Title

Frequency and production technology of bladelets in Late Middle Paleolithic, Initial Upper Paleolithic, and Early Upper Paleolithic (Ahmarian) assemblages in Jebel Qalkha, southern Jordan

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Abstract

Bladelets and microliths have been recognized as key parts of the late prehistoric cultural dynamics on a global scale and recently discussed in relation to the range expansion of *Homo sapiens* in the late Pleistocene. This paper focuses on some of the current issues on bladelet technology in the Levant, including 1) the occurrences of bladelets in the Late Middle Paleolithic (LMP) and Initial Upper Paleolithic (IUP) and 2) evolutionary reasons for the development of the UP bladelet technology.

To discuss the first issue, we examine frequencies and production technology of bladelets in the LMP, IUP, and Early Upper Paleolithic (Ahmarian) assemblages from the Jebel Qalkha area, southern Jordan. We then discuss the results in light of relevant data from other sites in the Levant. A clear increase in bladelets coincides with the Ahmarian, as already known, but we suggest that the unified production of blades and bladelets in the Ahmarian most likely derived from the IUP which provided a technological basis, on which the miniaturization of blades/bladelets was achieved in the Ahmarian through the changes in platform preparation technique. We also examine bladelet production in the LMP that shares some technological elements with the IUP bladelet production. However, they fundamentally differ from each other in the relationship of the bladelet production to the main flaking system of the whole assemblages.

To examine the second issue, we evaluate performance characteristics of bladelets from a viewpoint of changing mobility patterns from the LMP to the Ahmarian and suggest that the settlement/procurement patterns since the IUP provided conditions, in which the miniaturization of blade blanks became beneficial. The employment of bladelet technology is likely to have facilitated the transportability of tools/blanks and the efficient consumption of raw material, highlighting flexible implementations in response to variable conditions of raw material availability, mobility, and provisioning strategies. The bladelet technology was increasingly employed from the IUP to the Ahmarian probably as a versatile strategy in raw material economy, which was advantageous under variable mobility patterns and thus kept its popularity for a long time until the Epipaleolithic.

Keywords

Lithic technology; Bladelet; Levant; Middle Paleolithic; Upper Paleolithic; Mobility

1. Introduction

Among the most hotly debated issues in Paleolithic archaeology are the questions of how anatomically modern humans (AMHs) can be characterized by their behavioral patterns and how their behavioral characteristics and dynamics were related to their range expansion from Africa and the subsequent demise of archaic hominins (e.g., Neanderthals). Numerous studies focused on these questions have examined archaeological records from various geographic regions and discussed their differences and commonality on a global scale (Boyle et al., 2010; Dennell, 2020; Kaifu et al., 2015; Mellars, 1990; Mellars et al., 2007; Nitecki and Nitecki, 1994).

The inter-regional variability of archaeological records associated with AMH dispersals has been partly explained as cultural adaptation to diverse environmental settings (Dennell, 2020; Kaifu et al., 2015). Such explanations consider archaeological variability as reflecting behavioral and ecological flexibility of AMHs (O'Connor, 2015; Roberts and Amano, 2019). Cultural variability has also been examined from a perspective of cultural transmissions that involve factors such as demography, learning strategies, social structure, and mobility (papers in Aoki and Mesoudi, 2015; Lycett and Norton, 2010; Wakano et al., 2018).

As for the commonalities of Paleolithic archaeological records over wide regions, an on-going debate is whether the apparent similarity is linked to spreads of behavioral habits (e.g., certain manners of tool production) in association with the dispersals of AMHs from Africa or west Asia to surrounding regions (Bar-Yosef, 2007; Bar-Yosef and Belfer-Cohen, 2013; Mellars, 2006; Hublin, 2015). On the other hand, behavioral convergence (i.e., independent multiple origins) has also been suggested for some cultural elements, such as microliths and shell beads, that appear at discontinuous timings and areas with slight (but significant) variations in morphology and production technology (Clarkson et al., 2018; Hiscock et al., 2011; Stiner, 2014).

This paper focuses on the microlith technology in the Levant (Fig. 1) which occupies a crucial geographic location in the dispersal of *Homo sapiens* from Africa to Eurasia and is also known for the florescence of microliths in the late Pleistocene. As described by Belfer-Cohen and Goring-Morris (2002), the Levantine microlith technology has been characterized by two developmental stages, i.e., the emergence of microliths in the Upper Paleolithic (UP) followed by their technological change in the Epipaleolithic. The UP microliths were basically bladelets that were marginally retouched to only rarely create formal tools, such as el-Wad points. Toward the end of the UP, abrupt and invasive retouch (i.e., backing) began to be employed to modify bladelet blanks, and in the Epipaleolithic, backing became increasingly used often along with the microburin technique to create numerous standardized forms of microliths, many of which represented the diagnostic elements of Epipaleolithic industries (e.g., Kebara points, trapeze-rectangles, lunates, etc.).

This technological trend is illustrated by some quantitative data from the sites in the Jebel Qalkha area, southern Jordan (Henry, 1995; Kadowaki and Henry, 2019; Kadowaki et al., 2019a, 2019b). SOM Fig. S1 shows a general trend of miniaturization of blades/bladelets since the Ahmarian that is followed by an increase in backed microliths in the Epipaleolithic.

One of the current issues regarding bladelets is their occurrences in earlier periods, namely the Initial Upper Paleolithic and the Middle Paleolithic. In SOM Fig. S1, the error bars (±1σ) of length and width of blades/bladelets indicate that the IUP and MP assemblages also include pieces that are small enough to be categorized as bladelets (i.e., width < 12 mm and length < 50 mm following the definition by Tixier, 1963). Indeed, there are several reports on the production technology and use-wear of bladelets in several IUP and MP assemblages in the Levant, Europe, and Northern Asia (Boëda et al., 2015; Demidenko et al., 2020; Faivre, 2012; Hovers et al., 2011; Leder, 2014; Malinsky-Buller et al., 2014; Villa and Roebroeks, 2014; Zwyns et al. 2012).

The IUP bladelets are closely related to the research interest in AMH behavioral characteristics at the time of their wide dispersal in Eurasia. This is because IUP lithic technology shows wide geographic distributions in the Levant, Central–East Europe, and Central–North Asia beginning around 50–45 ka to which two *Homo sapiens* fossils in East Europe and Siberia are dated (Fu et al., 2014; Hublin et al., 2020; Kuhn and Zwyns, 2014). Human skeletal records in the Levant are ambiguous about the makers of the IUP (Kuhn et al., 2009), but many researchers have suggested the involvement of AMHs in the emergence of the Levantine IUP including the possibility of interbreeding/interaction with Neanderthals (Bar-Yosef and Belfer-Cohen, 2010a; Dennell, 2020;

Douka et al., 2013; Rose and Marks, 2014; Stringer, 2012). In addition, the Levantine IUP has been considered to have developed into the Ahmarian (indigenous Early Upper Paleolithic entity), as demonstrated by stratigraphic and technological sequences of lithic assemblages from key sites, including Ksar Akil (Ohnuma, 1988; Ohnuma and Bergman, 1990), Üçağızlı (Kuhn et al., 2009), Boker Tachtit (Marks and Kaufman, 1983), Boker A (Jones et al., 1983), and Wadi Aghar (Kadowaki et al., 2019b). Thus, the examination of IUP bladelets will enable us to discuss a question of whether they represent a precursor of the following fully-fledged bladelet technology in the Ahmarian.

