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ORIGINAL PAPER

What is the use of shaping a tang? Tool use and hafting of tanged tools in the Aterian of Northern Africa

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Abstract We present the results of detailed microscopic examination of tanged tools from the site of Ifri n'Ammar. The rock shelter has a particularly rich and well-preserved stratigraphy that has yielded a large variety of tanged tools, thus offering a possibility to test hypotheses on the possible links between tangs and hafting. Earlier methodological work has demonstrated that patterned wear forms on the non-active part of the tool as the result of hafted tool use, and that the characteristics of the wear traces depend on the exact hafting arrangement used. In the present study, wear analyses were combined with further experiments that involved the hafting of tanged tools with various materials and arrangements and aimed at understanding the development of this important morphological innovation. We suggest that functional data are needed to understand the relevance of the "Aterian tang" for hafting (or use), and whether this innovation was triggered by functional, cultural or environmental factors.

Keywords Aterian · Tang · Hafting

Introduction

The "Aterian" and "Mousterian" technocomplexes in North Africa have until recently been defined solely on the basis of the presence or absence of tanged tools and treated as two separate entities. However, these technocomplexes could in fact represent variants of one and the same industry, as has been repeatedly suggested in recent literature (Nami and Moser 2010; Linstädter et al. 2012; Dibble et al. 2013). With the exception of particular tool types that only occur in the Aterian, such as tanged tools and foliates, the composition of "Aterian" and "Mousterian" assemblages can be very similar, and distinguishing between the two technocomplexes is therefore often not feasible (cf. discussion in Kleindienst (2001) and Dibble et al. (2013)). Moreover, as pointed out by several researchers, the chronological relationship between the so-called Aterian and Mousterian industries remains unclear (e.g., Richter et al. 2010; Linstädter et al. 2012). This is witnessed by several sites with interstratified "Aterian" and "Mousterian" levels (Betrouni 1997; Wengler 2006; Aouadi-Abdeljaouad and Belhouchet 2008; Nami and Moser 2010).

The Aterian, as it is currently defined, covers a large geographical area in Northern Africa, reaching from the Maghreb to the Western Desert of Egypt and to the Sahel region (Debénath et al. 1986; Wendorf and Schild 1992; Garcea 1998; Kleindienst 2001; Van Peer 2001), and a considerable time span with dates ranging from MIS 6 to MIS 3 (Mercier et al. 2007; Barton et al. 2009; Richter et al. 2010; Jacobs et al. 2011, 2012; Dörschner et al. 2016). While this technocomplex has become more clearly defined in recent years (Hawkins 2001; Nami and Moser 2010; Bouzouggar and Barton

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2012; Dibble et al. 2013; Scerri 2013a; Spinapolice and Garcea 2013), the variability within it is still largely unknown. Several typological and technological analyses have contributed to an improved understanding of Aterian assemblages, but functional data have been largely lacking in these discussions in spite of the important new insights they could offer (see Massussi and Lemorini 2004–2005; Bouzouggar et al. 2007; Iovita 2011; Bouzouggar and Barton 2012; Scerri 2013b). More functional studies are needed if we want to evaluate the usefulness of the "Aterian tang" for hafting (or use), or to understand whether this innovation was triggered by functional, cultural, or environmental factors. It can be hypothesised that the appearance of tanged tools reflects a shift in hafting techniques. None of the previous studies have, however, included a detailed examination of hafting wear even though it has been assumed that tanged tools were inserted in handles or shafts of some sort (Bouzouggar et al. 2007; Garcea 2012).

As many Aterian assemblages are surface collections, a large part of the material that would be relevant for functional studies has suffered from intense aeolian erosion, which often makes high magnification analysis impossible and thus significantly reduces the level of detail that can be obtained through a functional approach. Fortunately, Aterian assemblages have also been recovered at sheltered and stratified sites, such as Ifri n'Ammar, which offer a much better potential for functional studies. In the Ifri n'Ammar assemblage, aeolian alterations play no major role and the site is thus an ideal candidate for a detailed functional analysis.

We present here the results of an analysis of tanged tools from the upper levels ("occupation supérieure") of Ifri n'Ammar. The functional analysis was combined with an experimental study that aimed at testing different hafting alternatives, gaining insights into the possible causes and implications of this important morphological adaptation, and creating a reference for the interpretation of the archeological wear patterns. The research presented here is part of a larger study of tanged and non-tanged tools, the goal of which is to contribute to a better understanding of the use and hafting of both.

Background

The Aterian and its tanged tools

Since the early days of prehistoric archeology in Northern Africa, the Aterian technocomplex has triggered the attention of archeologists. The first prehistoric discoveries of Aterian artefacts need to be viewed within the context of the political situation at the time, more in particular the colonial settlements during the French protectorate (1912–1956) (Sarvan 1985; Debénath 1992; Holl 2005). Archeological surveys were subsequently conducted by several European researchers who strived for a better understanding of the chronology of the lithic artefacts (Antoine 1950; Ruhlmann 1952; Balout 1955; Camps 1974; Debénath et al. 1986; Wengler 1997; Aumassip 2004). Several definitions of the Aterian have been proposed, and it triggered a huge debate around this cultural concept. In particular, the presence of tanged tools has been widely discussed (Caton-Thompson 1946; Balout 1955; Vaufrey 1955; Roche 1967; Tixier 1967; Bordes 1976–1977). The confusion in the understanding of North African Palaeolithic assemblages was caused primarily by the application of Bordes' typological system, developed based on French Mousterian tools (Bordes 1950, 1961). In addition, the distinction between Aterian and Maghrebian Mousterian assemblages was mainly based on the presence—or absence—of these "tanged tools" (Breuil 1931; Antoine 1934). Indeed, Reygasse defined the Aterian as a "Mousterian with tanged tools" (Reygasse 1922). Most researchers agree today that a "culture" or an "entity" cannot be defined based on a "fossil directeur" in order to group assemblages into certain industries (Hawkins 2001; Nami and Moser 2010; Linstädter et al. 2012; Dibble et al. 2013; Scerri 2013b). As suggested by others, identifications of "Aterian assemblages" are often only based on the presence of a few tanged tools (Wendorf and Schild 1992; Garcea 1998; Bouzouggar and Barton 2012; Scerri 2013a). When the evidence of different Aterian sites (stratified sites and surface collections) is evaluated based on available published sources (Howe 1967; Texier 1985–1986; Rodrigue 1992; Wengler 1993; Rodrigue and Letan 2004; Barton et al. 2009; Nami and Moser 2010; Dibble et al. 2012; El Hajraoui et al. 2012; Spinapolice and Garcea 2013), it can be observed that the ratio of tanged tools compared to the total amount of retouched tools or to the assemblage as a whole is quite low (Table 1). Indeed, tanged tools never exceed 10.55% of the retouched tools from surface collections and only 4% in the case of stratified sites. The difference in percentage is likely due to a collection bias during field survey given the easy recognition of tanged tools, next to an overall bias towards tools and a greater surface area that is covered. Tanged tools only form a small portion of excavated Aterian assemblages and their frequency may have been overestimated. Similarly, foliates show the same pattern but with an even smaller representation. Figures are highly skewed as 106 of the 115 foliates were recovered at a single

Table 1 List of stratified sites and surface collections showing the frequency of tanged tools, foliates, and sidescrapers compared to the total number of retouched tools

Sites		Assemblage	Tools	Tanged tools	% tools/tanged tools	Foliates	% tools/foliates	Sidescrapers	% tools/side scrapers	References
Dar es Soltan I “lowest Aterian assemblage”	Stratified sites	–	248	29	11.69%	–	–	–	–	Barton et al. (2009)
Dar es Soltan I “second Aterian assemblage”			185	33	17.84%					Barton et al. (2009)
Subtotal Dar es Soltan I		–	433	62	14.3%	–	–	–	–	
El Aliya, layer 5		–	431	6	1.39%	13	3.02%	47	10.90%	Howe (1967)
El Aliya, layer 6			750	6	0.80%	90	12.00%	86	11.47%	Howe (1967)
El Aliya, layer 7			13	1	7.69%	1	7.69%	1	7.69%	Howe (1967)
El Aliya, layer 9			54	0	0.00%	2	3.70%	2	3.70%	Howe (1967)
Subtotal El Aliya		–	1248	13	1.00%	106	8.49%	136	10.90%	
Contrebandier, layer 4b		54	7	3	42.86%	0	0.00%	2	28.57%	Dibble et al. (2012)
Contrebandier, layer 4c		101	12	3	25.00%	0	0.00%	5	41.67%	Dibble et al. (2012)
Contrebandier, layer 4d		227	29	3	10.34%	0	0.00%	4	13.79%	Dibble et al. (2012)
Contrebandier, layer IV-2		689	63	10	15.87%	1	1.59%	29	46.03%	Dibble et al. (2012)
Contrebandier, layer V-1a		101	12	2	16.67%	0	0.00%	3	25.00%	Dibble et al. (2012)
Contrebandier, layer V-1b		100	5	1	20.00%	0	0.00%	0	0.00%	Dibble et al. (2012)
Contrebandier, layer V-2		253	18	3	16.67%	0	0.00%	2	11.11%	Dibble et al. (2012)
Subtotal Contrebandier		1525	146	25	17.10%	1	0.68%	45	30.82%	
El Mnasra, layer 4		82	5	1	20.00%	0	0.00%	1	20.00%	El Hajraoui et al. (2012)
El Mnasra, layer 5		485	32	1	3.13%	0	0.00%	11	34.38%	El Hajraoui et al. (2012)
El Mnasra, layer 6		700	15	1	6.67%	0	0.00%	3	20.00%	El Hajraoui et al. (2012)
El Mnasra, layer 7		231	14	1	7.14%	0	0.00%	3	21.43%	El Hajraoui et al. (2012)
Subtotal El Mnasra		1498	66	4	6.00%	0	0.00%	18	27.27%	
Chaperon rouge I		2629	206	5	2.40%	3	1.46%	31	15.05%	Texier (1985–1986)
Ifri n’Ammar “occupation supérieure”		4545	671	63	9.39%	5	0.75%	264	39.34%	Nami and Moser (2010)
Ifri n’Ammar “occupation inférieure”		374	119	8	6.72%	0	0.00%	14	11.76%	Nami and Moser (2010)
Subtotal Ifri n’Ammar		4919	790	71	9.00%	5	0.63%	278	35.19%	
Rhafas, layer 2		1769	599	31	5.18%	0	0.00%	143	23.87%	Wengler (1993)
Rhafas, layer 3a		384	144	3	2.08%	0	0.00%	43	29.86%	Wengler (1993)
Rhafas, layer 3b		942	682	1	0.15%	1	0.15%	175	25.66%	Wengler (1993)
Rhafas, layer 6d		2263	961	1	0.10%	0	0.00%	521	54.21%	Wengler (1993)
Rhafas, layer 55		458	156	1	0.64%	0	0.00%	68	43.59%	Wengler (1993)
Subtotal Rhafas		5816	2542	37	1.46%	1	0.04%	950	37.37%	
Total stratified sites		16,387	5431	217	4,00%	116	2.14%	1458	26.85%	

Table 1 (continued)

Sites		Assemblage	Tools	Tanged tools	% tools/tanged tools	Foliates	% tools/foliates	Sidescrapers	% tools/side scrapers	References
Station Météo 2	Surface collections	1252	407	23	5.65%	0		59	14.50%	Wengler (1993)
Oued Thalma		2000	542	63	11.62%	0		228	42.07%	
Station d'Assa		–	392	33	8.42%	0		17	4.34%	Rodrigue (1992)
Kheneg el Hammam		2626	456	30	6.58%	4		122	26.75%	Rodrigue and Letan (2004)
Wadi Ain Zargha (site SJ-98-28)		948	171	53	30.99%	0		17	9.94%	Spinapolice and Garcea (2013)
Jefara (site SJ-00-57)		109	23	3	13.04%	0		2	8.70%	Spinapolice and Garcea (2013)
Jefara (site SJ-00-58)		101	28	5	17.86%	0		12	42.86%	Spinapolice and Garcea (2013)
Wadi Ghan (site SG-0061)		176	18	5	27.78%	0		3	16.67%	Spinapolice and Garcea (2013)
Total surface collections		7212	2037	215	10.55%	4	0.20%	460	22.58%	
Total		23,599	7468	432	5.78%	120	5.89%	1918	25.68%	

site and most of these from layer 6 at El Aliya (Table 1). By contrast, sidescrapers are common at all sites.

Tangs and tool use

While the implication of the presence of tanged tools for the understanding of the Aterian as a whole is well debated, another relevant aspect concerns their potential use. From early onwards, researchers considered them to represent the earliest indications of the existence of hafting techniques (Clark 1970) and the first evidence of hafted projectile points, as illustrated by the writings of Caton Thompson, who stated that "the invention of the tanged point probably a javelinhead must have given the inventors, whoever they were, a decided advantage in aggressive action against rival human groups not yet so equipped" (Caton-Thompson 1946—in Hawkins 2001: 30). Indeed, the first researchers studying Aterian tanged tools assumed a use as projectiles (Marchand and Aymé 1935; Caton-Thompson 1946), even though tanged scrapers had already been discovered at the time (Tixier 1958–1959). Other researchers assigned tanged tools erroneously to the Neolithic period, based on their co-occurrence with more recent artefacts in surface collections (Camps 1974).

