrin	6	^{14}C (AMS)	Bone	33,300 ± 230	37,687–38,553	Neronian	Lyon 2755 OxA	(Slimak, 2007; Slimak, 2008)	
Néron	III	^{14}C (Conv.)	Charcoal (pine)	43,000 ± 1100	45,178–47,417	Quina Mousterian	Gif/LSM 9132	(Defleur et al., 1994b)	
Oullins	Ra/Rb	AAR	Bones	31,750 ± 583		Micromousterian		(Debard, 1988; Lafont et al., 1984)	Levels Ra and Rb had not yet been separated stratigraphically at the time of collection of samples. Given that subsequent analyses revealed a hiatus in sedimentation between these layers, the date obtained is questionable as samples were merged from both (Debard, 1988).
Ranc de l'Arc	5	^{14}C (AMS)	Charcoal	41,300 ± 1900 and 42,200 ± 1600 (40,500 ± 1600 on humic fraction of latter)	43,358–46,764 and 44,344–47,322	Typical Mousterian	Gif, no number given	(Defleur et al., 1990)	
Ranc de l'Arc	4 and 5	TL	Flint	46,100 ± 3900		Typical Mousterian		(Valladas et al., 1999)	Date is average of five samples

Table 4 (*Continued*)

Site	Layer or Depth	Dating Method(s)	Material Dated	Age	^{14}C Calibrated Date using OxCal 4.1.5 (68.2% probability) in cal BP	Industry	Laboratory Number	References	Notes
Tournal	H	U-Pa, U-Th and ESR	Bone: Cervid tibia diaphysis fragment: J29 # 247	35,000 ± 7000		Denticulate Mousterian		(Yokoyama et al., 1987)	Date is average of three methods. Other uranium-series dates were far too young and/or stratigraphically incoherent (Bischoff et al., 1988; Yokoyama et al., 1987).

AAR: amino acid racemization; ^{14}C: radiocarbon; AMS: accelerator mass spectrometry; Conv.: conventional; ESR: electron spin resonance; TL: thermoluminescence; U-Pa: uranium-protactinium; U-Th: uranium-thorium. The radiocarbon calibrated dates were obtained using the OxCal 4.1.5 calibration curve (Bronk Ramsey, 2001; Bronk Ramsey, 2009), which is based on the IntCal09 dataset (Reimer et al., 2009). A few other sites' layers in Mediterranean France were radiocarbon-dated to the recent Mousterian, but have not been included in this table because their date is considered inaccurate (too young or not finite). This concerns the sites of Grotte de l'Esquicho-Grapaou (Evin et al., 1983), Abri Moula (Crégut-Bonnoure and Guérin, 1986; Defleur et al., 1993; Delibrias and Fontugne, 1990; Evin et al., 1983), Abri des Pêcheurs (Evin et al., 1985), Trou du Renard (Delibrias and Fontugne, 1990) and Grotte Tournal (Bize) (Evin et al., 1983). Uranium series and ESR dates on bones and stalagmitic flowstone from Abri des Pêcheurs suggest that the deposits date to between 120,000 and 40,000 BP (Masaoudi et al., 1994).

a Levallois method aimed at producing elongated and pointed blanks was used at the former whereas a discoid debitage on core-flakes aimed at the production of short and backed flakes was employed at the latter. In addition, Soyons points, one of the criteria for the Neronian, are very rare at Saint-Marcel. The lithic characteristics of Saint-Marcel are instead more similar to the uppermost levels at Grotte Mandrin, which have been labelled as post-Neronian II (Slimak, 2007; Slimak, 2008).

