Additional chronometric data for the small flake assemblages ('Asinipodian') from Pech de l'Azé IV (France) and a comparison with similar assemblages at the nearby site of Roc de Marsal.

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Abstract

The chronological positions of the technological and typological variants of the Mousterian in southwest France have been the subject of debate for over fifty years. While some relative stratigraphical sequences provide a (regional) pattern, which could be interpreted at least in parts as chronological succession, chronometric dating appears to falsify this hypothesis. On a linear time scale much of the data suggests broadly overlapping Mousterian variants in the late Middle Palaeolithic. New thermoluminescence data for a less common Mousterian variant (Asinipodian) are presented for Pech de l'Azé IV and discussed within the framework of similar assemblages from Roc-de-Marsal. The two Asinipodian assemblages at Pech de l'Aze IV provide TL mean ages for Layers 6A and 6B of 74 ± 4 ka and 70 ± 4 ka, respectively. This data fits well into the previously established geochronological framework for the site and the weighted context TL-age of 72 ± 3 ka is in excellent agreement with OSL age estimates for the same layer. The Asinipodian assemblage from layer 6 and the similar small flake assemblages at Roc de Marsal thus can be placed in MIS 5a to 4. The outstanding concurrency between several chronometric dating methods for the sequence of Pech IV, as well as for the cluster of Pech sites and elsewhere, suggests that chronometric ages provide reliable estimates for the interpretation of the timing of the dated occurrences. However, coherence on a chronostratigraphical succession of the technocomplexes/facies is only achieved on a local scale for the Pech sites and elsewhere. The Mousterian variants, as they are defined, overlap considerably in time, and call into question their interpretation as a succession of chronological units on a larger geographical scale, while a correlation with climate change of the technological units is not clear either.

The agreement in chronometry and interpretation of the lithic sequences on identical analytical grounds of these two sites might indicate that differences in lithic analysis/definitions at least contribute to, if not are, the general problem.

Introduction

Since the early part of the 20th century, it was recognized that the Mousterian of southwest France varied in ways such that apparently distinct technocomplexes, or facies, could be distinguished on the basis of relative frequencies of particular tool types (Peyrony 1920; Peyrony 1930; Breuil 1932; Breuil and Lantier 1959; Bordes 1961; Bordes 1976; Bordes 1981). Despite some criticisms (Rolland and Dibble 1990; Dibble and Rolland 1992), their use continues today, though their definition is now based more on technological criteria than on typological frequencies of retouched tool counts (Delagnes *et al.* 2007). Various interpretations of this variability have been offered (Peyrony 1920; Bordes 1961; Mellars 1965; Binford and Binford 1966; Rolland and Dibble 1990; Dibble and Rolland 1992; Morin *et al.* 2014; Thiébaut *et al.* 2014).

In this debate, whether or not the facies, or at least some of them, are temporally ordered has been a consistent research focus. As noted by Mellars (1965; 1969) early in the debate, the Mousterian of Acheulian Tradition (MTA) occurs late in many sequences, and likewise, when both Ferrassie and Quina Mousterian are present at the same site, the latter nearly always overlies the former (Mellars 1996). This is in contrast to the facies of Denticulate Mousterian and Typical Mousterian, both of which can occur anywhere within a site's sequence, while the Asinipodian, the last of the Mousterian facies defined by Bordes (1975), has only been recognized in a few sites (Dibble and McPherron 2006; 2007).

While intra-site stratigraphic sequences represent a strong argument for establishing chronological ordering, the application of chronometric dating across many sites is required to confirm the validity of locally observed patterns across a region. Obtai-

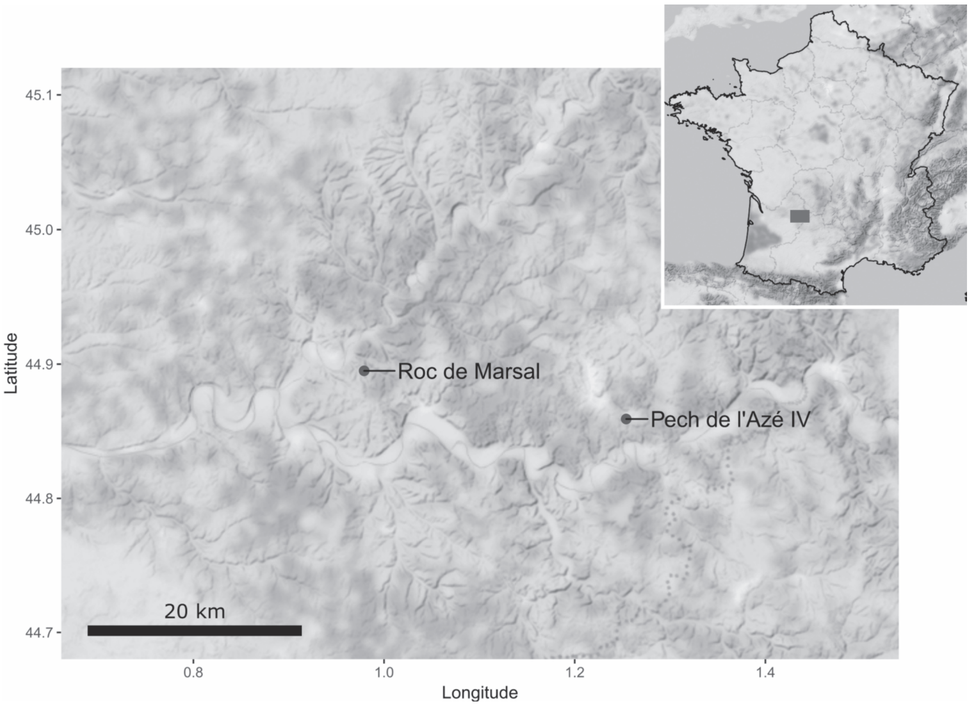

Figure 1: *Locations of the Middle Palaeolithic sites of Pech de l'Azé IV and Roc de Marsal.*

