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Neanderthal mobility and technological change in the northeastern of the Iberian Peninsula: The patterns of chert exploitation at the Abric Romaní rock-shelter



Mobilité des Néandertaliens et changements technologiques dans le Nord-Est de la péninsule Ibérique : les modalités d'exploitation du silex dans l'abri sous roche Abric Romaní

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ABSTRACT

Understanding the changes in the technological organization of prehistoric hunter-gatherers is important to research into hominin foraging activities. During the Middle Paleolithic, the coexistence or the replacement between Levallois and discoïd technologies has frequently been recorded, but there is still no clear understanding of the reasons for their alternating and fragmented use in the archaeological record. This paper aims to contribute with new data to the current debate, by exploring the chert assemblages from levels O and M of the Abric Romaní rock-shelter. The results reveal that the change from Levallois in level O to discoïd in level M is accompanied by the use of different axes of mobility, a reduction in the foraging radius and a more careful management of raw materials. A cross comparison with other archaeological evidences indicates the general pattern in the Northeast of the Iberian Peninsula during the late Middle Paleolithic, in which the use of Levallois technology is associated with chert and high mobility patterns whereas discoïd technology is more closely linked to the use of local raw materials and a lower degree of mobility. The modifications to the mountainous environments and to the distribution of preferred prey animals may have influenced the Neanderthals' mobility patterns and contributed to modifying their technical behaviours in order to obtain better foraging incomes.

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R É S U M É

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Comprendre les changements dans l'organisation technique des chasseurs-cueilleurs est important pour l'étude d'activités humaines liées à la recherche de subsistance (nourriture). Pendant le Paléolithique moyen, la coexistence des technologies ou le remplacement de la technique Levallois par la technique discoïde a été souvent soulignée mais, à partir des données archéologiques, il est difficile de comprendre à ce jour les raisons de leur alternance ou de l'usage de l'une plutôt que de l'autre. Le but de cet article est d'apporter un éclairage à cette question à partir des données provenant des assemblages présents dans les niveaux O et M de l'Abric Romani. Cette étude montre que le changement entre l'assemblage Levallois présent au niveau O et l'assemblage discoïde du niveau M va de pair avec un changement de mobilité, une réduction du rayon de recherche de nourriture et une plus grande exploitation de la matière première. La comparaison avec d'autres ensembles archéologiques dans le Nord-Est de la péninsule Ibérique montre que, pendant le Paléolithique moyen tardif, dans lequel la technique Levallois est associée au silex, une grande mobilité s'observe, alors que la technique discoïde est plutôt en relation avec un usage local de la matière première et une moindre mobilité. Les modifications relatives à un environnement plus montagneux et à une préférence pour certaines proies pourraient avoir influencé la mobilité des Néandertaliens et avoir modifié leur comportement technique afin d'obtenir de meilleures ressources.

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1. Introduction

An important aspect of studies of human evolution is an understanding of the factors that caused prehistoric hunter-gatherers to change their knapping strategies, and the benefits that these changes brought to their subsistence activities. Since the beginning of the Paleolithic investigation, the typological changes, detected in the archaeological record, have been interpreted as the result of cultural differences between Paleolithic tribes (Breuil, 1913; Peyrony, 1920). After the post-war years, this concept has been developed by Bordes (1950, 1953, 1961) to explain the variability of the Middle Paleolithic record assuming the existence of different and neighbouring cultural traditions identified on the base of typological frequencies of retouched tools and Levallois blanks. In the same period, the advent of processual archaeology promoted other hypotheses to explain the changes in the prehistoric material culture (Binford, 1962, 1972). Technological organization, mobility patterns and raw material availability have been considered to be the main influences on the technical behaviors of forager groups (Andrefsky, 1994; Bamforth, 1986; Binford, 1979; Bousman, 1993; Kelly, 1983; Kuhn, 1992; Surovell, 2009; Torrence, 1983). Generally speaking, individuals organized their technologies according to their needs, and lithic production could be resumed between activities in anticipation of use (curation) or based on immediate demands (expediency) (Binford, 1977, 1979). Hunter-gatherers repeatedly plan their feeding strategies, moving through their territory on the basis of water availability, animal migrations or mating events (Binford, 1983; Kelly, 1995; Lieberman, 1993). These movements made provisioning raw materials for tools a crucial activity, as it made it possible to cope with the daily need for cutting edges for hunting, butchering animals and accomplishing diverse domestic tasks (Binford, 1980; Kuhn, 1992). In this situation, technological variability in prehistoric hunter-gatherers might be interpreted

as a set of behaviours and expedients aimed at obtaining better results from foraging incomes.

During the Middle Paleolithic, Neanderthals used various technologies, changing between methods with relatively rigid schemes of core shaping (preferential Levallois, uni-/bipolar recurrent Levallois, laminar) and methods with lower degree of blank predetermination (Levallois recurrent centripetal, discoid, Quina, handaxe *façonnage*) (Boëda et al., 1990; Delagnes and Meignen, 2006). Within these flaking strategies, special attention has been paid to two of the most widely used methods: the Levallois and discoid technologies. Levallois is the technology that marks the beginning of the Middle Paleolithic in Eurasia (Picin et al., 2013; Rolland, 1995; Scott and Ashton, 2011). This new knapping concept was characterized by a hierarchical division of the core volume and by preparing the flaking surface, which made it possible to predetermine the shape of the final product. This feature has been interpreted as marking a significant improvement in the cognitive and neurological capacities of late Middle/Upper Pleistocene populations, because configuring and exploiting the core entailed imagining the shapes of the flakes before they were detached, and therefore required complex mental templates (Boëda, 1994; Wynn and Coolidge, 2010). Conversely, discoid technology is a more simplistic flaking method, which was used from the Lower Paleolithic to the Neolithic (Boëda, 1993; Peresani, 2003; Shea, 2013; Stout et al., 2010; Vaquero and Carbonell, 2003). It is characterized by the alternant exploitation of two production surfaces and the lacking of any technical procedures used to impose specific core morphologies. The applicability of the discoid concept is highly flexible and could be employed at any stage of different flaking reduction processes. In this scenario, the complex sequences of Levallois production could be associated with a curated technology, whereas the discoid method reflects a more expedient approach (Vaquero et al., 2012; Wallace and Shea, 2006). During the Middle Paleolithic, the coexistence or the replacement

of Levallois and discoid technologies has frequently been recorded, and there is still no clear understanding of the reasons for their alternating and fragmented use in the archaeological record.

Currently, the most widely accepted hypothesis proposes a strict association between the technologies and the characteristics of the raw materials used, as indicated by the utilization of good quality chert for Levallois modalities and poorer raw materials for simpler knapping methods (Dibble, 1985; Fish, 1981; Geneste, 1988; Otte, 1991; Tavoso, 1984; Turq, 1989). The technological change from Levallois to discoid has therefore been interpreted as the result of a scarcity of high-grade raw materials (Dibble, 1985; Otte, 1991; Turq, 1989) or an over-exploitation of the good quality outcrops. The latter was probably linked to an increase of the number of occupations and a reduction in the foraging radius (Dibble and Rolland, 1992). The hypothesis that the characteristics of the stone used were a significant factor in the changes in Neanderthals' technical behaviour was also suggested to explain the differences recorded between assemblages of retouched tools, with high quality chert used for the production of scrapers whereas mediocre raw materials were utilized for denticulates (Bar-Yosef et al., 1992; Geneste, 1988; Meignen et al., 2007; Moncel et al., 2008; Turq, 1989; Wengler, 1990).