Here, we examine frequencies and production technology of IUP bladelets by using two IUP assemblages (Wadi Aghar and Tor Fawaz) in the Jebel Qalkha area, southern Jordan. They are characterized through their comparison with a LMP assemblage (Tor Faraj) and an Ahmarian assemblage (Tor Hamar) in the same area. The results will be discussed by reviewing relevant data from other sites in the Levant. Because the data of other sites are obtained from publications of various studies (SOM Tables S2–6), they are not strictly standardized for comparison. Therefore, we use the compiled data only as supplementary evidence in interpreting the results of our analyses using the Jebel Qalkha materials.

Based on the evaluation of the bladelet occurrences in the LMP, the IUP, and the Ahmarian, we will then discuss evolutionary reasons for the increasing adoption of bladelet technology from the IUP to the Ahmarian in the Levant. For this purpose, we follow a theoretical framework of evolutionary explanations for microliths proposed by Elston and Kuhn (2002) and papers therein. In their explanatory framework, microliths are considered as part of technological solutions/compromises to achieve goals within technological organization employed by human foragers under specific ecological and social conditions. In the technological organization (Nelson, 1991), microliths (i.e., tool production and use) are linked to behaviors of other aspects such as subsistence, mobility, and social interactions. Adoption of certain technological solutions like microliths is decided by accounting for costs and benefits of the technology and relevant activities in several aspects, such as time, energy, and risk (Bamforth and Bleed, 1997; Torrence, 1989).

In this explanatory framework, several reasons for the Levantine microliths have been proposed by Belfer-Cohen and Goring-Morris (2002) and Neely (2002) who suggested several factors, such as projectile-point propulsion mechanisms, hafting technology, raw material economizing behaviors, functional variability, and mobility. Their discussions were more focused on the latter stage of the Levantine microlithic, i.e., the Epipaleolithic with more standardized backed microliths while this paper aims to focus on the increase of bladelets from the IUP to the Ahmarian.

As shown by the Levantine record, microlith technology entails significant variations. Thus, multiple reasons may be involved in the adoption of microliths, and they are likely to vary according to the cases. Thus, the reasons should be examined in each case according to specific technological characteristics and ecological/environmental conditions in a given context (Neely 2002; Torrence 2002). In discussing the rise of bladelets from the IUP to the Ahmarian, we will consider specific technological and ecological settings at that time. However, the evolutionary reasons for the increase of bladelets hopefully provide implications that are widely applicable to the behavioral ecology of human foragers.

2. LMP, IUP, and Ahmarian assemblages in the Jebel Qalkha area, southern Jordan

For the analyses of bladelets, we used four lithic assemblages from the Jebel Qalkha area, southern Jordan (Table 1; Fig. 2). The Jebel Qalkha area (ca. 1000 m a.s.l.) is part of a highland zone along the eastern side of Wadi Araba in southwestern Jordan. The area was originally investigated between 1976 and 1999 by one of the authors (Henry 1994, 1995, 2003, 2017a, 2017b), and the renewed fieldwork has been in progress since 2016 (Kadowaki and Henry, 2019). The four lithic assemblages used in this study were collected in the renewed excavations at Tor Faraj (LMP), Wadi Aghar (IUP), Tor Fawaz (IUP), and Tor Hamar (Ahmarian). The four sites are located close to each other (less than 2 km) within the same geological settings characterized by extensive exposure of Umm ‘Ishrin Sandstone (Rabb’a, 1987). A few spots of chert sources are located 2–8 km away from the sites while more extensive chert outcrops are distributed in the Ma’an Plateau, 15–20 km to the northeast.

Tor Faraj (29° 56' 19.9"N, 35° 19' 33.6"E) is known as a LMP rock-shelter site because of its late Levantine Mousterian assemblages and radiometric dates from Layers C and D2 upper in which three occupational levels (combined to Floors 1 and 2) were intensively studied (Henry, 1995, 2003). The lithic assemblage used in this study was collected in Layer E which was stratigraphically lower than Floors 1 and 2, intervened by 40 cm thick deposits (Layer D2 lower) with low density of artifacts. As briefly reported in Kadowaki and Henry, 2019, the density of lithics in Layer E is comparable to those of Floors 1 and 2 and associated with many charcoal fragments, probably representing another occupational level. The Layer E lithic assemblage also shows techno-morphological characteristics of the late Levantine Mousterian although there are several differences from the upper assemblages.

Wadi Aghar is a shallow rock-shelter site (29°56'11.99"N, 35°19'53.53"E) where IUP lithics were collected. The shallow deposits (less than 1 m in thickness) were divided into Layers A, B, C, D1, and D2. The previous work excavated Layers A–C while the renewed work excavated Layers B–D2. The lithic assemblages from the two investigations are techno-typologically similar to each other (Coinman and Henry 1995; Kadowaki et al., 2019b). This study uses the IUP assemblage from Layers C–D1 that were dated to 45–40 ka.

Tor Fawaz is another rock-shelter site (29°56'49.44"N, 35°20'9.03" E) with shallow deposits up to 1m in maximum. The original excavations in 1983/84 excavated five 1 m x 1 m units (Units 1–5), and the excavation in 1994 opened a larger unit (3 m x 4 m) behind the dripline. In the latter unit, ca. 1m deposits were divided into Layers A, B1, B2, C, and D from the top. The previous studies of the lithic assemblages suggested unique techno-typological characteristics that do not fit a conventional scheme of UP traditions, i.e., the Levantine Aurignacian or the Early Ahmarian (Coinman and Henry 1995; Kerry and Henry 2003) while several researchers have suggested a possible correlation to the IUP (Belfer-Cohen and Goring-Morris, 2003; Goring-Morris and Belfer-Cohen, 2018; Stutz et al., 2015). The renewed excavation in 2017 opened five 1 m x 1 m units (Units 6–10) and collected lithic artifacts from 30–45 cm deposits that likely correlated to Layers B2 and C in the 1994 trench. A preliminary study of the new lithic assemblage indicates the IUP affiliation (Kadowaki et al., 2019a). This new assemblage is used in the present analysis.

Tor Hamar (29°56'17.34"N, 35°19'8.90"E) is also a rock-shelter site, but unlike the preceding three sites, Tor Hamar has multi-component deposits. More than 2 m thick deposits at the site consist of Layers A–E1 with the Mushabian (Middle Epipaleolithic), Layer E2 with the Qalkhan (Early Epipaleolithic), and Layers F–G with the Ahmarian (Early Upper Paleolithic) cultural remains (Henry, 1995). The previous investigations opened ten 1 m x 1 m units (Units 1–10) while the renewed fieldwork continued excavations in Units 7–10 and opened a new unit (Unit 11) (Kadowaki and Henry, 2019). This study uses an Ahmarian assemblage collected from Layers F and G in the recent excavation in Units 9 and 10.