ning chronometric dates for Mousterian assemblage variability, preferentially with multiple methods, is important to the resolution of this debate. Thus in this paper, new thermoluminescence (TL) dates from the deeply stratified Mousterian site of Pech de l'Azé (Pech) IV, southwest France (Fig. 1), are presented. The dates are obtained for Layer 6 which is characterized by small flake production ('Asinipodian') (Bordes 1975; Dibble and McPherron 2006; 2007). Similar assemblages emphasizing small flake production are also present at the base of the sequence recently excavated at the nearby site of Roc de Marsal (Fig. 1). A comparison of the dates from these two sites with their very distinctive small flake assemblages will serve as a very specific test as to whether Mousterian variability in southwest France has a chronological component.

Chronometric dating results are presented within the framework of Marine Isotope Stages (MIS) (defined after Lisiecki and Raymo 2005), which sometimes allows a more precise interpretation of the age by including the climatological data available for a given layer/site. It is assumed that the short terrestrial delays observed for Holocene marine oxygen isotope records (e.g. Sharapova *et al.* 2008), applies to the later Pleistocene as well and oxygen isotope data from marine records can be used for the correlation of terrestrial records. The potential lack of exact synchronicity has to be emphasized, which leads to an understanding of such stages as 'climatic stages' or 'climatic substages' following Railsback *et al.* (2015). The chronometric data is used to determine the nominally possible MIS attribution within the 95% probability level (doubled 1-σ uncertainties) and contrast this information to climatological information available for the sedimentological/archaeological layer under question. Climatological data sometimes allows the elimination of a nominal MIS attribution and thus a more precise age estimate can be provided for interpretation.

The chronometric framework of the late French Middle Palaeolithic

For the late Middle Palaeolithic, a summary by Guibert *et al.* (2008) shows a complex pattern of broadly overlapping Mousterian facies. For their analysis they collected and compared data for >340 chronometric ages on a linear (calibration of C14) time scale. Critical evaluation of the association between the dated samples and their archaeological context is, even now, not always a high priority in many dating applications despite a wealth of publications and explicit work on the subject, e.g. the typology of events (Dean 1978). All data was ranked by Guibert *et al.* (2008) according to a set of quality criteria involving contextual association of the samples, pretreatment and other methodological aspects. Dates with ranks falling below a particular threshold were considered unreliable and discarded from their analysis. Accounting for the potentially fundamental problem when characterizing Mousterian assemblages, the use of varying criteria or of inter-analyst variability, however, is beyond the reach of most studies emphasizing the chronometric data. The same is true here, but we are focusing on two sites excavated, studied and analysed by the same team, thus the criteria employed, as well as the approach for assemblage characterization, are identical.

After applying their criteria, and with the above caveats in mind, many fewer dates remain. With these, Guibert *et al.* (2008) present a 'visual qualitative analysis' for three of the Mousterian facies (MTA, Quina and Denticulate). Their approach avoids having to make questionable statistical assumptions. The results should not be regarded as a definition of time slices for any of the facies, or to provide the timing of the beginning or ending of technocomplexes (Guibert *et al.* 2008). Having actually found and dated one of the first or last appearances of a facies can be questioned and the interpretations thus should be rather related to first/last 'found' or 'dated' occurrences.

Even with a restriction to high quality chronometric data, which should provide the most coherent temporal pattern, a simple chronological succession of facies is not apparent in the data (Guibert *et al.* 2008; Richter *et al.* 2013). Contrary to these regional data, especially to work on Pech IV (Richter *et al.* 2013), a comprehensive dating study, based primarily on OSL dating of the sedimentation, provides a coherent picture for the cluster of sites at Pech de l'Azé (Pech I, II and IV), which suggests a strong chronological component to the Mousterian variability present there (Jacobs *et al.* 2016). The discrepancy between, for instance, these results for the Pech site complex on a local scale and the larger regional scale analysis is potentially attributed to the use of different techniques from different laboratories for the various age estimates (Jacobs *et al.* 2016). If the use of different techniques from different laboratories is preventing us from detecting a chronological pattern, this should, however, be the case at the Pech site cluster as well. It is interesting to note, that the dating results for the Pech site cluster, performed in different laboratories and with different techniques, provide a rather coherent picture (see discussion below). Furthermore, this data is also, especially at Pech IV, in excellent agreement with the OSL ages (Tab. 3). Using one technique from one laboratory (as Jacobs *et al.* (2016) have done) allows for a higher resolution analysis due to the shared systematic uncertainties, which can be largely omitted for comparative analysis (Aitken 1985). But this type of approach naturally restricts the analysis to sites for which such comparable data are available. Furthermore, it has potentially the disadvantage of sharing the same systematic bias for all data included in such an interpretation. In comprehensive analysis for a large scale interpretation it might be preferable to include multiple methods with variable systematics, even if this might mean less resolution, but there appears to be no reason for a systematic bias.