Grotte Mandrin's Neronian level bears traits which are similar especially to the upper levels of Abri du Maras, the latter containing elongated points as well as blades. At the latter site, there are 10% Levallois blades and cortical blades (length > twice width) due to the use of Levallois and direct flaking methods on pebbles (Moncel, 1996). At the end of the Mousterian, blade Levallois production (uni-bipolar method) was practised at certain sites (Combier, 1967; Defleur et al., 1994b; Slimak, 2007), while at other sites elongated flakes (length equal to twice width) by unipolar-bipolar Levallois or discoid methods (Abri Moula, Le Figuier, Baume Néron) or regular flakes (Saint-Marcel) were produced. As mentioned above, the production of elongated products seems to have begun far earlier in this region (MIS 8-7 at the site of Payre through a discoid flaking method and isotope stage 5 at the site of Baume Flandin through Levallois and direct flaking methods on flint slabs) (Moncel, 2003; Moncel et al., 2008a; Moncel et al., 2008c).

A number of occupation-types are seen in southeastern France during the late Mousterian or MIS 3 (Daujeard and Moncel, 2010) (see Fig. 1 for site location; and see Daujeard, 2008 for zooarchaeological and taphonomical criteria): regular, but short-term hunting camps at Le Figuier 1' (Combier, 1967; Daujeard, 2008; Moncel, 2001b; Moncel et al., 2008), in the upper levels (almost entirely B) of the Grotte Mandrin sequence (Giraud et al., 1998), La Combette (Texier et al., 1998) and Adaouste (Defleur et al., 1994a); long-term residential camps at Saint-Marcel (Daujeard, 2004; Daujeard, 2008; Moncel, 1998; Moncel et al., 2004), Abri du Maras 1-1' (Combier, 1967; Daujeard, 2008; Moncel, 1996; Moncel and Michel, 2000; Moncel et al., 2008c), Baume des Peyrards (Daujeard, 2008; de Lumley, 1969) and probably Abri Moula VIII and Baume Néron (Defleur, 1991,1995; Defleur et al., 1994b, 2001), as well as ephemeral stops at Balazuc (Combier, 1968; Daujeard, 2008), Hortus (de Lumley et al., 1972) and Abri des Pêcheurs (Daujeard, 2008; Moncel et al., 2008b; Moncel et al., 2008c).

4.2. Concluding remarks

The Late Mousterian in Mediterranean France, and the Middle Rhone Valley in particular, is thus quite diverse (Moncel, 2003). It merits further investigation to establish the precise chrono-cultural and techno-typological relationship between the various manifestations of the final Neanderthals, especially given its key crossroads location along two routes of passage. The importance of more extensive and precise chronometric dating in this region of well-characterised samples clearly associated with human occupation is evident. The new dates from Saint-Marcel, on well-preserved cutmarked ungulate bones, are among the very rare ones that exist. The encouraging results obtained for Saint-Marcel layer f, are spurring us to pursue the dating on the underlying level g as our next step.

Regarding the potential relationship between Neanderthals and modern humans, these new dates overlap (at one or two standard deviations) with the recently obtained Protoaurignacian/Early Aurignacian AMS radiocarbon dates in southern France at the site of Isturitz, in the western Pyrenees (Szmidt et al., 2010). The author(s) of the Protoaurignacian and Early Aurignacian are still uncertain given the rarity of human remains in this period (Churchill and Smith, 2000; Gambier, 1989; Trinkaus, 2005; Wild et al., 2005; Zilhão et al., 2007). If these industries are eventually attributed to *Homo sapiens*, as is the case for the Late Aurignacian, and if one posits that Mousterian occurrences in Europe are exclusively attributed to Neanderthals, this overlap clearly demonstrates the potential for interaction in the larger southern France region. One important next step would be to focus our attention on comparing chronometrically-dated assemblages reliably attributed to the Late Mousterian to those of the Protoaurignacian and Early Aurignacian. Wider debates arising over the likelihood and extent of acculturation and behavioural innovation between Neanderthals and *Homo sapiens* for instance, depend on it (Arrizabalaga et al., 2009; Clark, 1997; d'Errico et al., 1998; Jöris and Street, 2008; Mellars, 1999; Mellars, 2009; Roebroeks, 2008; Straus, 1990; Straus, 2003; Straus, 2005; Zilhão, 2006; Zilhão and d'Errico, 2003).

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