3. Chrono-cultural scope

Before describing analytical methods, we briefly summarize chrono-cultural backgrounds of the LMP, the IUP, and the Ahmarian in the Levant. The MP lithic assemblages in the Levant share broadly common techno-typological characteristics that are described as the Levantine Mousterian (e.g., Hovers, 2009; Meignen, 2019; Shea, 2003, 2013). A traditional scheme of the Levantine Mousterian cultural-chronology is a tripartite division based on the chrono-stratigraphic evidence at Tabun Cave, i.e., Tabun-D or Phase 1, Tabun-C or Phase 2, and Tabun-B or Phase 3 (Copeland, 1975; Shea, 2003). However, some researchers have suggest a two-phase scheme (Jelinek, 1982; Culley et al., 2013) or techno-typological variability within each of the phases (Hovers, 1998, 2009; Groucutt et al., 2019). Here, we focus on LMP assemblages that are dated approximately between 75–50 ka.

The lithic assemblages that we categorize as the IUP in this study have been grouped under various names, such as UP Phase 1 (Neuville, 1951), Emiran (Garrod, 1951; Rose and Marks, 2014; Shea, 2013), MP-UP transition (Marks, 1983, 1993), the IUP (Marks and Ferrings, 1988; Kuhn, 2003; Kuhn and Zwyns, 2014; Bar-Yosef and Belfer-Cohen, 2010a, 2010b), and the Bokerian (Leder, 2014). Despite the varying nomenclature, researchers generally show concordance when assigning lithic assemblages to this group. Hereafter, this study employs the term IUP in a broad sense to include the assemblages following the Levantine Mousterian and preceding the Ahmarian.

The second UP phase in this study is the Early Upper Paleolithic (EUP) or Ahmarian (according to the recent definition by Goring-Morris and Belfer-Cohen, 2018). The presence of bladelet production has been recognized since the first definition of the Ahmarian industry (Marks, 1981; Gilead, 1981), and later studies illustrated many cases of bladelet technology in Ahmarian assemblages (papers in Goring-Morris and Belfer-Cohen, 2003; Davidzon and Goring-Morris, 2003; Ohnuma, 1988). Other UP industries, dated later than the Ahmarian with some overlap, such as the Levantine Aurignacian, are also characterized by the production of bladelets but are not included in this study as we wished to focus on the study of the assemblages from the Jebel Qalkha area that includes the Ahmarian from Tor Hamar.

The variability in each of the MP, the IUP, and the Ahmarian groups so defined has been recognized by many researchers examining the diachronic and geographic structures of lithic technology (e.g., Goring-Morris and Belfer-Cohen, in press; Hovers and Belfer-Cohen, 2013; Kadowaki, 2013; Leder, 2014; Meignen, 2019; Shea, 2003; Shea et al., 2019). Diachronic changes in the IUP have been recognized from stratigraphic records at several sites, such as Boker Tachtit (Marks and Kaufman, 1983), Tor Sadaf (Fox, 2003; Fox and Coinman, 2004), Ksar Akil (Ohnuma, 1988; Ohnuma and Bergman, 1990), and Ücağızlı (Kuhn et al., 2009). Geographic variability of the IUP has been recognized since early on, as represented by differential distributions of Emireh points and chamfered pieces (Garrod, 1951, 1955; Nishiaki, 2018; Leder, 2018). In the Ahmarian, at least two geographic variations, i.e., northern and southern facies, have been recognized (Abulafia et al., in press; Goring-Morris and Davidson, 2006; Hauck, 2015; Kadowaki et al., 2015, 2019b). However, this study is more concerned with the large scale, long-term variability between the LMP and the Ahmarian.

4. Methods

Using the LMP, IUP, and Ahmarian assemblages from the Jebel Qalkha area, we examined 1) the frequency of bladelets, 2) core reduction technology for blades/bladelets, and 3) platform preparation of blade/bladelets to characterize the occurrences and production technology of bladelets through time.

4.1. Frequency of bladelets

We examined the frequency of bladelets with two quantitative data. The first is the relative frequency of bladelets among debitage categories listed in Table 1. The second is the distributions of length and width of blades/bladelets.

Regarding the debitage categories, definitions of blades and bladelets are critical in this study. A blade is defined as a flake whose length is equal to or greater than twice its width. Usually, a blade also has parallel lateral sides and ridges. In the Levantine Paleolithic study, a definition of bladelet by Tixier (1963) is often employed. A bladelet is a blade with a length < 50 mm and a width < 12 mm (e.g., Belfer-Cohen and Goring-Morris, 2002; Kerry and Henry, 2003; Marks, 1976; Ohnuma, 1988; Shea, 2013).

Cortical flakes/blades have cortex covering more than 50% of their dorsal surfaces while partially cortical flakes/blades/bladelets have less than 50 % coverage of cortex. The identification of Levallois products is based on the Levallois flaking concept defined by Boëda (1994) and Eren and Lycett (2012). Although the Levallois flaking is primarily the volumetric concept and hierarchical exploitation of cores, we identified Levallois points/blades/flakes by observing their lateral and distal convexities as well as the platforms that show large, often facetted platforms.

We analyzed the relative frequency of bladelets by combining several debitage categories according to four morphological classes including, points, flakes, blades, and bladelets. For example, a blade category includes Levallois blades, blades, partially cortical blades, and cortical blades. A bladelet category includes bladelets and partially cortical bladelets. For this analysis, we excluded retouched tools, core trimming elements, spalls, cores, chips, and chunks to focus on morphological variations of unretouched blanks (Marks 1976: 371).

The distributions of length and width of blades/bladelets were examined with histograms of length and width. We used only complete pieces for length while we used also broken blades/bladelets for width if they were not laterally broken (i.e., retaining original width).

4.2. Production technology for blades/bladelets

We examined production technology of bladelets by observing several attributes, including 1) core morphologies and flaking concepts, 2) dorsal scar patterns, 3) platform types, 4) relative platform size, and 5) overhang removals.

We observed cores with bladelet scars to characterize the core morphologies and flaking concept for the production of bladelets. The dorsal scar patterns of blades/bladelets were classified into unidirectional, bidirectional, crossed, and centripetal. We used only complete blades/bladelets for Tor Hamar and Tor Fawaz assemblages while we used complete pieces and those missing only proximal or distal ends for Tor Faraj and Wadi Aghar to increase the sample size.

Regarding the platform types, we followed a standard scheme by Inizan et al. (1999), but also included a category of 'partially faceted type'(Kadowaki, 2018) that has been defined by Ohnuma (1988) and Ohnuma and Bergman (2013). According to Ohnuma and Bergman (2013), the partially faceted platform is defined by small faceting, directed from the dorsal surface onto the butt area, which aims "to remove the overhang at the core striking platform edge left by previous flake removals" (Ohnuma and Bergman, 2013: 11). The partially faceted butt shows multiple facets, but it is distinguished from the multi-faceted type by the location (sometimes concentration) of small facets at spots, where dorsal ridges meet the butt. We used blades/bladelets retaining the proximal ends.