The first functional studies on Aterian tanged tools were performed from 2004 onwards. Massussi and Lemorini (2004–2005) presented the results of a functional analysis on a few tanged tools from Jebel Gharbi, Libya. Based on a low magnification analysis, they proposed that the notches—forming the transition to the tang—were the true active zones (Massussi and Lemorini 2004–2005). High magnification analysis proved impossible due to patination. Other researchers have argued that the short tangs could have been the active part (Garcea 2012; Spinapolice and Garcea 2014). Both interpretations rely on the assumption that hafting does not result in wear traces, following the hypothesis once formulated by Keeley (1982: 804) that well-hafted tools should not move in their haft and therefore no wear traces should form. Another wear study was performed on 26 tanged tools from the Moroccan site of Rhafas (layer 2 and 3a) and an unknown number of tanged pieces from the Contrebandier site (Bouzouggar et al. 2004–2005). The tangs were considered as the non-active part, and traces of longitudinal and transversal movements on animal material were observed on the distal part (Bouzouggar et al. 2004–2005). Overall, the tang is rarely considered to be the active area; it is generally considered to have been embedded in some kind of handle (Bouzouggar and Barton 2012; Garcea 2012). Hafting wear has not yet been examined for Aterian tools, even though extensive experimentation has demonstrated that hafting can result in explicit and identifiable wear (e.g., Rots 2003; Rots et al. 2006). Specifically, the characteristics of such wear depend on the exact mode of hafting and the tool's use (Rots 2010a). This methodology has been applied to various Middle Palaeolithic and Middle Stone Age assemblages (Rots and Van Peer 2006; Rots 2009; Rots et al. 2011; Rots 2013; Rots et al. 2015). This development implies that the wear traces observed by other researchers on the tangs may well be linked with hafting instead of use. After all, it should not be neglected that hafting traces were sometimes mistaken for traces of use in blind tests (Unrath et al. 1986).

It is therefore an appropriate time to re-evaluate the wear evidence on tanged tools and to examine whether or not the tangs are adaptations to accommodate hafting. The site of Ifri n'Ammar is particularly appropriate in this context given the abundance of tanged tools in contrast to several other sites (cf. Table 1). The analysis presented here includes the largest sample of tanged tools that was yet examined for wear evidence. At the same time, a detailed microscopic analysis may provide more evidence regarding the use of tanged tools and may challenge or confirm recently proposed hypotheses like the resharpening of tanged points in the haft (Hawkins 2001; Iovita 2011; Scerri 2013a), or the one concerning the recycling of tanged projectile points into other tool types (Iovita 2011).

Materials

The site of Ifri n'Ammar

Ifri n'Ammar is a rock shelter located in the eastern Rif, a mountain range belonging to the Atlas Mountains. During the Spanish protectorate, archeological research was almost absent in the Rif region (Nami and Moser 2010). Only the site of Taforalt was studied over a longer period and some Palaeolithic finds from the Moulouya region were published (Mikdad et al. 2000). In order to evaluate the archeological potential of this region, the Commission for Archaeology of Non-European Cultures (KAAK) started the project "Préhistoire et Protohistoire du Rif Oriental Marocain," in collaboration with the Moroccan Institut des Sciences de l'Archéologie et du Patrimoine (Rabat). The excavation permit covers almost 9000 km^2 in eastern Mediterranean Morocco, between Al Hoçeima and the Moulouya estuary (Fig. 1). Surveys and excavations have been conducted since the beginning of the research program and about 300 archeological prehistoric and protohistoric sites have been discovered (Mikdad et al. 2012).

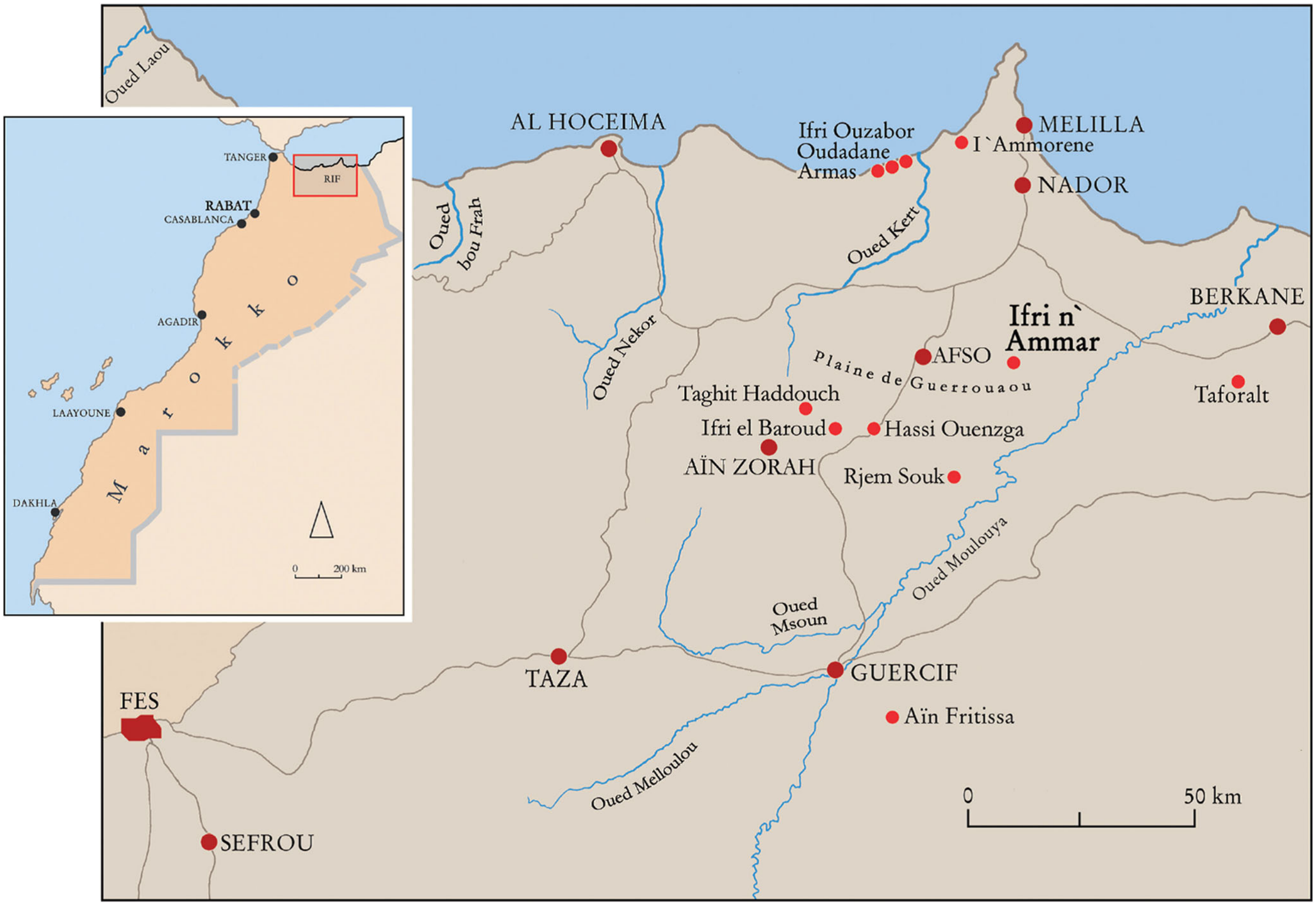


Fig. 1 Map showing the research area of the project "Préhistoire et Protohistoire du Rif Oriental Marocain" and the location of the analysed site of Ifri n'Ammar (from Nami and Moser 2010)

Fig. 2 The rock shelter of Ifri n'Ammar, view to the south

The rock shelter of Ifri n'Ammar was discovered during a survey in 1996 (Mikdad et al. 2000). Paleolithic artefacts were exposed from the first excavation season, and the site quickly attracted the focus of all local activities. Thanks to its topographical location at the edge of a narrow valley and the confluence of two wadis (Fig. 2). Ifri n'Ammar combines ideal conditions for a prehistoric settlement (Nami and Moser 2010). The area is situated between the Guerouaou and the Moulouya plain, a mixture of highlands and alluvial plains, and a favorable biotope for fauna, which must have attracted hunters and gatherers during the Middle and the Upper Pleistocene.

The maximum sediment depth inside the rock shelter of Ifri n'Ammar is between 7 and 8 m. The Upper and Middle Palaeolithic levels are protected against erosion by "a sediment trap," caused by a rock collapse from the top of the rock shelter (Nami and Moser 2010). The Middle Palaeolithic artefacts are conserved in more than 3 m of sediment (Fig. 3). Thermoluminescence dates on flint artefacts of the Middle Palaeolithic sequence have refined the chronology. The upper section was dated to a period from 80 to 130 ka and the lower section to a period from 143 to 171 ka (Richter et al. 2010). Calcrete layers seal the different archeological layers (Richter et al. 2010), and a calcareous crust also separates the so-called occupation supérieure and the occupation inférieure of the Middle Palaeolithic sequence. It corresponds to a period of about 15 ka during which the rock shelter was only sporadically occupied by humans (Nami and Moser 2010). The observations of Nami and Moser (2010) showed that the Middle Palaeolithic sequence contains more lithics in the "occupation supérieure" than in the levels below the calcareous deposits (Nami and Moser 2010). About 62% of the material in the upper layers is composed of knapping waste, allowing the reconstruction of the *chaine opératoire* (Nami and Moser 2010). Flakes dominate the assemblage, and side scrapers are the most frequent tool type (Nami and Moser 2010). The tanged tools were discovered in the upper levels of the "occupation supérieure" together with a few foliates.

The raw material is known to originate from within a radius of about 60 km around the site (Nami and Moser 2010), mainly from secondary deposits such as the Oued Moulouya pebbles and the Oued Kert, but also

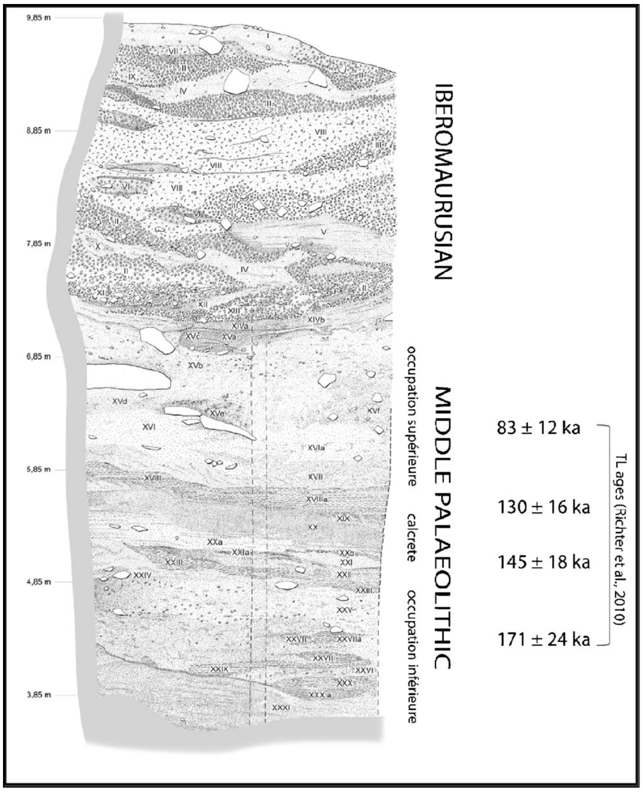


Fig. 3 Stratigraphy of Ifri n'Ammar (northeast profile) modified after Nami and Moser (2010)

from the primary position site Ain Zohra. There seems to be no relevant change in acquisition strategy in the different occupations (Nami and Moser 2010). The tanged tools were produced in the same locally available material as the non-tanged tools (Nami and Moser 2010).

The Aterian at Ifri n'Ammar

The site of Ifri n'Ammar presents an interesting case to examine the link between the presence of tanged tools, assemblage size, and the tool kits of levels with and without tanged tools. Notably, the number and variety of retouched tools in the upper occupation is significantly higher for the levels with tanged tools in comparison to the levels without and the frequency of tanged tools correlates well with the assemblage size and tool frequency (Table 2). We could, therefore, hypothesise that the presence/absence of tanged tools may be a factor of duration of occupation or alternatively, linked with the site's function given that no significant technological differences could be observed between them. The high number of sidescrapers should also be noted: while they dominate in all levels, they are clearly more abundant in the levels with tanged tools at Ifri n'Ammar.