A recent synthesis of the dynamics of Mousterian settlements in western France, based on comparing technological and faunal data, confirmed the relationship between the properties of the raw materials and the knapping strategies applied (Delagnes and Rendu, 2011). Discoid and Quina methods have been found associated in contexts of high mobility for the acquisitions of migrating large ungulates. This feature supports the hypothesis that the applicability of these knapping methods to different types of stones facilitated their use during long displacements. Conversely, the laminar and Levallois technologies, which were more dependent on better quality chert nodules, have been found linked to a broader spectrum of prey and in smaller foraging areas (Delagnes and Rendu, 2011). This latter result contrasts with evidence from other regions, where complete or retouched Levallois flakes were the lithic items farther transported (Geneste, 1988; Kuhn, 1991; Otte, 1991; Turq et al., 2013).

Although the raw material hypothesis may be valid for some regions, the causes of the technological change between Levallois and discoid may have varied during the Middle Paleolithic in relations with the distinct hominin's technological backgrounds and the different climatic, physiographic and ecological characteristics of the territories. This paper aims to contribute new data to the current debate, by exploring the chert assemblages from levels O and M of the Abric Romaní rock-shelter.

2. Methods and materials

Firstly, the lithic assemblages were studied in order to macroscopically identify the different chert varieties. The analysis was then carried out by following the *chaîne opératoire* concept and the general descriptions documented by Boëda (Boëda, 1993, 1994, 2013). The flake assemblages are discriminated in base of dimensional criterion and are

analyzed only those in which the sum of the length and the width is equal or bigger than 4 cm. The research covered the whole lithic assemblage from level M, whereas, for level O, only artefacts from the richest area of about 20 m² (lines 58–62) in the western part of the rock-shelter were taken into account.

2.1. Abric Romaní rock-shelter

The Abric Romaní rock-shelter (41°32' latitude N, 1°41'30" longitude E) is located near the town of Capellades (Barcelona province, Spain) in the travertine cliff called Cinglera del Capelló at 280 m ASL (Fig. 1). The karst system is rich in natural shelters (e.g., Balma dels Pinyons, Balma de la Costa de Can Manel and Abric Agut), which have yielded archaeological finds dating from the Middle Paleolithic up to the Mesolithic (Vaquero et al., 2013). The Abric Romaní archaeological site was discovered in 1909 by Amador Romaní I Guerra (1873–1930), who carried out several field campaigns between 1909 and 1930. The excavations affected the upper part of the stratigraphy up to level J and a test well, known as Romaní well, was dug at the base of Pit 2 providing evidence of the site's complete stratigraphic sequence (Bartrolí et al., 1995). A second phase of investigations was carried out between 1956 and 1962 under the direction of Dr. Ripoll Perelló, director of the Archaeological Museum of Barcelona, but the information about these fieldworks are scarce (Bartrolí et al., 1995). The present archaeological research into the site began in 1983 under the direction of the senior author.

The stratigraphic sequence consists of 15 archaeological levels and has been dated by U-series and radiocarbon methods as between 40 and 70 ka BP (Bischoff et al., 1988; Vallverdú-Poch et al., 2012) (Fig. 2). Below the Proto-Aurignacian level, the remaining anthropogenic occupations are attributed to the Middle Paleolithic. Interdisciplinary works point out the recurrence of Neanderthal settlements, both short-term (Carbonell, 1992; Vallverdú et al., 2005, 2010) and long-term (Carbonell i Roura, 2012; Fernández-Laso et al., 2011), with abundant evidences of combustion structures, exploitation (skinning, bone breakages, bone tool making) and consumption of animal remains, and lithic production.

Paleo-environmental studies at the site document the rapid and abrupt climatic changes of the Dansgaard–Oeschger (D–O) cycles and Heinrich events from the start of MIS 3 to the Hengelo interstadial or D–O 12 (Burjachs and Julià, 1994; Burjachs et al., 2012). In the chronological period between 57 and 50 ka BP, the climate reveals short and abrupt oscillations with vegetation characterized by dominance of *Pinus* followed by abrupt advances and setbacks of mesic taxa (Burjachs and Julià, 1994; Burjachs et al., 2012; Vaquero et al., 2013). Only during short warming phases, mesothermophilous taxa developed and humidity increased (Burjachs and Julià, 1994). In level O, paleobotanical and micro-vertebrate studies document the cold and moist environment between D–O 17 and 16 (Burjachs et al., 2012; López-García et al., 2014). Conversely in level M, pollen analysis documents the cool and dry condition between D–O 14 and 15 (Vinogradova, 2014).

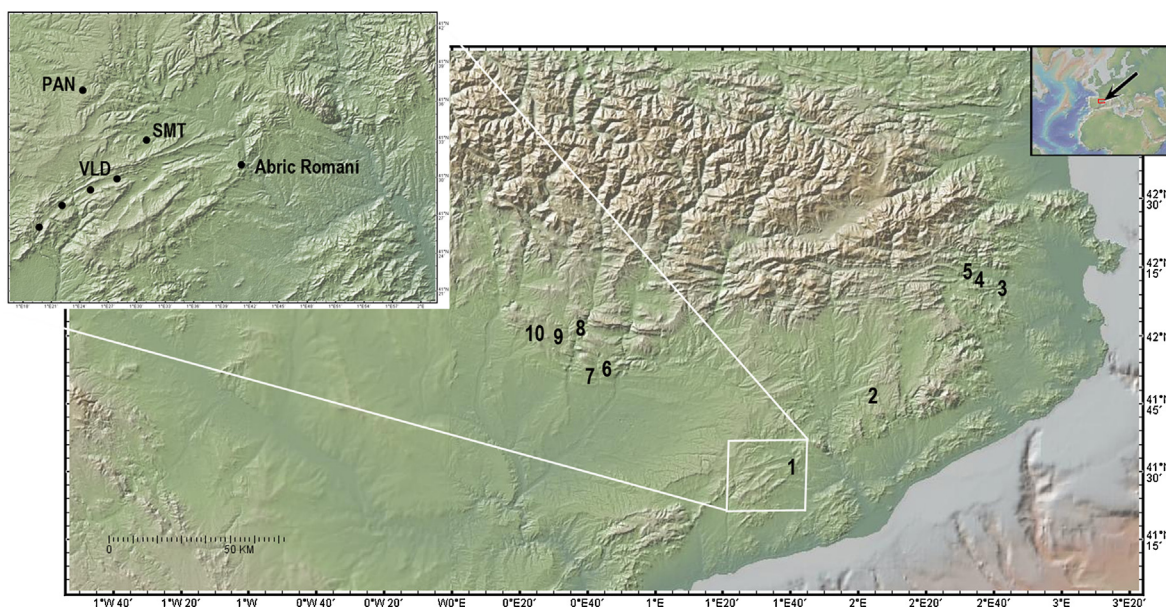


Fig. 1. Geographical localization of the archaeological sites discussed in text (1 – Abric Romaní, 2 – Teixoneres, 3 – Arbreda, 4 – Cova 120, 5 – Ermitons, 6 – Cova Gran, 7 – Roca del Bous, 8 – Fuentes de San Cristóbal, 9 – Gabasa, 10 – Tragó) and chert outcrops used at Abric Romaní rock-shelter (VLD – Valldeperes, SMT – San Martí de Tous, PAN – Panadella-Montemaneu) (base map from GeoMappApp).