The relative platform size is defined as a ratio of the platform area (platform width x platform depth) to the cross-sectional area of the blank (width x thickness of the blank). The smaller the value is, the smaller the platform size is in comparison to the width and thickness of the blank. This measurement is similar to the ratio of platform width to width analyzed by Wiseman (1993). The distributions of this value were examined by histograms.

Lastly, we examined the traces of overhang removals at the platform of blades/bladelets. When the removal traces are present, they were divided into coarse flaking and fine flaking (or abrasion/grinding). The latter technique is known to have increased since the Ahmarian (Ohnuma, 1988; Kuhn et al., 2009). We used blades/bladelets retaining the proximal ends.

To evaluate the patterns of the above quantitative data, we use Mann-Whitney U test and Pearson's chi-square test according to the measurement scales.

5. Results

5.1. Frequency of bladelets

Fig. 3 shows relative frequencies of bladelets in comparison with points, flakes, and blades in the four assemblages from the Jebel Qalkha. Tor Hamar (Ahmarian) shows the greatest percentage of bladelets (33.7%) while those of Tor Fawaz (IUP), Wadi Aghar (IUP), and Tor Faraj (LMP) are small (around 6%). The two IUP assemblages differ from Tor Faraj by the increase in the ratio of blades.

As shown in Fig. 4, the dominance of bladelets in Tor Hamar is also illustrated by histograms of length and width of blades/bladelets that have a clear peak in 20–30 mm in length and 8–10 mm in width. In Tor Fawaz, Wadi Aghar, and Tor Faraj, bladelets occur as a minor component in the smaller ranges of length and width of blades. However, it is notable that width distributions of blades/bladelets from Wadi Aghar and Tor Faraj show relatively high peaks in bladelets.

5.2. Production technology of bladelets

5.2.1. Bladelet cores

Among the ten cores in Tor Faraj Layer E (LMP), six pieces are Nahr Ibrahim cores (Nishiaki 1985; Solecki and Solecki, 1970) that show small flake scars. The remaining four pieces are Levallois cores, including one unidirectional convergent method, one preferential method, and two centripetal recurrent methods. None of these show clear bladelet scars.

Instead, a retouched tool classified as a burin shows a bladelet scar and multiple elongated facets (Fig. 5). The assemblages from Tor Faraj Layers C and D2 upper also include burins, accounting for 12.71% of retouched tools, and some of them show multiple faces extending to dorsal or ventral surfaces (Henry, 2003: Fig. 4.12: b and c). In such cases, spalls likely assume bladelet forms. In addition, according to a refitting analysis of lithics from Layers C and D2 at Tor Faraj (Demidenko and Usik, 2003), a dominant practice of Levallois point production was associated with a minor non-Levallois method for a serial production of elongated blanks. This method is represented by a few cases of refits of unidirectionally detached blades with little or no platform preparation (Demidenko and Usik, 2003: 154). The report also illustrates a couple of pyramidal cores with elongated blank scars (Demidenko and Usik, 2003: Fig. 6.25).

In the IUP assemblages (Wadi Aghar and Tor Fawaz), bladelet scars are observable in several cores made on blocks and flakes (Figs. 6 and 7). The cores-on-blocks include along-axis types (Leder, 2014, 2016) and volumetric types. Along-axis cores assume a flat overall shape consisting of two convex surfaces. Only one surface is used for the detachment of blanks while the other is used for striking platforms, thus resembling the Levallois concept (Boëda, 1994). Along-axis cores are characterized by the dominant use of axial flaking, i.e., unidirectional or bidirectional flaking (thus, along axis), for producing blanks as well as for maintaining the convex working surface. Unidirectional flaking is dominant in the along-axis cores with bladelet scars. In volumetric cores, working surfaces extend around a wide periphery of the striking platform (i.e., cylindrical and pyramidal cores) or is located at a narrow side of the core (i.e., narrow-fronted cores). There are also bladelet cores on flakes or blades (Fig. 6.5; Fig. 7.10 and 7.11). Lateral margins of thick flakes or blades are exploited for the detachment of narrow blanks, thus assuming a burin-like morphology (Zwyns et al., 2012).

Bladelet cores are abundant in the Tor Hamar assemblage (Fig. 8). Although detailed technomorphological analyses are in progress, most bladelet cores show prismatic or pyramidal forms with volumetric exploitation of blocks with a working surface located at a narrow side of the core, i.e., the narrow-fronted core (Goring-Morris and Davidzon, 2006). There are also several bladelets cores made on flakes.

5.2.2. Dorsal scars and platforms

In Tor Faraj, bladelets differ from blades and Levallois blades in the relative frequencies of dorsal scar patterns (Fig. 9; p-value of Pearson's chi-square test < 0.01). The unidirectional pattern is dominant in bladelets while other patterns (i.e., bidirectional, crossed, and centripetal) are more frequent in blades and Levallois blades. Such a difference between bladelets and blades is not observable in the other assemblages (p-value of Pearson's chi-square test > 0.05). The unidirectional pattern is the most frequent type in blades/bladelets from Wadi Aghar, Tor Fawaz, and Tor Hamar.

Regarding the platform types (Fig. 10), the plain platform is the most frequent type for blades/bladelets in all the assemblages. Levallois blades are characterized by relatively high frequencies of the faceted type. Focusing on bladelets, it is notable that the faceted platform occurs often in bladelets from Tor Faraj and Wadi Aghar while the linear and punctiform types increase in Tor Hamar. Tor Hamar is also characterized by the very low occurrences of faceted platforms.

As shown in Fig. 11, the relative platform size clearly decreased in Tor Hamar (p-value of Mann-Whitney U test < 0.01) while the size distributions are similar among Tor Faraj, Wadi Aghar, and Tor Fawaz (p-value of Mann-Whitney U test > 0.05). In the latter three assemblages, bladelets do not necessarily have small relative platforms which are as large as those of blades and Levallois blades.

Fig. 12 shows frequencies of overhang removals on blades/bladelets from the four assemblages. Tor Hamar is distinct from the other three by greater frequencies of fine flaking for the removal of overhangs. Coarse flaking or the absence of overhang removal is dominant in blades/bladelets from Tor Faraj, Wadi Aghar, and Tor Fawaz.

6. Discussion

6.1. Frequency of bladelets in the LMP, IUP, and Ahmarian

The results of this study indicated a clear increase in bladelets in Tor Hamar (Ahmarian) while the frequency of bladelets is commonly low in Tor Faraj (LMP), Wadi Aghar (IUP), and Tor Fawaz (IUP) (Figs. 3 and 4). To evaluate this trend, we plotted the percentage of bladelets in all blank types (See Section 4.1. and below for the definition of blank types) and the percentage of bladelets in blades/bladelets for the Jebel Qalkha assemblages and other LMP, IUP, and Ahmarian assemblages for which relevant data have been published (Fig. 13; SOM Table S2). The selected blank types are Levallois points, Levallois flakes, Levallois blades, flakes, blades, and bladelets as they are reported in the publications (see SOM Table S2 for references). Primary elements, core trimming elements, and spalls are not included because they are technological categories including various forms.