The functional analysis of the tanged tools from the Aterian assemblage of Ifri n'Ammar is part of a broader functional study for which about 200 artefacts were selected so far, based on their preservation and without restrictions in tool types. The selection is derived from the assemblages that were previously published and that were excavated in the main trench and in the extended area towards the left wall (Nami and Moser 2010). We focus on the tanged artefacts from the upper occupation, because only one of the eight tanged tools identified for the lower occupation revealed to have an undeniable tang (cf. see below).

A tang or not a tang

At Ifri n'Ammar, the morphological and technological variability of the Aterian tangs is high, independent of the tool type. Intuitively, this variety in tang morphologies does not seem to warrant a direct link between tangs and hafting, as one would expect some degree of formalisation. Tangs were classified following Tixier (1958–1959) and Hawkins (2001), but in this study, a single notch, for instance, was considered insufficient to classify a tool as being tanged. Tangs had to be shaped with bifacial bilateral retouch (four or three directions) or with unifacial retouch on both edges in order to be accepted. Of the 63 tools that were identified as tanged tools for the upper occupation (Nami and Moser 2010), 41 were available for the present study. According to the defined criteria, 37 tools proved to show an undeniable tang. All simple notches ($n = 4$) were discarded.

Table 2 Frequency of retouched tools, "occupation supérieure," Ifri n'Ammar

Typological category		Tanged tools	Sidescrapers	Mousterian points	Notched tools	Denticulates	Endscrapers	Foliates
"Occupation supérieure"	Enl. 26	1	59	6		3	4	2
	Enl. 27	5	69	5	3	1	6	1
	Enl. 28	8	31	5	2		3	2
	Enl. 29	10	30	4	3	5	4	2
	Enl. 30	13	14	3		7	3	1
	Enl. 31	16	14	1	2		3	
	Enl. 32	4	15		3	6	3	1
	Enl. 33	5	15	1	3	4	4	1
	Enl. 34	1	17	2	1	2		
	Enl. 35		24	1		1		2
	Enl. 36		14	2	2		1	2
	Enl. 37		20	5				1
	Enl. 38		14	3				
	Enl. 39		15	4		1		
	Enl. 40		17	4				
	Enl. 41		6	1		1	1	
	Enl. 42		6	1				
	Total	63	380	48	21	31	32	15

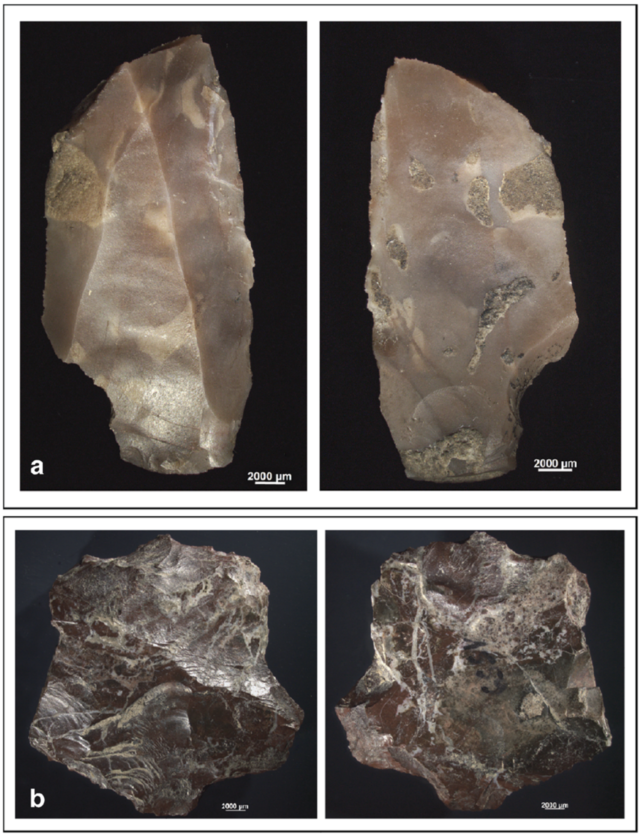


Fig. 4 Examples of excluded tanged tools: **a** tool with simple notch (IA 1532, "occupation supérieure"); **b** tool with accidental damage that creates a "tang," heat-damaged (IA 1559, "occupation inférieure")

For the lower occupation, eight tools were identified as tanged tools by Nami and Moser (2010), seven of which were available for this study. Only one proved to have an undeniable tang. Discarded tools showed a simple notch (*n* = 1), or lateral removals (not comparable to the tang morphologies) that converged to a point on the distal or lateral edge of the tool (*n* = 2), or the tangs were a result of accidental damage (*n* = 3) instead of an intentional morphological modification (Fig. 4).

Methods

Analysis

The archeological tools were examined for wear traces with three types of microscopes using different magnifications and lighting techniques: a Zeiss stereomicroscope Stemi 2000C or Discovery V12 (magnifications up to ×120), a Zeiss Macro-Zoom Microscope V16 (magnifications up to ×180), and a Zeiss metallurgical reflected-light microscope Axio Imager (magnifications ×50–500) with polarizing filters and DIC. The interpretation of the wear patterns is based on comparisons with an existing experimental reference collection consisting of more than 2000 tools (e.g., Rots et al. 2001, Rots 2010a), over 1000 of which were used for various activities, in the hand or hafted in various arrangements. The reference collection also includes production, transport, and trampling experiments. In addition, an experimental set was created specifically for this study (see below).

The tanged pieces from Ifri n'Ammar have been well-curated since their discovery, but they were manipulated intensively: they were cleaned, labelled with varnish and ink, handled during drawing and photography, and they were exposed during an exhibition. For these reasons, a systematic residue analysis was not attempted but attention was devoted to possible remains of more resistant residues such as adhesives.

Experimentation

Goal

The goal of the experiment was to examine the efficiency of different hafting systems, to understand the relevance of the "Aterian tang" for hafting purposes and to evaluate its effect on tool use. Attention was devoted to documenting the wear traces that may occur on tanged tools as a result of manufacture, retouch, use, and hafting. The intense retouch needed to shape a tang necessitates a good understanding of the wear traces that result from this process in order to guarantee an adequate interpretation of the wear traces on the archeological tools.

Three sets of experiments were designed to explore (1) the different possibilities of hafting and using tanged tools, (2) the impact of a tang's morphology on tool hafting and use, and (3) the use of tanged points as projectiles.

Protocol

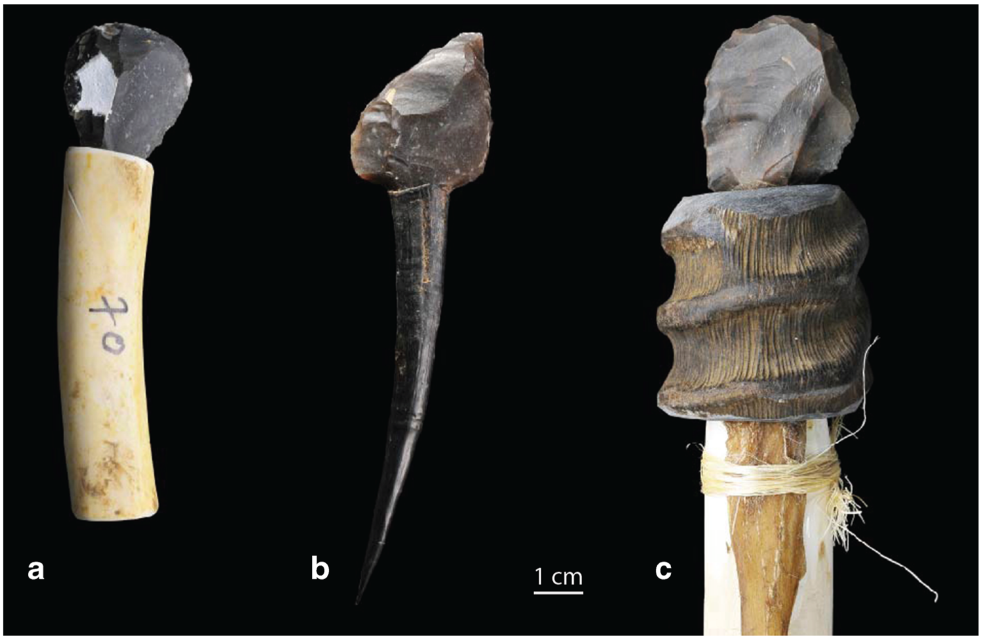
An experienced knapper (C. Lepers) produced 50 tanged tools out of Belgian Harmignies flint and 50 tanged tools out of Moroccan flint collected from primary deposits at the site of Ain Zohra. The tang morphologies were based on the morphological and technological traits of the unbroken Ifri n'Ammar tanged tools. The blanks were detached by direct percussion with a hard stone hammer. The proximal part was shaped into a tang (unifacial or bifacial retouch) with a soft stone hammer (sandstone). All pieces were examined macroscopically and microscopically after knapping to record the production traces (Rots 2010b) and to prevent confusion with traces of use or hafting (Rots 2002a, 2010a). Sixty-eight tools were subsequently hafted and used in controlled experiments for different tasks. Use durations ranged from a few minutes up to 1 hour.

The first experiment consisted of 33 tanged tools manufactured out of Belgian Harmignies flint (Table 3).

Table 3 Details of experiment 1: different hafting arrangements versus different tool uses

ID experimental tools	Hafting						Use		
	Haft type	Haft material	Wrapping	Binding	Adhesive	Efficiency	Motion	Worked material	Use duration
47/26	Male	Horn (antelope)	–	–	Resin	No	Scraping	Fresh wood	30 min
47/34	Male	Bone (deer)	–	–	–	No	Scraping	Fresh wood	20 min
47/25	Male	Bone (sheep)	Dry leather strip	–	–	No	Scraping	Dry wood	40 min
47/16	Male split	Wood (hazelnut)	–	Dry leather	Resin	No	Scraping	Dry wood	4 min
47/01	Male split	Wood (hazelnut)	–	Dry leather	Resin	Yes	Scraping	Dry wood	3 min
47/64	Male	Horn (antelope)	Raw hide	Vegetal	–	Yes	Scraping	Dry hide	20 min
47/66	Male	Bone (deer)	Raw hide	Vegetal	–	No	Scraping	Dry hide	3 s
47/15	Male	Bone (sheep)	Dry leather strip	–	–	Moderate	Scraping	Soaked antler	28 min
47/44	Male	Bone (deer)	–	–	–	No	Scraping	Soaked antler	5 s
47/11	Male	Bone (sheep)	–	–	–	Moderate	Scraping	Meat from bone	5 min
47/100	Male	Horn (antelope)	–	Vegetal	–	No	Scraping	Meat from bone	3 min
47/13	Male split	Wood (hazelnut)	–	Dry leather	Resin	Moderate	Sawing	Horn (antelope)	10 min
47/46	Male	Bone (sheep)	–	–	–	No	Sawing	Horn (antelope)	8 min
47/39	Male split	Wood (hazelnut)	–	Dry leather	Resin	Yes	Sawing	Horn (antelope)	3 min
47/18	Male	Bone (sheep)	–	–	Resin	No	Sawing	Horn (antelope)	1 min
47/20	Male	Wood (briar)	–	–	Resin	Moderate	Sawing	Dry wood	10 min
47/14	Male	Horn (buffalo)	–	–	–	No	Scraping/sawing	Radish	22 min
47/29	Male	Horn (buffalo)	–	–	Resin	No	Shaving	Dry wood	17 min
47/22	Male	Wood (briar)	–	–	–	No	Shaving	Dry wood	7 min
47/74	Male	Bone (sheep)	Dry leather strip	–	–	No	Cutting	Meat	6 min
47/101	Male	Wood (briar)	–	–	–	No	Cutting	Meat	2 min
47/23	Male	Horn (antelope)	–	–	Resin	Yes	Perforating	Dry wood	15 min
47/04	Male	Bone (sheep)	–	–	–	Moderate	Perforating	Dry wood	15 min
47/27	Male	Horn (antelope)	–	–	Resin	Moderate	Perforating	Dry wood	11 min
47/72	Male	Bone (deer)	–	–	–	Moderate	Perforating	Ostich egg	20 min
47/73	Male	Horn (antelope)	–	Sinew	–	Yes	Perforating	Ostich egg	4 min
47/03	Male	Horn (antelope)	–	–	–	Yes	Perforating	Shell	25 min
47/12	Wrapping	Raw hide (deer)	Raw hide	Sinew	–	Yes	Perforating	Shell	21 min
47/05	Wrapping	Raw hide (deer)	Raw hide	Sinew	–	Yes	Perforating	Shell	20 min
47/06	Wrapping	Raw hide (deer)	Raw hide	Sinew	–	Yes	Perforating	Shell	18 min
47/77	Wrapping	Raw hide (deer)	Raw hide	Sinew	–	Yes	Perforating	Shell	17 min
47/76	Male	Bone (deer)	Dry leather strip	Vegetal	–	Moderate	Perforating	Shell	10 min
47/21	Male	Horn (antelope)	Raw hide	Sinew	–	Efficient	Perforating	Shell	8 min

Fig. 5 Experimental tanged tool inserted in **a** bone male handle; **b** male horn handle; **c** wooden stick and secured with raw hide, vegetal bindings, and antelope horn



Different haft materials were used, all potentially available at the site at the time of occupation (Hutterer 2010): sheep bone (cf. Barbary sheep, *Ammotragus lervia*), horn (antelope and buffalo), and raw hide. These materials lend themselves to male hafting modes by which the stone tool is inserted in a hole in the handle (Stordeur 1987, Rots 2010a); it is intuitively the most logical configuration for tanged tools. The tools were inserted in a handle out of hard animal material and secured with pressure or by adding resin and/or bindings (e.g., leather, hide, sinew, vegetal) (Fig. 5). Other tools were simply wrapped in wet deer skin which was secured with vegetal bindings or sinew and then left to dry. No actual “handle” out of hard material (such as wood or bone) was added for the latter tools; the skin itself was extended beyond the proximal extremity of the tang and served as a kind of handle once the skin was dry and hard (Fig. 6). Tools were used for various activities to explore the efficiency of different hafting systems (cf. Table 3).