Fig. 1. Localisation géographique des sites archéologiques évoqués dans le texte (1 – Abric Romaní, 2 – Teixoneres, 3 – Arbreda, 4 – Cova 120, 5 – Ermitons, 6 – Cova Gran, 7 – Roca del Bous, 8 – Fuentes de San Cristóbal, 9 – Gabasa, 10 – Tragó) et les affleurements des silex utilisées à Abric Romaní (VLD – Valldeperes, SMT – San Martí de Tous, PAN – Panadella-Montemaneu) (fond de carte de GeoMappApp).

The archeological levels considered in this study are characterized by large assemblages of faunal and lithic remains together with wood imprints and hearths (Chacón et al., 2013; Fernández-Laso et al., 2011; Vallverdú et al., 2012). In level O, dated by a weighted mean about 55 ka BP, anthropogenic activities were mainly carried out in two areas located in the western part of the rock-shelter (Chacón et al., 2015; Gabucio et al., 2014b). Analysis of the faunal remains has revealed high frequencies of red-deer (*Cervus elaphus*), horses (*Equus ferus*) and aurochs (*Bos primigenius*) with occasional consumption of rhino (*Stephanorhinus hemitoechus*), wild cat (*Felis silvestris*), hare (*Oryctolagus cuniculus*), bear (*Ursus* sp.) and goat (*Capra aegagrus*) (Gabucio et al., 2014a, b). In level M, dated to between 54.9 ± 1.7 and 51.8 ± 1.4 ka BP, six main activity areas were identified, showing a diverse use of the space in comparison with the previous occupation (Fernández-Laso, 2010). The prey species most frequently found are red-deer, horses and aurochs, whereas hare, bear and lynx (*Lynx* sp.) were occasionally eaten. Seasonal studies of the teeth of the herbivores placed the hunts between autumn and early winter (Fernández-Laso et al., 2010) (Figs. 3 and 4).

Petrographic surveys of the area around the Abric Romaní rock-shelter document the abundance of diverse lithic raw materials (Chacón et al., 2013; Vaquero et al., 2012). Limestone, sandstone and quartz nodules, in primary and secondary positions, are present within a radius of 5 km from the site. In this area, there is a scarcity of chert pebbles, and the main lithological formations are located further away at San Martí de Tous (465 m ASL, ≥ 12 –15 km), Valldeperes (365 m ASL, ≥ 20 –25 km) and

Panadella-Montemaneu (709 m ASL, ≥ 25 –28 km). In the archaeological assemblages, chert is the raw material most commonly used; patination has, however, considerably affected the surfaces of the flakes, limiting the information available as to procurement strategies. The only lithological type for which a broad comparison of the gathering activities for the two levels can be made is that from Panadella-Montemaneu, because patination turns this raw material light brown, which is very different from the light and dark grey-blue tones of rocks from the San Martí de Tou and Valldeperes outcrops (Vaquero et al., 2012).

3. Results

3.1. Level O lithic technology

The chert lithic assemblage from level O of the Abric Romaní rock-shelter is composed of 1965 items (Table 1). Flakes and fragments of flakes make up the bulk of the assemblage, whereas there are relatively few cores and retouched tools (Table 1). There are also many chips, but they are not included in this study. The assemblage suffered significant post-depositional alteration of the chert surfaces, making difficult to identify the different raw materials. In the chert collection, the raw material is principally indeterminate (85%) and the lithological type Panadella-Montemaneu (15%) is present with a little amount. The main causes of indetermination are patination (93.6%), thermal fractures (4.5%), concretion (1.6%) and rounding (0.3%). In this study, the indeterminate raw material is referred to as O whereas the raw material Panadella-Montemaneu is referred to as PAN.

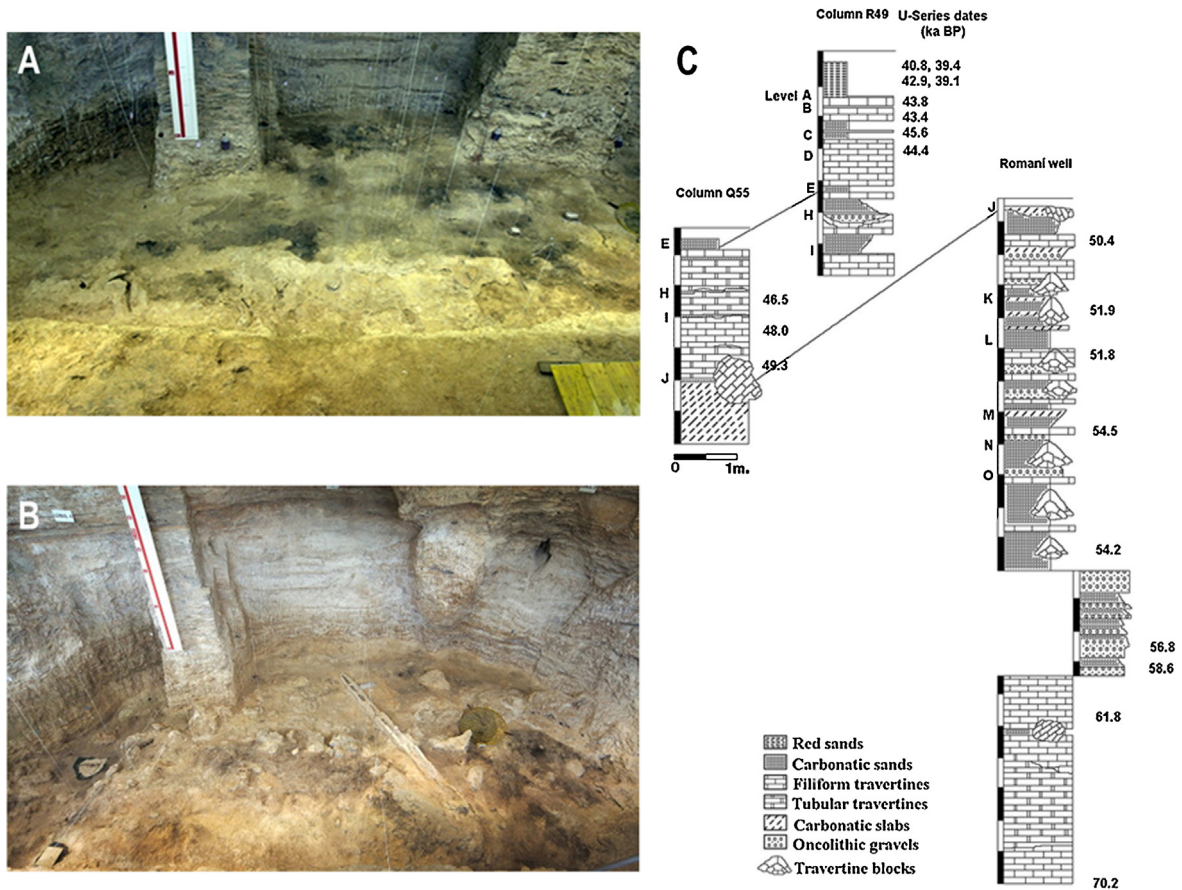


Fig. 2. General overview of level M (A), level O (B) and lithostratigraphy (C) of Abric Romaní rock-shelter (Capellades, Barcelona) (photo credit: IPHES).
Fig. 2. Présentation générale du niveau M (A), du niveau O (B) et de la lithostratigraphie (C) d’Abric Romaní (Capellades, Barcelone) (crédit photo : IPHES).

Table 1
 Raw counts and percentages of the lithic assemblages of level O and M of Abric Romaní.
Tableau 1
 Nombres et pourcentages des assemblages lithiques des niveaux O et M d’Abric Romaní.

	Level O	%	Level M	%
Cores	39	1.8	69	3.5
Cores fragments	5	0.4	11	0.6
Flakes	961	48.9	1003	51.4
Flakes fragments	936	47.6	835	42.8
Retouched tools	1	0.1	11	0.6
Retouched tools fragments	1	0.1	8	0.4
Chunks	22	1.2	16	0.8
Total	1965	100	1953	100

The technological analysis documented that both tested and untested chert nodules were brought into the rock-shelter. The large number of cortical pieces and chunks indicates that the decortication phases occurred at the site (Tables 2 and 3). Of the cores, only 5 have a rounded and weathered cortex, distinctive of secondary high-energy deposition, suggesting that the nodules were gathered from primary outcrops or in natural sections in which the chert formations were exposed.

An examination of the assemblage of cores and flakes determined that the Levallois recurrent centripetal method had been systematically used (Tables 2 and 3) (Fig. 3). The recovery of cortical and semi-cortical flakes confirms that Levallois cores were configured and exploited in the rock-shelter. The configuration of the cores volume was maintained through the detachment of predetermining Levallois and trimming striking platform flakes. The convexity of the cores was instead created by core-edge flakes and core-edge *dos limité* flakes. The small number of core-edge *dos limité* flakes indicates that they were by-products of the flaking sequence, not the intended products. Although several preferential Levallois cores were identified, there are very few preferential Levallois flakes, whereas Levallois centripetal flakes are numerous (Table 3). This characteristic suggests that the use of the preferential Levallois modality was probably linked to a technical shift at the end of the reduction sequence rather than to a primary flaking strategy.

An analysis of secondary *chaînes opératoires* confirms that the main concept of flake production was based on the centripetal exploitation of the core volume. In fact within Levallois, recurrent centripetal cores were recovered several hierarchized centripetal and centripetal cores (Table 2). Generally speaking, the hierarchized centripetal

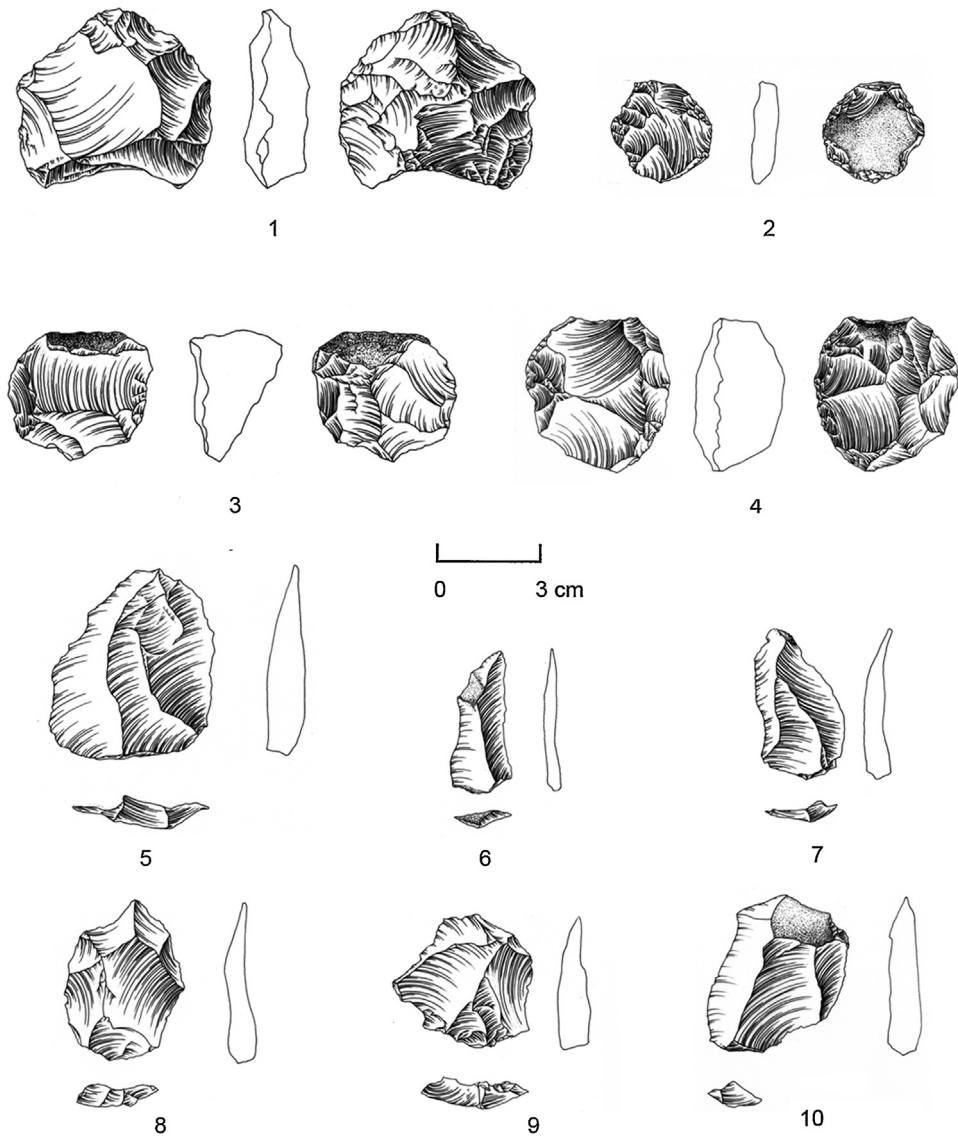


Fig. 3. Levallois preferential cores (1–3), Levallois recurrent centripetal cores (2–4) and Levallois flakes (5–10) of level O (drawings S. Alonso).

Fig. 3. Nucléi Levallois preferentiels (1–3), nucléi Levallois centripètes récurrents (2–4) et éclats Levallois (5–10) du niveau O (dessins S. Alonso).

Table 2

Raw counts and percentages of the core assemblages of level O of Abric Romani.

Tableau 2

Nombres et pourcentages des assemblages de nucléi du niveau O d'Abric Romani.