As a result, the four assemblages from Jebel Qalkha are plotted close to other assemblages of the same chrono-cultural entities, suggesting that the results of this study reflect general patterns in the Levant. The clearest trend is the increase in the frequency of bladelets in Ahmarian assemblages. Exceptions include the low percentage of bladelets in the Ahmarian assemblage from Kebara Unit III (Bar-Yosef and Belfer-Cohen, 2019) and the high occurrences of bladelets in the IUP assemblages from Umm el-Tlel (Boëda and Bonilauri, 2006). Clarifying the reasons for these exceptions is difficult at present and is not the scope of this paper.

It is notable that the frequency of bladelets in Tor Faraj Layer E is not exceptional but within the range of three other LMP assemblages with greater sample size (i,e, Far'ah II, Kebara Unit V, and 'Ein Qashish). If we accept the trends in Fig. 13, IUP assemblages tend to show greater percentages of bladelets in all blank types than LMP assemblages (p-value of Mann-Whitney < 0.01). This pattern holds even if we exclude the two exceptional IUP assemblages from Umm el Tlel (p-value of Mann-Whitney U = 0.011). In contrast, the percentage of bladelets in blades/bladelets is not significantly different between the IUP and the LMP assemblages even if we include the Umm el Tlel samples (p-value of Mann-Whitney U > 0.05).

These observations indicate that 1) the production of blades/bladelets increased from the LMP to the IUP but 2) the size of blades/bladelets was similar between the LMP and the IUP. The latter point is also illustrated by Fig. 14 that plots the length and the width of blades/bladelets from the LMP, IUP, and Ahmarian assemblages in Jebel Qalkha and other relevant sites in the Levant (see SOM Table S3 for data sources). The blades/bladelets of the Ahmarian assemblages are generally smaller than those of the LMP and the IUP (p-value of Mann-Whitney U test < 0.01 except for the difference of length between the Ahmarian and the LMP), but there is no significant difference in size between IUP and LMP blades/bladelets (p-value of Mann-Whitney U test > 0.05).

6.2. Core reductions producing bladelets in the LMP, IUP, and Ahmarian

Based on the observations of cores and scar patterns of blades/bladelets from the Jebel Qalkha area (Figs. 5–9), we suggest that the bladelet production in Tor Faraj (LMP) had little connection with the main Levallois flaking system but was linked to the reduction of single platform volumetric cores (Demidenko and Usik, 2003: Fig. 6.23 and Fig. 6.25) or multi-faceted burins (Fig. 5). Indeed, studies of Amud and 'Ein Qashish assemblages also suggest the production of blades/bladelets from single platform volumetric cores (Hovers et al., 2011; Malinsky-Buller et al., 2014). Single platform volumetric cores with elongated blank scars are also observable in the reports of Rosh Ein Mor (Crew, 1976: 93–94; See Goder-Goldberger et al., 2020 for a recent chronological assessment to the LMP).

The above recognition of bladelet production in the LMP raises a new question of how it compares with the bladelet production in the IUP. In the Wadi Aghar and Tor Fawaz assemblages, bladelet scars are observable on along-axis cores, volumetric cores, and burin-cores (Figs. 6 and 7). According to the studies of IUP assemblages from Ksar Akil, Umm el-Tlel, and Abou Halka (Boëda et al., 2015; Boëda and Bonilauri, 2006; Leder, 2014; Ohnuma, 1988), bladelets were produced through at least two methods. The first is the alternating production of bladelets and pointed blades. Pointed blades were removed from a large portion along the flaking axis of the working surface while bladelets were removed from the restricted area in the working surface near the platform of the core. Thus, negative scars of bladelets are left on the dorsal surface of pointed blades near their proximal end (e.g., Umm el-Tlel points). Another method is through specific bladelet cores that are made either on blocks or thick flakes/blades. The bladelet cores on flakes/blades often assume shapes like burins, so called burin-cores. Multi-faceted burins in the Boker Tachtit assemblages have recently been recognized as burin-cores for bladelets (Marks and Kaufman, 1983; Demidenko et al., 2020).

Given the above observations, single platform volumetric cores for bladelets were likely common technological elements in both LMP and IUP. Bladelet cores-on-flakes (particularly burin-cores) occurred in several IUP assemblages, and we suggest their occurrences in the LMP assemblages from Tor Faraj (Fig. 5; Henry, 2003: Fig. 4.12: b and c). Along-axis cores for bladelets in the IUP are similar to the Levallois cores in the volumetric concept, but their occurrences in the LMP are currently unclear possibly due to the scarcity of studies paying attentions to bladelet production in the LMP.

Despite some common technological elements in the LMP and the IUP for the bladelet production, it is important to recognize that they are fundamentally different from each other in the relationship of the bladelet production to the main flaking system of the whole assemblage. As we pointed out above, the LMP bladelet production had little connection to the main Levallois reductions while the IUP bladelet production is closely linked to the main blade production in the whole assemblages. In fact, the bladelet detachment in the IUP can be considered as extensions, i.e., later stages, of the blade core reduction with along-axis cores and volumetric cores-on-blocks. This is illustrated by the unimodal distributions of length and width of blades/bladelets (Fig. 4) as well as by the similarity in dorsal scar patterns between blades and bladelets (Fig. 9) from Wadi Aghar and Tor Fawaz.

The close link between the bladelet production and the blade production has been well known for the Ahmarian assemblages (Belfer-Cohen and Goring-Morris, 2002; Davidzon and Goring-Morris, 2003). In fact, the length and width of blades/bladelets from Tor Hamar show a clear unimodal distribution with a peak in the range of bladelets (Fig. 4) and the dorsal scar patterns are similar between blades and bladelets (Fig. 9). Based on these observations, we suggest that the unified production of blades and bladelets in the Ahmarian most likely derived from the IUP. Thus, the increase in bladelets in the Ahmarian ('microlithization' according to Belfer-Cohen and Goring-Morris, 2002) was not necessarily a result of the 'emergence' of a new bladelet technology but can be understood as the miniaturization of blades produced by core reduction systems stemming from the IUP.

6.3. Platform preparations in the LMP, IUP, and Ahmarian

The miniaturization of blades (i.e., increase in bladelets) in the Ahmarian was associated with the changes in the platform types, the relative platform size, and the overhang removals. Our study of the Jebel Qalkha assemblages showed the decrease in faceted platform types and the increase in linear/punctiform types in the Ahmarian assemblage from Tor Hamar (Fig. 10). In Tor Hamar, the relative platform size decreased significantly (Fig. 11), and the overhang removal by fine flaking increased (Fig. 12).

These changes in the platform attributes are consistent with the known trends demonstrated by the stratigraphic sequences from the IUP to the Ahmarian at Ksar Akil and Üçağızlı (Kuhn et al., 2009; Ohnuma, 1988) as well as other sites shown in Figs. 15 and 16. Fig. 15 shows relative frequencies of three groups of platform-types (the faceted group, the punctiform/linear group, and the plain type) at several IUP and Ahmarian assemblages (See SOM Table S4 for data sources). The faceted group includes the multi-faceted type, the partially faceted type, and the dihedral type. The Ahmarian assemblages are characterized by the decrease in the faceted-type group with increases in plain or punctiform/linear types. The increase in punctiform/linear types is linked to the miniaturization of the relative platform size. Fig. 16 shows relative frequencies of the three kinds of overhang-removals (absent, flaking, and abrasion/grinding). Again, the Ahmarian assemblages are separated from the IUP by the increase in abrasion/grinding (which corresponds to our 'fine flaking' in Fig. 12; See SOM Table S5 for data sources).