The second experiment consisted of 16 tanged end-scrapers manufactured out of Moroccan flint (Table 4). The end-scrapers were produced with four different ratios between tool length and tang length based on the dimensions of the archeological tanged tools. Four sets of four tools (one per ratio) were prepared, one set per included hafting mode: (1) insertion in a male bone handle and secured with pressure; (2) insertion in a male bone handle and secured with a dry leather strip around the haft boundary; (3) insertion in a male bone handle and secured with a little bit of resin; (4) wrapping with raw hide (Fig. 7) (cf. Table 4). All scrapers were used on a dry hide that was stretched on a wooden frame. All tools were used for hide working with the experimenter standing in front of the hide and using the hafted tool in a downward scraping motion involving some percussion when necessary (Fig. 8).

The third experiment involved 19 replicas of tanged points used as thrusting spear points (Table 5). Sixteen tools were manufactured out of Moroccan flint and three out of Belgian flint. With the exception of one tool, they were all retouched on their distal part. The hafting arrangements were inspired by the hafting modes used by Alaskan Eskimo for tanged spear points (Witthoft 1969). The morphology of the latter is very

Fig. 6 Experimental tanged tool wrapped in wet deer skin and secured with deer sinew

Table 4 Details of experiment 2: different tang lengths versus different hafting arrangements

ID	Hafting					Tang lengths (mm)	Tool lengths (mm)	Different ratios between tool /tang length	Efficiency	Use		
	Haft material	Haft type	Wrapping	Binding	Adhesive					Use duration	Motion	Worked material
47/53	Bone	Male	–	–	–	20.34	52.05	2.5	Moderate	20 min	Scraping	Dry hide streched on a wooden frame
47/51	Bone	Male	–	–	–	17.79	53.41	3	No	2 min		
47/54	Bone	Male	–	–	–	16.09	55.64	3.5	No	6 min		
47/52	Bone	Male	–	–	–	10.02	50.14	5	No	12 min		
47/63	Bone	Male	Dry leather strip	–	–	10	32	3	No	4 min		
47/59	Bone	Male	Dry leather strip	–	–	10.97	41.74	4	No	1 min		
47/60	Bone	Male	Dry leather strip	–	–	10.67	48.8	4.5	No	1 min		
47/61	Bone	Male	Dry leather strip	–	–	9.89	48.52	5	No	15 s		
47/58	Bone	Male	–	–	Resin	18	44.32	2.5	Moderate	18 min		
47/56	Bone	Male	–	–	Resin	14.11	49	3.5	No	2 min		
47/55	Bone	Male	–	–	Resin	11.02	42.9	4	Moderate	20 min		
47/57	Bone	Male	–	–	Resin	11	66.04	6	No	2 min		
47/99	Hide	Wrapping	Raw hide	Sinew	–	20.25	51	2.5	Yes	20 min		
47/68	Hide	Wrapping	Raw hide	Sinew	–	14.8	50.76	3.5	Yes	20 min		
47/62	Hide	Wrapping	Raw hide	Sinew	–	11.03	45	4	Yes	20 min		
47/67	Hide	Wrapping	Raw hide	Vegetal	–	8.9	43.86	5	No	2 min		

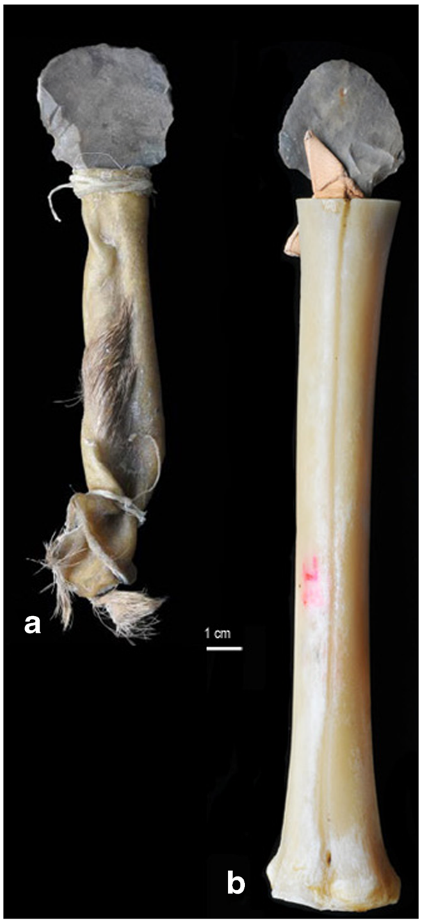


Fig. 7 **a** Experimental tanged scraper wrapped in raw hide; **b** experimental tanged scraper inserted in a male bone handle and secured with a dry leather strip

Fig. 8 Experimental hafted tanged scrapers used for hide working: **a** downward scraping motion; **b** percussion motion

similar to the Aterian points and tangs are equally short and robust. Sixteen experimental points were inserted in a notch at the distal extremity of spear shafts manufactured out of spruce wood (*Picea abies*). The tangs were secured with resin (30% beeswax and 70% *Picea abies* resin) and bindings out of sinew. Five experimental tools were hafted up to the upper limit of the tang, and 11 were secured in the shaft up to the mesial tool part (Fig. 9). Two other points were hafted up to the upper limit of the tang in a notch of a foreshaft of horse bone and secured with sinew glue and sinew bindings (cf. Fig. 9). One point was hafted up to the upper limit of the tang in a notch of an antelope horn foreshaft and secured with sinew glue and sinew bindings (cf. Fig. 9). All spears were between 2 and 2.3 m long and varied in thickness between 23 mm (distal extremity) and 35 mm (proximal extremity). The spears were thrusted by an experienced experimenter (J. Coppe) in an artificial target composed of a bone carcass encased in ballistic gel and covered with a stretched fresh animal hide (Fig. 10) (Coppe and Rots, *submitted*). Each spear was thrust up to a maximum of five times, but thrusting was stopped as soon as the point showed macroscopic damage (Fig. 11). No other projecting mode was tested for the Aterian tangs, as the available experimental reference at TraceoLab already included different types of projecting modes (about 500 used points). In our experience, thrusting leads to more severe damage to the points than throwing because the impact is more violent. It was therefore considered the most appropriate projecting mode to test the efficiency of different hafting modes for tanged points.

Evaluation

The experiments confirm that tangs are time-intensive to produce and that their shaping requires experience. In spite of the assumed link between Aterian tangs and hafting, this link was significantly challenged during the experiments because the short and robust tangs are not easy to haft. Aterian tangs are significantly different from, for instance, tanged tools from the Gravettian period: Gravettian tangs have a very different shape (e.g., round or oval instead of trapezoidal cross section) and are much longer (several centimeters long). The results of a wear study on tanged burins from the Gravettian site of Maisières-Canal suggest that these tools were most likely hafted in a handle of hard animal material (antler) (Rots 2002a). The length of a tang is crucial for its fixing: a long

Table 5 Details of experiment 3: thrusting spears

ID	Hafting					Action: thrusting			Results
	Haft material	Haft type	Binding	Adhesive	Haft limit	N = shots	Penetration	Impacted material	
47/80	Spear (spruce wood)	Notch	Sinew	Resin	Mesial	2	17 cm	Skin-ballistic gel-bone (ribs)	Distal and lateral scars
47/81	Spear (spruce wood)	Notch	Sinew	Resin	Tang	2	–	Skin	De-hafting/no damage
47/82	Spear (spruce wood)	Notch	Sinew	Resin	Mesial	4	22 cm	Skin-ballistic gel-bone (ribs)	Lateral scars
47/83	Spear (spruce wood)	Notch	Sinew	Resin	Mesial	2	–	Skin	No damage
47/84	Spear (spruce wood)	Notch	Sinew	Resin	Mesial	2	31 cm	Skin-ballistic gel-bone (ribs)	No damage
47/85	Spear (spruce wood)	Notch	Sinew	Resin	Tang	2	43 cm	Skin-ballistic gel-bone (ribs)	No damage
47/86	Spear (spruce wood)	Notch	Sinew	Resin	Mesial	2	26 cm	Skin-ballistic gel-bone (ribs)	Lateral scars
47/87	Spear (spruce wood)	Notch	Sinew	Resin	Mesial	1	–	Skin	Distal bending fracture
47/88	Spear (spruce wood)	Notch	Sinew	Resin	Mesial	2	6 cm	Skin-ballistic gel-bone (ribs)	Lateral scars
47/89	Spear (spruce wood)	Notch	Sinew	Resin	Mesial	2	21 cm	Skin-ballistic gel-bone (ribs)	Distal and lateral scars
47/90	Spear (spruce wood)	Notch	Sinew	Resin	Mesial	1	33.5 cm	Skin-ballistic gel-bone (ribs)	Distal scars
47/91	Spear (spruce wood)	Notch	Sinew	Resin	Tang	1	18.5 cm	Skin-ballistic gel-bone (ribs)	Distal bending fracture
47/92	Spear (spruce wood)	Notch	Sinew	Resin	Tang	5	26.5 cm	Skin-ballistic gel	No damage
47/93	Spear (spruce wood)	Notch	Sinew	Resin	Tang	1	50 cm	Skin-ballistic gel-bone (ribs)	De-hafting lors du retirage/distal and lateral scars
47/94	Spear (spruce wood)	Notch	Sinew	Resin	Mesial	1	24.5 cm	Skin-ballistic gel-bone (ribs)	Distal and lateral scars
47/95	Spear (spruce wood)	Notch	Sinew	Resin	Mesial	1	17 cm	Skin-ballistic gel-bone (ribs)	No damage
47/96	Bone foreshaft (horse bone)	Notch	Sinew	Sinew glue	Tang	1	–	Skin	Explosion of the spear and de-hafting
47/97	Horn foreshaft (antelope horn)	Notch	Sinew	Resin	Tang	3	38 cm	Skin-ballistic gel-bone (ribs)	Explosion of the spear, lateral scars, proximal scar
47/98	Bone foreshaft (horse bone)	Notch	Sinew	Resin	Tang	1	28 cm	Skin-ballistic gel-bone (ribs)	De-hafting, lateral scars

Fig. 9 Experimental hafted tanged points used for thrusting: **a** hafted in a foreshaft of antelope horn; **b** hafted in a foreshaft of horse bone; **c** secured with resin and sinew bindings

Fig. 10 **a** Artificial target composed of a bone carcass encased in a ballistic gel, covered with fresh animal hide (after Coppe and Rots, *submitted*); **b** experimental tanged tools thrusted in the artificial target

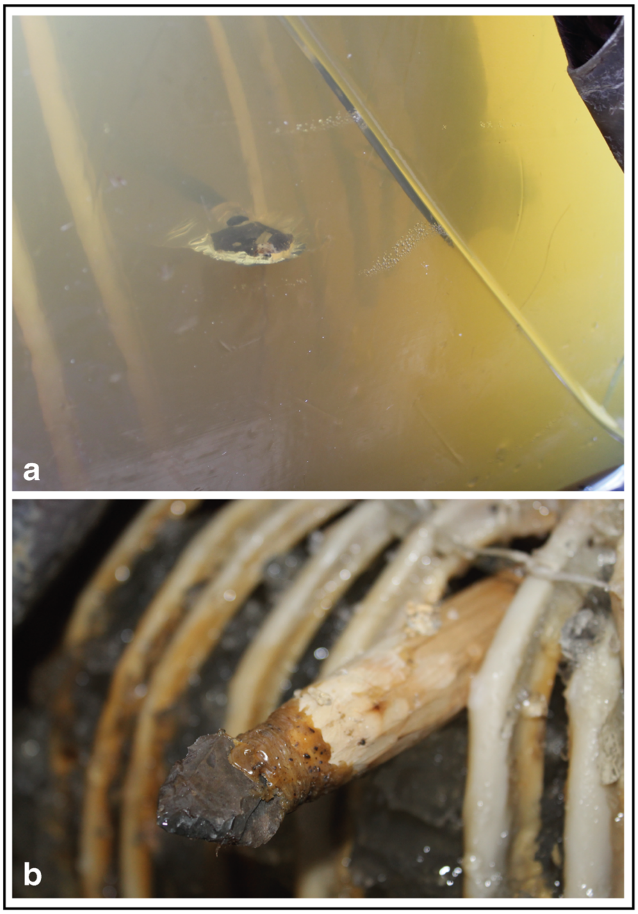


Fig. 11 **a** Penetration of the experimental armatures Exp 47/97 through the target; **b** penetration of the experimental armature Exp 47/85 during the decomposition of the ballistic gel

tang is easier to secure in a male handle without additional adhesives than a short tang. By contrast, a short and robust tang will not break as easily as a long tang. Indeed, except for a single broken tang, attributed to post-depositional damage, no mesial fractures (at the transition towards the tang) were recorded at Ifri n'Ammar. Even if a link between the Aterian tangs and hafting can be demonstrated, it is clear that the hafting mode is likely to vary significantly in comparison with other tang morphologies.

The results of the first experiment on the potential hafting and use of Aterian tanged tools demonstrated that the short and robust Aterian tangs could only be hafted and used effectively when the hafting mode is appropriate. An effective hafting mode was an insertion in a male handle made out of sheep bone or horn (antelope and buffalo) with or without adhesives or ligatures, but only for particular use motions: it worked well for perforating motions, but not for scraping or shaving motions. Indeed, in terms of the tang morphology, the second experiment demonstrated that the pressure on the haft boundary was much too strong in scraping motions: scrapers tilted in their handles and eventually loosened even when varying working angles and pressures were tested. While several hafting arrangements were reasonably efficient, the raw hide hafting (not involving an actual handle) was most remarkable, and it was undeniably facilitated by the presence of a tang. To our knowledge, it concerns a hafting method that was not yet tested experimentally before, but it proved simple to produce, efficient, and very flexible. It differs from a wrapping (tested by for instance Beyries 1987 and Rots 2010a) by the fact that the leather is extended beyond the stone tool and is twisted into a true handle. The raw material is easily available and does not require much preparation. There are no constraints for the morphology and size of the stone tools that could be hafted, but tanged tools proved to be easier to haft using this method than non-tanged ones. An important advantage of using raw hide as a handle is that the length of the tang plays no role. De-hafting is easy as the handle can simply be soaked in water. The raw hide can subsequently be recycled several times without any loss in efficiency. A similar procedure involving raw hide can also be used to fix a tanged tool without adhesives in all kinds of male handles, or to fix it to a wooden spear with minimal effort. Also, in these cases, the usefulness of the tang is striking because it allowed the continuous transition between the stone tool and the shaft without creating a protruding part at the joint. After all, one of the major problems when hafting points to spears is the joint between the stone tool to the shaft: if it is too wide, it will block the spear from penetrating sufficiently far into the animal.

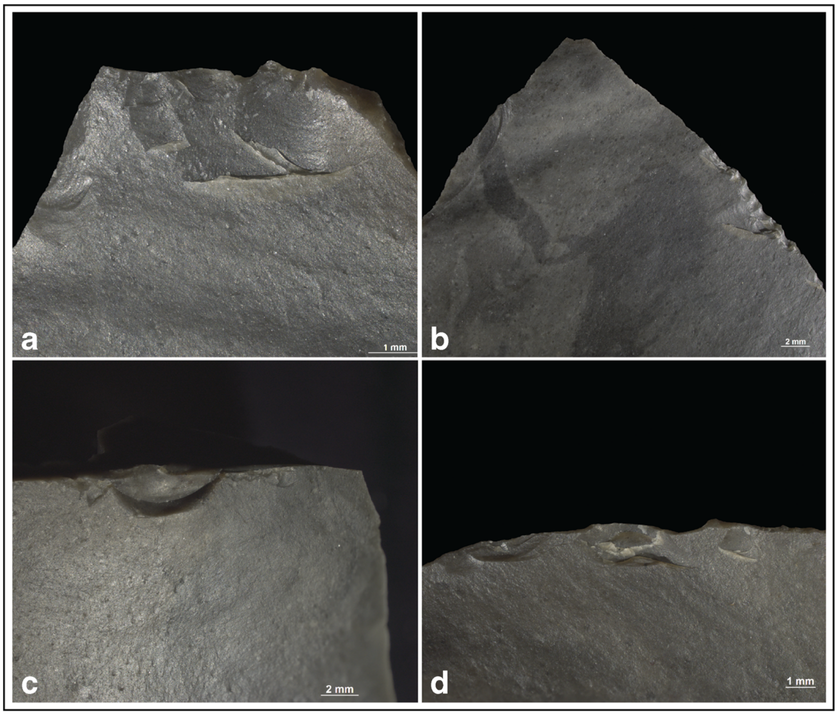
Also, the third thrusting experiment provided interesting results. Indeed, the tang length did not appear to have a major role and also the extension of its fixing (tang only or up to the mesial part) did not influence the efficiency of the spear point. On a total of 36 hits, 13 of the 19 points proved to show wear features in the form of unifacial removals on their tips (Table 6) (see

Table 6 Wear traces documented on the experimental armatures of experiment 3

Experimental spear points

ID	Low magnification						High magnification		
	Transversal fractures			Unifacial scars			Scarring	Mlits	Bright spots
	Initiation	Termination	Spin-offs	Distal	Lateral	Termination			
47/80				X	X	Ventral, fissured and complex (different terminations), same orientation	X		
47/81									
47/82					X	Ventral, fissured and complex (different terminations), same orientation	X		
47/83									
47/84									
47/85									
47/86					X	Ventral, step/hinge	X		
47/87	Bending	Hinge/step	X				X	X	
47/88					X	Ventral, feather	X		
47/89				X	X	Ventral, fissured and complex (different terminations), same orientation	X		
47/90				X		Ventral, hinge/step			
47/91				X		Ventral, step and fissured	X		X
47/92									
47/93				X	X	Ventral, step	X		
47/94				X	X	Ventral and dorsal, fissured and complex (different terminations)	X		
47/95									
47/96									
47/97					X	Ventral, fissured and step	X		
47/98					X	Ventral and dorsal, fissured and complex (different terminations), same orientation	X		

Fig. 12 Examples of distal edge damage related to armature use: **a** Exp 47/91—scarring with a superposition and fissured abrupt terminations on the ventral face (×25.0); **b** Exp 47/80—lateral removals with fissured abrupt terminations on the ventral face (×8.0); **c** Exp 47/87—a bending fracture and a hinge-step termination associated with spin-off's, on the ventral face (×10.0); **d** Exp 47/82—lateral removals, with step or abrupt fissured terminations on the ventral face (×16.0)



Coppe and Rots, *submitted*, for a discussion of the terminologies). One tool has a bending fracture associated with spin-offs and with microscopic features such as MLIT's (i.e., microscopic linear impact traces, cf. Moss 1983) (Fig. 12). Other tools show scarring with fissured abrupt, complex terminations (different terminations) (cf. Fig. 12). Unifacial removals were most abundant, and in particular the importance of lateral removals should be noted in comparison to tip damage (cf. Fig. 12) (cf. Rots and Plisson 2014; Coppe and Rots *submitted*). Fissured and multiple terminations are most abundant.

The experiments also allowed the completion of the reference for various wear traces related to tanged tools. As mentioned, production wear is particularly important for correctly assessing traces that occur within the concavity that forms the transition between the tang and the tool. The hammer blows can create wear patterns which should not be confused with hafting-related wear (cf. Rots 2010a, 2010b). In most cases, production wear proved to be visible under low magnification: short retouch striations from direct percussion (Rots 2010b) occurred on the ventral face within the concavities at the start of the tang (Fig. 13). Use-wear formation on the

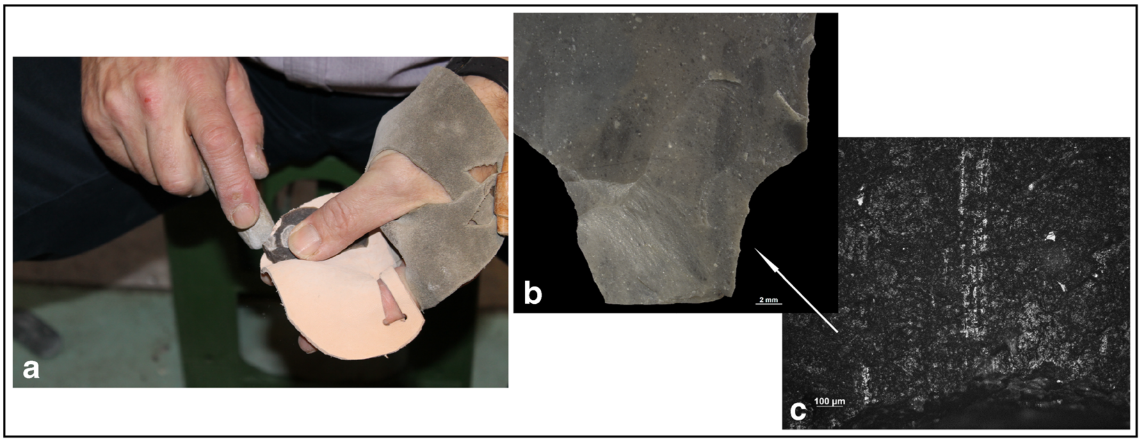


Fig. 13 Experimental production of tanged tools: **a** manufacture of the tang with a sandstone hammer; **b** detail of the tang of Exp 47/64 (×5.6); **c** knapping striations on the ventral proximal edge of Exp 47/64 (×100)

fine-grained Moroccan flint proved to be comparable to what is known for other flint types, and it was very similar to the archeological flint. With regard to hafting, abrasion and scarring proved to be produced on the edges and ridges of the tang at the moment that the tool was pressed into the handle in the case of a male hafting in hard animal material. Overall, the experimental hafting wear patterns proved to correspond to what was described earlier (cf. Rots 2010a) and mainly the hafting material, the hafting mode and the tool's use proved to influence its formation. For the hafting in raw hide that was not experimentally tested before, traces are somewhat comparable to what was described for leather wrappings (cf. Rots 2010a), but witness the more important friction that occurs within the hardened hide. A light hide-like polish occurred on the edges and ridges of the hafted part of the tools.

Results of the macroscopic and microscopic analysis

A total of 37 tools of the tanged tool assemblage (total = 63, see above) were examined.

Alterations

Surface alterations of different intensities were frequent, and they severely damaged a number of tanged pieces (Fig. 14). In the case of important alterations, the wear analysis was limited to an examination under a stereomicroscope (n = 13). The preservation state of the material was recorded on a relative scale of 0–4 (0 = no visible alteration; 1 = light alteration; 2 = moderate alteration; 3 = important alteration; 4 = complete alteration) based on an evaluation of the amount of gloss, patina, and/or heat alteration (Table 7). For the latter, the presence of incipient cracks, scars, and transversal fractures were recorded.

Tool use

Use-related wear traces were observed on 17 out of 37 tools. The confidence level (CL) of each interpretation was evaluated on a scale of 1 (poor confidence) to 4 (high confidence). On 10 other tools were wear features either absent or insufficiently developed to be diagnostic. For the remaining artefacts (n = 10), alterations were so severe that a detailed analysis was impossible and no functional interpretation was therefore provided. The results are summarised in Table 8.

A significant number of tanged points from Ifri n'Ammar proved to be used as armatures (n = 11 out of 14 points). Macroscopically, these tools showed intense impact-related damage on the tip consisting of various types of unifacial scars or transversal bending fractures, in addition to lateral edge scarring (Fig. 15)

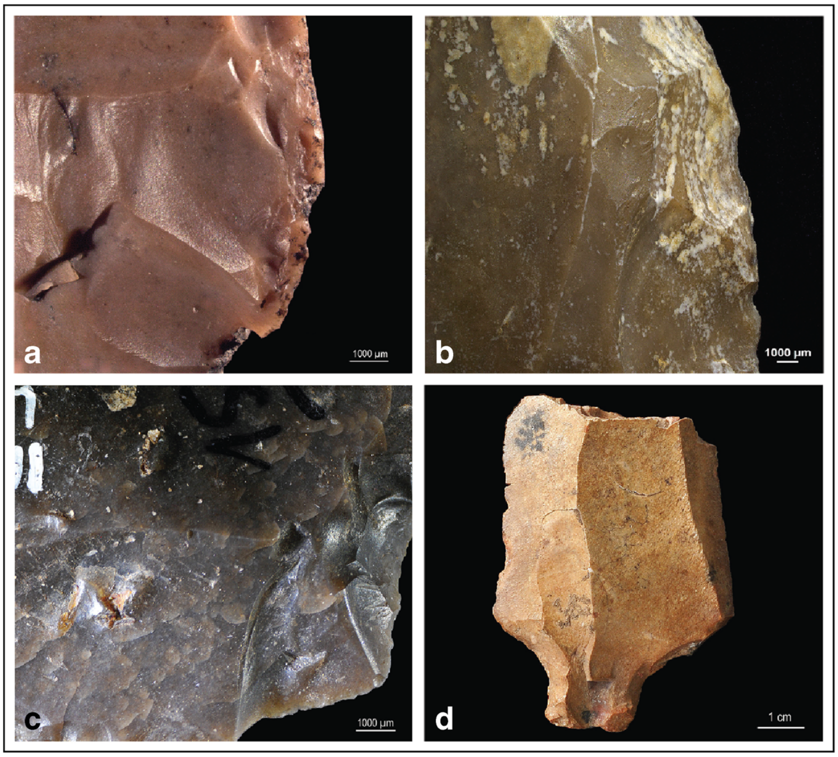


Fig. 14 The preservation state of the archeological material, examples of altered pieces: **a** light gloss; **b** patination; **c** heat alteration; **d** heavily altered tanged tool with fracture related to heat

Table 7 Summary of the examined archeological tanged tools from Ifri n'Ammar with the recorded state of preservation and the analytical approach used

ID	Raw material	Gloss intensity	Patina intensity	Heat alteration			Alteration degree (0–4)	Analytical approach	
				Incipient cracks	Negatives	Fractures		Low magnification	High magnification
4379	Flint	Important	Moderate		X		3	X	X
1505	Flint	Moderate	Absent				1	X	X
1508	Chalcedony	Important	Moderate				2	X	X
1509	Flint	Important	Moderate	X			3	X	
1510	Flint	Light	Moderate				2	X	X
1512	Flint	Moderate	Absent		X		3	X	X
1513	Flint	Important	Light		X		3	X	X
1514	Flint	Moderate	Absent	X		X	2	X	X
1515	Flint	Moderate	Light	X			3	X	X
1517	Volcanic rock	Important	Absent				3	X	X
1518	Black schist	Important	Important	X		X	4	X	
1519	Flint	Moderate	Absent				2	X	X
1520	Flint	Moderate	Light	X			2	X	X
1522	Flint	Important	Absent				3	X	X
1523	Rhyolite	Important	Absent				3	X	X
1525	Flint	Light	Light		X		3	X	X
1527	Flint	Moderate	Light	X	X		3	X	X
1528	Flint	Moderate	Light				2	X	X
1529	Silicified limestone	Important	Important	X			4	X	
1533	Flint	Important	Important	X	X		4	X	
1534	Flint	Important	Important	X		X	4	X	
1535	Flint	Important	Light	X	X		3	X	
1536	Silicified limestone	Important	Important		X	X	4	X	
1537	Flint	Important	Moderate	X	X		4	X	
1538	Flint	Important	Important	X	X	X	4	X	
1539	Flint	Important	Moderate	X	X	X	3	X	X
1540	Flint	Important	Moderate		X	X	4	X	
1541	Flint	Important	Important	X		X	4	X	
1542	Chalcedony	Important	Important		X	X	4	X	
1543	Flint	Moderate	Moderate	X			2	X	
1546	Flint	Light	Absent				1	X	X
1547	Flint	Light	Absent				1	X	X
1550	Flint	Moderate	Moderate	X			3	X	X
1551	Flint	Moderate	Important				3	X	X
1552	Flint	Important	Important	X		X	3	X	
1564	Radiolarian rock	Light	Moderate	X			2	X	X
1566	Flint	Moderate	Absent				2	X	X

(Table 9). On 8 out of 11 tools, the wear traces were also associated with microscopic linear impact traces (MLIT; Moss 1983) or bright spots, caused by the friction of a detached flint particle following the impact into the target (Fig. 16). Interestingly, only unretouched points showed a distinct transversal fracture on the apex ($n = 2$), while retouched points generally suffered from a combination of impact scars on the apex. This is a

Table 8 Summary of the functional interpretations of the analysed tanged tools from Ifri n'Ammar

Tool use: interpretations					
ID	Armatures	Scrapers	Used but uncertain function	Unused/ uncertain	Undetermined (too altered)
4379		X (Cl 3)			
1505				X	
1508	X (CL 2)				
1509				X	
1510		X (Cl 4)			
1512	X (CL 3)				
1513				X	
1514				X	
1515	X (CL 3)				
1517				X	
1518					X
1519			X (CL 3) butchering? (CL 0)		
1520	X (Cl 4)				
1522				X	
1523				X	
1525	X (CL 2)				
1527	X (CL 1)				
1528		X (CL 4)			
1529					X
1533					X
1534					X
1535		X (CL 3)			
1536					X
1537					X
1538					X
1539				X	
1540					X
1541					X
1542					X
1543				X	
1546	X (CL 3)				
1547	X (CL 3)				
1550	X (CL 3)				
1551	X (CL 3)				
1552				X	
1564	X (CL 3)				
1566	X (CL 4)				

result of the more important resistance of retouched edges to scarring and fracturing. On three armatures, the distal edge damage witnesses an end-on impact combined with a rotating aspect composed of either a fracture associated with lateral damage, or distal lateral damage with opposing initiations on both lateral edges (cf. Fig. 16) (Rots et al. 2011).

Aside from the armatures, five end-scrapers were identified. Two of those were severely altered, but an explicit use-related rounding could be observed under

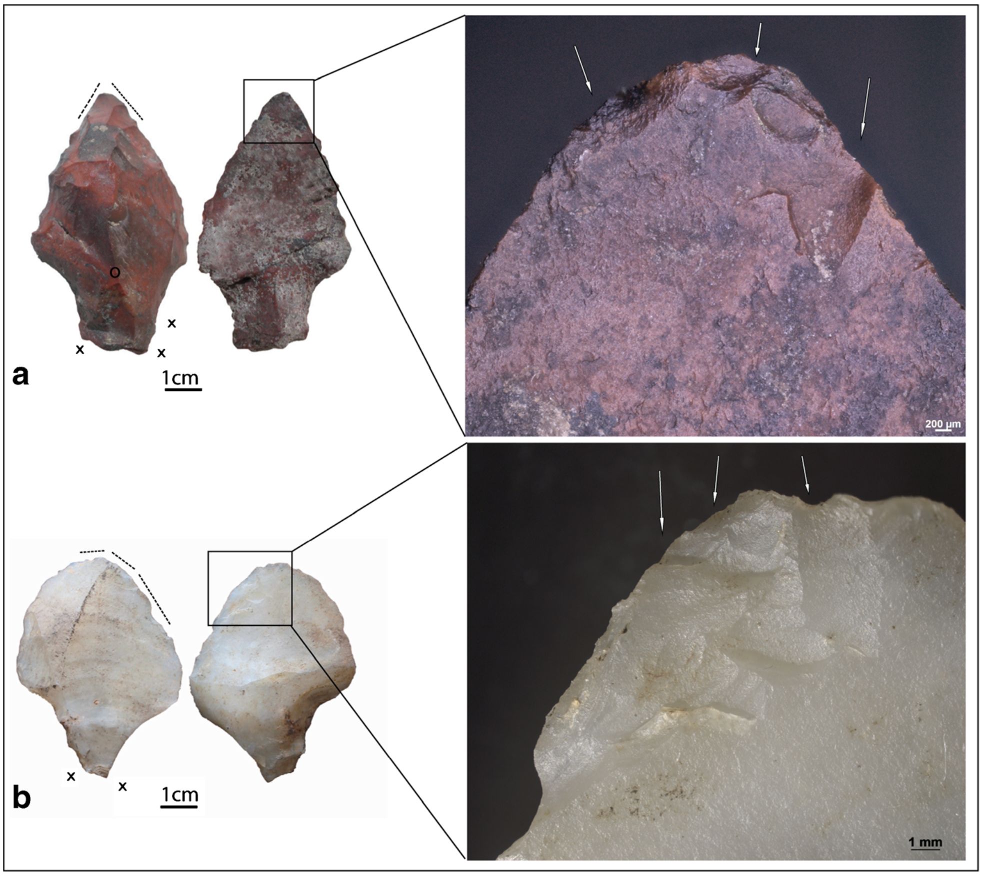


Fig. 15 Examples of distal edge damage related to armature use: **a** armature IA 1564 and a detail of the distal scarring with multiple ventral abrupt terminations (×32.0); **b** armature IA 1508 and a detail of the distal edge damage with abrupt, fissured, and different terminations on the ventral face (×12.5) . The pictures on the left were adapted from Nami and Moser 2010: Figs. 85 and 86)

low magnification on the scraper-head of all five tanged tools. On four end-scrapers, the use-wear traces were cut by negatives from resharpening. The three better preserved tools were also analysed under high magnification, and a characteristic use polish was visible that can be attributed to fresh hide working (Fig. 17).

Table 9 Wear traces on the tanged armatures from Ifri n'Ammar observed under low and high magnification

Archeological armatures										
ID	Low magnification						High magnification			
	Transversal fractures			Unifacial scarring			Scarring	Mlits	Bright spots	Striations
	Initiation	Termination	Spin off's	Distal	Lateral	Termination				
1508				X	X	Ventral, different abrupt and fissured terminations				
1512	Bending	Ventral, hinge/step	X		X	Ventral, step				
1515				X	X	Ventral, fissured, step, same orientation				
1525					X	–				X
1527				X		–				X
1546				X		Dorsal, step		X	X	
1547	Bending	Ventral, hinge/step		X		Ventral, step	X		X	
1550				X	X	Ventral, different step terminations			X	
1551				X	X	Ventral, step		X		
1564				X		Ventral, different abrupt terminations			X	
1566				X		Ventral, abrupt and fissured			X	

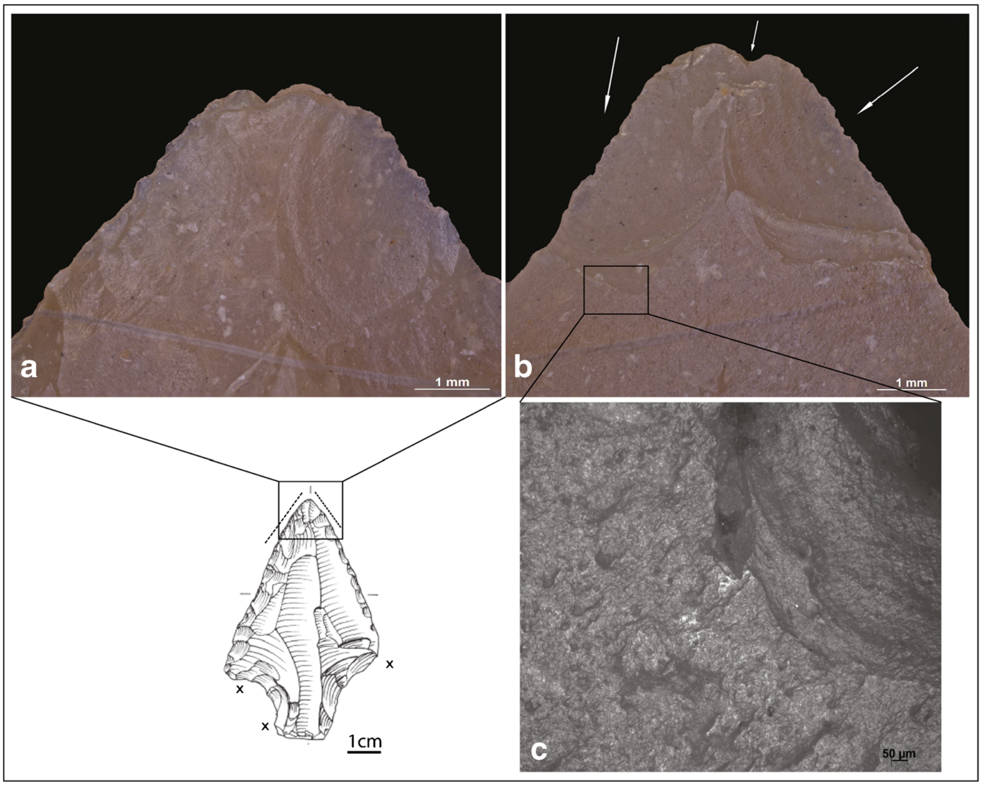


Fig. 16 Armature IA 1566: **a**, **b** detail of the distal edge damage: step-hinge termination on the ventral face, with opposing initiation on both edges (×25.0); **c** bright spot visible on the ventral face in association with tip damage (×100). Drawing adapted from Nami and Moser (2010: Fig. 77)

The wear traces were difficult to interpret on one remaining tool, IA 1519. The tip showed small scars (posterior to the retouch), combined with a longitudinal scar on the distal lateral left edge and bifacial scarring associated with polish and light striations on the right distal edge. This use wear evidence is likely the result of butchering activities, but it remains uncertain, and a possible use as armature cannot be excluded (Fig. 18).

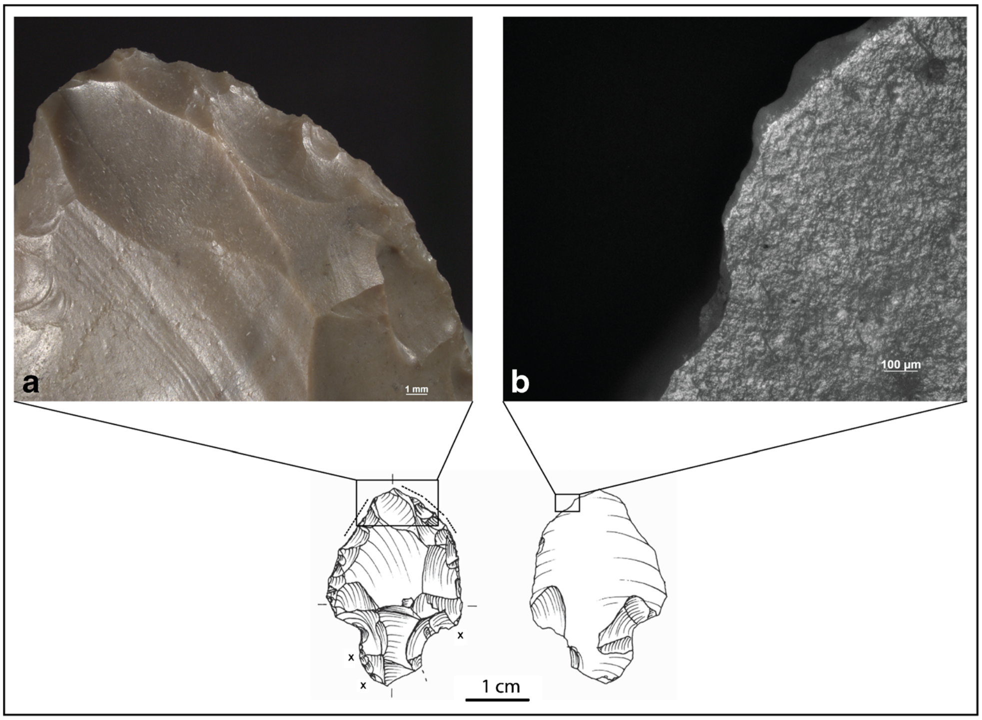


Fig. 17 Hide scraper IA 1528: **a** macroscopic detail of the working edge (×10.0); **b** microscopic detail of rounding and polish cut by removals from resharpening (×100). Drawing adapted from Nami and Moser (2010: Fig. 77)

Fig. 18 IA 1519, used but uncertain function (butchering activities?): **a** microscopic detail with polish on the right edge, cut by posterior scars (×200); **b** macroscopic detail of the distal part and right edge. The general picture of the tool was adapted after Nami and Moser (2010: Fig. 82)

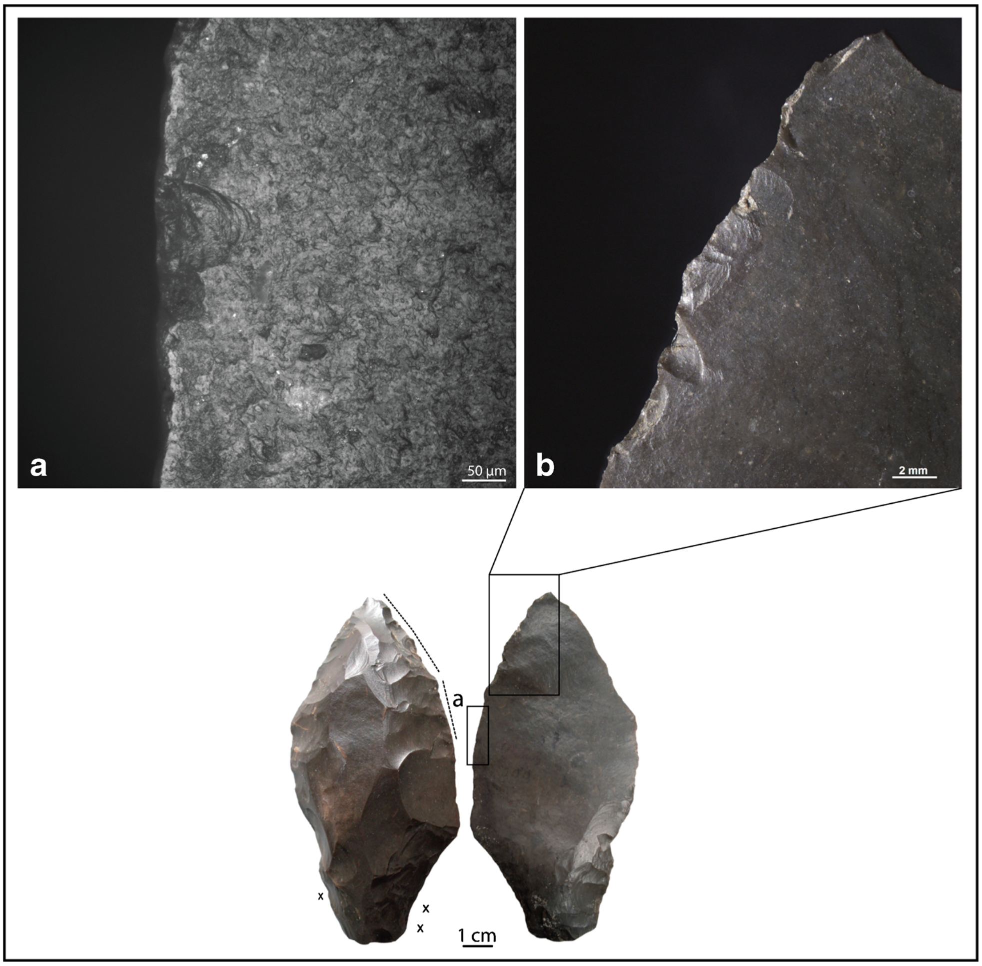


Fig. 19 Hafting wear on the tang of IA 1546: **a** friction on the ventral ridge, mesial part of the armature (×500); **b** rounding and friction on the lateral edge of the tang (×200). The general picture of the tool was adapted from Nami and Moser (2010: Fig. 84)

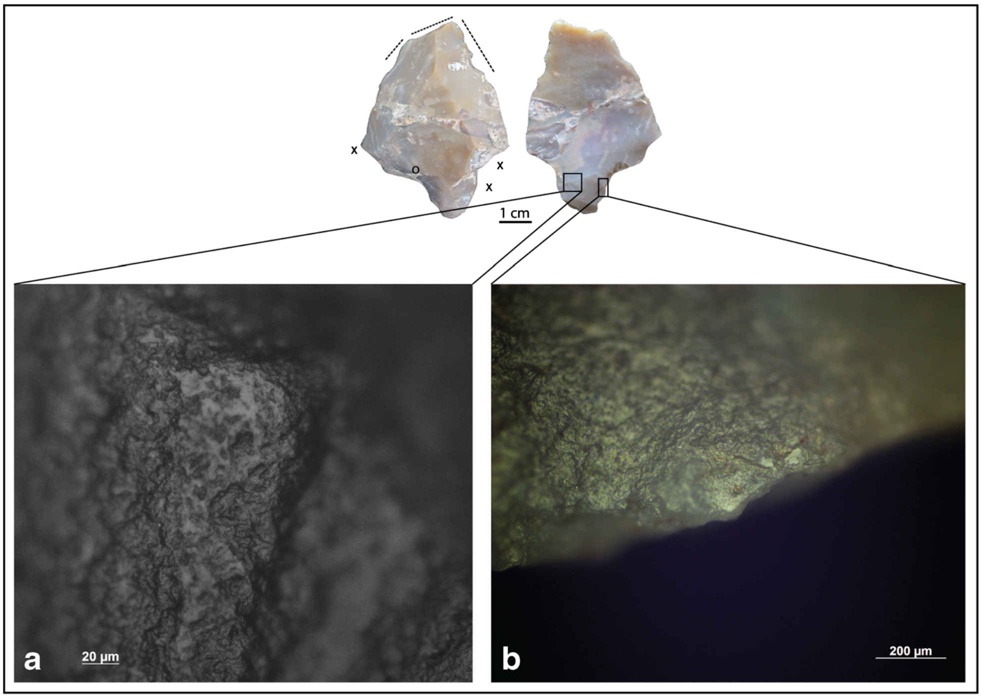


Table 10 Hafting wear observations on the proximal portion of the used tanged tools from Ifri n'Ammar

Hafting wear

Functional interpretations	ID	Macroscopic observations					Microscopic observations						Confidence level (CL 1–4)
		Fractures	Scarring	Incipient fissure	Rounding	Abrasion	Scarring	Rounding	Polish	Abrasion	Striations	Bright spot's	
Armatures	1508		X				X						CL 1
	1512	X					X				X		CL 2
	1515		X							X		X	CL 2
	1525						X						CL 1
	1527				X			X					CL 1
	1546	X	X				X	X	X				CL 3
	1547		X								X		CL 2
	1550						X		X		X		CL 3
	1551			X		X			X	X	X	X	CL 3
	1564		X			X				X			CL 3
	1566						X						CL 2
Scrapers	4379												(important alteration)
	1510						X				X	X	CL 3
	1520		X	X					X				CL 3
	1528		X				X						CL 2
	1535					X				X			CL 1
Butchering?	1519		X				X						CL 1

The confidence level (CL) was evaluated on a scale of 1 (poor confidence) to 4 (high confidence)

Prehensile mode: are the Aterian tangs an adaptation for hafting?

At Ifri n'Ammar, the distal parts of several tanged tools were fractured or damaged (*n* = 16) but only one mesial fracture occurred (limit of tool/tang). The latter tang fractured due to heat, which also damaged the tool's surface. The absence of broken tangs is largely due to their short and robust nature, but it is nevertheless interesting with regard to their possible hafting. After all, hafting-related fractures generally occur around the haft boundary as most tension is exerted in that area (Rots 2010a). This leverage effect is limited for the Aterian tanged tools because of the short tang length. In addition, their sturdy nature is reinforced by the fact that the tangs were shaped on the proximal parts of the flakes and that they were centered on the main dorsal ridge, which maximises their strength (Hawkins 2012).

A first aim was to determine whether the tanged tools from Ifri n'Ammar were hafted or not. The interpretation of wear traces, such as polishes, striations, or bright spots, was restricted by the degree of post-depositional damage or alteration. Nevertheless, the combination of macroscopic and microscopic wear traces provided evidence of hafting on a significant number of tanged tools (11/17) with a sufficiently good preservation. Some of the traces were moderately developed while others were more pronounced. They consisted mainly of polish, scarring, abrasion or bright spots on the lateral edges, the ventral face or the main dorsal ridge of the tangs (Fig. 19). These types of traces and patterns correspond to what was observed on the experimental tanged tools and to what has been described by Rots (compare Rots 2003, 2010a). We can thus conclude that the Aterian tanged tools from Ifri n'Ammar were indeed used while hafted. According to Rots (2008), the transversal cross section influences the location of hafting traces. On tangs with a triangular or trapezoidal cross section, the contact with the male haft will be the heaviest on the edges and on the main ridge. Such a wear pattern was observed on the tanged tools from Ifri n'Ammar (*n* = 6). Indeed, we observed ventral friction and/or scarring posterior to the retouch scars on the lateral edges and/or friction on the dorsal proximal ridges.

Secondly, effort was invested to identify the exact hafting mode based on the hafting wear patterns and their comparison with the experimental datasets. As stressed earlier (e.g., Rots 2003), the identification of the hafting mode is generally far more difficult than identifying whether or not a tool was used hafted and it largely depends on the preservation. Edge scarring was important and it was observed on several tools, in

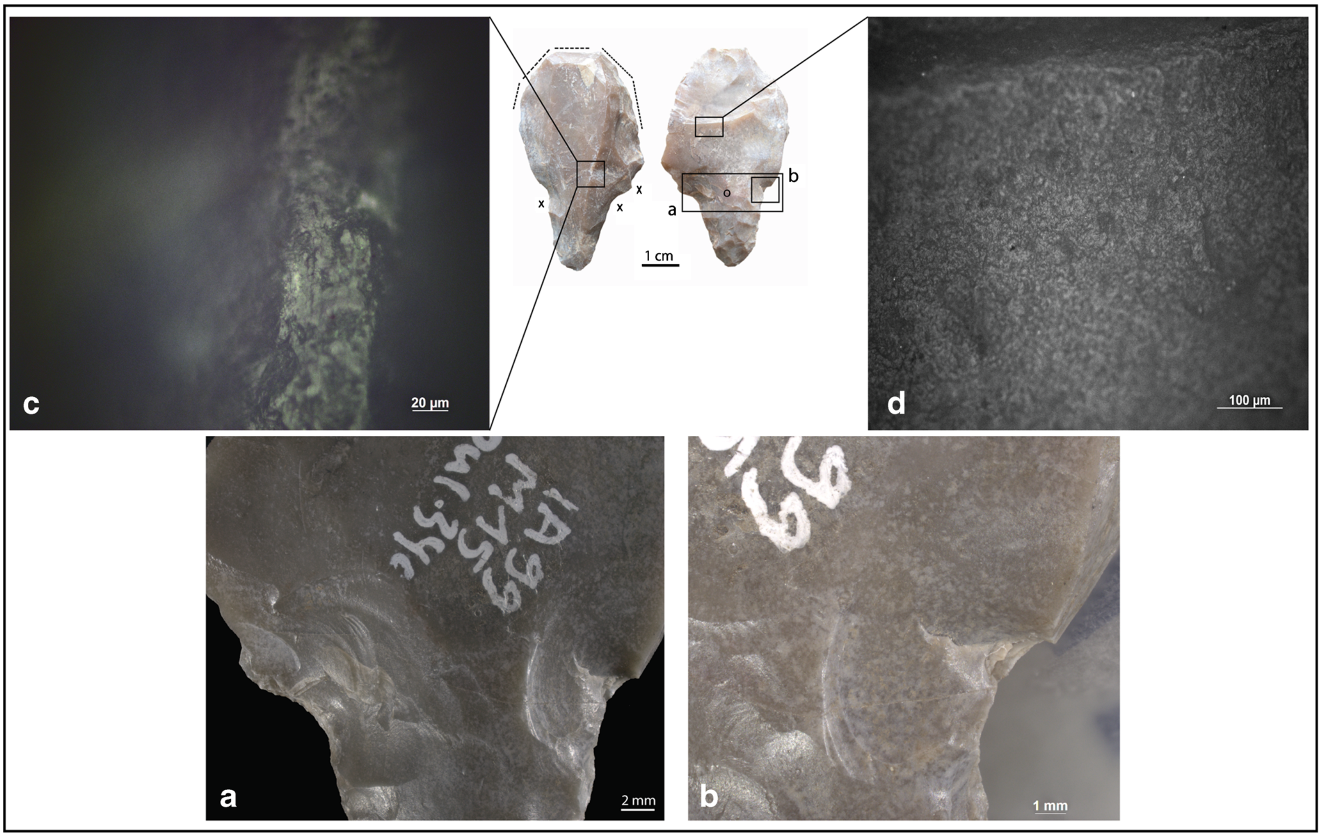


Fig. 20 Armature IA 1551 with intense distal edge damage and hafting wear on the tang: **a** macroscopic detail of the incipient fissure (×8.0); **b** detail of the incipient fissure (×10.0); **c** striation and light friction on the dorsal ridge, mesial part of the tool (×500); **d** a MLIT associated with the distal fracture (×200). The general picture of the tool was adapted from Nami and Moser (2010: Fig. 87)

association with long hafting striations with an oblique orientation to the lateral edges (Table 10). Such associations typically result from a friction with a detached flint particle within the haft, which mainly occurs in the case of hard haft material (Rots 2002b). Bright spots associated with small scars on the lateral edges of the tangs were also recorded, as well as heavily developed abrasion on the prominent dorsal and ventral main ridges of the tangs. Both aspects are again suggestive for a contact with a hard haft material (cf. Fig. 20), in particular in the case of "male" hafts. We could further observe heavy crushing or scarring superposing the retouch scars and caused by the friction within the haft during use. These features are comparable to the ones found on experimental tools which were inserted with pressure into male bone handles.

In general, the tanged scrapers and the tanged points showed similar hafting wear patterns, but armatures showed more intense proximal edge damage with bending-initiated fractures ($n = 3$) posterior to the retouch negatives on the tang. These fractures occurred as a result of the counter-pressure upon impact and such damage was absent on the tanged scrapers. In addition, incipient fissures were observed in the mesial part of one armature and on one end-scraper. On the armature, the fissure was associated with an abrasion of the dorsal ridge, and bright spots on the ventral face of the tang. This wear pattern could be linked with its use as armature (Fig. 20). The fissure observed on the end-scraper seems to have formed during the manufacture of the tool or during the resharpening of the distal part.

In sum, we conclude that the wear evidence indicates that tanged points and tanged scrapers from Ifri n'Ammar were used while hafted. The exact hafting material could not be identified at this stage of the analysis, but scarring, abrasion, polish, or bright spots were probably caused by hard animal material.

Discussion

Tanged tools have always trigged the attention of researchers, but as many authors suggested before, definitions of "Aterian assemblages" are in some cases only based on the presence of a few tanged tools (Wendorf and Schild 1992; Garcea 1998; Bouzouggar and Barton 2012; Scerri 2013b). Indeed, as we have shown, an erroneous idea may exist about the frequency of tanged tools in Aterian assemblages. On most sites, their number is fairly limited and definitions vary as to what modifications are sufficient to classify a tool as being tanged. At Ifri n'Ammar, except for the presence or absence of tanged tools, the diversity of tool types is identical. By contrast, the density of retouched artefacts proved significantly higher for the levels with tanged tools in comparison to the levels without tanged tools, which appears to suggest that the higher frequency of tanged tools in the former may simply be a question of the duration of occupation and/or site function. The "Aterian" and "Mousterian" could represent variants of one and the same industry, as has been suggested previously (Dibble et al. 2013).

With its favourable topographical location, at the confluence of two wadis, the rock shelter Ifri n'Ammar must have attracted hunter–gatherer groups. As stated, the conditions during the Aterian ranged from savannah to both more humid and semi-arid environments (Larrosaña 2012; Scerri 2013a; Dörschner et al. 2016), which also finds confirmation in the results of a preliminary analysis of the faunal remains at Ifri n'Ammar (Hutterer 2010). Indeed, most of the animals (e.g. Roan antelope, Zebra, Gundi) are characteristic of savannah and grassland habitats (Hutterer 2010). The presence of 28 species of vertebrates, including land and freshwater turtles (*Testudo*, *Mauremys*), also suggests a favourable location for human groups who exploited their environment to its full extent (Stoetzel et al. 2014). Ethnographic data from hunters and gatherers in arctic landscapes indicate an intensive use of all available resources (Krupnik 1993), and it is likely that this would also be valid for other enviro-nmental settings. The functional evidence for the tanged component of Ifri n'Ammar confirms such a strong focus on the exploitation of animal resources, both in terms of the Aterian subsistence (hunting, butchering) and their manufacturing activities (e.g., hide-working, handles). It remains to be examined whether also the non-tanged component confirms this pattern. Also, the large number of burned and calcinated bone fragments at Ifri n'Ammar and other Aterian sites confirms the important reliance on animals (Nespoulet et al. 2008; Costamagno et al. 2005; Théry-Parisot et al. 2005; Campmas et al. 2008). Even though it could not yet be confirmed (Campmas et al. 2008), researchers have argued that these remains could correlate with combustion struc-tures (Nespoulet et al. 2008), implying that the faunal mate-rial may have been used as fuel and the bones may thus have disappeared from the archeological record. Also, the presence of several worked bone pieces from Aterian levels (Nespoulet et al. 2008; Nami and Moser 2010) illustrates the intense use of animal material. We, therefore, argue that the Aterian may be the reflection of highly mobile groups who followed animal herds, for example gazelles who often dominate the faunal spectrum at several Aterian sites (Campmas 2012). Next to an intensive exploitation of animal resources, the evidence may also suggest a use of plant materials to sustain their durability. Indeed, a likely hafting in a hard animal material could also be identified for the tanged points, which implies the use of foreshafts. Foreshafts may be used for various purposes, but often, they are used to protect the wooden shaft against fracturing, amongst others by facilitating de-hafting of the foreshaft upon impact in the animal. It extends the use life of the wooden shaft and it allows easy replacement if a stock of foreshafts with hafted stone points is available. The Alaskan Eskimo use walrus as foreshaft to haft their tanged spear points (Witthoft 1969), and our experiments demonstrated that also horn and bone foreshafts are very effective.

The functional study of the tanged tools from Ifri n'Ammar indicate that the tanged tools were hafted and used for hunting and animal processing activities. Indeed, out of the 37 analysed tanged tools, 11 were interpreted as armatures, 5 as hide scrapers, and 1 as a possible butchering tool. A combination of macroscopic and microscopic hafting wear was identified on 12 out of 17 used tools. Identifying the exact hafting mode proved more difficult, but it could be argued that hafting in hard animal material was likely. Aterian tangs are characterised by their short and robust nature and they were originally explained in terms of the appearance of hafting (e.g., Clark 1970). While it can indeed be confirmed that the tanged tools from Ifri n'Ammar were used while hafted, hafting expertise appeared much earlier, with evidence for hafted percussion tools from about 200 ka in Northeast Africa (Rots and Van Peer 2006, Rots et al. 2011). Tangs could therefore only witness the appearance of a particular hafting technique. As demonstrated based on the functional study, the tanged tools from Ifri n'Ammar are likely to have been used while hafted in a handle manufactured out of hard animal material (e.g., bone). Therefore, the appearance of tangs could perhaps be linked with a more important integration of animal material in the tool manufacturing process. In addition, the functional study allowed us to confirm that both projectiles and hide-working scrapers were used while hafted. In terms of the evolution of hafting, this observation is important as it has been suggested earlier (e.g., Rots 2015a) that a distinction should be made between stone tools for which hafting is a prerequisite for their use (such as percussion tools and projectiles) and other hafted tool functions. An elaboration of hafting towards "non-essential" tool functions is demonstrated for the tanged hide-working scrapers of Ifri n'Ammar, which testifies the embedded nature of hafting expertise in the Aterian tool technology. Hafting is not a condition for hide-working, but it may significantly facilitate tool manipulation and the exertion of pressure (as confirmed experimentally). It also significantly enhances hide-working when hides are worked while fixed on a frame.

The hypotheses that the potential link between the frequency of hafting and a site's function (Rots 2015b), which implies that only tools are hafted for tasks that are frequently exerted at a site (e.g., butchering knives in the case of hunting stands), is supported by the data from Ifri n'Ammar. The site appears to have a strong focus on hunting and animal processing activities, and all tools used for these activities proved to have been used hafted. Evidently, this hypothesis needs to be tested more in-depth by including non-tanged implements in the analysis.

The tanged scrapers of Ifri n'Ammar all proved to have been used for hide-working activities, and the use-wear evidence testifies that different resharpening cycles took place (use-wear proved to be cut by resharpening scars). It is likely that this process took place while the tools were still in their haft, as was also observed ethnographically (e.g., Rots and Williamson 2004). No explicit evidence of resharpening was observed on the tanged points. It has been argued by Iovita (2011) that intensively retouched tanged points or other tanged tools are the result of repeated resharpening events and that tanged projectile points could have been recycled into other tool types. This hypothesis was evaluated in relation to the functional results for Ifri n'Ammar. Firstly, the tanged points of Ifri n'Ammar show a variety in size (tangs and tools) and weight with regard to retouch intensity: small and large retouched points occur as well as small and large unretouched points. No gradual transition in retouch intensity and size reduction could be identified. Also, scrapers are systematically manufactured on sturdier blanks than the majority of the points. Secondly, a few unretouched tanged points were discarded as such, which contradicts recycling for these points and seems to suggest a relatively short use life. Thirdly, the most intense hafting traces (fractures, heavy scarring or incipient fissures associated with abrasion) were only observed on armatures, confirming their intense use. Such well-developed hafting traces were not observed on tanged scrapers, which should be the case if they would be the result of a longer use life than the points (recycled from points). Hafting traces—in contrast to use-wear traces—are not removed by resharpening and their intensity gradually increases throughout the entire use cycle of the tool (Rots 2005). We therefore conclude that the tanged scrapers of Ifri n'Ammar are not resharpened or recycled points. Interestingly, however, two retouched points show evidence of a double patination, which does indicate the recycling of older tools into points.

Conclusion

The shaping of tangs on stone tools in Aterian assemblages has been thought to reflect early evidence of hafting, but also, contradictory claims were made concerning the link between the tangs and hafting. We presented the results of a functional analysis of the Aterian tanged tools from the "occupation supérieure" of Ifri n'Ammar (Morocco) in combination with the results of an experimental study on the relevance of the short and robust Aterian tang with regard to hafting. In contrast to previous studies, the analyses presented here include data from both tanged points and scrapers. Both tool types proved to have been used while hafted for the exploitation of animal resources. The points proved to have been used as armatures in hunting activities, while the scrapers were used in hide-working activities. While this evidence is definitely not the earliest evidence of hafting, we argue that it indicates the appearance of specific hafting arrangements in which animal material played a crucial role. Indeed, a hafting in hard animal material was suggested for both the scrapers and the points, implying the use of foreshafts for the latter. The functional evidence in combination with faunal evidence seems to suggest that the Aterian assemblages may be the reflection of highly mobile groups who followed animal herds. Further functional studies will focus on the non-tanged tool component from the assemblages from Ifri n'Ammar in order to further evaluate our hypotheses. Only a confrontation between both tool components will allow further insights into assemblage variability and its potential link with tool use and hafting.

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