	O	%	PAN	%	TOT	%
Levallois preferential	3	14.3	3	16.7	6	15.4
Levallois rec. unidirectional			1	5.6	1	2.6
Levallois rec. centripetal	8	38.1	6	33.3	14	35.9
Levallois undetermined	1	4.8			1	2.6
Hierarchized centripetal	3	14.3	2	11.1	5	12.8
Centripetal	2	9.5			2	5.1
Unidirectional	1	4.8	2	11.1	3	7.7
Simple core	1	4.8	1	5.6	2	5.1
Core-on-flake	2	9.5	3	16.7	5	12.8
Total	21	100	18	100	39	100

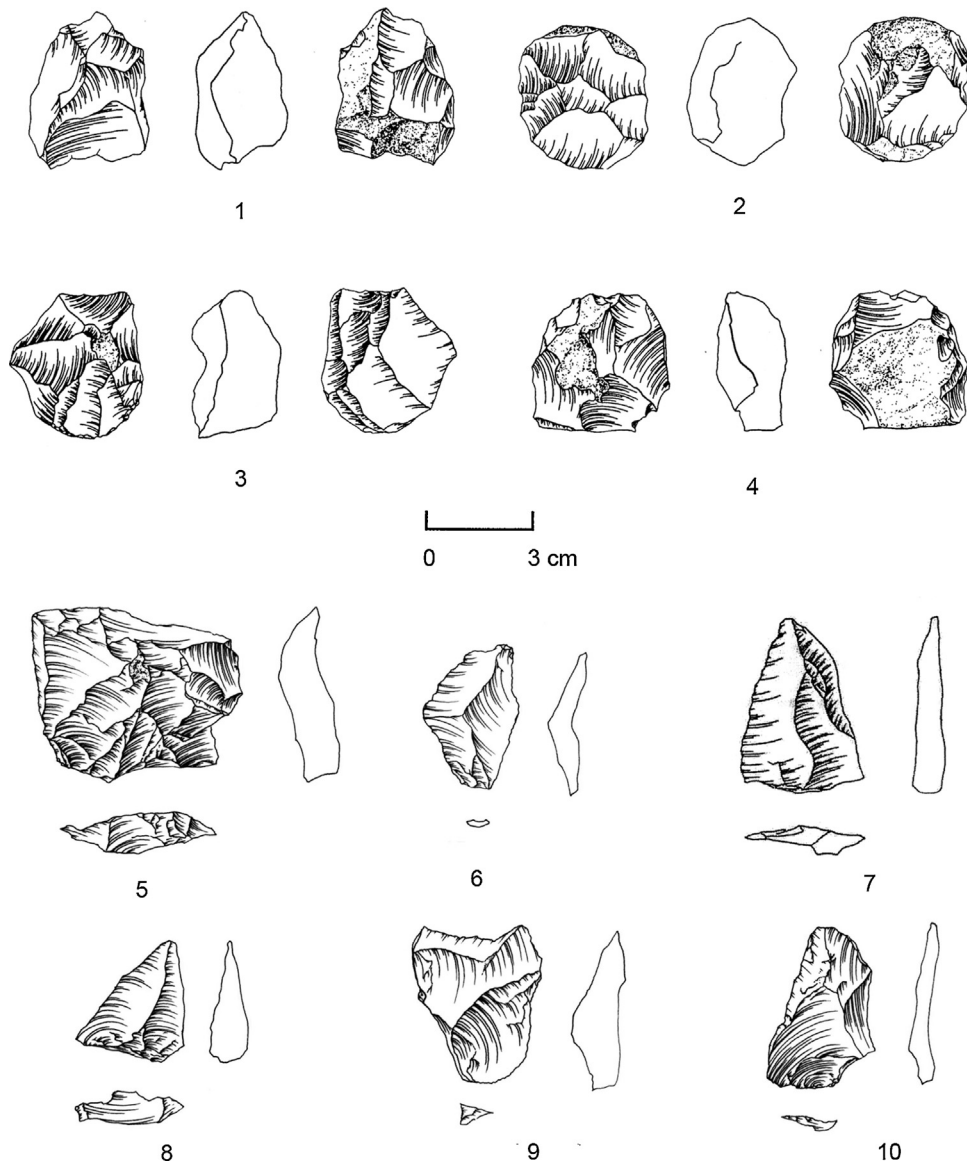


Fig. 4. Discoid cores (1–4), centripetal flakes (5–7) and pseudo-Levallois points (8–10) of level M (drawings S. Alonso).
Fig. 4. Nucléi discoïdes (1–4), éclats centripètes (5–7) et points pseudo-Levallois (8–10) du niveau M (dessins S. Alonso).

method has been interpreted to lie between the discoid and Levallois technologies, due to the dynamic processes involved in the flaking methods (Vaquero and Carbonell, 2003). The appearance of this kind of core in secure Levallois contexts might be explained as an adaptation of the knapper to an unexpected change in the angle of the striking platform rather than a variability of the methods. In fact, knapping errors or inclusions in the raw materials may have modified the convexity of the core, and general reconfiguration might be very difficult in a later phase of core exploitation. Centripetal cores could re-enter in the same sphere of adaptability. In fact, one core might be a fractured Levallois core that was re-used for a short sequence of convergent exploitation of two flakes whereas for the other the knapper took advantage of an unprepared side of the

core that had an angle that facilitated the detaching of three flakes. In cores-on-flakes, there is one example in which the centripetal method was used, and the overall morphology of the blank reminds one of the Levallois recurrent centripetal methods (Table 2). The other core-on-flake instead shows a simpler approach with the detachment of one flake. The remaining cores of the secondary chaînes opératoires lack any preparation of the flaking surface (Table 2). The unidirectional and simple cores could therefore be considered opportunistic, since the exploitation sequence is very short and few flakes were detached – which were probably made to meet an urgent need.

It is worth noting that only 2 retouched artifacts were recovered – a denticulate and a notched tool (Table 6). A previous study documented the presence of higher

Table 3

Raw counts and percentages of the flake assemblage of level O of Abric Romani.

Tableau 3

Nombres et pourcentages de l'assemblage d'éclats du niveau O d'Abric Romani.

	O	%	PAN	%	TOT	%
Cortical flake (> 50%)	92	5.7	22	8.2	114	6.0
Cortical flake (< 50%)	120	7.4	41	15.2	161	8.5
Naturally core-edge flake	32	2.0	12	4.5	44	2.3
Cortical core-edge flake	16	1.0	6	2.2	22	1.2
Trimming striking platform	89	5.5	13	4.8	102	5.4
Ordinary flake	31	1.9			31	1.6
Predetermining Levallois flake	102	6.3	14	5.2	116	6.1
Levallois preferential	2	0.1			2	0.1
Levallois rec. centripetal	64	3.9	11	4.1	75	4.0
Core-edge removal flake	91	5.6	11	4.1	102	5.4
Core-edge <i>dos limité</i> flake	13	0.8	2	0.7	15	0.8
Kombewa-type flake	7	0.4			7	0.4
Re-shaping flaking surface	34	2.1	3	1.1	37	2.0
Knapping accident	115	7.1	18	6.7	133	7.0
Fragment with cortex	246	15.1	60	22.3	306	16.1
Fragment without cortex	574	35.3	56	20.8	630	33.2
Total	1628	100	269	100	1897	100

Table 4

Raw counts and percentages of the core assemblage of level M of Abric Romani.

Tableau 4

Nombres et pourcentages de l'assemblage de nucléi du niveau M d'Abric Romani.

	M	%
Discoïd	19	27.5
Hierarchized centripetal	5	7.2
Centripetal	1	1.4
Unidirectional	5	7.2
Orthogonal	3	4.3
Trifacial	4	5.8
Polyhedral	6	8.7
Core-on-flake	26	37.7
Total	69	100

frequencies of serrated tools in the eastern area of the rock-shelter (Picin et al., 2011), indicating that there was a different location at the site where domestic tasks involving flake resharpening or tool discarding were carried out.

3.2. Level M lithic technology

The chert lithic assemblage of level M of Abric Romani rock-shelter contains 1953 items (Table 4). Flakes and fragments of flakes make up the bulk of the collection, whereas there are relatively few cores and retouched tools (Table 4). There are also many chips in the assemblage, but they are not included in this study. In the assemblage, the raw materials are mostly indeterminate (85%) while the ascription to the chert formations of San Martí de Tous (6%), Valldeperes (7%) and Panadella-Montmaneu (2%) is very low. The main causes of the indeterminacy are patination (84.4%), thermal fractures (10.7%), concretion (4.4%) and rounding (0.2%). Because of this problem, the indeterminate items were grouped with those from San Martí de Tous and Valldeperes and all analyzed as a single group called M. The lithic remains from Panadella-Montmaneu (PAN) are considered separately because they are less affected by patination, and could be precisely identified by macroscopic examination.

The large numbers of cortical flakes, cores and chunks (Table 5) show that chert nodules were brought into the rock-shelter, tested and then, if their flaking properties were poor, discarded after few flakes had been detached. The assemblage contains no artifacts having the weathered cortex that is typical of secondary depositions in high-energy water, suggesting that the raw materials were collected from primary outcrops or exposed sections.

A technological study of the chert assemblage has demonstrated that bifacial discoïd technology was the most commonly used method (Table 4) (Fig. 4). The fact that several naturally core-edge flakes and cortical core-edge flakes were identified corroborates the theory that the cores underwent decortication and configuration in the rock-shelter. The convexities of the core's volume were maintained through the detachment of core-edge removal flakes and pseudo-Levallois points (Table 5). During the reduction phases, a large number of centripetal flakes were produced (Table 5). It is worth noting the significant number of pseudo-Levallois points in the assemblage, which suggest that they were not only by-products of the discoïd method but were also the intended artifacts, which were transported. Occasionally, after knapping errors, or achievement of the maximum convexity of the cores, some technical flakes were stroked to translate the striking platform (Table 5) in order to continue the production by means of a peripheral striking platforms or turning the discoïd reduction towards a polyhedral strategy (Slimak, 2003). In level M, these blanks were detached in the same direction of the striking platform and are characterized by an axial crest. As an example of the use of this technical expedient is the recovery of few polyhedral cores and a discoïd core in which could be observed the creation of a second striking platform and, when the core started to become rounded, a short sequence of bidirectional flakes were produced.

The pattern of detaching few more flakes, once the maximal exploitation of the core was achieved, is commonly seen in the Abric Romani sequence (Chacón, 2009; Picin, 2014; Vaquero, 1997). In level M, it was also detected in the cases of 4 discoïd cores and 1 orthogonal core. The flexible

Table 5

Raw counts and percentages of the flake assemblage of level M of Abric Romaní.

Tableau 5

Nombres et pourcentages de l'assemblage de éclats de niveau O de Abric Romaní.

	M	%	PAN	%	TOT	%
Cortical flake (> 50%)	117	6.5	3	7.1	120	6.5
Cortical flake (< 50%)	190	10.6	10	23.8	200	10.9
Naturally core-edge flake	37	2.1			37	2.0
Cortical core-edge flake	19	1.1			19	1.0
Ordinary flake	62	3.5	1	2.4	63	3.4
Centripetal flake	152	8.5	4	9.5	156	8.5
Core-edge removal flake	126	7.0	4	9.5	130	7.1
Pseudo-Levallois point	92	5.1	2	4.8	94	5.1
Kombewa-type flake	13	0.7	2	4.8	15	0.8
Re-shaping of the flaking surface	80	4.5	1	2.4	81	4.4
Translation striking platform flake	8	0.4	1	2.4	9	0.5
Knapping accident	75	4.2	4	9.5	79	4.3
Fragment with cortex	246	13.7	3	7.1	249	13.5
Fragment without cortex	579	32.2	7	16.7	586	31.9
Total	1796	100	42	100	1838	100

approaches taken by the knappers in attempting to continue flake production before discarding the cores indicate how important the raw materials were to Neanderthals. In this mind-set, discoid is the technology that best allows cores to be the homogeneously reduced and the production of flakes to continue uninterrupted. The fact that just a few small flakes were detached is a clear indication of the strict economic patterns followed in the strategies for procuring and using chert nodules. Moreover, the discoid method was applied whatever the dimension of the initial core. For example, the use of discoid exploitation in two fragments shows that the concept was rooted in the Neanderthals' technical behavior and was also utilized in short reduction sequences.

In secondary *chaînes opératoires*, the concept of centripetal exploitation is maintained with the recovery of 4 hierarchized centripetal cores (Table 4). In these artifacts, the bifacial and alternating flake production was abandoned as result of the volumetric division between a hierarchized flaking surface and a surface of preparation of the striking platform. This shift in how flake production was organized may have been constrained by the morphology of the initial nodule or by a change in the overall shape of the core during reduction. Such a change was probably due to a knapping error or an invasive detachment. In fact, 3 cores have flat morphology of the surface of the preparation of the striking platform. Although these cores have been heavily reduced, they each have a very short lateral edge for performing a bifacial reduction. Hierarchized centripetal exploitation may therefore have been a necessity rather than the initial concept chosen for the reduction sequence. The other hierarchized centripetal core, however, has a sub-pyramidal shape, which suggests a longer reduction sequence, with a hierarchical sub-division of the volume of the core.

Other artifacts were also found in the assemblage of cores (unidirectional, centripetal and orthogonal cores), in which the exploitation patterns have been interpreted to be opportunistic, due to the use of chunks or core fragments for producing a few flakes and the use of one side of the striking platform. Even if some chert chunks or

Table 6

Raw counts and percentages of retouched tools of levels O and M.

Tableau 6

Nombres et pourcentage.

Tools	Level O	%	Level M	%
Notched tool	1	50	8	40
Denticulate	1	50	9	45
Double denticulate			1	5
Scraper			2	10
Total	2	100	20	100

fragments do indeed have poor flaking qualities, in any case, the production of just a few flakes indicates a general determination to use as much as possible of the raw material before discarding it. In cores-on-flakes, this approach is even more accentuated because the starting blanks are very small. They were, however, exploited as much as was possible, as is demonstrated by one core-on-flake in which bifacial reduction was changed to unidirectional, in order to continue with production. In the analysis, some of the Kombewa-type flakes have probably been classed as debris because of their small size, and only further refitting studies might disclose their association with cores-on-flakes reductions. The technological attribution of the Kombewa-type flakes, according to Bourguignon and Turq (2003), shows that the centripetal concept and the use of a unidirectional pattern were maintained when the available volume was insufficient to continue with the reduction, or the striking platform was constrained by the morphology of the flake.

In the chert assemblage, there are few retouched tools in comparison with the number of flakes, and they are mainly notched tools and denticulates (Table 6). This is a common feature in the Abric Romaní sequence, since the ratio of stone tools to the number of complete flakes is also low in other levels, except for level J, which is slightly richer in stone tools (Picin, 2012). Serrated tools are the commonest stone tools in Abric Romaní, whereas scrapers are rare and so far have mostly been recorded in level E (Picin et al., 2011).

Table 7

Total weight (g) and percentages of the chert assemblages of level O and M of Abric Romani.

Tableau 7

Poids total (g) et pourcentages des assemblages de silex des niveaux O et M d'Abric Romani.

	Level O	%	Level M	%
IND	11,469.7	87.6	18,529.4	98.9
PAN	1,620.1	12.4	206.9	1.1
Total	13,089.8	100	18,736.3	100

4. Discussion

The technological analyses of the level O and M chert assemblages point to several aspects of our understanding of the change in Neanderthals' technical behaviours at Abric Romani. The main feature that emerged from the study was the more extensive use of the Panadella-Montemaneu outcrop and therefore the more frequent utilization of another mobility axis in comparison with those identified in level M (Table 7). In the Abric Romani sequence, the association between flaking methods and the use of different outcrops was flexible. For example, in level J – characterized by discoid technology – Panadella lithic items account for 6% (Vaquero et al., 2012), showing that even if this route was nearly abandoned in level M, it was maintained in the groups' traditions and re-used when particular needs arose or when it would be of specific benefit.

Some authors have pointed out that the adoption of a particular technology by Neanderthals has been influenced by the quality of the raw material (Dibble, 1985; Fish, 1981; Geneste, 1988; Otte, 1991; Tavoso, 1984; Turq, 1989). In the case of level O, the higher quality Panadella chert is used rather less than the other varieties of chert. The Levallois methods were also used on poorer grade nodules, emphasizing that it was the technology that guided the strategy for procuring raw materials and not the flaking properties of the nodules. This characteristic is important because it indicates that certain types of chert were collected intentionally. In terms of cost, the distances to the Panadella-Montemaneu outcrops exceed the foraging radius observed in ethnography (Binford, 1980; O'Connell et al., 1988; Vita Finzi and Higgs, 1970; Zeanah, 2000), suggesting an overnight stop on the way from the rock-shelter and when returning to it. If the embedded foraging strategy is a better choice for hunter-gatherers (Surovell, 2009), it could be assumed that Neanderthal groups occupying level O collected the chert during their hunts and thus roamed further, and hunted close to the Panadella-Montemaneu area more frequently. Conversely, in level M, the Neanderthals reduced their foraging territory and visited the Panadella-Montemaneu area more sporadically, shifting their attention to other areas close to Vallderes and San Martí de Tous, or towards the hinge zones between the Prelittoral Range and the Vallès-Penedès depression.

In reducing their range, the Neanderthals also modified the aims of lithic production and changed their technology from Levallois recurrent centripetal to bifacial discoid.

In fact, if the area exploited was smaller, with outcrops available within the foraging radius, the planning strategies became simpler and the need to transport blanks is reduced because the requirements that arose could be satisfied more easily. Moreover, the Levallois technology brought fewer benefits, because a simpler technology may well have been just as useful, and involved a less costly core configuration. The most abundant type of lithic item in level M is the centripetal flake, a type of blank that varies more in shape than the Levallois artifacts from level O (Picin et al., 2014). However, when the range of mobility was smaller the transport costs of thicker and heavier centripetal blanks was lessened because of the shorter distances travelled, and this was balanced by the fact that the amount of useful cutting edge was similar to that obtained with Levallois flakes (Picin et al., 2014).

The use of the discoid method also promoted the introduction of a different approach to managing the raw materials, with more careful use of the chert nodules before they were discarded. Clear examples of this different approach are the intense exploitation of the discoid cores and the specific pattern of detaching two more flakes from a previous scar once the overall discoid exploitability was achieved. Other evidence is provided by the number of cores-on-flakes, which are more numerous in a discoid context (Table 4). The bigger thickness of discoid blanks permits the configuration of a striking platform and a centripetal exploitation in a discoid unifacial modality (Picin, 2014). Given the small size of the blanks available at the site, their potential for producing other flakes is very low. However, despite this, instead of being discarded, they have been transformed into new cores, prolonging their use-life. The use of small flakes has been previously documented in the short occupation of level N (Vallverdú et al., 2010) and recycling patterns have been found in level M (Vaquero et al., 2015), level L, level J and level E (Vaquero, 2011). When the discoid method was first used, this entailed new ways of provisioning and organizing raw materials. The lithic materials discarded at the site became easily available resources that could be re-used, thus sparing the Neanderthals the journey to the outcrops (Vaquero, 2011). This strategy, however, could only be used for domestic activities carried out at the sites, as transporting small flakes to be re-used make unpredictable the possible production of new flakes or the resharpening events.

In level M, there was no apparent memory of the Levallois background in the way the discoid method was used; there was a sharp shift from one technology to the other. The change to the foraging radius could possibly be related to a shift in the exploited habitats. The changes in the altitudinal zones of the mounting environments and in the distribution of preferred prey animals may have influenced the Neanderthals' mobility patterns and contributed to modifying their technical behaviour. From this perspective, the technological change between Levallois and discoid could be interpreted as a tactical adjustment to the climatic and environmental variations in which the cost and benefit of using a particular flaking strategy were carefully weighed.

4.1. Paleoenvironment and technological change in the North-East of the Iberian Peninsula

A general overview of the dynamics of Neanderthal settlements reveals their preference for, and selection of, natural shelters located close to, or in mountain ranges. These locations were ideal for making full use of different ecological zones where, between the valleys and the surroundings at higher altitudes, there were abundant biotic and abiotic resources. The north-eastern of Iberian Peninsula is characterized by different territorial physiographic entities: the Catalan Costal Depression and Costal Range, the Catalan Transversal Range, the Catalan Central depression (including the Ebro basin), the Pre-Pyrenees and Pyrenees. Paleocological analyses of the late Middle Paleolithic records in these territories reveal vegetational variability of the landscapes with pine forests with or without junipers, junipers forests, mixed pine-oak forests, grasslands and xerophytic steppes (Burjachs and Julià, 1994; Burjachs et al., 2012; González-Sampérez et al., 2005; Renault-Miskovsky and Burjachs, 1992). During the MIS 3, the presence of pine forest remained stable from the coast to the Pyrenees with the lowering of the *Pinus sylvestris* tree boundary – that nowadays reaches 800 m ASL – at about 300 m ASL (Burjachs and Julià, 1994). During stadial phases and Heinrich events are recorded an increase of steppe vegetation (Asteraceae, Poaceae and *Artemisia*) whereas, during interstadial periods, are documented an expansion of mesothermophilous arboreal taxa (*Quercus* sp., *Olea-Phillyrea*, *Rhamnus*, *Betula*, *Corylus*, *Ulmus*, *Fagus*) and, in lower percentages, other thermophilous taxa (*Pistacia*, *Cistus*, *Syringa*, *Juglans*, *Hedera*, *Coriaria*, and *Erica*). In some areas, the influence of the Mediterranean climate supported the development of refugia for temperate mesothermophilous vegetation during cold stages (Burjachs et al., 2012; González-Sampérez et al., 2005).

In the Eastern Pyrenees, within the Abric Romaní rock-shelter, other archaeological sites have been identified that have provided evidence of both long-term and short-term Mousterian occupations. The Levallois method has been identified at the Roca del Bous rock-shelter in level N10 in a high mobility context in which chert nodules were gathered from outcrops distant about 15 km (Mora et al., 2008), whereas at Cova Gran level S1B, the chert raw material was collected in the neighbourhoods of the sites (Martínez-Moreno et al., 2010). At Cova Gran, paleocological information are still unavailable while at Roca del Bous, the anthracological analysis indicates only the occurrence of *Juniperus* sp. and *P. sylvestris-nigra*, two arboreal taxa common in the Pre-Pyrenees during stadial and interstadial phases (Piqué, 1988).

At Arbreda Cave, the archeological evidence from the Mousterian levels indicates that both the Levallois and discoid methods were used on local rocks (metamorphic rocks, quartz and flint), whereas the transported artifacts made from exogenous raw materials – from locations up to 100 km away in the eastern Pyrenees – were mainly Levallois flakes (Duran and Soler, 2006). Paleobotanical analyses are available only for level I and indicate the presence of two interstadial stages, characterized by temperate and humid environment separate by a cold and dry phase.

P. sylvestris is the dominant arboreal taxon whereas, during warm phases, *Acer* sp., *Rhamnus* sp. and *Prunus* sp. are recorded (Renault-Miskovsky and Burjachs, 1992). The study of micro-mammals confirms this interpretation for the presence of species associated with open forests (*Myotis myotis* and *M. myotis-blythii*) and humid environments (*M. myotis-blythii* and *Microtus agrestis*) (López-García and Cuenca-Bescós, 2010).

In the nearby Ermitons Cave, the small lithic collections from the Mousterian levels IV–VI are characterized by high frequencies of retouched tools and the use of Levallois technology on local raw materials (Maroto, 1993). The paleoclimatic evidences are based on the micro-mammals analysis and the discovery of the species *Apodemus sylvaticus*, *Pliomys lenki* and *Glis glis* indicates temperate environmental conditions (Maroto, 1982).

The use of discoid technology has been detected in the uppermost levels (S5–S7) of the Tragó Cave (Martí et al., 2009), at the Gabasa Cave (Santamaría et al., 2008) and in level G of the Fuentes de San Cristóbal Cave (García-Antón et al., 2011). The lithic analysis of the assemblages from Tragó Cave and Gabasa Cave show that the discoid method was used in a pattern of reduced mobility, with knapping of local raw materials located near to the sites (Martí et al., 2009; Santamaría et al., 2008). At Tragó Cave, paleoecological data are still missing whereas at Gabasa Cave pollen analysis on hyena coprolites reveals a mosaic glacial landscape with big frequencies of *Pinus*, *Juniperus*, Poaceae and *Artemisia* (González-Sampérez et al., 2005). In level G of the Fuentes de San Cristóbal Cave, the raw material most frequently used is flint gathered from within a radius of about 9 km (García-Antón et al., 2011). Paleobotanical analyses show the occurrence of pines, junipers associated with *Buxus sempervirens*, *Viburnum opulus* and *Quercus* sp. suggesting an arboreal Mediterranean refugium (Allué, 2002; Llácer, 2005).

Cave sites with short occupations and small fragmented lithic assemblages have also been documented, and are characterized by a combination of Levallois, discoid and expedient knapping methods. At Cave 120 level IV–V, a few Levallois artifacts were found, together with flakes produced opportunistically (Agustí et al., 1991). Pollen and anthracological analysis suggest mild climate for the presence, within pines and junipers, of *Quercus* sp., *Corylus avellana*, *Fraxinus* sp., *Phillyrea* sp. and *Arbutus unedo* in level IV, and *Ulmus* sp. in level V whereas micro-mammals document the presence of *Glis glis* and *Pliomys lenki* (Agustí et al., 1991). At Teixoneres Cave level III, the reduction sequences are fragmented including Levallois flakes and cores, some by-products of the discoid method, and ordinary flakes (Rosell et al., 2010). Paleobotanical studies document woodland areas composed of pines and oaks with high frequencies of *Corylus* and presence of *Buxus sempervirens* suggesting warm and humid environmental conditions (López-García et al., 2012).

All this archaeological evidence shows a general pattern in the Northeast of the Iberian Peninsula during the late Middle Paleolithic, in which the use of Levallois technology is associated with chert and longer distance

mobility patterns during climatic ameliorations. Discoid technology is, on the other hand, more closely linked to the use of local raw materials and a lower degree of mobility. The fact that there are several examples of coexistence between the two methods in the region could be interpreted as an adaptation to the size and quality of the metamorphic rocks or else to careful economic management of the raw materials. This feature is particularly evident in the pre-Pyrenean and Pyrenean areas, where good quality chert sources are more scattered. Furthermore, even when the stone outcrops were located close by, analyses of the lithic assemblages generally show hyper-exploitation of the cores, accompanied by the use of expedient methods (unifacial and polyhedral) in which chunks or core fragments were re-used for short flake production sequences. The recycling patterns also included retouched tools and core-on-flakes with the clear intention of producing small blanks (Duran and Soler, 2006; Martí et al., 2009; Santamaría et al., 2008; Vaquero, 2011).

5. Conclusion

The Abric Romaní rock-shelter was a residential camp for Neanderthal foragers who inhabited the Anoia valley in the chronological interval corresponding to level O and level M. The technological change from Levallois to discoid technology could be interpreted as a cultural adaptation by the Neanderthals to a climatic shift from a moist climate to dryer conditions. The changes in the distribution of biotic resources may have modified their technical behaviour towards knapping strategies that were more beneficial when mobility was reduced. The similarities between the settlement dynamics and use of the rock-shelter, combined with other behaviours related to domestic activities, suggest the hypothesis that the site was occupied by local Neanderthals who inhabited the area for long chronological intervals, and the cultural hypothesis of migrations of foreign groups bringing different flaking technologies is therefore rejected.

The use of Levallois technology in long displacements, and discoid technology when the foraging radius was smaller, are technical strategies commonly found at other Mousterian settlements in the Northeast of the Iberian Peninsula. From this perspective, the similarities – on a regional scale – of the use of different knapping methods may have been a result of contact and interaction between different Neanderthal groups as a consequence of “culturally mediated migration” (Premo and Hublin, 2009) or patrilocal mating behaviors (Lalueza-Fox et al., 2011). At the European level, the research into the Mousterian technological changes documented broad regionalism in the development and spread of flaking strategies (Bourguignon, 1997; Delagnes and Meignen, 2006; Picin et al., 2013; Ruebens, 2013; Turq, 2000). Further research focusing on the diversities and similarities of local archaeological records during the Middle Paleolithic will be pivotal to our understanding of the adaptability of Neanderthals to different territories and environments.

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