These changes in platform attributes may have been related to the change in the hammer mode from the hard hammer to the soft hammer, as already pointed out by several researchers (Kuhn, 2009; Meignen, 2012; Ohnuma, 1998; Ohnuma and Bergman, 1990; Wiseman, 1993). The hammer mode can be examined by the observations of several attributes, such as lips and bulbs, which require further studies.

6.4. Reasons for the increase in bladelets in the Levant

Given the above observations on the frequency and production technology of bladelets in the LMP, the IUP, and the Ahmarian in the Levant, here we discuss what factors could have encouraged their production. For this question, knowledge about the usage of bladelets would be helpful, but such data on bladelets in the Levant are very limited. It is generally assumed that bladelets were used as standardized components of cutting-edges attached to a haft, and a variety of tools could be created by changing haft forms and attachment methods (Belfer-Cohen and Goring-Morris, 2002; Kuhn, 2002). However, no preserved examples of such multicomponent tools have been discovered in the Levantine MP or UP.

A use-wear study of IUP bladelets from Umm el-Tlel indicates their attachment to hafts and the use for cutting animal and vegetal materials (Boëda and Bonilauri, 2006; Boëda et al., 2015). The study suggests an attachment of a bladelet at a tip of haft as one of several reconstructions of hafting methods, but its use in projectile technology is not suggested. Given this result, the bladelet technology in the IUP cannot be effectively linked to projectile use. This view is consistent with the fact that IUP points are dominated by Levallois-like large points (Fig. 17). Fig. 17 shows the length and width of points from several LMP, IUP and Ahmarian assemblages (See SOM Table S6 for data sources). The points in the Ahmarian are mostly el-Wad points, and those of the IUP are Levallois-like points and pointed blades. The LMP points are Levallois points. As we have shown above, there were bladelets in the IUP assemblages, but they were rarely retouched to make points unlike the Ahmarian.

In the Ahmarian, the use of bladelets as blanks for small points, such as el-Wad points, has been widely recognized as a chrono-cultural maker (e.g., Gilead, 1981; Marks, 1981; Goring-Morris and Belfer-Cohen, 2003; Ohnuma, 1988). This suggestion for a link between bladelets and small points is also supported by the present study that shows the increase in bladelets and the miniaturization of points as concurrent phenomena from the IUP to the Ahmarian (Figs. 13 and 17). It has been suggested that small points were used as part of projectile weapons, such as dart tips and arrowheads (Belfer-Cohen and Goring-Morris, 2002; Shea, 2006).

However, the projectile tip explains only part of the uses of bladelets because the relative frequency of bladelet points (e.g., el-Wad points) in bladelet blanks including unretouched bladelets are ca. 5% on average even in the Ahmarian assemblages. Although the actual use of bladelets for points may have been more frequent given their off-site use for hunting, currently available evidence does not allow us to regard it as a dominant incentive for bladelet production. In fact, other uses of bladelets are indicated by the presence of lightly retouched bladelets and the use-wear analysis of bladelets from Umm el-Tlel (Boëda and Bonilauri, 2006; Boëda et al., 2015).

Other performance characteristics of bladelets, possibly more relevant to their initial development in the Levantine UP, are their transportability and efficiency in raw material consumption. Both of these characteristics derive from the small size and mass of bladelets, which increase their portability, allow their production in areas with restricted raw material availability, and achieve high rates of cutting-edge production (Eren et al., 2008; Hoggard and Stade, 2018; Muller and Clarkson, 2016). Benefits from these characteristics are expected to have shaped land use patterns in the Levantine UP, which consist of several behavioral aspects, such as mobility, foraging locality, and provisioning strategy.

Traditionally, an ephemeral nature of UP occupations (thus high mobility) has been suggested from numerous small open-air sites in the arid marginal zone and the limited areal extent of UP occupations in cave sites in the Mediterranean coastal zone (Gilead, 1991; Bar-Yosef and Belfer-Cohen, 2010a). Increased mobility in the UP has been suggested also by a regional study in the central Negev (Marks and Freidel, 1977), which proposed an exploitation of large areas by UP foragers with a circulating settlement system.

More recently, frequent residential moves and short occupations were suggested for Ücağızlı Layers I–C (the IUP and the early part of the Ahmarian) on the basis of game use patterns and the nature of hearth features (Kuhn, 2004). In these layers, high residential mobility was linked to the exploitation of distant flint sources (15–30 km away), from which flint was transported to the site in the form of finished tools and blanks that indicate the provisioning of individuals (Kuhn, 2004). In addition, the ephemeral nature of IUP occupations has been suggested on the basis of thin occupational layers or a limited range of on-site activities at Emireh, Boker Tachtit, and Wadi Aghar (Barzilai and Gubenko, 2018; Kadowaki et al., 2019b). Given such high mobility patterns with a strategy of provisioning individuals, the transportability of carried items and the cutting-edge length of tools/blanks per unit mass are likely significant factors in technological efficiency.

Such UP settlement/procurement patterns contrast to the MP indicating more intensive occupations and exploitation of resources in rather restricted areas, such as the Mediterranean core zone in the LMP (Hovers and Belfer-Cohen, 2013; Meignen et al., 2006) and the central Negev (Marks, 1983, 1993; Marks and Freidel, 1977). In addition, seasonal changes in the nature of occupation have been suggested for the MP sites in southern Jordan; a winter base camp (Tor Faraj), located in the lower piedmont, is characterized by intensive and spatially organized occupation with dense accumulation of refuse while a shift to greater mobility during summer is indicated by an ephemeral camp (Tor Sabiha) in the higher piedmont (Henry, 1995, 2003, 2017a).

However, the IUP and the Ahmarian occupations may not have been always ephemeral but likely to have varied depending on such factors as site-functions, demography, and resource predictability. In fact, Kuhn (2004) suggests that UP occupations at Üçağızlı became more intensive and accommodated a larger and more diverse group of inhabitants in layers B and B1–B4 (the upper portion of the Ahmarian), which show expanded dietary breadth and greater density of stones, bones and ash. Importantly, this shift in occupational nature was associated with a change in raw material economy, which emphasizes the import of nodules or partially prepared cores in bulk from distant sources of good quality flint, indicating the strategy of provisioning places (Kuhn, 2004).

In provisioning of places, the transportability of bladelets may not have been very relevant to technological efficiency unless they were transported out of the site with logistical forays to exploit distant resources. Instead, the production of bladelets was probably beneficial in realizing economical consumption of costly raw material from distant sources. This is because the exploitation of cores can be extended by producing small blanks. The production of small blanks, like bladelets, create greater length of cutting-edge per unit mass of stone (Eren et al., 2008; Muller and Clarkson, 2016), thus reducing the consumption of raw material. At Üçağızlı layers B and B1–B4, a concern for efficient flint utilization is indicated by common occurrences of opposed platform cores, which are interpreted as "efforts to get the most out of cores of flint from distant sources" (Kuhn, 2004: 445). The same explanation can also apply to the production of bladelets if we assume a size reduction of blades from the IUP to the Ahmarian at Üçağızlı.

In addition to the diachronic change in raw material economy, as observed at Üçağızlı, its synchronic variations have been suggested for southern Levantine Ahmarian sites, where the size of blades and blade cores varies depending on the availability of raw material. For example, at sites far from flint sources in the northern and southern Sinai, blades and blade cores tend to be smaller and bladelets are retouched more frequently than those from the sites near flint sources, such as Qadesh Barnea and the central Negev (Gilead, 1983, 1991; Gilead and Bar-Yosef, 1993). Such a correlation between the intensity of bladelet production/use and the availability of flint indicates that the bladelet technology was implemented in a flexible manner in the Ahmarian; it was intensified in response to raw material restrictions and was relaxed under greater availability of flint. In the former situation, bladelet technology can be explained as a key strategy that helped foragers to exploit resources in areas devoid of flint. This may also apply to the situations in the Jebel Qalkha area in southern Jordan, where chert sources are limited in the extensive exposure of sandstone (Henry, 1995; Henry and Mraz, 2020). In fact, blades/bladelets from Tor Hamar tend to be smaller than other Ahmarian assemblages (Fig. 14).

The above argument for a causal link between mobility and lithic technology is somewhat similar to that proposed by Marks (1983, 1993), who explained a lithic technological change from the Levallois method to IUP blade production as an adaptation to increasing mobility under climatic deterioration. Marks explained that the IUP blade technology developed as a result of attempts to maximize the number of usable blanks per unit of raw material (Marks, 1983) in response to "less and less security as to the predictability of available flint sources" (Marks, 1983: 92), a problem incurred by increased mobility to exploit broader areas (see Henry et al., 2017 and Kadowaki et al., 2019b for more recent discussion on the expansion of resource exploitation territories from the MP to the UP).

However, according to recent experimental studies (Eren et al., 2008; Hoggard and Stade, 2018; Muller and Clarkson, 2016), blade production or the elongated form does not necessarily maximize the length of cutting-edge per unit mass of raw material. Instead, attributes related to size (such as width, thickness, and mass) are more significant factors for increasing the rate of cutting-edge production per unit mass of stone. Thus, given the large size of the IUP blades/bladelets (Fig. 14), they may not have been an optimal strategy for efficient flint utilization. In this sense, the increase of bladelets from the IUP to the Ahmarian can be understood as a further technological development in raw material economy that was selected under the UP settlement/procurement system.

7. Conclusion

The development of bladelet technology in the Ahmarian has been known as the first stage of 'micolithization' in the Levant (Belfer-Cohen and Goring-Morris, 2002), and the recent issue is the occurrences of bladelets in the IUP which is a critical chrono-cultural entity related to the range expansion of *Homo sapiens* in Eurasia (Boëda et al., 2015; Demidenko et al. 2020; Kuhn and Zwyns, 2014). Concerned with these backgrounds, this study examined the frequency and production technology of bladelets in the LMP, the IUP, and the Ahmarian mainly using four lithic assemblages from the Jebel Qalka area, southern Jordan, and discussed the results by referring to relevant data in the Levant.

Consequently, a clear increase in bladelets coincided with the Ahmarian, as already known. However, it was preceded by the slight increase in bladelets in the IUP assemblages (i.e., bladelet percentages in all blank types in Fig. 13). Importantly, this increase in bladelets was not associated with the miniaturization of blades (Fig. 14) but related to a shift in the main core reduction technology from the LMP Levallois systems to the volumetric (and along-axis) core reduction focusing on the production of blades/bladelets. There were some common technological elements for bladelet production in the LMP and the IUP, such as single platform volumetric bladelet cores, burin-cores, and platform attributes (i.e., large, often faceted platform with few overhang removals). However, they were fundamentally different from each other in the relationship of the bladelet production to the main flaking system. The LMP bladelet production had little connection to the main Levallois reductions while the IUP bladelet production is closely linked to the main blade production in the whole assemblages. Such unified production of blades and bladelets provided a technological basis, on which the miniaturization of blades/bladelets was achieved in the Ahmarian through the changes in platform preparation technique (Figs. 15 and 16 and possibly the shift to the soft hammer mode). Thus, we understand the microlithization in the Ahmarian not as a result of the 'emergence' of new bladelet technology but as a result of continuous technological development since the IUP.

The production and use of bladelets has often been suggested as a key behavior that gave advantage to AMHs in their competition with Neanderthals (Brown et al., 2012; Shea, 2007). However, in the Levant, the full development of the bladelet technology linked with the point production occurred in the Ahmarian, well after the disappearance of Neanderthals in the Levantine fossil record. In the IUP, which is temporally closer to this paleoanthropological horizon, bladelets still constituted a minor component of lithic technological repertoires.

However, it is notable that the establishment of bladelet technology in the Ahmarian was preceded by an incipient stage in the IUP when a shift in mobility patterns from the LMP had already taken place. This temporal sequence indicates that the settlement/procurement patterns since the IUP provided conditions in which the miniaturization of blades became beneficial. Currently available records indicate that UP land-use patterns are characterized by increased mobility in general (particularly in the IUP), but also involved diachronic and synchronic variability (i.e., both ephemeral and intensive occupations), associated with different provisioning strategies (i.e., provisioning of individuals and places: Kuhn, 2004). This means that there are some cases of bladelet production/use associated with high mobility, conforming to the previous models by Neely (2002) and Clarkson et al. (2018), but other cases that are associated with intensive occupations (e.g., Üçağızlı layers B and B1–B4), somewhat similar to the cases in the Middle and Late Epipaleolithic in the Levant (Neely, 2002) and possibly South Africa (Clarkson et al., 2018).

From the above observations, we suggest that significant performance characteristics of bladelets in the Levantine UP were the transportability and the efficient consumption of raw material, which were implemented flexibly in response to variable conditions of raw material availability, mobility, and provisioning strategies. Bladelet technology was employed as a versatile strategy in raw material economy, which was advantageous under variable mobility patterns and thus kept its popularity for a long time until the Epipaleolithic.

Lastly, paleoenvironmental data will also need to be examined in future as a potential background of the changing procurement/settlement systems. Further examinations of bladelet technology in the Levantine MP and UP will hopefully provide insights into broader issues, such as behavioral characteristics and dynamics of AMHs during their range expansion.

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References

Abulafia, T., Goder-Goldberger, M., Berna, F., Barzilai, O., Marder, O., in press. A technotypological analysis of the Ahmarian and Levantine Aurignacian assemblages from Manot Cave (Area C) and the interrelation with site formation processes. Journal of Human Evolution, https://doi.org/10.1016/j.jhevol.2019.102707

Aoki, K., Mesoudi, A. (Eds.), 2015. Learning strategies and cultural evolution during the Palaeolithic. Springer Japan.

Bamforth, D.B., Bleed, P., 1997. Technology, flaked stone technology and risk. In: Barton, C.M., Clark, A.G. (Eds.), Rediscovering Darwin: evolutionary theory and archeological explanation. Archeological papers of the American Anthropological Association Number 7, pp. 109–139.

Bar-Yosef, O., 2007. The archaeological framework of the Upper Paleolithic revolution. Diogenes 54 (3) 3–18.

Bar-Yosef, O., Belfer-Cohen, A., 2010a. The Levantine Upper Palaeolithic and Epipalaeolithic. In: Garcea, E.A.A. (Ed.), South-eastern Mediterranean peoples between 130,000 and 10,000 years ago. Oxbow Books, Oxford and Oakville, pp. 144–167.

Bar-Yosef, O., Belfer-Cohen, A., 2010b. The Middle to Upper Palaeolithic transition in western Asia. In: Boyle, K.W., Gamble, C., Bar-Yosef, O. (Eds.), The Upper Palaeolithic revolution in global perspective: papers in honour of sir Paul Mellars. McDonald Institute for Archaeological research, Cambridge, pp. 85–101.

Bar-Yosef, O., Belfer-Cohen, A., 2013. Following Pleistocene road signs of human dispersals across Eurasia. Quaternary International 285, 30–43.

Bar-Yosef, O., Belfer-Cohen, A., 2019. The Upper Paleolithic industries of Kebara Cave. In: Meignen, L., Bar-Yosef, O. (Eds.), Kebara Cave, Mt. Carmel, Israel: The Middle and Upper Paleolithic archaeology Part II. Peabody Museum of Archaeology and Ethnology, Harvard University, Massachusetts, pp. 309–401.

Barzilai, O., Gubenko, N., 2018. Rethinking Emireh Cave: The lithic technology perspectives. Quaternary International 464, 92–105.

Belfer-Cohen, A., Goring-Morris, N., 2002. Why microliths? Microlithization in the Levant. In: Elston, R.G., Kuhn, S.L. (Eds.), Thinking small: Global perspectives on microlithization. Archeological papers of the American Anthropological Association Number 12, pp. 57–68.

Belfer-Cohen, A., Goring-Morris, N., 2003. Final remarks and epilogue. In: Goring-Morris, A.N., Belfer-Cohen, A. (Eds.), More than meets the eye: Studies on Upper Palaeolithic diversity in the Near East. Oxbow Books, Oxford, pp. 274–280.

Boëda, E., 1994. Le Concept Levallois: Variabilité des Méthodes. Centre de la Recherche Scientifique (CNRS), Paris.

Boëda, E., Bonilauri, S., 2006. The intermediate Paleolithic: the first bladelet production 40,000 years ago. Anthropologie XLIV/1, 75–92.

Boëda, E., Bonilauri, S., Kaltnecker, E., Valladas, H., Al-Sakhel, H., 2015. Un débitage lamellaire au Proche-Orient vers 40000 ans cal BP. Le site d'Umm el Tlel, Syrie centrale. L'Anthropologie 119, 141–169.

Boyle, K.W., Gamble, C., Bar-Yosef, O. (Eds.), 2010. The Upper Palaeolithic revolution in global perspective: papers in honour of sir Paul Mellars. McDonald Institute for Archaeological research, Cambridge.

Brown, K.S., Marean, C.W., Jacobs, Z., Schoville, B.J., Oestmo, S., Fisher, E.C., Bernatchez, J., Karkanas, P., Matthews, T., 2012. An early and enduring advanced technology originating 71,000 years ago in South Africa. Nature 491, 590-593.

Clarkson, C., Hiscock, P., Mackay, A., Shipton, C., 2018. Small, sharp, and standardized: Global convergence in backed-microlith technology. In: O'Brien, M.L., Buchanan, B., Eren, M.I. (Eds.), Convergent evolution in stone-tool technology. Massachusetts: The MIT Press, Cambridge, pp. 175–220.

Coinman, N., Henry, D.O., 1995. The Upper Paleolithic sites. In: Henry, D.O. (Ed.), Prehistoric Cultural Ecology and Evolution: Insights from Southern Jordan. Plenum Press, New York, pp. 133–214.

Copeland, L., 1975. The Middle and Upper Palaeolithic of Lebanon and Syria in the light of recent research. In: Wendorf, F., Marks, A.E. (Eds.), Problems in prehistory: North Africa and the Levant. Southern Methodist University Press, Dallas, pp. 317–350.

Crew, H.L., 1976. The Mousterian site of Rosh Ein Mor. In: Marks, A.E. (Ed.), Prehistory and paleoenvironments in the Central Negev, Israel. Vol. I: the Avdat/Aqev area, Part 1. Southern Methodist University Press, Dallas, pp. 75–112.

Culley, E.V., Popescu, G., Clark, G.A., 2013. An analysis of the compositional integrity of the Levantine Mousterian facies. Quaternary International 300, 213–233.

Davidzon, A., Goring-Morris, A., 2003. Sealed in stone: the Upper Palaeolithic Early Ahmarian knapping method in the light of refitting studies at Nahal Nizzana XIII, western Negev, Israel. Journal of the Israel Prehistoric Society 33, 75–205.

Demidenko, Y.E., Škrdla, P., Rychtaříková, T., 2020. Initial Upper Paleolithic bladelet production: bladelets in Moravian Bohunician. Přehled výzkumů 61(1), 21–29.

Demidenko, Y.E., Usik, V.I., 2003. Into the mind of the maker: refitting study and technological considerations. In: Henry, D.O. (Ed.), Neanderthals in Levant: behavioral organization and the beginnings of human modernity. Continuum, London, pp. 107–155.

Dennell, R., 2020. From Arabia to the Pacific: How our species colonized Asia. Routledge, London and New York.

Douka, K., Bergman, C.A., Hedges, R.E.M., Wesselingh, F.P., Higham, T.F.G., 2013. Chronology of Ksar Akil (Lebanon) and implications for the colonization of Europe by anatomically modern humans. PLoS One 8, e72931.

Elston, R.G., Kuhn, S.L. (Eds.), 2002. Thinking small: Global perspectives on microlithization. Archeological papers of the American Anthropological Association Number 12.

Eren, M.I., Greenspan, A., Sampson, C.G., 2008. Are Upper Paleolithic blade cores more productive than Middle Paleolithic discoidal cores? A replication experiment. Journal of Human Evolution 55, 952–961.

Eren, M.I., Lycett, S.J., 2012. Why Levallois? A morphometric comparison of experimental 'preferential' Levallois flakes versus debitage flakes. PLoS ONE 7 (1), e29273.

Faivre, J.-P., 2012. A material anecdote but technical reality: bladelet and small blade production during the recent Middle Paleolithic at Combe-Grenal rock shelter. Lithic Technology 37 (1) 5–25.

Fox, J., 2003. The Tor Sadaf lithic assemblages: a technological study of the Early Upper Palaeolithic in the Wadi al-Hasa. In: Goring-Morris, A.N., Belfer-Cohen, A. (Eds.), More than meets the eye: studies on Upper Palaeolithic diversity in the Near East. Oxbow Books, Oxford, pp 80–94.

Fox, J., