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Impossible Neanderthals? Making string, throwing projectiles and catching small game during Marine Isotope Stage 4 (Abri du Maras, France)

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ABSTRACT

Neanderthal behavior is often described in one of two contradictory ways: 1) Neanderthals were behaviorally inflexible and specialized in large game hunting or 2) Neanderthals exhibited a wide range of behaviors and exploited a wide range of resources including plants and small, fast game. Using stone tool residue analysis with supporting information from zooarchaeology, we provide evidence that at the Abri du Maras, Ardèche, France, Neanderthals were behaviorally flexible at the beginning of MIS 4. Here, Neanderthals exploited a wide range of resources including large mammals, fish, ducks, raptors, rabbits, mushrooms, plants, and wood. Twisted fibers on stone tools provide evidence of making string or cordage. Using a variety of lines of evidence, we show the presence of stone projectile tips, possibly used in complex projectile technology. This evidence shows a level of behavioral variability that is often denied to Neanderthals. Furthermore, it sheds light on perishable materials and resources that are not often recovered which should be considered more fully in reconstructions of Neanderthal behavior.

1. Introduction

The arguments over Neanderthal behaviors and capabilities continue unabated. Recently, two competing threads have emerged within this debate. One emphasizes the relative inflexibility of Neanderthals from a cognitive (e.g. Wynn and Coolidge, 2004), behavioral (e.g. Fa et al., 2013) and technological perspective (e.g. Stiner and Kuhn, 2009). This line of argument often generally speaks of "Neanderthal" capabilities or behaviors as if this group of hominins always did the same things no matter the temporal or ecological circumstances (Brown et al., 2011). The other emphasizes an increasing recognition of the variability of Neanderthal behavior and the elucidation of previously unrecognized behaviors including personal ornamentation (Peresani et al., 2011; Morin and Laroulandie, 2012; Finlayson et al., 2012), a wide and varied diet (Henry et al., 2011; Blasco and Fernández Peris, 2012; Cochard et al., 2012; Salazar-García et al., 2013), and even maritime navigation (Ferentinos et al., 2012). This recognition of behavioral variability through space and time argues for adaptation of Neanderthal groups to local conditions (Clark, 2002; Hardy, 2010).

In both cases, much research effort is devoted to reconstructing Neanderthal subsistence. Influenced heavily by stable isotope analysis, Neanderthals are most often portrayed as top-level carnivores who derive the vast majority of their food from large terrestrial herbivores (Balter and Simon, 2006; Bocherens, 2009; Richards and Trinkaus, 2009). However, the relatively small number of Neanderthals sampled for isotope studies so far are from northern, interior areas of their range and should not be taken as indicative of the entire population (Pearson, 2007; Brown et al., 2011). Furthermore, analyses of this hypothetical high protein diet have suggested that it is unrealistic to support life in the long run (Hardy, 2010; Hockett, 2012).

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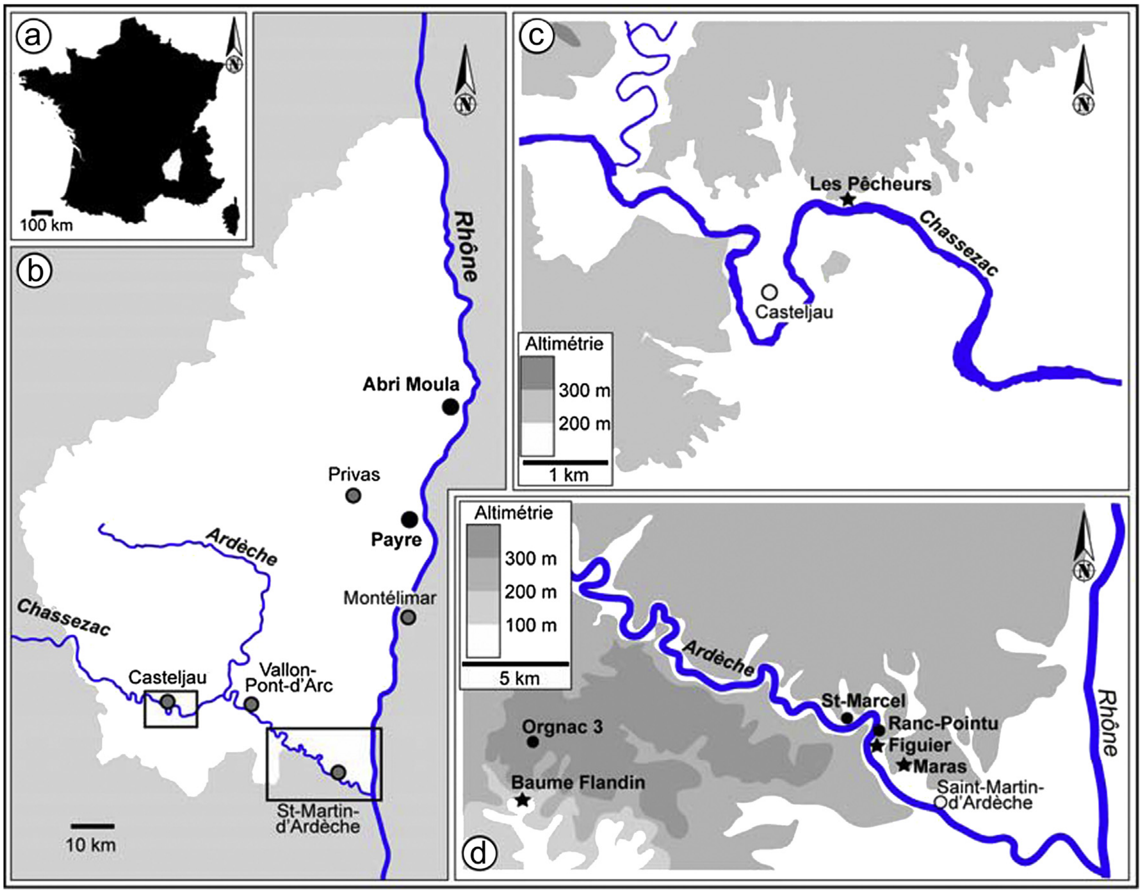

Fig. 1. Location of the site of the Abri du Maras.

Increasingly, evidence is emerging at some sites that Neanderthals exploited a wider range of smaller, faster prey including birds (Blasco and Fernández Peris, 2009, 2012), rabbits (Blasco and Fernández Peris, 2009, 2012; Cochard et al., 2012), and fish (e.g. Le Gall, 1990, 2000; Roselló-Izquierdo and Morales-Muñiz, 2005; Hardy and Moncel, 2011) as well as a detailed knowledge and use of plant foods (Hardy and Moncel, 2011; Henry et al., 2011; Salazar-García et al., 2013). This evidence goes against the widespread argument that the hunting of fast and agile prey such as birds, leporids, and fish as well as the exploitation of plant foods are defining features of "modern" behavior which only occurred systematically in the Upper Paleolithic (Stiner et al., 1999, 2000; Klein, 2001; Richards et al., 2001, 2005; Drucker and Bocherens, 2004; Klein et al., 2004; Balter and Simon, 2006; Richards, 2009). Recently, Fa et al. (2013) have gone as far as to suggest that Neanderthals' inability to switch to rabbit as prey factored into their extinction. This returns us to a picture of Neanderthals as inefficient foragers incapable of adapting to changing conditions (Klein and Cruz-Uribe, 2000; Klein et al., 2004). Such a view suggests that Neanderthals would have gone extinct well before they did (Sorensen and Leonard, 2001; White, 2006).

Other researchers offer a different view where some limited behavioral change takes place with Neanderthals but only post 50 kya (Langley et al., 2008; Stiner and Kuhn, 2009). In this scenario, behavioral complexity, as reflected by composite technology and evidence for symbolic thought, appears with some "late Neanderthals", most notably with the Chatelperronian (d'Errico et al., 1998, 2003). However, this is often presented as being too little, too late for Neanderthals.

Here, we present evidence for behavioral variability and complexity among Neanderthals at the beginning of Marine Isotope Stage 4 (MIS 4) at the Abri du Maras located above the Ardèche River in southern France. Using residue analysis of stone tools with supporting evidence from zooarchaeology, we show that Neanderthals at the Abri du Maras had a detailed knowledge of their surrounding environment, captured fast and agile prey (rabbits, fish and birds), exploited a range of plant species, and used composite technology such as hafted stone points and the manufacture of string and cordage. Overall, we present evidence which demonstrates that Neanderthals at the Abri du Maras were far from inefficient foragers.

2. Site background

The site of the Abri du Maras is located in a small valley less than 1 km from the Ardèche River, a tributary of the Rhône River and close to the Rhône Valley (Fig. 1). Its elevation is 170 m *a.s.l.* and 70 m above the Ardèche River. First excavated in the 1950's and 1960's, new excavations have taken place since 2006 in order to obtain more data on the oldest human occupations and open a large excavated area. This site was famous in the past for a Middle Paleolithic (MP) deposit with a Levallois laminar debitage (level 1) and covering seven distinct levels (levels 8–2) with MP assemblages (Combier, 1967; Moncel et al., 1994). Little is known of the bottom of the sequence due to reduced excavation during early fieldwork.

Geological study attests that the cave roof collapsed over time and the youngest occupations were settled under a shelter (Debard, 1988). The oldest occupations, however, took place under a large cave roof and are located in front of the shelter as it is nowadays. In 2006, new excavations yielded two thick and distinct deposits in a test pit located in front of the site. We were not able to distinguish the different lenses observed in the past and preferred instead to name large phases of sedimentation (Fig. 2). The oldest one was named layer 5 (ancient levels 8–6), an organic brown level, covering the limestone substratum. The second one is layer 4 (ancient levels 5 and 4), with homogeneous eolian silts (loess) with few small blocks of limestone, recovered in three levels (layers 3, 2, and 1), similar to the previous excavations and contains the youngest occupations (Moncel et al., 2010). Rich lithic and faunal remains and fire places characterize our level 4 which has been excavated over more than 40 m^2. Two sub-levels are visible with a higher density of archaeological remains (4.1 and 4.2). They are related to a greater quantity of blocks coming from the roof collapse during humid phases in MIS 4.

U/Th dating has been applied to bones which yielded ages of 72 ± 3 ka, 87 ± 5 ka, 89 ± 4 ka, and 91 ± 4 ka for the summit of our layer 5/bottom of our layer 4 (end of MIS 5/beginning of MIS 4) (Moncel et al., 1994; Moncel and Michel, 2000). They are confirmed by new preliminary ESR-U/Th dating on *Cervus elaphus* teeth sampled at the summit of layer 5 (95 ± 6 ka) (Richard, 2012). According to the sedimentary analyses and aspect of sediments between layers 5 and 4, there is no clear chronological gap along the sequence. The only hiatus was observed for the youngest MP level (level 1 excavated in the past). Our layers 5 and 4 at the bottom were deposited in a continuous period of time without phases of erosion. The age of layer 4 is consequently a little bit younger than 90 ka. From a paleoclimatic point of view, the sequence shows a progressive change between layers 5 and 4 (interglacial/glacial or interstadial/stadial transition). From temperate and humid conditions (layer 5), a cooling is recorded and conditions become colder and drier during the deposition of layer 4.

This is consistent with the paleontological study performed on the whole sequence which shows more temperate taxa at the bottom. This includes *Sus scrofa*, *Capreolus capreolus* and mainly *C. elaphus* among the Cervids and an increase over time of *Equus caballus*, *Rangifer tarandus* and *Bison* sp. The main species for the youngest level is reindeer which attest to an increase of cold climatic conditions and a decrease of forested areas between level 5 and level 4 corresponding to the beginning of MIS 4 (Debard, 1988; Moncel et al., 1994, 2010).

3. Lithic technology

Layer 4 has been excavated over more than 40 m^2 and has yielded more than 3600 artifacts (40 artifacts/m^3). The vertical distribution indicates two concentrations of artifacts. These densities could represent two large phases of occupation of the site for layer 4. No significant difference was observed between these two phases and the material has been studied as a single unit. Most are flint flakes, blades, bladelets and points between 15 and 90 mm long. The flaking is mainly of Levallois-type (Fig. 3). Two large groups of products may be distinguished: 1) small and middle-size flakes, flakes, bladelets and Levallois points made on the site on core-flakes, 2) long flakes, blades and points, most of them Levallois, made outside and brought to the site. Most of the series is not retouched (less than 5% are scrapers, denticulates, and points). Neanderthals collected flint in two large areas: 1) on the northern plateau located along the right side of the Rhône Valley (part of the Barremo-Bedoulian flint outcrops) at a distance of between 10 and 30 km to the north, and 2) on the southern plateau, on the right edge of the Ardèche River. This second source requires a river crossing to reach these outcrops. Some flint types remain undetermined.

4. Methods-stone tool function

A sample of 129 stone tools from Layer 4 was examined for the presence of in situ residues and wear patterns. To reduce the possibility of modern contamination, all artifacts were placed in self-sealing plastic bags upon excavation where they remained, unwashed, until the time of analysis. Artifacts were examined under bright-field incident light using an Olympus BH30 microscope (magnification 50–500×) or Dino-Lite Digital Microscopes (AD-413ZT, magnification 20–220×; AM4013ZT4, magnification 430–490×). Images were recorded using a DinoEye USB camera (AM423XC) and DinoCapture 2.0 software. All residues observed were photographed and their location noted on a line drawing of each artifact. Identification of residues was based on comparison with a large modern reference collection (over 1000 experimental artifacts) and with published sources (Brunner and Coman, 1974; Catling and Grayson, 1982; Brom, 1986; Beyries, 1988; Anderson-Gerfaud, 1990; Hoadley, 1990; Teerink, 1991; Fullagar, 1991, 2006; Hather, 1993; Hardy, 1994; Kardulias and Yerkes, 1996; Williamson, 1996; Hardy and Garufi, 1998; Pearsall, 2000; Haslam, 2004; Dove

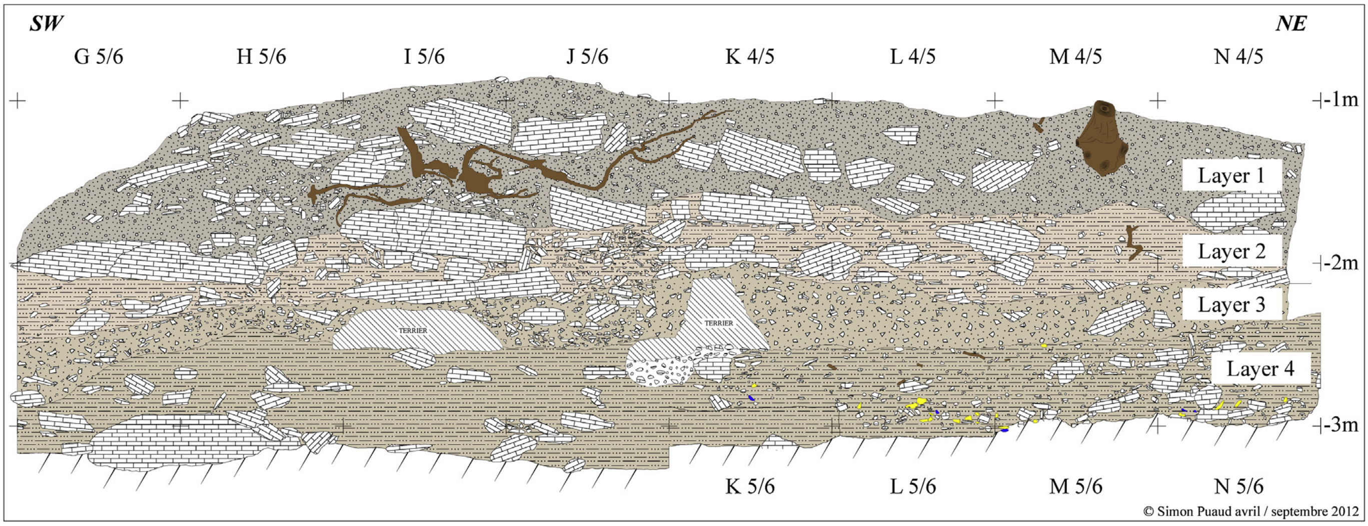

Fig. 2. Main transversal section of the Abri du Maras and location of layer 4.

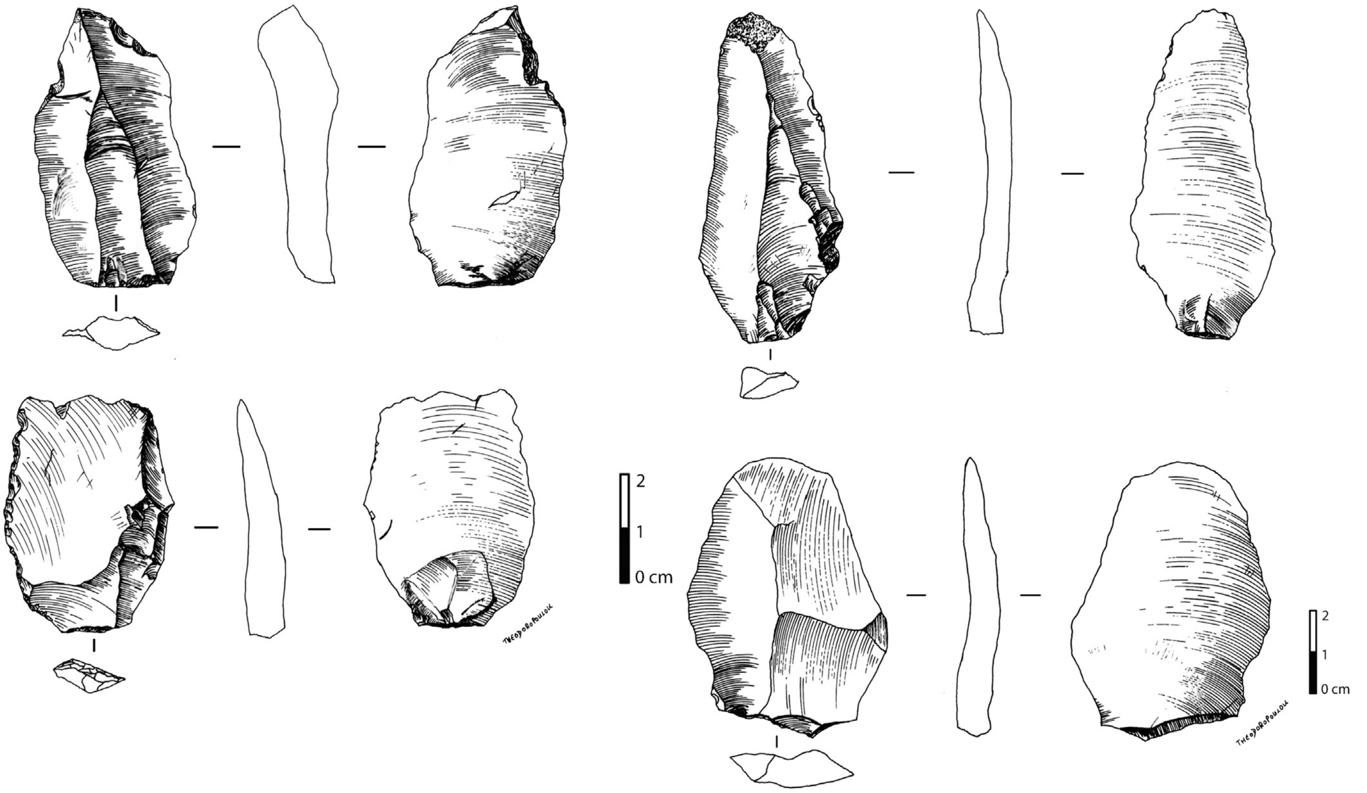

Fig. 3. Levallois flakes, pointed and elongated Levallois products of layer 4 at the Abri du Maras.

et al., 2005; Huffman et al., 2008; Crowther, 2009; Genten et al., 2009; Warren, 2009). Identifiable residue categories include wood, bark, plant fibers, starch grains, calcium oxalate crystals, plant tissue, resin, hair, feathers, fish scales, skin, and bone (Hardy and Moncel, 2011). Starch grains can potentially be mistaken for fungal spores or other materials and identification under reflected light is therefore considered preliminary (Haslam, 2006). For all identifications, a suite of related residues (e.g. hair fragments, collagen, bone or plant cells, starch grains, plant fibers) strengthened the confidence of the identification (Lombard and Wadley, 2007). Calcium oxalate crystals (raphides) can be mistaken for rod-shaped calcite crystals (Crowther, 2009). Putative raphides were treated with acetic acid, which dissolves calcite, to confirm identification.

Because the main goal of the study was residue analysis, observations of use-wear played only a supporting role. Clues to the relative hardness of the use-material and the use-action included the identification of striations, edge rounding and microflake scars (Odell and Odell-Vereecken, 1980; Mansur-Franchomme, 1986). Use-wear polishes were also recorded but their identification proved difficult on the Abri du Maras artifacts which limited their use to helping identify areas of use on a tool. Residue distribution and co-occurrence of wear patterns were used to help determine if residues were use-related. In some cases, even when patterning did not strongly suggest that residues were use-related, the presence of residues nonetheless provided evidence of particular activities.

4.1. *Residue preservation*

The flint at the Abri du Maras is covered with a microscopic post-depositional film of chalcedony composed primarily of silica (Fernandes, 2012). This film partly or totally covers residues and aids in their preservation. The presence of residues included under this cover attests to the contemporaneity of residues with tool use. Several cores and two unmodified cobbles from the site were examined with the same methods and showed no residues, further bolstering the case that the residues observed were ancient in origin and likely related to use. Ironically, this same film may also obscure certain details of the structure of a residue and makes use-wear polish identification difficult.

5. Results

Seventy-six percent (98/129) of the artifacts examined showed some type of evidence that could potentially provide clues for tool use. The remaining 31 artifacts showed no evidence of use. Three of these 31 had single isolated hair fragments but the evidence was

Table 1
Results by material.[a]

Material	Frequency	%
Butchery/hideworking	17	13.2
Bone	1	0.1
Bird	3	2.3
Rabbit	3	2.3
Fish	3	2.3
Plant	38	29.4
Fibrous plant/reeds	12	9.3
Plant and animal	3	2.3
Starchy plant	2	1.5
Hafted Proj. Pt.	6	4.7
Hafted other	3	2.3
Wood	22	17.1
Mushroom	2	1.5
Hard material	4	3.1
Unknown	31	24.0

[a] Note: since multiple materials were sometimes found on a single artifact, percentages do not add to 100.

insufficient to infer tool function. Results are summarized in Table 1 and individual materials discussed below.

Layer 4 has been studied as a single unit; results do not show differences between the two sub-levels.

5.1. Plant and wood processing

Plant and wood fragments are often difficult to identify specifically due to a lack of diagnostic anatomy (Hardy and Garufi, 1998; Monnier et al., 2012). At the Abri du Maras, numerous plant residues occur which are insufficiently diagnostic to assign specifically or even to distinguish between woody and non-woody plants. In some cases, however, more specific identifications are possible, even if they are not exact. In attempting to identify plant residues at the Abri du Maras, we conducted a series of plant processing experiments on plants with edible underground storage organs which could have been potential food sources for Neanderthals. These included wild parsnip (*Pastinaca sativa*), greater burdock (*Arctium lappa*), bur-reed (*Sparganium erectum*), arrowhead (*Sagittaria latifolia*), and cattail (*Typha latifolia*). Fig. 4 shows an example of a plant residue from Abri du Maras (artifact I8 10) in comparison to rhizome cortex from bur-reed. Bur-reed is fully hardy (PFAF, 2013) and would have been able to grow in the cold conditions present around the site during the beginning of MIS 4. Unfortunately, while the anatomy is very similar, it is not possible to be fully confident of the identification given the large number of wild edible plants in Europe. Further experimentation with wild edible plant foods to document the anatomical characteristics that are observed during plant processing with stone tools will allow us to make more confident identifications in the future.

Plant fragments identifiable as wood through diagnostic anatomy (tracheids, vessel elements, etc.) are present on a wide variety of artifacts from the Abri du Maras. In some cases, the wood fragments are found along a working edge indicating the use of the artifact in modifying wood, possibly for the creation of other wooden tools. In other cases, wood fragments are confined to one end of an artifact or point and may represent the remnants of a haft (see below).

5.2. Fibers and twisted fibers

Two types of fibrous material were observed on the artifacts from Abri du Maras, anatomically nondescript fibers and long, multicellular strands or tubes (Fig. 5). Botanically, fibers are “slender, attenuated cells, many times longer than wide” (Dickson, 2000: 399). Fibers are found in a wide variety of plants, including bast fibers of the inner bark of trees and plants. While it is possible to identify plant fibers taxonomically, fragments of fibers often lack the diagnostic anatomy to do so (Catling and Grayson, 1982). Further complicating the identification is the fact that diagnostic anatomy may be lost during the processing of fibers for use (Hurcombe, 2008). Additionally, plants with long leaves and parallel veins, such as reeds and rushes, may be shredded to produce fibers composed of multicellular veins or tubes (Hurcombe, 2008). In the sample from the Abri du Maras, 4 artifacts exhibited fibers as botanically defined, while a further 8 showed vein or tube-like multicellular structures that could function as fibers. Neither of these fiber types showed diagnostic anatomy that would allow a taxonomic identification. The multicellular fibers, however, are similar in anatomy to veins or vessel elements from long leafed monocots and likely derive from reeds, rushes, or similar plants (Catling and Grayson, 1982). In addition to fibers being present on artifacts from the Abri du Maras, 4 unicellular fibers and one multicellular fiber show one or more twists along their length (Fig. 6).

These fibers are not twisted in their natural state (K. Hardy, 2008; Hurcombe, 2008) which suggests that they were twisted by the inhabitants of the Abri du Maras and may therefore provide evidence of the manufacture of string or cordage. In previous woodworking experiments involving incising, planning, whittling, scraping, and boring (Hardy and Garufi, 1998), no twisted fibers were observed. Unpublished experiments conducted by BH involving the scraping, cutting, and slicing of a variety of non-woody plants (roots, tubers, reeds, etc.) also produced no twisted fibers such as those observed here. While not definitive, the lack of twisted fibers in these experiments lends some credence to the hypothesis that these derive from cordage. Future experiments

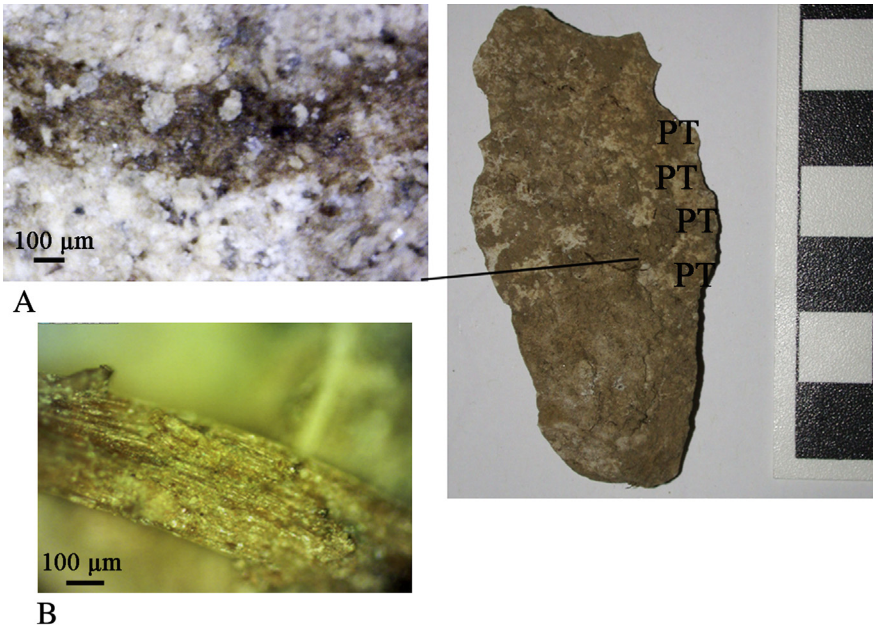

Fig. 4. Rhizome cortex: A) plant fragment on artifact I8 10, O.M. 225×; B) rhizome cortex of burr-reed (*Sparganium erectum*), O.M. 225×; PT = plant tissue, shows distribution of plant residues on artifact surface.

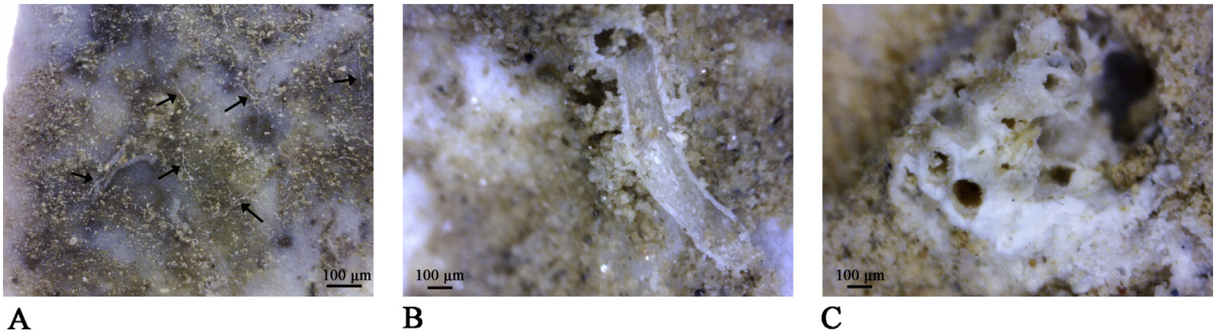

Fig. 5. Fibers: A) scattered plant fibers (I7 71) O.M. 100×; B) plant fiber (J6 36) O.M. 225×; C) tube-like vascular element (I7 97) O.M. 225×; D) cluster of tube-like vascular elements (E6 33) O.M. 225×.

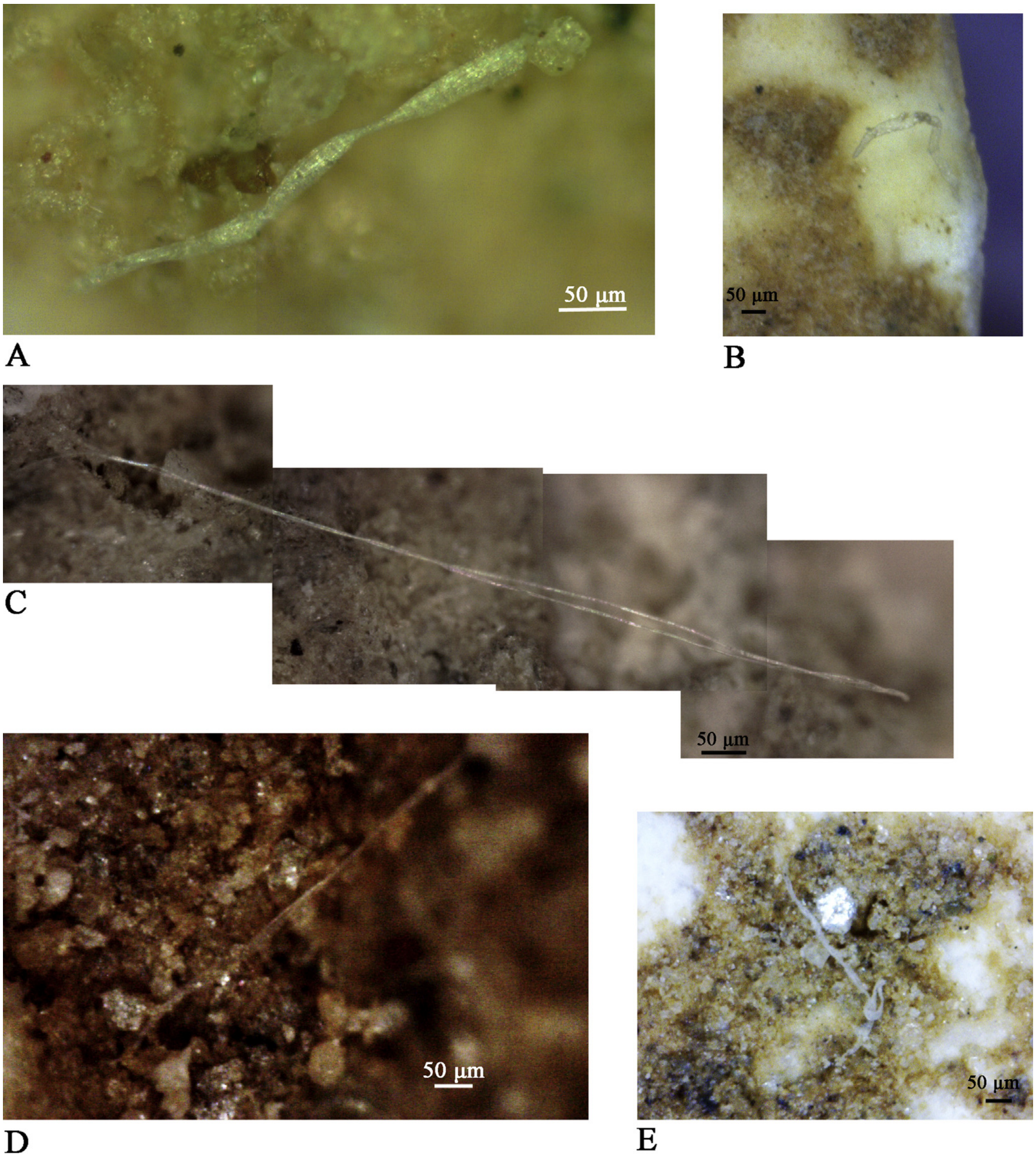

Fig. 6. Twisted fibers: A) photomosaic of twisted vessel element (N6 583) O.M. 100×; B) twisted plant fiber (I7 66 O.M. 225×; C) photomosaic of twisted plant fiber (F6 13) O.M. 485×, left edge disappears below chalcedony film; D) twisted plant fiber (L6 164) O.M. 225×; E) twisted plant fiber (J6 36) O.M. 225×.

involving cordage and plant processing will help clarify the potential sources of twisted fiber.

5.3. Spores

Two artifacts have spores on their surfaces (Fig. 7). On the first artifact (M6 718), the spores are concentrated along one edge, a pattern that may suggest that they are related to the use of the tool. They are brown to dark brown in color, elliptical and measure approximately 5 × 7 μm, and most closely resemble mushroom spores from the experimental comparative collection. The second artifact (M6 473) has spores scattered over the entire surface. They are similar in color and shape, but smaller, measuring approximately 3 × 5 μm. The patterning on one tool and the finding of spores on only 2 of 129 artifacts along with their presence under the silica film suggests that these are ancient in origin and not the product of recent fungal growth. Although they could be airborne in origin (Lacey et al., 2006), the patterning on the first artifact along with their relative rarity on the artifacts from the Abri du Maras further suggest that they are not. While it is not possible to identify the exact origin of these spores, they closely resemble mushroom spores in the experimental comparative collection.

5.4. Butchery/animal processing

Seventeen artifacts in the sample (13.2%) have residues that link them to butchery or animal processing activities. These residues include fragments of hair, skin, collagen or bone, often in combination. While hair can be diagnostic to the species level when cuticle and medulla patterns are visible, it is difficult and often not possible to identify individual hair fragments (Teerink, 1991). Most of the hair, skin, and collagen fragments are not sufficiently diagnostic to attempt species identification. However, on two tools (a Levallois blade and a flake) from the Abri du Maras, three hair fragments are preserved that show a dumbbell-shaped cross-section which can be diagnostic of some leporids (European rabbit, *Oryctolagus cuniculus*, or hare, *Lepus europaeus)* (Fig. 8). A ladder-shaped medulla can aid in identification but is not visible. A faint scale pattern is visible on the cuticle of one hair fragment and shows transversal, streaked scales with smooth margins, which more closely resembles *O. cuniculus* than *L. europaeus*. This hair fragment measure 18 μm across which would place it towards the tip of a guard hair if it is rabbit (Teerink, 1991). The two other hair fragments (no cuticle visible) measure 24 and 28 μm across respectively and would fall within the same category as the first. These characteristics are consistent with rabbit but are insufficient to confirm fully the identification.

Zooarchaeological analysis of layer 4 has yielded three skeletal elements which have been assigned to *O. cuniculus* (a proximal part of a third right metacarpal, a fragment of an indeterminate upper molar and a fragment of a femoral diaphysis). In addition, one scapula can be assigned to an indeterminate hare (*Lepus* sp.) and one fragment of an incisor which remains as an indeterminate lagomorph.

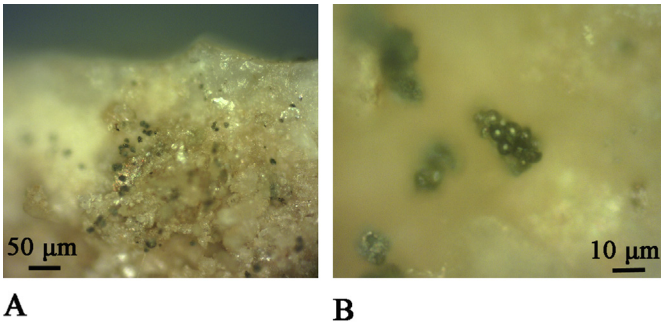

Fig. 7. Spores on M6 718 A) O.M. 100×; B) O.M. 500×.

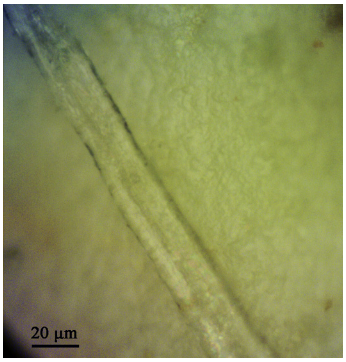

Fig. 8. Rabbit hair on J6 17, O.M. 485×.

Two of these five Lagomorpha remains have yielded evidences of butchery marks (Fig. 9) (Binford, 1981; Shipman and Rose, 1983, 1984; Behrensmeyer et al., 1986; Olsen and Shipman, 1988; Blasco et al., 2008; Lyman, 2008; Domínguez-Rodrigo et al., 2009). One is a femoral mid-shaft fragment. This fragment has two groups of ten cutmarks and two green bone fractures. Cutmarks are clustered, V-shaped, short, straight or curved and oblique. They are all present on the mid-shaft portion of the femur, which is the fleshiest part of the leg. Their location and morphology allow us to identify them as marks resulting from defleshing activities (Binford, 1981; Nilssen, 2000; Pobiner et al., 2008).

The two fractures could be identified as green bone fractures by their outline, shaft circumference fracture angle and surface edge (Fig. 10). They are curved, oblique and smooth, typical features of green breakage. Moreover the bone circumference is incomplete (C2 category: more than half in at least a portion of the bone

Fig. 9. Cutmarks on a femoral mid-shaft fragment (Lagomorpha cf. *Oryctolagus cuniculus*).

length). Association with cutmarks and the archaeological context of the faunal accumulation which is mainly anthropic (see below) allows us to argue that they are indeed hominin-made fractures. Their cause may be due to long bone marrow recovery.

The other cutmarked fragment is a proximal piece of a right scapula belonging to a young individual which has been identified as *Lepus* sp. (Fig. 11). This fragment bears some short and deep V-shaped cutmarks on its posterior edge which may be associated with shoulder disarticulation (Binford, 1981; Nilssen, 2000; Pobiner et al., 2008). The zooarchaeological findings together with the identification of putative rabbit hair on a Levallois blade and a flake demonstrate the processing of leporids at the Abri du Maras.

5.5. Feathers

Three artifacts have downy feather barbule fragments (Fig. 12) suggesting that they may have been used in bird processing of some kind. Feathers are potentially identifiable to the Order level (Chandler, 1916; Brom, 1986) based partially on the arrangement and configuration of prongs at nodes. A flake (N7 6) shows a downy barbule with indistinct nodes and a node with an asymmetric prong (Fig. 12 A,B). The combination of these anatomical characteristics suggests that it belongs to the Accipitriformes (Brom, 1986). This order of birds of prey includes hawks, eagles and vultures.

A second flake (M6 473) has a downy feather barbule with two prongs at its tip (Fig. 12 C). This, along with another barbule fragment with indistinct nodes on the same artifact, suggests that it belongs to the Anseriformes (ducks, geese, and swans) (Brom, 1986; Robertson, 2002). This artifact also shows hair fragments, mushroom spores, twisted fibers, and plant fragments making functional interpretation difficult.

The final flake (H6 26) has one downy barbule fragment with two indistinct prongs at the tip. While this might be consistent with Anseriformes, it is insufficient to make a confident identification. This feather occurs with collagen and hair fragments with patterning that suggests the flake was used in butchery, possibly of mammal and bird.

5.6. Fish

Two flakes have fragments of possible fish scales (Fig. 13). These fragments are confined along one edge of each tool and match the general anatomy of cycloid scales (Genten et al., 2009; Warren, 2009). The birefringence observed also disappears under cross-polarized light which is characteristic of fish scales. Surface texture of these possible scales is not clearly visible. This may be due to post-depositional alteration or to the presence of the chalcedony film that covers the residue. Supporting evidence in the form of bone fragments, iridiophores, and other fish-related residues on the artifact is lacking, however, making this identification of fish processing less confident than that made at the Middle Paleoltihic site of Payre (Hardy and Moncel, 2011). Nonetheless, unlike at Payre, fish remains are present at the Abri du Maras.

Fig. 10. Cutmarks on a femoral mid-shaft fragment (Lagomorpha cf. *Oryctolagus cuniculus*).

Fig. 11. Cutmarks on a proximal fragment of a *Lepus* scapula. They have been identified as shoulder disarticulation marks.

A number of fish bones, mostly vertebrae, scales and fragments, have been retrieved. Out of a total number of 167 fish remains, 46 could be identified to at least the Family level. Two families are present: cyprinids (NISP = 34) and percids (NISP = 12). Among cyprinids the only species recognized is the chub (*Squalius cephalus*), thanks to a pharyngeal bone and several vertebrae, while among percids the European perch (*Perca fluviatilis*) is represented by its typical ctenoid scales. Both species are very common in slow running rivers of today's western Europe. No signs of chewing or digestion have been observed on the fish bones. Estimated body weights range between 550 and 850 g. Few predators are able to catch and carry fish of this size. Hence, the possibility of Neanderthals as predators cannot be discarded, and the presence of these fish remains in layer 4 may be considered the result of anthropic activity. Once again, the combination of residue and zooarchaeological analyses provides corroborating evidence and strengthens the case of Neanderthal fishing.

5.7. Hafted projectile points

Five pointed pieces from the Abri du Maras show types of impact fractures that have been suggested as diagnostic of use as weapon tips (Villa et al., 2009; Lazuén, 2012, Table 2). A sixth has a broken tip but is also discussed here as a possible weapon tip. Included in the discussion of these possible projectile points are evidence of macrofractures (e.g. Lombard, 2004; Villa et al., 2009; Pargeter, 2011), residue analysis (e.g. Lombard and Pargeter, 2008; Lombard and Phillipson, 2010; Lombard, 2011), and morphometrics (e.g. Shea, 2006; Sisk and Shea, 2009, 2011; Shea and Sisk, 2010). Calculations of tip cross-sectional area (TCSA) and tip cross-sectional perimeter (TCSP, calculated for triangular cross-section for unifacial points or rhomboid cross-section for bifacial points) follow formulas provided elsewhere (Hughes, 1998; Shea, 2006; Sisk and Shea, 2009, 2011; Shea and Sisk, 2010). We make comparisons with different categories of experimental, ethnographic, and archaeological samples. For discussion of TCSA, we refer to Shea (2006) who suggests that thrusting spear points have TCSA values ranging from 100 to 250 mm^2. Tips that have TCSA values less than 100 mm^2 are considered too fragile for thrusting and are more likely to have been thrown. In addition, following more recent work (Sisk and Shea, 2009, 2011; Shea and Sisk, 2010),

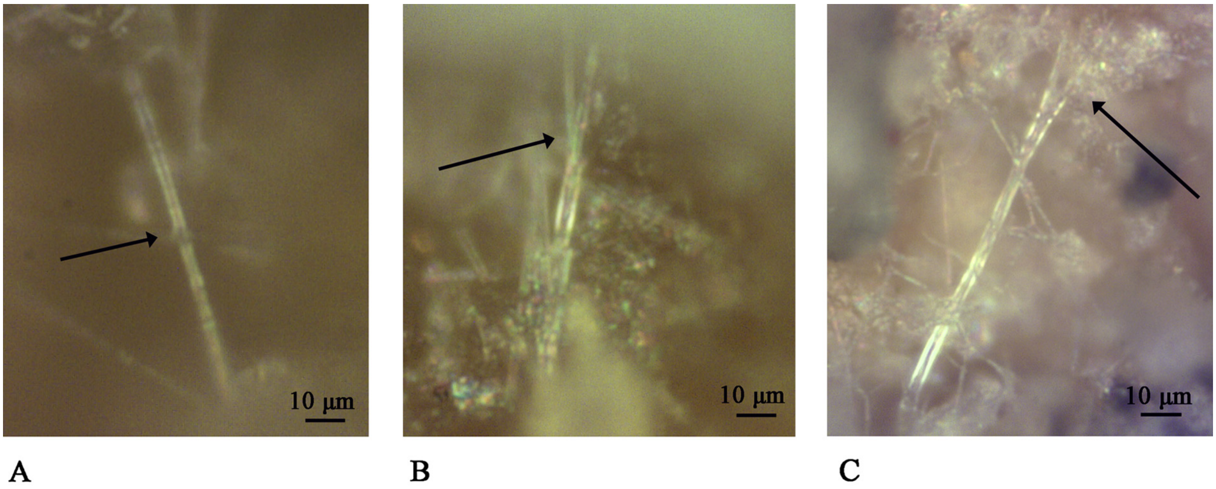

Fig. 12. Feathers: A) downy barbule with indistinct node (N7 6)) O.M. 500×; B) downy barbule with one asymmetric prong (N7 6) O.M. 500×; calcite crystals visible in background of both photos; C) downy barbule with two prongs at tip (M6 473) O.M. 500×.

we discuss TCSP as a potentially better predictor of penetration performance with comparison to ethnographic dart points and African Middle Stone Age samples (Shea, 2006; Sisk and Shea, 2011). As Sisk and Shea (2011) only present summary data, TCSP for bifacial rhomboid cross-section was calculated for ethnographic dart points based on data provided by Thomas (1978) and Shott (1997), (range = 28.6–65 mm; Table 2). TCSP for points from the Abri du Maras was calculated individually according to the cross-section of the artifact (Sisk and Shea, 2011). As our sample is small and non-probabilistic, we discuss each artifact individually.

Point # 1 (K6 429, Fig. 14A–B) is a pointed flake with a snapped tip and a burin-like fracture (length 13.9 mm). The length of this fracture exceeds the length of 6 mm defined by O'Farrell (2004, 2005) as diagnostic of impact. Both edges have grinding damage on the proximal 1/3 of the flake which may be related to hafting. The TCSA (148 mm^2) falls well within the range of experimental thrusting spears (Shea, 2006). The TCSP (rhomboid cross-section) is 77.3 mm which is comparable to the mean of several MSA assemblages (Sisk and Shea, 2011, Table 2).

Point # 2 (L6 148, Fig. 14 C–D) is another Levallois point with a burin-like fracture (length 6.3 mm). The length of this fracture exceeds the length of 6 mm defined by O'Farrell (2004, 2005) as diagnostic of impact. No evidence of hafting is present, but the TCSA is 105 mm^2, near the threshold where it may have been too thin to be effective as a thrusting spear tip (Shea, 2006) and near that of Porc Epic bifacial points (103.29 mm^2) (Sisk and Shea, 2011, Table 2). The TCSP (rhomboid cross-section) is 63.1 mm, within the range of ethnographic dart tips.

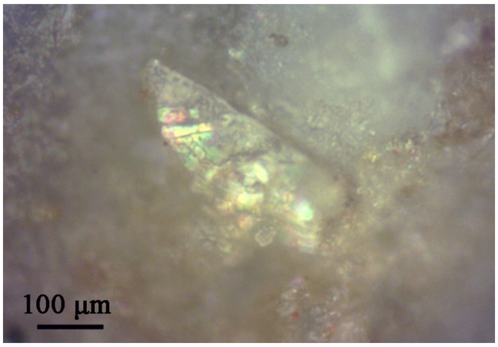

Fig. 13. Putative fragment of a cycloid fish scale (M6 368) O.M. 100×.

Point # 3 (K7 21, Fig. 14E–F) is a Levallois point with a short burin-like fracture (length 3.2 mm). Plant tissue fragments are found on the dorsal and ventral surfaces. It is unclear if they are related to hafting. The TCSA is 117 mm^2, toward the lower end of the experimental thrusting spears (Shea, 2006). The TCSP (rhomboid cross-section) is 57.6 mm, within the range of ethnographic dart points and just above the mean of the Aterian Aoulef assemblage (Sisk and Shea, 2011, Table 2).

Point # 4 (F6 39, Fig. 14G–H) shows crushing of the tip and a spin-off fracture (3.0 mm in length). The edges along the proximal 1/3 of the piece show crushing which may be indicative of hafting (Rots, 2012). Plant residues are found on the proximal third on the dorsal surface and may also be related to hafting. The TCSA is 185 mm^2 placing it slightly above the mean for experimental thrusting spears described by Shea (2006). The TCSP (rhomboid cross-section) is 76.7 mm which places it above the range for ethnographic dart points, but well within the range of multiple MSA samples (Sisk and Shea, 2011, Fig. 3).

Point # 5 (I8 5, Fig. 14I) is a Levallois point which is snapped at the tip and is included hear based largely on its morphology. Several plant fragments of the proximal half of the dorsal surface may be related to hafting, but the patterning is not strong. The TCSA is 78 mm^2 which places it well below the experimental thrusting spear range (Shea, 2006) and close to the mean reported for Aterian points from Aoulef (81.13 mm^2). The TCSP (triangular cross-section) is 54.6 mm, well within the range of ethnographic dart tips and almost identical to the mean reported for Aoulef (54.76 mm) (Sisk and Shea, 2011, Fig. 2, Table 2).

Point # 6 (K6 168, Fig. 14J–N) is another Levallois point with a step termination fracture (4.5 mm in length). There are numerous wood and skin fragments on both the dorsal and ventral surfaces which are likely related to binding and hafting. The TCSA is 80 mm^2, close to the mean reported for Aterian tanged points from Aoulef (81.13 mm^2). The TCSP (rhomboid cross-section) is 64.8 mm, at the upper end of the range of ethnographic dart points.

5.8. Calcite crystals and raphides

Sixteen artifacts had rod-like crystal structures on their surfaces. Crowther (2009) has shown that calcite crystals are similar in morphology and may be mistaken for raphides (calcium oxalate crystals) that are found in many plants. In order to distinguish between the two, acetic acid may be applied to the artifact surface.

Table 2
Possible projectile points.

Square	No.	Type	Width	Thickness	TCSA (mm^2)	TCSP Rhom (mm)	TCSP Tri (mm)	Impact type	Scar length (mm)
F6	39	Point	37	10	185	76.7	79	Crushing and spin-off	3.0
I8	5	Lev. Pt.	26	6	78	53.4	54.6	Snap	n/a
K6	168	Lev. Pt.	32	5	80	64.8	65.5	Step termination	4.5
K6	429	Flake	37	8	148	75.7	77.3	Burin-like	13.9
K7	21	Lev. Pt.	26	9	117	55.0	57.6	Burin-like	3.2
L6	148	Lev. Pt.	30	7	105	61.6	63.1	Burin-like	6.3

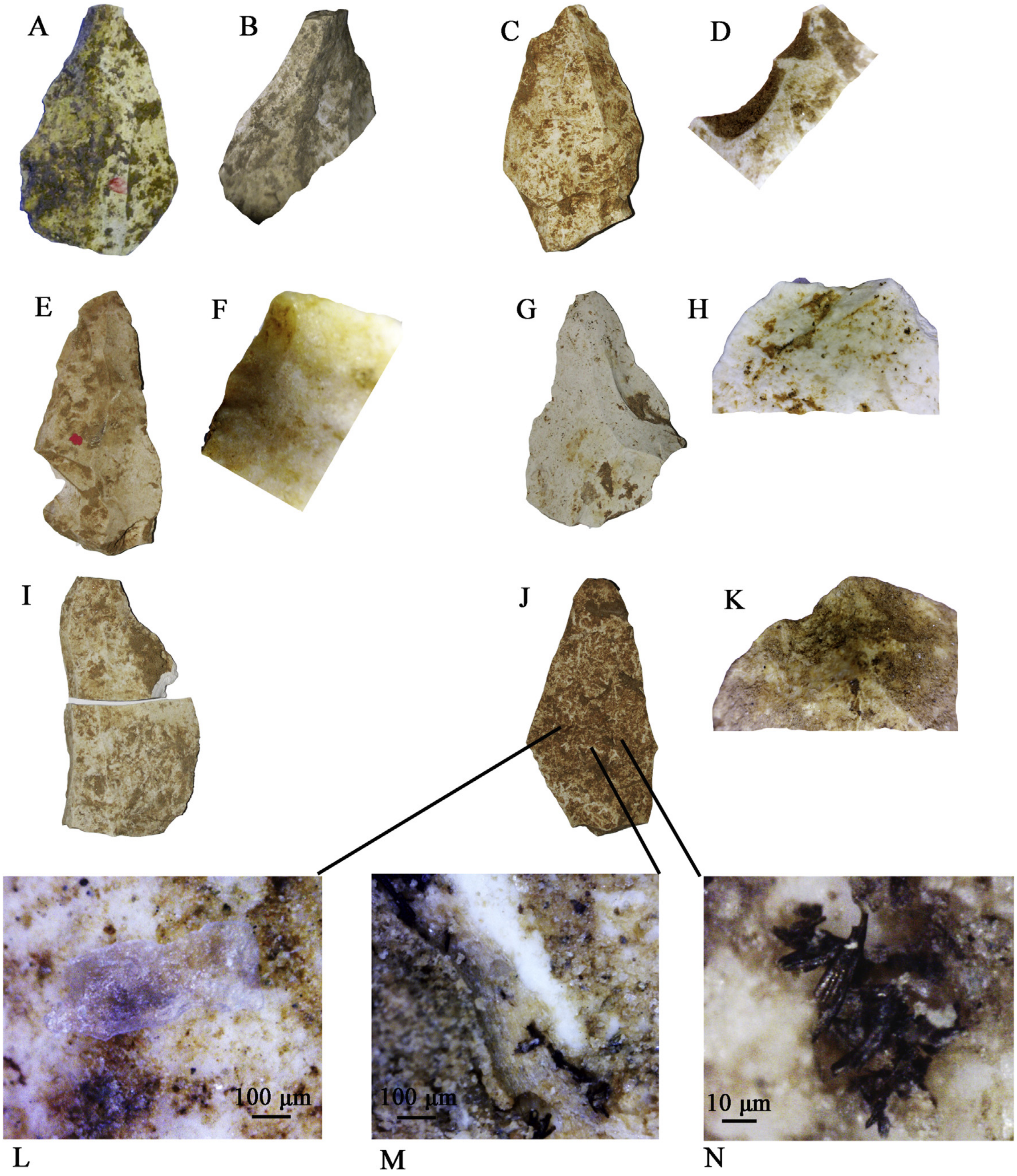

Fig. 14. Projectile points A) K6 429; B) burin-like scar, 13.9 mm long; C) L6 148; D) burin-like scar, 6.3 mm long; E) K7 21; F) burin-like scar, 3.2 mm long; G) F6 39; crushing and spin-off fracture; I) I8 5; J) K6 168; K) step termination fracture, 4.5 mm long; L) skin fragment, O.M. 225×; M) wood fragment, O.M. 225×; N) charred wood fragments, O.M. 485×.

Calcium oxalate is resistant to acetic acid while calcite will dissolve. Six of these artifacts were treated with acetic acid while being observed microscopically. In all cases, the structures dissolved indicating that they are calcite crystals and not raphides. We infer that the remaining artifacts also exhibited calcite crystals.

5.9. *Spatial distribution of use-materials*

Figs. 15 and 16 provide spatial information on the distribution of artifacts by use-material. For the sake of clarity, these maps are divided into two sub-levels of layer 4 described above, although the two sub-levels are grouped for all other analyses. For the most part, the processing of individual materials is not highly localized and takes place across the analyzed portion of the site. There are a few not able exceptions. The two tools with mushroom spores are found in the same square (M6, not pictured). Artifacts with fish residues are found in the same location as the fish remains recovered during excavation (Fig. 16). The patterning of the residues on the artifacts suggests that they are related to fish processing and are not just incidental. The artifacts with leporid hairs are likewise localized in the same square (Fig. 16). Finally, six of the artifacts with reed residues are found in squares E6 and F6.

6. Discussion

6.1. *Fibers and twisted fibers*

Fibers of varying sizes gain strength and length when they are twisted or plied together. K. Hardy notes that "String, cordage, or something that ties things together is such a fundamental part of everyday life that it is completely taken for granted" (2007:271). Fiber artifacts are rare in the archaeological record, partially due to their perishability but also because few archaeologists are trained to recognize them (Adovasio et al., 2007). Direct evidence in the form of twisted and plied fibers comes from Ohalo II in Israel (c. 19 ka, Nadel et al., 1994) and Lascaux, France (c. 18 ka, Leroi Gourhan, 1982; Genten et al., 2009). Other indirect evidence of cordage comes from the imprints of woven material on clay at Gravettian sites such as Pavlov I (c. 27 kya, Adovasio et al., 1996). Balme (2011) has argued that because the migration of modern humans c. 50 ka would have required martime technology, the first inhabitants of Australia must have had string and cordage technology. Vanhaeren et al. (2013) have recently argued for the use of string at Blombos Cave, South Africa based on use-wear patterns on perforated shells at least 72 ka. Indirect evidence for the use and manufacture of string may be even older. Perforations in a wolf incisor and a bone point at Repolusthöhle in Austria (c. 300 ka) suggest the use of string with these artifacts as pendants (Bednarik, 1995), although a leather thong may serve the same purpose. Thus, indirect and direct evidence of the use of string and cordage is of potentially of great antiquity, but the implications for its manufacture and use are not often discussed (K. Hardy, 2008). Under exceptional preservation conditions, such as dry caves or waterlogged sites, wooden and fiber artifacts can make up 95% of an archaeological assemblage (Adovasio et al., 2007). Clearly, this perishable material must have been more common than the archaeological record would indicate.

Numerous plant and animal fibers can be used to produce string. Human or animal hair, hide, sinew, and gut are all used as animal

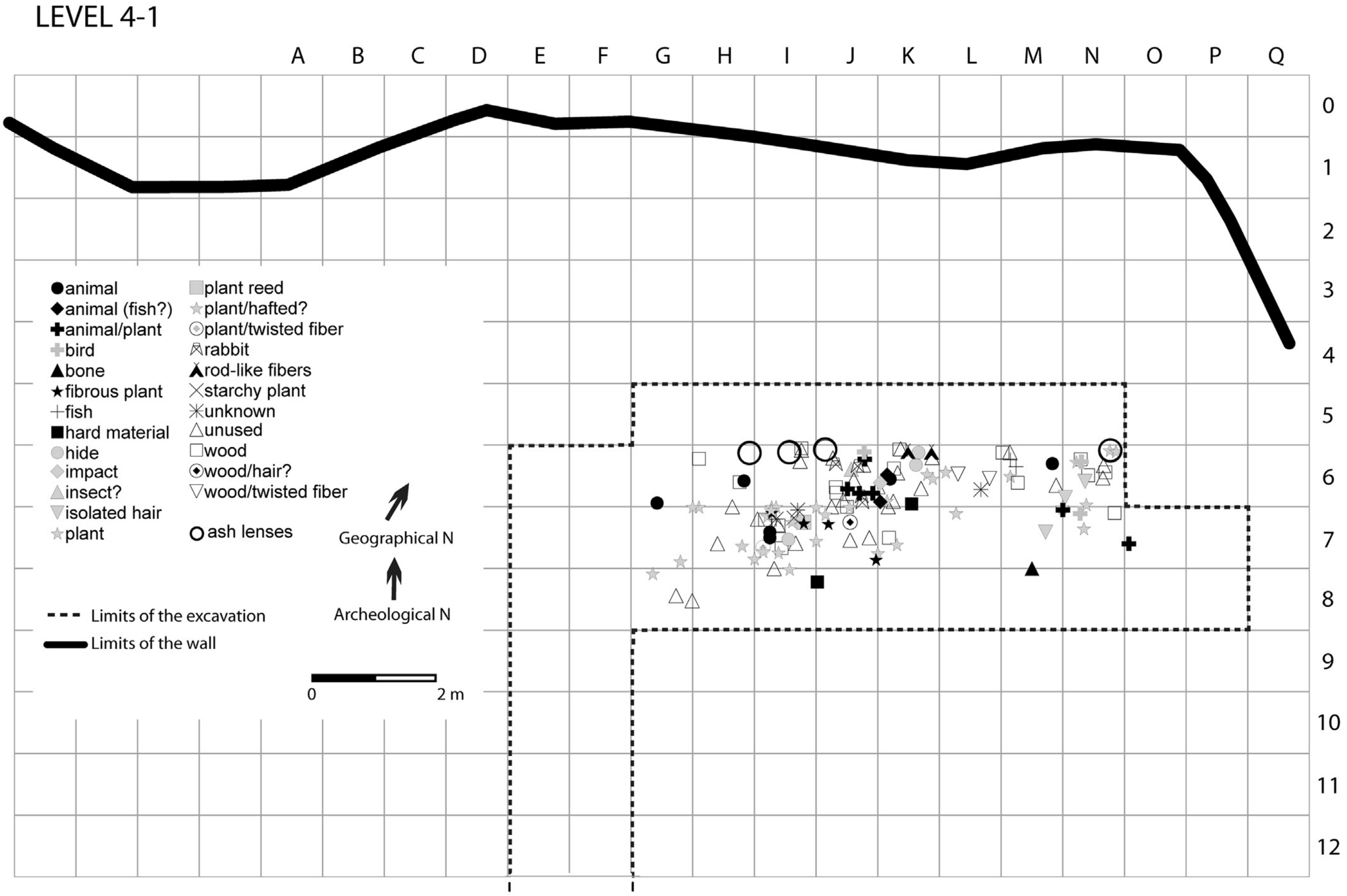

Fig. 15. Spatial distribution of analyzed artifacts by use-material, Level 4-1.

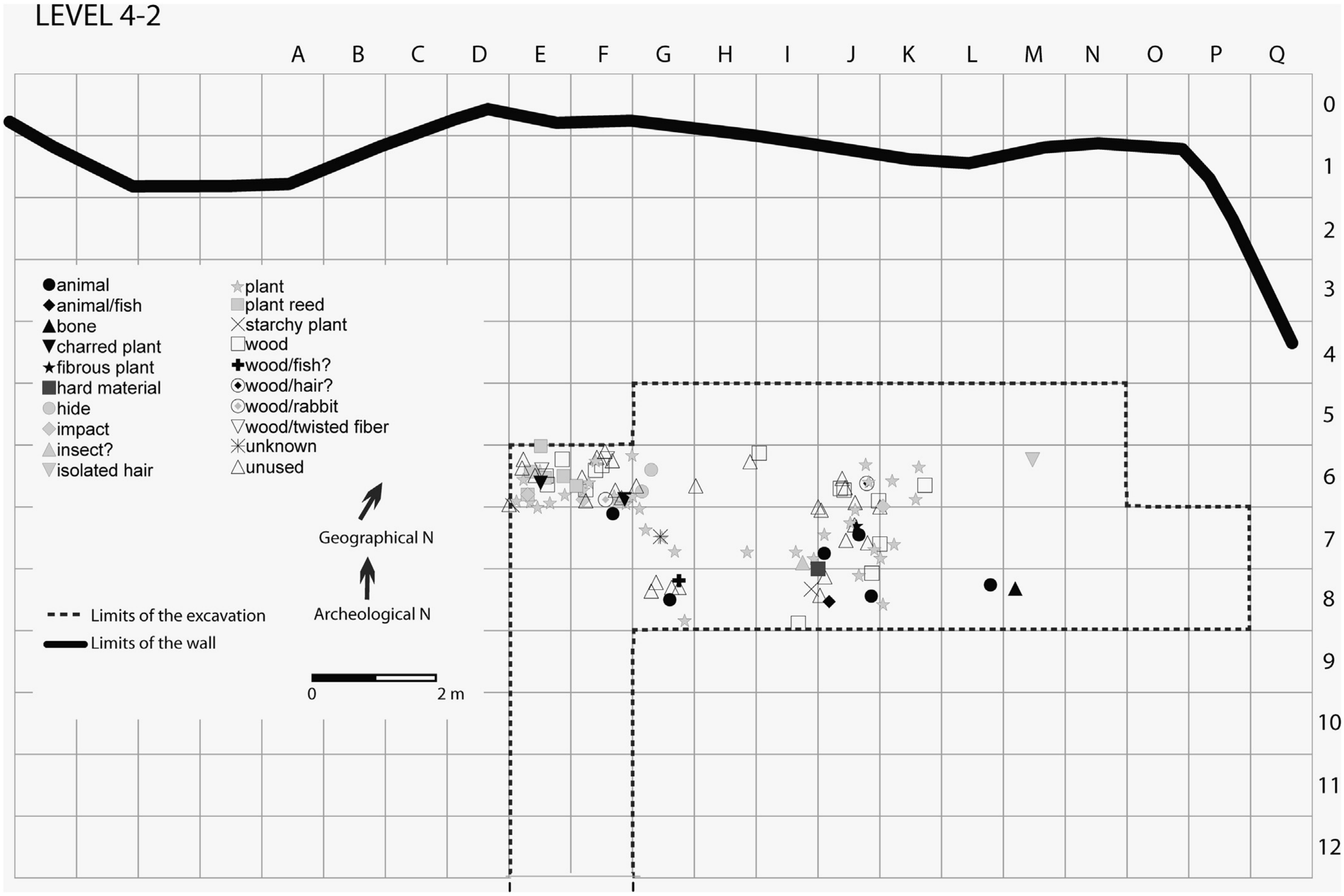

Fig. 16. Spatial distribution of analyzed artifacts by use-material, Level 4-2.

sources for string (K. Hardy, 2008). For plants, bast fibers from the inner bark of trees are commonly used to make cordage. Lime, oak, willow, ash and elm all have bast fibers suitable for cordage. Among non-woody plants, flax (*Linum usitatissimum*), nettle (*Urtica doica*), and hemp (*Cannabis sativa*) are commonly used even today. To make cordage from these plants, their fibers must first be harvested and cleaned of the surrounding tissue. These are not the only plants which can produce fiber for cordage. Various reeds and rushes, including cattails (*Typha* sp.), bulrush (*Scirpus lacustris*), bur-reed (*Sparganium* sp.), rushes (*Juncus* sp.) and common reeds (*Phragmites* sp.) can also be used for the production of string. For these plants, the bladelike leaves are typically shredded longitudinally before being twisted to form string (Hurcombe, 2008).

Since macroscopic remains have not been found prior to 19 ka, it is important to examine other less direct forms of evidence where fiber or string production may leave traces on a microscopic level which may be visible through use-wear and residue analyses (Hurcombe, 1994). For most of the Paleolithic, the best potential source of evidence for cordage is stone tools. Hurcombe (1998) describes several different points in the *chaîne opératoire* of fiber production where stone tools are likely to be used, including plant harvesting, processing of fibers, and cutting loose ends from cordage.

The production of string along with simple knowledge of knotting, weaving, and looping, make possible a wide range of products including “nets, containers, packaging, baskets, carrying devices, ties, straps, harness, clothes, shoes, beds, bedding, mats, flooring, roofing and walling” (Hurcombe, 1994: 204), among others. In addition, string facilitates the construction of complex, multi-component technologies such as hafts or snares. Finally, string would have been essential for seafaring, maritime technologies used for the colonization of islands, and for many types of fishing (Balme, 2011; O’Connor et al., 2011; Ferentinos et al., 2012).

The fibers on the stone tools from the Abri du Maras could have come from one of these uses. In some cases, multiple fibers are seen on a single tool with patterning to suggest that they are found along a cutting edge. In other cases, fibers are isolated or have no particular patterning. In this latter case, the fibers may not be related to tool use. They may instead come from contact with string or cordage. Carrying stone tools in a string bag is one possibility.

The evidence for cordage production at the Abri du Maras highlights several areas that require further research. The processes involved in cordage production add another element to consider when reconstructing prehistoric land use patterns. In order to make cordage, appropriate plants would have to be located which could mean travel to particular environments (e.g. forests, wetlands, etc.). In many cases, collecting fibers for cordage production is a seasonal activity. In order to obtain the longest, most useful cordage from cattails, for example, it is best to harvest them in late summer after they have reached their maximum height, but before the leaves have dried out (Hurcombe, 2008). Some fibers for cordage production must be retted for a period of weeks or months in order to obtain suitable fibers, leading to more concerns in planning seasonal movements. String production is also labor and learning intensive (Fyfe and Bolton, 2011). Although time estimates vary, Mackenzie (1991) reports that, for modern groups in New Guinea, producing enough string to make a string bag would require 60–80 h of work followed by another 100–160 h for the production of the bag itself. Lupo and Schmitt (2002) observe that among the Bofi of central Congo gathering raw material for a communal hunting net among could take 2–4 months, although the net itself could be made in 3–5 days.

Paleolithic archaeologists have a tendency to focus heavily on reconstructing subsistence activities (Hurcombe, 2000). Within subsistence, the focus is primarily on animals (Hardy, 2010) with even more narrow focus on large animals, partly because their remains preserve better (Speth, 2010). This focus is justified to some extent as archeologists can only work with the evidence they find. However, this means we are missing a huge component of everyday life. The preservation bias of the archaeological record limits the avenues being investigated. The fiber evidence presented here is a reminder that if we don't look for it, we won't find it.

6.2. *Mushrooms*

Residue analysis has revealed the possible presence of mushroom spores on two artifacts at the Abri du Maras. Although additional comparative analysis is necessary to confirm this identification, we feel it is warranted to discuss the potential use of mushrooms by Neanderthals in this context. While it is not possible to identify individual species of mushrooms based solely on spores, a review of the mushrooms found today in Europe shows several edible species with similar spores (Phillips, 2006; Huffman et al., 2008). These include the choice edible *Agaricus arvensis* (horse mushroom), the edible *Coprinus micaceus* (mica cap), and the edible *Psathyrella candolleana* (crumble tuft). In addition to being edible, these mushrooms may have medicinal uses. *Agaricus* contains the compound campestrin which inhibits the growth of both gram-positive and gram-negative bacteria. *Psathyrella candolleana* shows activity against gram-positive bacteria and has anti-fungal properties (Rogers, 2011).

There are several *Agaricus* species with similar spores, including *Agaricus silvicola* (wood mushroom) and *A. silvaticus* (blushing wood mushroom). Both of these species are reported as edible (Phillips, 2006), but some sources suggest avoiding them as they may cause intestinal upset (Huffman et al., 2008). In this case, the spores are not patterned on the artifact surface and cannot necessarily be linked to use. In addition, this artifact also exhibits hair fragments, feather barbules, and plant tissue. This amalgam of different residues makes functional interpretation of this artifact difficult.

While it is not possible to identify the specific types of mushroom or whether they were brought to the site in fresh or dried condition, their presence provides another glimpse into the hidden world of perishable items possibly used by Neanderthals. In fact, mushrooms are virtually invisible in the archaeological record. Aside from rare examples such as the Tyrolean Iceman (Ötzi), who had 3 different types of fungi (*Fomes fomentarius*, tinder fungus; two fragments of polypore, *Piptoporus betulinus*, function unknown) as part of his equipment (Pöder, 2005), they generally leave no trace. Mushrooms certainly have nutritional value, particularly in terms of protein, carbohydrate and mineral content (Agrahar-Murugkar and Subbulakshmi, 2005; Barros et al., 2007) and form not only a staple part of many diets but have also been used recently for survival food (under war conditions in Boznia and Herzegovina, Redzic et al., 2010). Furthermore, given their potential medicinal properties, the possibility of mushrooms being used as medicine by Neanderthals also exists (cf. Neanderthal medics, K. Hardy et al., 2012).

6.3. *Projectile points*

In the case of the Abri du Maras, we have a small sample of candidate artifacts which may have functioned as some type of weapon tip, presumably for hunting. From the fracture and wear analysis, 5 of 6 artifacts exhibit fractures on their tip which have been described as possibly diagnostic impact fractures (spin-off, step termination and burin-like fractures). Recently, Pargeter (2011) was able to reproduce all of these types of fractures in trampling experiments with cattle, albeit in small percentages. At the Abri du Maras, only 81 of 3640 artifacts are broken (2.2%). This low frequency of breaks suggests that trampling at the site is unlikely. Furthermore, the fact that the Abri du Maras is a rockshelter located 70 m above the Ardèche River makes it an improbable location for large herbivores to have frequently traversed.

Residue analysis provides another line of evidence that can help support the interpretation that these artifacts may have served as weapon tips. Three of the six artifacts show plant, wood and/or skin residues confined to the proximal 1/3–1/2 of the artifact and may be related to hafting and binding. Once again, this line of evidence, insufficient by itself, adds to the case that these were hafted points.

Morphometrics such as TCSA and TCSP are both used as proxies of the potential penetrating capabilities of pointed artifacts in hunting situations. Comparisons of TCSA against known ethnographic dart and arrow points and experimental spear thrusting data (Shea, 2006) clearly show that even the large examples from the Abri du Maras are well within the range of experimental thrusting spear tips and that some are possibly too thin and fragile to have been effective as thrusting spears (Shea, 2006). According to the analysis of TCSA alone, these would have been more suitable to have been used on hand-thrown projectiles. More recently, TCSP has been proposed as a more reliable predictor of the penetrating efficiency of stone points (Sisk and Shea, 2009, 2011). TCSPs on artifacts from the Abri du Maras range from 54.6 to 79 mm. These all fall well within the range of a variety of MSA assemblages analyzed by Sisk and Shea (2011). Furthermore, four of the six artifacts described here fall within the range of TCSP reported for ethnographic dart points (Sisk and Shea, 2011, Fig. 2) and are very close to the means for both TCSA and TCSP reported for Porc Epic unifacial points, Aterian points from Aoulef, and Aterian points from Azrag reported by Sisk and Shea (2011, Table 2). In their analysis, the TCSP values for these assemblages showed no statistically significant differences from ethnographic dart points, and the authors argue that they represent plausible dart points, and hence complex projectile technology, in the African MSA.

We do not provide statistical analysis here as the sample size is small and non-probabilistic. Nor do we suggest that the data conclusively demonstrate that at least some of these artifacts may have been part of complex projectile systems. However, the combination of evidence presented hear strongly argues for the use of at least some of these points as weapon tips. The precise mode of use is more difficult to determine. They certainly could have functioned as thrust or thrown spears. Furthermore, based on the morphometrics and criteria outlined by Sisk and Shea (2011), it is *plausible* that as many as 4 of the artifacts we described *could* have functioned as dart points in part of a complex projectile system. This evidence is by no means definitive, but does suggest that the possibility of complex projectile technology in the European Middle Paleolithic should not be discounted without further research.

7. General discussion

In a recent review of the literature on Neanderthal subsistence, Brown et al. (2011: 247–248) identify four major themes: 1) Neanderthals were high trophic-level carnivores and obligate meat-eaters; 2) Neanderthals were scavengers who hunted and gathered opportunistically; 3) Neanderthals could exploit a wide range of slow and sessile resources, but capture of small, fast, agile prey only occurred when the sessile prey was gone; and 4) Neanderthals were inefficient hunters specializing in large prey but incapable of exploiting alternative resources successfully. The evidence we present here from the Abri de Maras does not match any of these four themes, nor should it necessarily. Attempts to identify "Neanderthal subsistence" inevitably fail as Neanderthals lived over a wide geographic and temporal range and would surely have adapted to local conditions (Clark, 2002; Hardy, 2010). The fact that the evidence for subsistence at the Abri du Maras does not match these four themes underscores the *variability* that was present in Neanderthal subsistence.

Our analysis of the Abri du Maras also highlights another common feature of Neanderthal studies; they are heavily focused on subsistence. While reconstructing subsistence is important, and getting enough to eat is paramount for the survival of any group, not all decisions are based on subsistence. The preservation of fibers and twisted fibers presented here emphasizes the point that other activities, such as the procurement of raw material for and manufacture of string, should be taken into account when reconstructing past lifeways (K. Hardy, 2008; Hurcombe, 2008).

7.1. Subsistence at Abri du Maras

For layer 4 (NISP = 664 and NR = 9520), the faunal spectrum is composed, in order of abundance, of *R. tarandus*, *Equus* spp., *C. elaphus*, *Bison priscus*, *Capra ibex*, *Megaloceros giganteus*, *O. cuniculus* and *Lepus* sp. (Daujeard, 2008; Daujeard and Moncel, 2010). One bird remain, the only one known form the site, has been unearthed but is unidentified. There are no carnivore remains, nor chewing or ingestion marks. Root-etching is the most severe post-depositional alteration hindering the identification of marks (one third are undecipherable).

Faunal remains are mainly related to Neanderthal activities. Twenty percent of the reindeer, horse, megaceros and lagomorph remains bear cutmarks and almost 70%–90% have green bone fractures. The rare indices of seasonality (cementochronology and periods of tooth eruption) indicate occupations contemporary with the reindeer autumnal migrations. Ungulates are represented by all age classes. We observe patterns consistent with hominins having first access to all carcasses, and bringing back the whole carcasses or the best pieces to the site. The scarcity of head, axial and foot elements suggest that sometimes animals were first processed at the kill site and then selectively transported back to the rock-shelter.

Parts of carcasses have been processed at the site and numerous butchery activities have been identified: skinning, disarticulation, tendon and tongue removal, defleshing (the main butchery activity), periosteum scraping, marrow processing, meat heating and/or bone utilization as fuel or retouchers. All these domestic activities highlight complete *chaînes opératoires* and systematic behaviors in carcass treatment strategies. In addition, however, we also see evidence of exploitation of smaller animals including leporids, fish, and birds.

Leporids in general, and rabbits in particular, have received much attention in the recent literature. Starting with the idea that Neanderthals were incapable of or inefficient at catching small, fast prey (Klein, 2001), archaeologists have begun to note the numerous sites in the Lower and Middle Paleolithic which nonetheless show evidence of leporid exploitation.

Taphonomic analyses on accumulations of small mammal faunas (including abundant lagomorphs remains) discovered in Lower and Middle Paleolithic sites (Caune de l'Arago, Terra Amata and Lazaret, Cueva Negra) have shown that "small game," in the form of occasional hunting of rabbit and hare, was practiced since the Lower Paleolithic (Desclaux, 1992; El Guennouni, 2001; Desclaux et al., 2011; Walker et al., 2013). Data provided by small vertebrate accumulations in Middle Paleolithic sites has confirmed the persistence of this practice (Costamagno and Laroulandie, 2004). Nevertheless, the hunting and consumption of small animals are not widespread in the Middle Paleolithic and are more common with denser Upper Paleolithic populations (Stiner et al., 1999, 2000). However, there are exceptions in the Middle Paleolithic. At Bolomor Cave (Spain), small prey (mostly rabbits) exceeds 50% of the MNI in some levels and were processed by Neanderthals (Blasco and Fernández Peris, 2012). At this site, as at Abri du Maras, carnivore activity is rare on the faunal accumulations, which suggests that Neanderthals had access to a large spectrum of prey around the site, small and large, with a low degree of competition. Similar results were recently published for Layer 4 at Les Canalettes where faunal remains are dominated by rabbits (Cochard et al., 2012). The presence of cutmarks and shaft cylinders suggests that humans were the accumulating agent. Unlike these sites, the Abri du Maras displays a very low abundance of small game suggesting that Neanderthals did not heavily exploit this ecological niche. Nevertheless, at the Abri du Maras, we have cut-marked rabbit and hare bones and possible rabbit hairs on stone tools, providing two lines of evidence for rabbit exploitation. While we wish to heed our own advice and not generalize to all Neanderthals, the growing number of Neanderthal sites with demonstrated exploitation of leporids suggests that this activity, while not always common, was certainly within the behavioral repertoire of numerous Neanderthal groups.

According to Stiner et al. (1999, 2000), this scarcity of small game supports the notion that the occupants of the Abri du Maras constituted a small and/or relatively mobile group of foragers in a landscape sparsely populated by other human groups. As already stated by Yeshurun et al. (2007) for data from Misliya Cave, this assumption needs to be tempered in regards to the archaeological context of each site and regional area. At the Abri du Maras, the richness and the density of lithic and faunal material suggest either large and almost quasi-permanent human occupations, or multiple, seasonal and short-term occupations. Besides environmental and seasonal constraints and the logistical organization of territories, choices among various subsistence strategies are also due to cultural traditions specific to each human group.

Despite the fact that fish remains have been reported from hominin sites as far back as 1.95 Ma at FwJj20 in Kenya (Braun et al., 2010) and 700 ka at Cueva Negra, Spain (Walker, personal communication, 2013), fish also fall into the category of small fast prey which are often seen primarily or exclusively as the purview of anatomically modern humans (Henshilwood and Marean, 2003). While they are fewer in number than with rabbits, Middle Paleolithic sites with fish remains do exist and continue to increase in number. These include Milán, Almada and Abreda Caves, Spain (Roselló-Izquierdo and Morales-Muñiz, 2005; Adán et al., 2009), Grotte XVI, France (Rigaud et al., 1995), Devil's Tower and Vanguard Cave, Gibraltar (Stringer et al., 2008), Raj Cave, Poland (Patou-Mathis, 2004), Grotta Maggiore, Italy (Fiore et al., 2004), Ust-Kanskaya Cave, Siberia (Derevianko et al., 2005) and Figueira Brava Cave, Portugal (Bicho and Haws, 2008). While rabbits may be subject to taphonomic bias due to their small body size, fish remains are even more likely not to be preserved or recovered due to their small size and fragility (Erlandson, 2001). In this case, we have preserved fish remains. Furthermore, the recent observation of fish remains on artifacts at Payre (Hardy and Moncel, 2011) and here at the Abri du Maras offer a new tool in the detection of fish exploitation.

Evidence for the exploitation of birds by Neanderthals is also becoming more common. Use of bird feathers for decoration or symbolic purposes has recently been announced at Fumane (Peresani et al., 2011), Combe Grenal, Les Fieux (Morin and

Laroulandie, 2012) and from numerous sites in Gibraltar (Finlayson et al., 2012). Consumption of birds by Neanderthals has been demonstrated at Bolomor Cave in Spain, including a diving duck (*Aythya* sp., Anseriformes) (Blasco and Fernández Peris, 2009). At the Abri du Maras, we have one osteological bird remain that is unidentified along with downy barbules suggesting the presence of both waterfowl and raptors. Given our evidence, it is not possible to determine what was done with these birds. Consumption or use of feathers as personal ornamentation is both possible.

7.2. Procurement strategies

In addition to having evidence of the exploitation of a diverse range of animal resources, including large herbivores and small, fast prey, we also have possible evidence for a wide range of procurement strategies. In the sample from Level 4, macrofracture analysis, residues and morphometrics all suggest the presence of hafted projectile points. Based on TCSA and TCSP, these points certainly fall within the range of experimentally effective stone-tipped spears (Shea, 2006). Furthermore, four fall within the range of ethnographic dart tips and overlap with several African MSA assemblages (Sisk and Shea, 2011). These results certainly present the possibility that Neanderthals at the Abri du Maras could have had composite projectile technology (i.e. dart thrower and points). Such technology is generally seen as being exclusive to modern humans and having arisen in Africa (Sisk and Shea, 2011). The preliminary evidence we present here suggests that this conclusion may be premature.

Besides projectile technology, residues indicating the manufacture of cord or string open up a wide array of possible procurement strategies. Snares, nets, and traps of various kinds all become possible with the production of string. While it is generally recognized that string production may go back as far as 300 ka or earlier, discussions of string and its implications are often ignored for the Paleolithic (see Lupo and Schmitt, 2002; Soffer, 2004; Wadley, 2010 for exceptions). In the case of the Abri du Maras, string and cordage could have facilitated the capture of rabbits, fish, and even birds. These prey are often seen as low-ranked items (Fa et al., 2013) due to their small body size and low caloric yield. Technology such as nets, however, may increase the amount procured in a given period and thus make these prey items of greater potential value. We cannot, of course, demonstrate that nets, snares and traps were actually in use at the Abri du Maras. The construction of these items and their monitoring and maintenance is highly time-consuming. Nevertheless, our observations suggest that string and cordage were being manufactured or used at the site. Besides nets and traps, the manufacture of simple bags and carrying devices has great implications for resource procurement and transport (Hurcombe, 1994). Moreover, as observed earlier, the acquisition of suitable raw materials for string production is often a seasonal activity. As we gain further insight into this world of perishable materials, it will be necessary to rethink resource acquisition and time scheduling among Neanderthals (cf. Stiner and Kuhn and Stiner, 2006).

7.3. Other resources

We have already discussed the possible use of reed and other plants as sources of fiber. Many of the reeds that are useful for fiber production, such as cattail and bur-reed, also have edible starchy underground storage organs (Jones, 2009; Hardy, 2010). Previous work at the site of Payre suggests the exploitation of these food sources by Neanderthals (Hardy and Moncel, 2011). In this case, a few putative starch grains were observed, but their identification has not been confirmed. The case for the consumption of USOs at the Abri du Maras therefore remains speculative.

7.4. Lithic technology and tool function

If we compare flint sources with technology and typology, we observe a relationship between the longest blades and points and flint outcrops located to the south of the site. The collection of this flint requires a crossing of the Ardèche River. Flaking that occurs on site is mostly done on flint gathered to the north of the site and on the adjacent plateau. These flint sources are located 10–30 km from the site.

Geologic origin does not appear to be important when we look at tool function. In terms of use, pieces have been selected according to their shape not their geologic origin. Some aspects of function, such as hafting, or use-materials, such as fish and birds, are found on diverse types of flint. Cutting actions are a bit more numerous on blades and elongated products coming for the most part from the south.

In comparing tool types and function, we find a large diversity of products used but mainly long blades for butchery (animal, bird, fish, rabbit), blades and flakes for cutting plant (with or without cortex and backing). Hafted projectiles are found on points but also blades or flakes, proof that the form is not so important. Hair, fibers, hard material, and piercing plants are found on pointed pieces. Woodworking is seen with pointed pieces or large backed flakes. Whittling plants and wood occurs mainly with flakes (with or without cortical backing). In terms of use-actions, scraping is seen largely on flakes and slicing on blades. For the few retouched pieces, we observe a microdenticulate for cutting fish, and some scrapers for cutting plant or whittling.

With the exception of projectile points which do not always require a specific morphology to be effective, the Neanderthal tool kit appears to be multipurpose without a strong correlation between specific tool types and specialized functions. This pattern has been observed at other Middle Paleolithic sites (Anderson-Gerfaud, 1990; Hardy et al., 2001; Hardy, 2004; Hardy and Moncel, 2011; Rots, 2012). Rather than see this ad hoc tool use as a sign of a limitation of the Neanderthal mind (Wynn and Coolidge, 2004), we consider this to be another aspect of Neanderthal behavioral flexibility and variability. Tasks are performed as needed with the materials at hand. This is an adaptable form of tool use as opposed to a more restrictive one where specialized tools are required for different tasks. Points composed a part of the tool kit, some of which were brought to the site. Although they are standardized products, they are multifunctional tools, either hafted or used as hand tools. New excavations of layer 4 give ideas of multiple, seasonal and short-term occupations in a shelter along a small valley protected against cold winds near the Ardèche River. A part of the tool kit production was planned before arriving on the site, from diverse flint sources. It is impossible to determine if these unretouched artefacts came from other sites or were produced at flint workshops on the way to the site. But the diversity of flint origins suggests mobility of products between sites. Flint is widespread in the area. Transport of pieces to the site may be related to the anticipation of activities to be conducted at the site. The importation of blades and large flakes to the site shows forethought and planning even if these tools were used for a variety of purposes.

8. Conclusions

The Abri du Maras overlooks the Ardèche River in southeastern France. The combination of analyses presented here (mainly residue analysis) has provided a more detailed view into Neanderthal lives than is generally possible. Neanderthals at the Abri du Maras caught and consumed a wide variety of foods, from large herbivores to rabbits, fish, plants, and possibly birds. The occupants of the Abri du Maras may have also been engaged in a variety of other activities: gathering mushrooms, gathering raw materials and manufacturing string, woodworking, constructing composite technologies such as complex projectiles and possibly nets or traps. Given the wide variety of resources exploited at the Abri du Maras, we should heed Hockett's recent caution that we may have "under-appreciated the amount of non-mammal foods eaten by Neanderthals" (2012: 81). We would add that the high diversity of resources used by Neanderthals has been generally under-appreciated for decades.

This diversity of resources and activities is certainly at odds with the image of the inflexible Neanderthal that has become popular in recent years (Klein, 2001; Wynn and Coolidge, 2004; Stiner and Kuhn, 2009; Fa et al., 2013). However, as previously stated, we do not wish to fall into the trap of ascribing the behaviors we see at the Abri du Maras to all groups of Neanderthals. Instead, we hope that the evidence we have presented here will encourage other researchers to be open and looking for a wider range of possibilities when it comes to Neanderthal behavior.

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References

Adán, G.E., Álvarez-Lao, D., Turrero, P., Arbizu, M., García-Vázquez, E., 2009. Fish as diet resource in North Spain during the Upper Paleolithic. J. Archaeol. Sci. 36 (3), 895–899.

Adovasio, J.M., Soffer, O., Klíma, B., 1996. Upper Palaeolithic fibre technology: interlaced woven finds from Pavlov I, Czech Republic, c. 26,000 years ago. Antiquity 70, 526–534.

Adovasio, J.M., Soffer, O., Page, J., 2007. The Invisible Sex: Uncovering the True Role of Women in Prehistory. Smithsonian Books, New York.

Agrahar-Murugkar, D., Subbulakshmi, G., 2005. Nutritional value of edible wild mushrooms collected from the Khasi hills of Meghalaya. Food Chem. 89 (4), 599–603.

Anderson-Gerfaud, P., 1990. Aspects of behavior in the Middle Paleolithic: functional analysis of stone tools from southwest France. In: Mellars, P. (Ed.), The Emergence of Modern Humans. Cornell University Press, Ithaca, pp. 389–418.

Balme, J., 2011. Of boats and string: the maritime colonisation of Australia. Quat. Int. 285, 68–75.

Balter, V., Simon, L., 2006. Diet and behavior of the Saint-Césaire Neanderthal inferred from biogeochemical data inversion. J. Hum. Evol. 51 (4), 329–338.

Barros, L., Baptista, P., Correia, D.M., Casal, S., Oliveira, B., Ferreira, I.C., 2007. Fatty acid and sugar compositions, and nutritional value of five wild edible mushrooms from Northeast Portugal. Food Chem. 105 (1), 140–145.

Bednarik, R.G., 1995. Towards a better understanding of the origins of body decoration. Anthropologie 33 (3), 1–16.

Behrensmeyer, A.K., Gordon, K.D., Yanagi, G.T., 1986. Trampling as a cause of bone surface damage and pseudo-cutmarks. Nature 319, 768–771.

Beyries, S., 1988. Functional variability of lithic sets in the Middle Paleolithic. In: Dibble, H., Montet-White, A. (Eds.), Upper Pleistocene Prehistory of Western Eurasia. University Museum Press, Philadelphia, pp. 213–224.

Bicho, N., Haws, J., 2008. At the land's end: marine resources and the importance of fluctuations in the coastline in the prehistoric hunter-gatherer economy of Portugal. Quat. Sci. Rev. 27, 2166–2175.

Binford, L.R., 1981. Bones: Ancient Men and Modern Myths. Academic Press, New York.

Blasco, R., Fernández Peris, J., 2009. Middle Pleistocene bird consumption at level XI of Bolomor Cave (Valencia, Spain). J. Arch. Sci. 36, 2213–2223.

Blasco, R., Fernández Peris, J., 2012. A uniquely broad spectrum diet during the Middle Pleistocene at Bolomor Cave (Valencia, Spain). Quat. Int. 252, 16–31.

Blasco, R., Rosell, J., Fernández Peris, J.F., Caceres, I., Vergès, J.M., 2008. A new element of trampling: an experimental application on the Level XII faunal record of Bolomor Cave (Valencia, Spain). J. Archaeol. Sci. 35, 1605–1618.

Bocherens, H., 2009. Neanderthal dietary habits: review of the isotopic evidence. In: Hublin, J.J., Richards, M.P. (Eds.), The Evolution of Hominin Diets: Integrating Approaches to the Study of Palaeolithic Subsistence. Springer, New York, pp. 241–250.

Braun, D.R., Harris, J.W., Levin, N.E., McCoy, J.T., Herries, A.I., Bamford, M.K., Bishop, L.C., Richmond, B.G., Kibunjia, M., 2010. Early hominin diet included diverse terrestrial and aquatic animals 1.95 Ma in East Turkana, Kenya. Proc. Natl. Acad. Sci. U. S. A. 107 (22), 10002–10007.

Brom, T., 1986. Microscopic identification of feathers and feather fragments of Palearctic birds. Bijdr. Dierkd. 56, 181–204.

Brown, K., Fa, D.A., Finlayson, G., Finlayson, C., 2011. Small game and marine resource exploitation by Neanderthals: the evidence from Gibraltar. In: Bicho, N.F., Haws, J.A., Davis, L.G. (Eds.), Trekking the Shore: Changing Coastlines and the Antiquity of Coastal Settlement. Springer, New York, pp. 247–272.

Brunner, H., Coman, B.J., 1974. The Identification of Mammalian Hair. Inkata, Melbourne.

Costamagno, S., Laroulandie, V., 2004. L'exploitation des petits vertébrés dans les Pyrénées françaises du Paléolithique au Mésolithique: un inventaire taphonomique et archéozoologique. In: Brugal, J.-P., Desse, J. (Eds.), Petits Animaux et Sociétés Humaines. XXIVème Rencontres Internationales d'Archéologie et d'Histoire d'Antibes, 23–25 octobre 2003, pp. 403–416.

Catling, D., Grayson, J., 1982. Identification of Vegetable Fibres. Chapman and Hall, New York.

Chandler, A.C., 1916. A Study of Feathers, with Reference to Their Taxonomic Significance. In: Univ. Calif. Publ. Zool., vol. 13, pp. 243–446.

Clark, G.,A., 2002. Neandertal archaeology-implications for our origins. Am. Anthropol. 104 (1), 50–67.

Cochard, D., Brugal, J.P., Morin, E., Meignen, L., 2012. Evidence of small fast game exploitation in the Middle Paleolithic of Les Canalettes Aveyron, France. Quat. Int. 264, 32–51.

Combier, J., 1967. Le Paléolithique de l'Ardèche dans son Cadre Bioclimatique. Bordeaux, p. 462.

Crowther, A., 2009. Morphometric analysis of calcium oxalate raphides and assessment of their taxonomic value for archaeological microfossil studies. In: Haslam, M., Robertson, G., Crowther, A., Kirkwood, L., Nugent, S. (Eds.), Archaeological Science under a Microscope [Electronic Resource]: Studies in Residue and Ancient DNA Analysis in Honour of Thomas H. Loy, Terra Australis, vol. 30, pp. 102–128.

Daujeard, C., 2008. Exploitation du milieu animal par les Néandertaliens dans le Sud-Est de la France. In: British Archaeological Reports, vol. SI1867.

Daujeard, C., Moncel, M.-H., 2010. On Neanderthal subsistence strategies and land-use: a regional focus on the Rhône Valley area in southeastern France. J. Anthropol. Archaeol. 29, 368–391.

d'Errico, F., Zilhao, J., Julien, M., Baffier, D., Pelegrin, J., 1998. Neanderthal acculturation in Western Europe? A critical review of the evidence and its interpretation. Curr. Anthropol. 39 (S1), 1–44.

d'Errico, F., 2003. The invisible frontier. A multiple species model for the origin of behavioral modernity. Evol. Anthropol. 12 (4), 188–202.

Debard, E., 1988. Le quaternaire du Bas-Vivarais d'apres l'etude des remplissages d'vens, de oorches, de grottes et d'abris sous soche. In: Dynamique sédimentaire, paléoclimatologie et chronologie, vol. 103. Dept. des Science de la Terre, Univ. Claude-Bernard, Lyon 1, Lyon, France. Doc. Lab. Geol. Lyon.

Derevianko, A.P., Postnov, A.V., Rybin, E.P., Kuzmin, Y.V., Keates, S.G., 2005. The Pleistocene peopling of Siberia: a review of environmental and behavioral aspects. Indo-Pacific Prehist. Assoc. Bull. 3, 57–68.

Desclaux, E., 1992. Les petits vertébrés de la Caune de l'Arago à Tautavel (Pyrénées-Orientales). Biostratigraphie, paléoécologie et taphonomie. Bull. Mus. Anthropol. Préhist. Monaco 35, 35–64.

Desclaux, E., Hanquet, C., El Guennouni, K., 2011. Origine(s) des accumulations de micromammifères dans quelques sites préhistoriques du Pléistocène moyen et supérieur d'Europe méridionale. In: Laroulandie, V., Mallye, J.B., Denys, C. (Eds.), Actes de la table ronde Taphonomie des petits vertébrés: référentiels et transferts aux fossiles (Bordeaux, octobre 2009), British Archaeological Reports, vol. IS 2269, pp. 101–118.

Dickson, W.C., 2000. Integrative Plant Anatomy. Harcourt, San Diego.

Domínguez-Rodrigo, M., de Juana, S., Galan, A.B., Rodriguez, M., 2009. A new protocol to differentiate trampling marks from butchery cut marks. J. Archaeol. Sci. 36, 2643–2654.

Dove, C.J., Hare, P.G., Heacker, M., 2005. Identification of ancient feather fragments found in melting alpine ice patches in southern Yukon. Arctic 58, 38–43.

Drucker, D., Bocherens, H., 2004. Carbon and nitrogen stable isotopes as tracers of change in diet breadth during Middle and Upper Palaeolithic in Europe. Int. J. Osteoarchaeol. 14, 162–177.

El Guennouni, K., 2001. Les Lapins du Pléistocène Moyen et Supérieur de Quelques Sites Préhistoriques de l'Europe Méditerranéenne: Terra-Amata, Orgnac 3, Baume-Bonne, Grotte du Lazaret, Grotte du Boquete de Zafarraya, Arma del Manie. Etude Paléontologique, Taphonomique et Archéozoologique (Unpublished PhD thesis). Muséum National d'Histoire Naturelle, Paris.

Erlandson, J.M., 2001. The archaeology of aquatic adaptations: paradigms for a new millennium. J. Archaeol. Res. 9, 87–350.

Fa, J.E., Stewart, J.R., Lloveras, L., Vargas, J.M., 2013. Rabbits and hominin survival in Iberia. J. Hum. Evol.. http://dx.doi.org/10.1016/j.jhevol.2013.01.002.

Ferentinos, G., Gkioni, M., Geraga, M., Papatheodorou, G., 2012. Early seafaring activity in the southern Ionian Islands, Mediterranean Sea. J. Archaeol. Sci. 39 (7), 2167–2176.

Fernandes, P., 2012. Itinéraires et Transformations du Silex: Une Pétroarchéologie Refondée, Application au Paléolithique Moyen (Ph.D. thesis). Univiersty of Bordeaux I.

Finlayson, C., Brown, K., Blasco, R., Rosell, J., Negro, J.J., Bortolotti, G.R., Finlayson, G., Sanchez Marco, A., Giles Pacheco, F., Rodriquez Vidal, J., Carrion, J.S., Fa, D.A., Llanes, J.M.R., 2012. Birds of a feather: Neanderthal exploitation of raptors and Corvids. PLoS One 7 (9), e45927.

Fiore, I., Gala, M., Tagliacozzo, A., 2004. Ecology and subsistence strategies in the Eastern Italian Alps during the middle Palaeolithic. Int. J. Osteoarchaeol. 1, 273–286.

Fullagar, R., 1991. The role of silica in polish formation. J. Archaeol. Sci. 18, 1–24.

Fullagar, R., 2006. Starch on artifacts. In: Torrence, R., Barton, H. (Eds.), Ancient Starch Research. Left Coast Press, Walnut Creek, pp. 177–204.

Fyfe, A., Bolton, J., 2011. An analysis of arrow and string bag craft variability in the upper Sepik and central new Guinea. Oceania 81 (3), 259–279.

Genten, F., Terwinghe, E., Danguy, A., 2009. Atlas of Fish Histology. Science Publishers, Enfield, New Hampshire.

Hardy, B.L., 1994. Investigations of Stone Tool Function through Use-wear, Residue and DNA Analyses at the Middle Paleolithic Site of La Quina, France (Ph.D. dissertation). Indiana University.

Hardy, B.L., 2004. Neanderthal behaviour and stone tool function at the Middle Palaeolithic site of La Quina, France. Antiquity 78, 547–565.

Hardy, B.L., 2010. Climatic variability and plant food distribution in Pleistocene Europe: implications for Neanderthal diet and subsistence. Quat. Sci. Rev. 29 (5), 662–679.

Hardy, B.L., Garufi, G.T., 1998. Identification of woodworking on stone tools through residue and use-wear analyses: experimental results. J. Archaeol. Sci. 25, 177–184.

Hardy, B.L., Moncel, M.-H., 2011. Neanderthal use of fish, mammals, birds, starchy plants and wood 125–250,000 Years Ago. PloS One 6 (8), e23768.

Hardy, B.L., Kay, M., Marks, A.E., Monigal, K., 2001. Stone tool function at the Paleolithic sites of Starosele and Buran Kaya III, Crimea: behavioral implications. Proc. Natl. Acad. Sci. U. S. A. 98, 10972–10977.

Hardy, K., 2008. Prehistoric string theory. How twisted fibres helped to shape the world. Antiquity 82 (316), 271–280.

Hardy, K., Buckley, S., Collins, M.J., Estalrrich, A., Brothwell, D., Copeland, L., García-Tabernero, A., García-Vargas, S., de la Rasilla, M., Lalueza-Fox, C., Huguet, R., Bastir, M., Santamaría, D., Madella, M., Wilson, J., Fernández Cortés, A., Rosas, A., 2012. Neanderthal medics? Evidence for food, cooking, and medicinal plants entrapped in dental calculus. Naturwissenschaften 99 (8), 1–10.

Haslam, M., 2004. The decomposition of starch grains in soils: implications for archaeological residue analyses. J. Archaeol. Sci. 31, 1715–1734.

Haslam, M., 2006. Potential misidentification of in situ archaeological tool-residues: starch and conidia. J. Archaeol. Sci. 33, 114–121.

Hather, J., 1993. An Archaeobotanical Guide to Root and Tuber Identification. In: Europe and Southwest Asia, vol. 1. Oxbow Books, Oxford.

Henry, A.G., Brooks, A.S., Piperno, D.R., 2011. Microfossils in calculus demonstrate consumption of plants and cooked foods in Neanderthal diets (Shanidar III, Iraq; Spy I and II, Belgium). Proc. Natl. Acad. Sci. U. S. A. 108 (2), 486–491.

Henshilwood, C.S., Marean, C.W., 2003. The origin of modern human behavior. Curr. Anthropol. 44 (5), 627–651.

Hoadley, B., 1990. Identifying Wood. Taunton Press, Newton, Connecticut.

Hockett, B., 2012. The consequences of Middle Paleolithic diets on pregnant Neanderthal women. Quat. Int. 264, 78–82.

Huffman, D.M., Tiffany, L.H., Knaphus, G., Healy, R.A., 2008. Mushrooms and Other Fungi of Midcontinental United States. Univ. of Iowa, Iowa City.

Hughes, S.S., 1998. Getting to the point: evolutionary change in prehistoric weaponry. J. Archaeol. Method Theory 5 (4), 345–408.

Hurcombe, L.M., 1994. From functional interpretations to cultural choices in tool use. In: Ashton, N., David, A. (Eds.), Stories in Stone. British Museum, London, pp. 144–155. Lithic Studies Society, Occasional Paper 4.

Hurcombe, L.M., 1998. Plant-working and craft activities as a potential source of microwear variation. Helinium 34 (2), 201–209.

Hurcombe, L., 2000. Time, skill and craft specialization as gender relations. In: Donald, M., Hurcombe, L. (Eds.), Gender and Material Culture in Archaeological Perspective. St. Martin's Press, New York, pp. 88–109.

Hurcombe, L., 2008. Organics from inorganics: using experimental archaeology as a research tool for studying perishable material culture. World Arch. 40 (1), 83–115.

Jones, M., 2009. Moving north: archaeobotanical evidence for plant diet in Middle and Upper Paleolithic Europe. In: Hublin, J.J., Richards, M.P. (Eds.), The Evolution of Hominin Diets: Integrating Approaches to the Study of Palaeolithic Subsistence. Springer, New York, pp. 171–180.

Kardulias, N., Yerkes, R., 1996. Microwear and metric analysis of threshing sledge flints from Greece and Cyprus. J. Archaeol. Sci. 23, 657–666.

Klein, R.G., 2001. Southern Africa and modern human origins. J. Anthropol. Res. 57 (1), 1–16.

Klein, R.G., Cruz-Uribe, K., 2000. Middle and Later stone age large mammal and tortoise remains from Die Kelders Cave 1, western Cape Province, South Africa. J. Hum. Evol. 38 (1), 169–195.

Klein, R.G., Avery, G., Cruz-Uribe, K., Halkett, D., Parkington, J.E., Steele, T., Volman, T.P., Yates, R., 2004. The Ysterfontein 1 Middle Stone Age site, South Africa, and early human exploitation of coastal resources. Proc. Natl. Acad. Sci. U. S. A. 101 (16), 5708–5715.

Kuhn, S.L., Stiner, M.C., 2006. What's a mother to do? the division of labor among Neanderthals and modern humans in Eurasia. Curr. Anthropol. 47 (6), 953–980.

Lacey, M.E., Lacey, M., West, J.S., 2006. The Air Spora: a Manual for Catching and Identifying Airborne Biological Particles. Springer, New York.

Langley, M.C., Clarkson, C., Ulm, S., 2008. Behavioural complexity in Eurasian Neanderthal populations: a chronological examination of the archaeological evidence. Camb. Arch. J. 18 (03), 289–307.

Lazuén, T., 2012. European Neanderthal stone hunting weapons reveal complex behaviour long before the appearance of modern humans. J. Archaeol. Sci. 39 (7), 2304–2311.

Le Gall, O., 1990. Les Moustériens et les poissons. In: Résumés des communications du colloque international sur les Moustériens charentiens, Brive-La Chapelle-aux- Saint (26-29 août 1990), pp. 32–34.

Le Gall, O., 2000. Les Moustériens étaient-ils pêcheurs? Bull. Soc. Anthropol. Sud-Ouest 34, 3–11.

Leroi Gourhan, A., 1982. The archaeology of Lascaux cave. Sci. Am. 246 (6), 80–88.

Lombard, M., 2004. Distribution patterns of organic residues on middle stone age points from Sibudu Cave, KwaZulu-Natal, South Africa. S. Afr. Archaeol. Bull. 59, 37–44.

Lombard, M., 2011. Quartz-tipped arrows older than 60 ka: further use-trace evidence from Sibudu, KwaZulu-Natal, South Africa. J. Archaeol. Sci. 38 (8), 1918–1930.

Lombard, M., Pargeter, J., 2008. Hunting with Howiesons Poort segments: pilot experimental study and the functional interpretation of archaeological tools. J. Archaeol. Sci. 35, 2523–2531.

Lombard, M., Phillipson, L., 2010. Indications of bow and stone-tipped arrow use 64,000 years ago in KwaZulu-Natal, South Africa. Antiquity 84 (325), 635–648.

Lombard, M., Wadley, L., 2007. The morphological identification of micro-residues on stone tools using light microscopy: progress and difficulties based on blind tests. J. Archaeol. Sci. 34, 155–165.

Lupo, K.D., Schmitt, D.N., 2002. Upper Paleolithic net-hunting, small prey exploitation, and women's work effort: a view from the ethnographic and ethnoarchaeological record of the Congo Basin. J. Archaeol. Method Theory 9 (2), 147–179.

Lyman, R.L., 2008. Quantitative Paleozoology. Cambridge University Press, Cambridge (MA).

Mansur-Franchomme, M.E., 1986. Microscopie du Matériel Lithique Préhistorique: Traces d'Utilisation, Altération Naturelles, Accidentelles, et Technologiques. CNRS, Paris.

Mackenzie, M., 1991. Androgynous Objects: String Bags and Gender in Central New Guinea. Harwood Academic, Philadelphia.

Moncel, M.-H., Michel, V., 2000. Première datation radiométrique par U–Th d'un niveau moustérien de l'Abri du Maras (Ardèche, France). Bull. Soc. Préhist. Fr. 97 (3), 1–5.

Moncel, M.-H., Gaillard, C., Patou-Mathis, M., 1994. L'Abri du Maras (Ardèche): Une nouvelle campagne de fouilles dans un site Paléolithique moyen (1993). Bull. Soc. Préhist. Fr. 91 (6), 363–368.

Moncel, M.-H., Daujeard, C., Crégut-Bonnoure, É., Boulbes, N., Puaud, S., Debard, É., Bailon, S., Desclaux, E., Escudé, É., Roger, T., Dubar, M., 2010. Nouvelles données sur les occupations humaines du début du Pléistocène supérieur de la moyenne vallée du Rhône (France). Les sites de l'Abri des Pêcheurs, de la Baume Flandin, de l'Abri du Maras et de la Grotte du Figuier (Ardèche), colloque Q6, Montpellier 2008. Quaternaire 21 (4), 385–413.

Monnier, G.F., Ladwig, J.L., Porter, S.T., 2012. Swept under the rug: the problem of unacknowledged ambiguity in lithic residue identification. J. Archaeol. Sci. 39 (10), 3284–3300.

Morin, E., Laroulandie, V., 2012. Presumed symbolic use of diurnal raptors by Neanderthals. PLoS One 7 (3), e32856.

Nadel, D., Danin, A., Werker, E., Schick, T., Kislev, M.E., Stewart, K., 1994. 19,000-year-old twisted fibers from Ohalo II. Curr. Anthropol. 35 (4), 451–458.

Nilssen, P.J., 2000. An Actualistic Butchery Study in South Africa and Its Implications for Reconstructing Hominid Strategies of Carcass Acquisition and Butchery in the Upper Pleistocene and Plio-pleistocene (Ph.D. dissertation). University of Cape Town.

O'Connor, S., Ono, R., Clarkson, C., 2011. Pelagic fishing at 42,000 years before the present and the maritime skills of modern humans. Science 334 (6059), 1117–1121.

Odell, G., Odell-Vereecken, F., 1980. Verifying the reliability of lithic use-wear assessments by blind tests: the low-power approach. J. Field Archaeol. 7, 87–120.

O'Farrell, M., 2004. Les Pointes de la Gravette de Corbiac (Dordogne) et Considérations sur la Chasse au Paléolithique Supérieur Ancien: Approches Fonctionnelles en Préhistoire. Société Préhistorique Française, Paris, pp. 121–138.

O'Farrell, M., 2005. Etude préliminaire des éléments d'armature lithique de l'Aurignacien ancien de Brassempouy. In: Le Brun-Ricalens, F. (Ed.), Productions Lamellaires Attribuées á l'Aurignacien: Chaînes Opératoires et Perspectives Technoculturelles, Archéologiques, vol. 1, pp. 395–412. Luxembourg.

Olsen, S.L., Shipman, P., 1988. Surface modification on bone: trampling versus butchery. J. Archaeol. Sci. 15, 535–553.

Pargeter, J., 2011. Assessing the macrofracture method for identifying Stone Age hunting weaponry. J. Archaeol. Sci. 38 (11), 2882–2888.

Patou-Mathis, M., 2004. Subsistence behaviours in a Middle Palaeolithic site in Poland: the Raj Cave. Int. J. Osteoarchaeol. 14, 244–255.

Pearsall, D., 2000. Paleoethnobotany: a Handbook of Procedures, second ed. Academic Press, New York.

Pearson, J.A., 2007. Hunters, fishers and scavengers: a review of the isotope evidence for Neanderthal diet. Before Farming 2, 1–15.

Peresani, M., Fiore, I., Gala, M., Romandini, M., Tagliacozzo, A., 2011. Late Neandertals and the intentional removal of feathers as evidenced from bird bone taphonomy at Fumane Cave 44 ky BP, Italy. Proc. Natl. Acad. Sci. U. S. A. 108 (10), 3888–3893.

PFAF, 2013. Plants for a Future: Edible, Useful, and Medicinal Plants for a Healthier World. PLants for a Future. http://www.pfaf.org (accessed 10.04.13.).

Phillips, F., 2006. Mushrooms. Macmillan, Oxford.

Pobiner, B.L., Rogers, M.J., Monahan, C.M., Harris, J.W.K., 2008. New evidence for hominin carcass processing strategies at 1.5 Ma, Koobi Fora, Kenya. J. Hum. Evol. 55, 103–130.

Pöder, R., 2005. The Ice man's fungi: facts and mysteries. Int. J. Med. Mushrooms 7, 357–359.

Redzic, S., Barudanovic, S., Pilipovic, S., 2010. Wild mushrooms and lichens used as human food for survival in war conditions: Podrinje-Zepa region (Bosnia and Herzegovina, W. Balkan). Hum. Ecol. Rev. 17 (2), 175–187.

Richard, M., 2012. Datations par les Méthodes Combinées ESR-U/Th et Caractérisation d'Email Dentaire de Sites du Paléolithique Moyen d'Ardèche. Master 2. Museum National d'Histoire Naturelle (unpublished).

Richards, M.P., 2009. Stable isotope evidence for European Upper Paleolithic human diets. In: Hublin, J.J., Richards, M.P. (Eds.), The Evolution of Hominin Diets: Integrating Approaches to the Study of Palaeolithic Subsistence. Springer, New York, pp. 251–257.

Richards, M.P., Jacobi, R., Cook, J., Pettitt, P.B., Stringer, C.B., 2005. Isotope evidence for the intensive use of marine foods by Late Upper Palaeolithic humans. J. Hum. Evol. 49 (3), 390–394.

Richards, M.P., Pettitt, P.B., Stiner, M.C., Trinkaus, E., 2001. Stable isotope evidence for increasing dietary breadth in the European mid-Upper Paleolithic. Proc. Natl. Acad. Sci. U. S. A. 98 (11), 6528–6532.

Richards, M.P., Trinkaus, E., 2009. Isotopic evidence for the diets of European Neanderthals and early modern humans. Proc. Natl. Acad. Sci. U. S. A. 106 (38), 16034–16039.

Rigaud, J.-P., Simek, J., Thierry, G., 1995. Mousterian fires from Grotte XVI (Dordogne, France). Antiquity 69, 902–912.

Robertson, G.R., 2002. Birds of a feather stick: microscopic feather residues on stone artifacts from Deep Creek Shelter, New South Wales. Tempus 7, 175–187.

Rogers, R., 2011. The Fungal Pharmacy: the Complete Guide to Medicinal Mushrooms and Lichens of North America. North Atlantic Books, Berkeley.

Roselló-Izquierdo, E., Morales-Muñiz, A., 2005. Ictiofaunas Musterienses de la peninsula Iberica: ¿Evidencias de pesca Neandertal? Munibe 57, 183–195.

Rots, V., 2012. Insights into early Middle Palaeolithic tool use and hafting in western Europe. The functional analysis of level IIa of the early Middle Palaeolithic site of Biache-Saint-Vaast (France). J. Archaeol. Sci.. http://dx.doi.org/10.1016/j.jas.2012.06.042.

Salazar-García, D.C., Power, R.C., Sanchis Serra, A., Villaverde, V., Walker, M.J., Henry, A.G., 2013. Neanderthal diets in central and southeastern Mediterranean Iberia. Quat. Int.. http://dx.doi.org/10.1016/j.quaint.2013.06.007.

Shea, J.J., 2006. The origins of lithic projectile point technology: evidence from Africa, the Levant, and Europe. J. Archaeol. Sci. 33, 823–846.

Shea, J.J., Sisk, M.L., 2010. Complex projectile technology and Homo sapiens dispersal into western Eurasia. PaleoAnthropology 2010, 100–122.

Shipman, P., Rose, J.J., 1983. Early hominid hunting, butchering, and carcass processing behaviors: approaches to the fossil record. J. Anthropol. Archaeol. 2, 57–98.

Shipman, P., Rose, J.J., 1984. Cutmark Mimics on modern and fossil Bovid bones. Curr. Anthropol. 25, 116–117.

Shott, M.J., 1997. Stones and shafts redux: the metric discrimination of chipped-stone dart and arrow points. Am. Antiq. 62, 86–101.

Sisk, M.L., Shea, J.J., 2009. Experimental use and quantitative performance analysis of triangular flakes (Levallois points) used as arrowheads. J. Archaeol. Sci. 36, 2039–2047.

Sisk, M.L., Shea, J.J., 2011. The African origin of complex projectile technology: an analysis using tip cross-sectional area and perimeter. Int. J. Evol. Biol.. http://dx.doi.org/10.4061/2011/968012.

Sorensen, M.V., Leonard, W.R., 2001. Neandertal energetics and foraging efficiency. J. Hum. Evol. 40 (6), 483–495.

Soffer, O., 2004. Recovering perishable technologies through use wear on tools: preliminary evidence for upper paleolithic weaving and net making. Curr. Anthropol. 45 (3), 407–413.

Speth, J.D., 2010. The Paleoanthropology and Archaeology of Big Game Hunting: Protein, Fat, or Politics. Springer, New York.

Stiner, M.C., Kuhn, S.L., 2009. Paleolithic diet and the division of labor in Mediterranean Eurasia. In: Hublin, J.J., Richards, M.P. (Eds.), The Evolution of Hominin Diets: Integrating Approaches to the Study of Palaeolithic Subsistence. Springer, New York, pp. 157–169.

Stiner, M.C., Munro, N., Surovell, T.A., Tchernov, E., Bar-Yosef, O., 1999. Palaeolithic growth pulses evidenced by small animal exploitation. Science 283, 190–194.

Stiner, M.C., Munro, N., Surovell, T.A., 2000. The tortoise and the hare: small game use, the broad spectrum revolution and Palaeolithic demography. Curr. Anthropol. 41, 39–73.

Stringer, C.B., Finlayson, J.C., Barton, R.N.E., Fernández-Jalvo, Y., Cáceres, I., Sabin, R.C., Rhodes, E.J., Currant, A.P., Rodríguez-Vidal, F., Giles Pacheco, F., Riquelme-Cantal, J.A., 2008. Neanderthal exploitation of marine mammals in Gibraltar. Proc. Natl. Acad. Sci. U. S. A. 105 (38), 14319–14324.

Teerink, B.J., 1991. Hair of West European Mammals: Atlas and Identification Key. Cambridge University Press, Cambridge.

Thomas, D.H., 1978. Arrowheads and atlatl darts-how stones got shaft. Am. Antiq. 43, 461–472.

Vanhaeren, M., d'Errico, F., van Niekerk, K.L., Henshilwood, C.S., Erasmus, R.M., 2013. Thinking strings: additional evidence for personal ornament use in the Middle Stone Age at Blombos Cave, South Africa. J. Hum. Evol. 64 (6), 500–517.

Villa, P., Boscato, P., Ranaldo, F., Ronchitelli, A., 2009. Stone tools for the hunt: points with impact scars from a Middle Paleolithic site in southern Italy. J. Archaeol. Sci. 36 (3), 850–859.

Wadley, L., 2010. Were snares and traps used in the Middle Stone Age and does it matter? A review and a case study from Sibudu, South Africa. J. Hum. Evol. 58 (2), 179–192.

Walker, M.J., López-Martínez, M., Carrión-García, J.S., Rodríguez-Estrella, T., San-Nicolás del-Toro, M., Schwenninger, J.L., López-Jiménez, A., Ortega-Rodrigáñez, J., Haber-Uriarte, M., Polo-Camacho, J.-L., García-Torres, J., Campillo-Boj, M., Avilés-Fernández, A., Zack, W., 2013. Cueva Negra del Estrecho del Río Quípar (Murcia, Spain): a late Early Pleistocene hominin site with an "Acheulo-Levalloiso-Mousteroid" Palaeolithic assemblage. Quat. Int. 294, 135–159.

Warren, R., 2009. The Potential Role of Fish in the Diet of Neanderthals. SR. Honors Thesis. Kenyon College, Gambier, Ohio.

White, M.J., 2006. Things to do in Doggerland when you're dead: surviving OIS3 at the northwestern-most fringe of Middle Palaeolithic Europe. World Arch. 38 (4), 547–575.

Williamson, B., 1996. Preliminary stone tool residue analysis from Rose Cottage Cave. S. Afr. J. Field Archaeol. 5, 36–44.

Wynn, T., Coolidge, F.L., 2004. The expert Neandertal mind. J. Hum. Evol. 46, 467–487.

Yeshurun, R., Bar-Oz, G., Weinstein-Evron, M., 2007. Modern hunting behavior in the early Middle Paleolithic: faunal remains from Misliya Cave, Mount Carmel, Israel. J. Hum. Evol. 53, 656–677.