Linking the Mousterian variability to palaeoclimatological changes has been suggested (e.g. Morin *et al.* 2014), but no consistent pattern on the scale of geographical occurrence of the Mousterian variants can be shown so far, and a link of the Quina facies with reindeer dominated assemblages to palaeoclimatology (Morin *et al.* 2014) has been questioned (Guérin *et al.* 2017).

Chronometrically, the Denticulate and the Quina facies, for example, can be only broadly linked to MIS 3 on the geographical scale on which the concept of Mousterian facies is actually applied (Richter *et al.* 2013). The MTA, which stratigraphically would appear to be one of the last manifestations of the Mousterian, exhibits a larger age range, from MIS 4 to MIS 3. These results led to the conclusions that facies are largely contemporaneous (Guibert *et al.* 2008; Richter *et al.* 2013). This is in accordance with e.g. Delagne & Meignen (2006) who investigated the intra- and inter- site variability and found their data showing similar ages for their technologically defined units, and Thiébaut *et al.* (2014) who argue that time does not explain Mousterian variability. In both of these latter cases, cultural factors are given priority as an explanation.

Pech de l'Azé IV

Pech de l'Azé IV (Bordes 1975; 1978; McPherron and Dibble 2000) is one of a complex of four late Middle Palaeolithic sites located in the Perigord region of southwest France (Fig. 1). Recent excavations (Turq *et al.* 2008; Turq *et al.* 2011) pushed the west section further west by one meter and produced the samples presented here (Fig. 2). Eight major Pleistocene layers were identified that matched, for the most part, the sequence original described by Bordes (Turq *et al.* 2011). At their thickest, the deposits are about 4.5m deep (Fig. 2).

The basal Layer 8 rests directly on bedrock and consists of bedded clayey-sand with a major organic anthropogenic component including multiple combustion features (Dibble *et al.* 2009; Goldberg *et al.* 2012). The lithic component appears to be relatively homogeneous and can be characterized throughout Layer 8 as being high in numbers of scrapers, low in notches/denticulates, and having a relatively high Levallois component. In classic Bordian systematics, it can be characterized as a Typical Mousterian.

Layer 7 is a relatively thin, cm-thick layer of coarse sand, with cryoturbated angular flint and bone-rich sand. The lithics are too battered to allow any accurate technological or typological analysis.

Layers 6, 5, and 4 are composed of silty-sands with varying sizes and quantities of limestone fragments. In particular, the upper portion of Layer 6 contains some large blocks of roof fall (Layer 6A). Tool frequency is relatively low in Layer 6, with notched tools more common than scrapers. Layer 6 is notable for the emphasis on small flake production using a variety of methods including Levallois, Kombewa, and truncated-facetted, and Layer 6 is the eponymous assemblage for the Asinipodian (Dibble and McPherron 2006; Dibble and McPherron 2007). Scrapers become more common starting with Layer 5 and Levallois remains common. Thus Layer 5 would be classified as Typical Mousterian facies. The emphasis on scrapers continues in Layer 4 but there is a gradual decline in Levallois production. While a facies attribution of the various assemblages within Layer 4 is difficult even Bordes (1978) avoided attributing them to a particular facies), there are clear Quina features, especially in the uppermost Layer 4A.

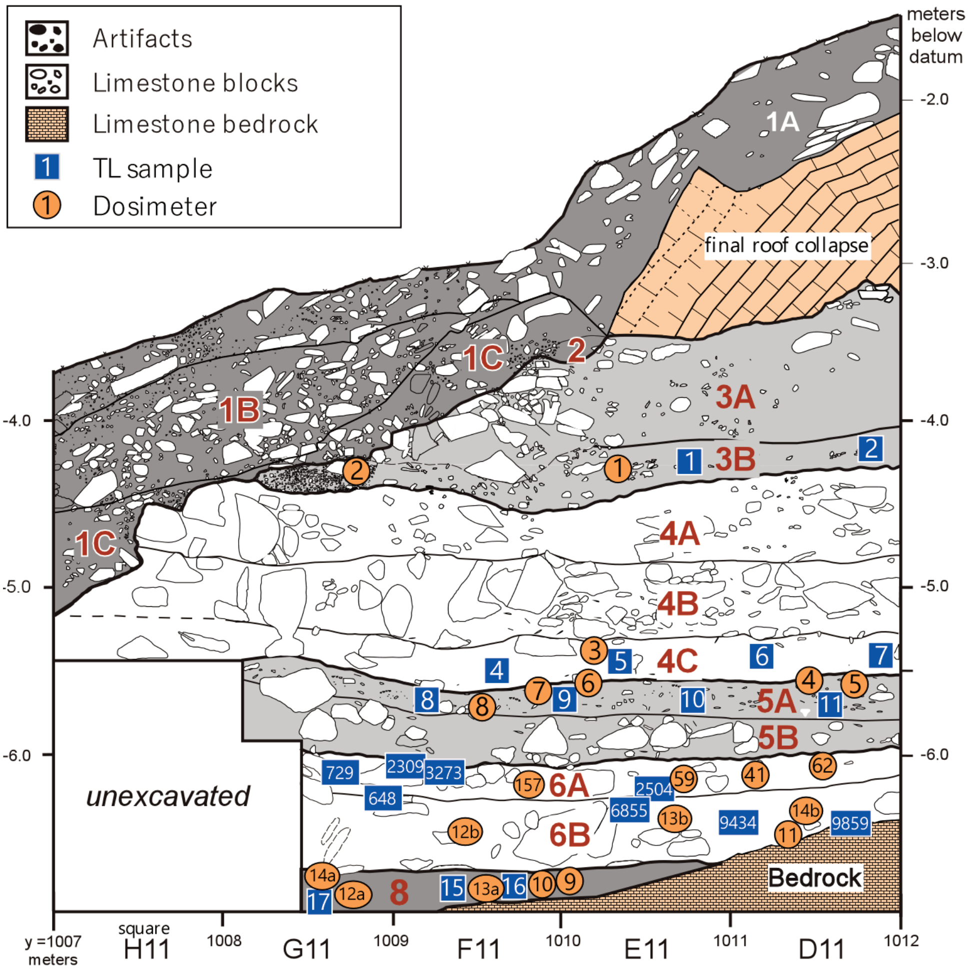

Figure 2: *Stratigraphy of Pech de l'Azé IV. The location of dosimeters and samples are projected onto the profile at x=999. Layer 8 contains a Typical Mousterian; 7 cryoturbated assemblage (Layer 7 is not exposed in this section); 6 Asinipodian; 5 Typical Mousterian; 4B,C Typical Mousterian; 4A Quina Mousterian; 3 Mousterian of Acheulean Tradition (MTA); 2-1 Holocene deposits.*

Layer 3 is the uppermost of the Pleistocene-aged deposits. The lithic component contains lower scraper counts, some backed knives, pseudo-Levallois points, and notches and denticulates. Bifaces and biface thinning flakes occur in this layer which is attributed to the MTA facies (McPherron *et al.* 2005; McPherron *et al.* 2012).

The Pech IV sequence has been the subject of multiple chronometric studies (see discussions in Richter *et al.* 2013; Jacobs *et al.* 2016), of which we discuss only the more recent approaches and concentrate on the lower part of the sequence (Tab. 3).

The last heating of flint, and thus a prehistoric activity, was dated by means of TL-dating for the sequence of Pech IV (Richter *et al.* 2013). The Typical Mousterian from Layers 8 and 5A were dated to 96 ± 5 ka and 74 ± 5 ka, respectively, while Layers

level	x (m)	y (m)	z (m)	square	dosim #	$D_{\gamma\text{-external}}$ (µGy a^{-1})
6A	999.014	1011.135	-6.11	D10	PA4-41	398
6A	999.058	1009.523	-6.47	F10	PA4-12b	390
6A	998.992	1010.721	-6.14	E10	PA4-59	416
6A	999.002	1011.574	-6.06	D10	PA4-62	485
6A	999.018	1009.836	-6.17	F10	PA4-157	353
					average	408 ± 44
6B	999.058	1010.668	-6.41	E10	PA4-13b	358
6B	999.059	1011.452	-6.364	D10	PA4-14b	446
					average	402 ± 44

Table 1: *Locations and results of Al_2O_3:C dosimeters.*

3B (MTA) and Layer 4C (Typical Mousterian) could only be dated to an age range from MIS 5a to 3 and MIS 4 to 3, respectively, due to small sample numbers available (Richter *et al.* 2013). The evidence for fire and, therefore, heated flints varies dramatically through the sequence (Dibble *et al.* 2009; Sandgathe *et al.* 2011). Thus, Layer 6 was only bracketed by the above age estimates, and here the remaining TL-data is presented to provide a full TL-data set for the entire stratigraphy within the limitations of sample availability. Excellent agreement with the above TL-results was obtained by Optically Stimulated Luminescence (OSL) dating of the sedimentation (see Tab. 3 and discussion below) at Pech IV (Jacobs *et al.* 2016). With the completion of this study two independent sets of chronometric data are available for almost the entire stratigraphical sequence, making Pech IV one of the best dated Middle Palaeolithic sites.

TL-dating method

The TL dates reported here follow the same methodology and techniques described in (Richter *et al.* 2000; Richter *et al.* 2013) and only the most relevant aspects are discussed here. An uncertainty of 10 % for the external γ-dose rates, as determined by α-Al_2O_3:C OSL-dosimeters, is employed. HpGe-γ-spectrometry (SiO_2 matrix) of the fine grained component of the sediments suggests secular equilibrium of the decay chains of U and Th. This indicates that there were no recent changes in the decay chains and allows the assumption of constancy of the external γ-dose rates, where the present day moisture is assumed to best reflect the average burial moisture.

The new TL dates were obtained from heated flint artefacts from Layers 6A and 6B, which were selected on the basis of the presence of macroscopic surface alterations (Richter 2007) and the heating plateau (Aitken 1985). Additive and regenerated growth curves (MAAR protocol) were constructed with 4-5 dose points each, consisting of 7-10 aliquots, and linear regression analysis provides the equivalent dose as well as the supralinearity correction. The sum of these two parameters gives the palaeodose a flint has received since its last heating in antiquity. The sensitivity to alpha radiation was determined by linear regression analysis of a multiple aliquot additive (MAAD) approach, comprising 3-5 dose points with 5-7 aliquots for α- and β-irradiation with calibrated Am^{241} and Sr^{90}/Y^{90} radioactive sources. The internal dose rates were determined through Neutron Activation Analysis of radionuclide concentration (Tab. 2) of the extracted core material (after 2 mm surface removal with a cooled low speed saw) following conversion by Adamiec and Aitken (1998). Because only unaltered parts from the samples were used, constancy of the internal dose rate is given.

EVA-LUM	Level	square	Inventory No.	X (m)	Y (m)	Z (m)	palaeodose (Gy)	b-value (Gy µm²)	U (ppm)	Th (ppm)	K (ppm)	$D_{int.eff}$ (µGy a^{-1})	$D_{\gamma\text{-ext.eff.}}$ (µGy a^{-1})	D_{cosmic} (µGy a^{-1})	$D_{internal}$ (% D_{total})	age (ka)
10/05	6A	G12	648	1000.563	1008.938	-6.326	50.7±2.0	1.56±0.04	0.74±0.06	0.42±0.03	362±12	169±8	481±40	95	26	78.1 ± 8.6
10/15	6A	G14	729	1002.067	1008.653	-6.095	48.0±1.4	0.96±0.04	1.23±0.09	0.35±0.03	581±21	257±13	487±40	95	34	64.4 ± 6.3
10/11	6A	E13	2504	1001.392	1010.668	-6.238	54.1±2.6	1.05±0.07	0.79±0.09	0.25±0.03	404±16	169±13	492±41	95	26	81.9 ± 10.1
10/12	6A	C12	2008	1000.654	1012.129	-6.195	57.6±1.8	1.38±0.04	0.65±0.08	0.25±0.03	796±24	181±12	483±40	95	27	86.7 ± 8.8
10/08	6A	C11	181	999.910	1012.056	-5.994	66.1±1.6	1.09±0.03	1.85±0.09	0.26±0.02	614±20	360±14	479±40	95	43	78.8 ± 6.9
10/14	6A	F13	2309	1001.28	1009.077	-5.990	40.1±1.3	0.75±0.05	0.55±0.07	0.3±0.03	591±20	142±11	489±41	95	23	63.6 ± 6.5
10/13	6A	F12	3273	1000.579	1009.11	-6.065	56.7±2.6	0.87±0.05	1.01±0.09	0.28±0.03	415±17	203±13	488±40	95	29	82.1 ± 9.9
														weighted mean 6A		**74 ± 4**
10/06	6B	D11	9859	999.479	1011.701	-6.525	54.3±1.2	0.86±0.03	1.23±0.06	0.55±0.02	837±50	291±10	461±39	82	39	72.1 ± 6.7
10/07	6B	D11	9434	999.948	1011.092	-6.411	53.7±1.4	0.87±0.03	0.93±0.05	0.29±0.01	1024±61	239±8	459±39	82	34	77.0 ± 7.1
10/09	6B	E11	6855	999.778	1010.440	-6.337	51.7±1.4	1.33±0.05	0.81±0.05	0.17±0.01	872±52	210±8	457±38	82	31	77.4 ± 7.2
10/10	6B	D11	9859	999.479	1011.701	-6.525	58.0±1.4	9.69±0.02	1.2±0.06	0.4±0.02	921±64	471±15	451±38	82	51	62.9 ± 5.3
														weighted mean 6B		**70 ± 4**

Table 2: *Locations and results of TL measurements, analytical data and calculated ages. An uncertainty of 10 % was employed for the external dose rates (see text).*

facies	Pech I	Pech II	Pech IV
MTA	*52-46* *58-42* *56-42*		
MTA	56-50 42–41 *51-37*		48-46 53-49
MTA	56-50 [$] *48-44*		54-48 >55 -44 *56-46*
MTA	53-49 47–44		
Mousterian / Quina		*80-68*	60-54
Mousterian / Quina			65-59
Typical Mousterian		63-57 *60-54*	72-64 79-62
Mousterian / Typical		*76-64*	80-76 79-69
Mousterian			
Mousterian /		63-57	
Asinipodian			81-73 75-69
Typical Mousterian		66-56 *65-58*	
Typical Mousterian		62-54 *87-73*	
Denticulate		96-74	
Typical Mousterian		*69-62* *	
Typical Mousterian		112 -98	99-91 101 -91
Typical Mousterian			

The data does not include chronometric dates with too low ranking (Guibert et al. 2008) to be considered reliable in (data from: Bowman et al. 1982; Soressi 2002) or data (Schwarcz and Blackwell 1983) which cannot be assigned to a specific layer within a stratigraphy according to Guibert et al. (2008). [$] we here use rounded values for the weighted mean from the data table and not from the text in Jacobs et al. (2016).

Table 4: *Summary of chronometric age estimates (1-σ) for the Late Middle Palaeolithic at the Pech following Bordes' composite sequence with* ***TL (weighted mean or range)***, ***OSL weighted means (rounded or +/- 1-σ of oldest or youngest date)***, ***coupled ESR/U-series***, ***ESR (LU mean)*** *and* ***^{14}C (IntCal09 calibrated)*** *for the Pech-de-l'Azé sites (*outlier discarded; data from: (Soressi* et al. *2007); Turq* et al.*, (2011); this study, and data which is either included in (Guibert* et al. *2008), as preliminary data (Turq* et al.*, data previously listed in the cited governmental report) or as such (Grün* et al. *1991; McPherron* et al. *2012; Richter* et al. *2013; Jacobs* et al. *2016).*

Results and discussion of TL-data

Only two dosimeters could be placed in Layer 6B, due to the limited presence of profiles. However, virtually identical results (Tab. 1) were obtained, which is not surprising given the similarity of these geological units.

Overall the age results (Tab. 2) are rather dependent on the external γ-dose rates because the stable internal dose rates (Richter 2007) contribute only between 26 and 51% to the total dose rate. Furthermore, the cosmic dose contribution for the heated flint samples from Pech IV is significant, ranging between 9 and 15% of the total dose rate (Tab. 2). The roof thickness had to be reconstructed (Richter *et al.* 2013) from the blocks present in the section and should be considered a minimum estimates, and the cosmic dose rate might have been slightly smaller because of a thicker roof, which would result in older ages.

The standard deviations of the ages for each layer do not exceed 10% and are thus in the range of the variation measured by the dosimeters, indicating that the range in calculated ages is mainly caused by the heterogeneity of the external γ-dose. It is assumed that the prehistoric heating took place for all samples at roughly the same time and that the age of this event is equivalent to the deposition of artefacts, fauna and sediment.

Four samples from Layer 6B were sufficiently heated and passed the heating plateau test (Aitken 1985) for dating application. The ages range from 77 to 63 ka (Tab. 2). The data are drawn from a normal distribution (Chi-square and Shapiro-Wilk) and a weighted mean age of 70 ± 4 ka can be calculated, which best represents the age of this layer, giving a range from 78 to 62 ka (2-σ), which encompasses MIS 5a to MIS 4.

The TL-results for the six samples from Layer 6A are very similar, ranging between 87 and 64 ka (Tab. 2). Again a normal distribution is present and a weighted mean age of 74 ± 4 ka can be provided,

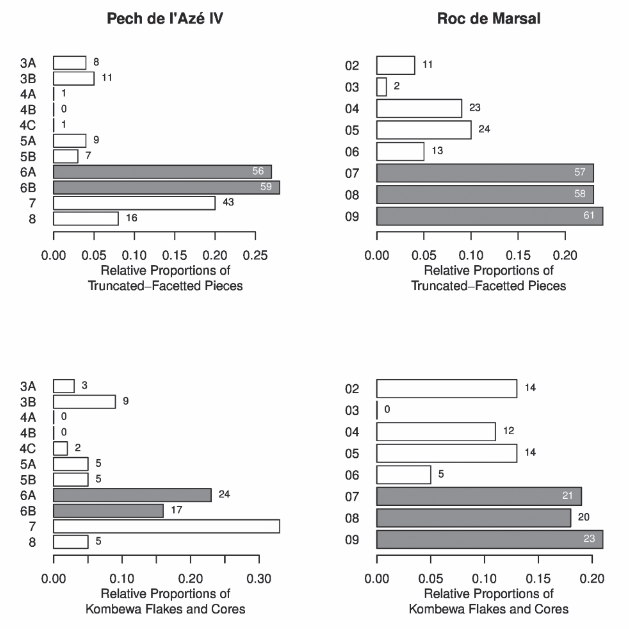

Figure 3: *Percentage of Levallois flakes and of scrapers in the Pech IV and Roc de Marsal sequences.*

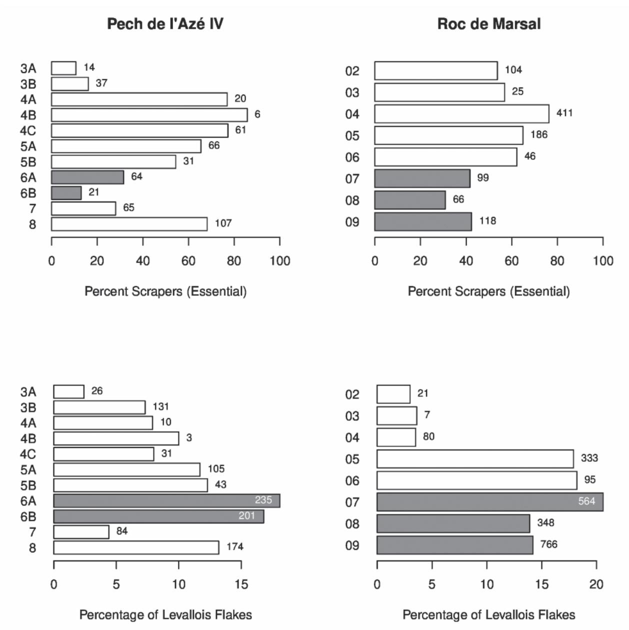

Figure 4: *Relative proportions of Kombewa cores and flakes and of truncated-facetted pieces at Pech IV and Roc de Marsal.*

which suggests an age range (2-σ) between 82 ka and 66 ka, comprising MIS 5a to 4 as well.

The inversion of these two mean ages with stratigraphy is apparent when uncertainties are considered. The weighted mean ages are statistically not different from each other and the ages of these two sublayers thus have to be considered as statistically identical. It is thus stratigraphy which provides at least a relative age information.

Together with the previous chronometric dating, a clear picture for the Pech IV sequence is provided (Tab. 3), with data from different techniques providing the same results . There is excellent agreement between these new TL-data and the OSL dating of the sediments from Layer 6 which range from 79.8 ± 6.1 ka to 74.1 ± 5.6 ka (Jacobs *et al.* 2016). The OSL weighted mean of 76.7 ± 3.7 ka for all samples from Layer 6 (Jacobs *et al.* 2016) corresponds well to the weighted average of all TL-data of 72 ± 3 ka for Layer 6. This translates to an age range of between 78 and 66 ka to be used for interpretation with other data.

The data set in Tab. 3 is coherent, with the ages generally increasing with depth and generally agreeing (doubled uncertainty as 2-σ as 95 % probability) where multiple dating techniques were employed. The only exceptions appear to be an outlier in the ESR data for the Typical Mousterian at Pech II and a diffuse picture for the second upper most MTA layer at Pech I.

There also appears to be gross consistency in the correlations of layers between the sites and their chronologies (Tab. 3). Thus, in the Pech sites, the MTA layers can be attributed to MIS 3, while the Quina Mousterian as well as the Asinipodian date between MIS 5a and 4. The Typical Mousterian with its variable stratigraphic position occurs in various layers between the end of MIS 5 to MIS 4 and maybe even MIS 3.

Comparison with Roc de Marsal

Roc de Marsal is a relative small (80 m^2) cave located approximately 20 km to the northwest of Pech IV. Its deposits are Middle Palaeolithic (with some Medieval remains as well), and the site is perhaps best known for the discovery in 1961 of a relatively complete Neandertal juvenile (see citations and discussions in Sandgathe *et al.* 2011; Goldberg *et al.* 2013). From 2004 to 2010, new excavations were conducted to obtain new samples, to better understand the formation of the cave and its deposits, and to date the sequence (Turq *et al.* 2008). A total of 12 layers (numbered 12 to 1 from bottom to top) were recovered, with Layers 9 through 2 assigned to the Middle Palaeolithic. At the base of the sequence, especially in Layers 9 and 7, the deposits contain a number of combustion features and dark sediments. These deposits alternate in the lower portion of the sequence with layers containing lighter sediments and few to no traces of fire. The upper part of the sequence, Layer 4-2, contains no evidence at all of combustion features, and the yellowish sediments mostly derive from the decomposition of the bedrock (Sandgathe *et al.* 2011; Aldeias *et al.* 2012; Goldberg *et al.* 2012).

From a lithic technology point of view, the lower part of the sequence (Layers 9-5) is characterized by the use of Levallois (Fig. 3), whereas the upper part of the sequence shows a shift to Quina technology. Scrapers are common throughout the sequence, but also show a steady increase in Layers 9-4. In Bordian systematics, Layers 9-7 would be considered Typical Mousterian, Layers 5-6 would be Ferrassie Mousterian, and Layers 4-2 would be attributed to Quina Mousterian. However, Layers 9-7 are quite comparable to Layer 6 at Pech IV (Fig. 3 and 4). They both show relatively low levels of scraper production and frequent use of Levallois technology. Most tellingly, however, they also show very high levels of small flake production in the form of Kombewa cores and truncated-facetted artifacts. It is especially in the use of truncated-facetted techniques that these layers at their respective sites stand out from the layers immediately above and below (noting that at Pech IV Layer 7 is difficult to interpret because it is so heavily reworked). Though we do not particularly favour the introduction of new facies names, if one were to assign a Mousterian facies to the Roc de Marsal Layers 9-7, it would be Asinipodian.

Further, besides the strong similarities of these two assemblage groups, the stone tools and to some extent the fauna, the Roc de Marsal sequence (Layers 9-2) corresponds roughly to the middle portion of the Pech IV sequence (Layers 6-4A). This argument is strengthened by the finding from the new excavations that Layer 4A at Pech IV is Quina Mousterian, and the layers between the 'Asinipodian' and Quina at both sites are dominated by scrapers and Levallois technology.

Thus here, with these two sites excavated by the same team, with the stone tools studied by the same team, and with a rather distinctive emphasis on small flake production appearing in the middle of the sequence at both, we have an opportunity to make a fairly specific test of the temporal component in Middle Palaeolithic variability. Like Pech IV, the site of Roc de Marsal has been the target of multiple dating studies using a variety of methods and materials including TL, OSL and IRSL on sediments, flints, quartz and feldspars (Guibert *et al.* 2009; Guérin *et al.* 2012; Guérin *et al.* 2017). At Roc de Marsal the OSL data do not agree with the TL results, which is attributed to the problematic definition of evaluation criteria of single grain data and mainly on a problematic dosimetric environment (Guérin *et al.* 2017). The tendency for older OSL ages at Roc de Marsal, even for heated sediment samples, in comparison with post-Infrared Luminescence (pIR) sediment dating especially points to dosimetric problems (Guérin *et al.* 2017). The feldspars used in pIR are less prone to such problems and agree well with the TL data, thus suggesting an age around 65 ka (1-σ ranges between ~80 ka and 55 ka) for the small flake assemblages from Layers 9-7 at Roc de Marsal. Such an age is well comparable to the Layer 6 small flake production TL-dates (78 - 66 ka) presented here for Pech IV, which are in agreement with OSL (84 -69 ka) dating of the same layer. This comparison shows chronostratigraphical coherent successions at Pech IV and Roc de Marsal, but the limitations on two sites only and to such a small geographical scale have to be kept in mind.

Conclusions

The debate on the interpretation of the observed variability in retouched tool frequencies and technologies of blank production in late Middle Palaeolithic assemblages from southwest France, one of the best documented areas for this time period, has lasted more than 50 years. Though various explanations of the underlying cause of the variability have been put forward, no consensus has been reached. As an example of the difficulties involved, Richter *et al.* (2013) have argued that the chronometric data from Pech IV do not support organizing the Mousterian of SW France into chronostratigraphic units occurring in a certain chronological order at a regional level. These conclusions were identical to Guibert *et al.* (2008), that the observation of diachronic data do not support the interpretation of this variability as chronological stages (i.e., contra Mellars (1965; 1969)). An interpretation of some variants as chronostratigraphical valid units in some cases but as invalid in other variants/cases, is not coherent and does not appear to provide a satisfying interpretation because their definitions share the same basis. When a specific ordering has been observed and the variants explained by a chronological appearance or climate changes (e.g. Morin *et al.* 2014; Jacobs *et al.* 2016), the pattern is demonstrable only on a local level or for a rather small and specific region, while these variants are used to describe and interpret assemblages on a large geographic scale. Such chronological coherence on a local scale has been demonstrated in a recent study of the Pech sites (Jacobs *et al.* 2016), and is also indicated by the data presented here in comparing Pech IV and Roc de Marsal.

These data are part of series of precise and accurate dates, which are replicated by different dating techniques and by different dating laboratories. This provides confidence in the chronometric dating of these sites. In the present study only high quality dating results are included, which have to be considered as state of the art and reliable. Thus it seems unlikely that the difficulty of verifying a chronological pattern in Mousterian variability lies with the methods employed. At Pech IV, there is not only excellent concurrency of TL- and OSL-dating, but there is also agreement between other dating methods for the Pech site cluster (see Tab. 3 with radiocarbon, ESR and TL data) and beyond (see Guibert *et al.* 2008 data).

Therefore, selected dating methods or selected dates or data sets cannot be rejected because of presumed reliability problems, while others are accepted. The same logic applies to the facies, all of which are defined on a common concept. There appears to be some lack of consistency in accepting some of these facies as chronostratigraphical units while rejecting others, which are defined within the same conceptual framework. However, it has to be acknowledged that there appears to be a pattern in the stratigraphies, mainly on a local basis, while it has to be questioned why the interpretations are different (chronostratigraphic versus non-chronostratigraphic) for units defined on the same grounds. Such a lack in consistency requires explanation.

Over and above the problems of attributing assemblages to Mousterian facies, the lack of clear chronological succession of these variants might also be the result of using analytical units - the facies - in the first place. These are likely simply so broad and complex that they ultimately mask or fail to measure the underlying behavioural patterns we are looking for. After spending almost a century debating the reasons why such patterns are apparent, perhaps it is time to realize that they are essentially arbitrary partitions that have outlived their usefulness for Middle Palaeolithic research and alternative ways in analysing lithic assemblages might be needed.

Employing multiple dating method approaches allows falsification of results and strengthens the grounds for the interpretation of chronostratigraphies as is shown here for Pech de l'Aze IV and also for Roc de Marsal (Guérin *et al.* 2017). This study also provides arguments in favour of the interpretation of the Roc de Marsal chronostratigraphy to be based on the TL and pIR data (Guérin *et al.* 2017) because of the agreement with TL-dating results for the similar industries of Layer 6 at Pech IV and Layers 9-7 at Roc de Marsal. However, the argument for the above is based on the notion that no analytical differences are present because of identical analytical approaches, and on the assumption that similar assemblages should follow at least locally a similar chronological pattern. The former argument has been shown to be a potentially valid reason for the observed inconsistencies (e.g. Denticulate vs. Quina Mousterian at Combe-Capelle (Dibble and Lenoir 1995), or La Folie being assigned as MTA-B (Bourguignon *et al.* 2002; Bourguignon *et al.* 2006) despite the lack of bifaces). The latter argument does not seem to hold up on a larger geographical scale, at least when based on the published accounts of unit/assemblage interpretation/classification. A parallel sequence at Pech IV and Roc de Marsal does not prove that a chronological succession of various industries took place across the region as a whole. But the agreement in chronometry and interpretation of their lithic sequences on identical analytical grounds here might indicate that differences in lithic analysis/definitions at least contribute to, if not are, the general problem.

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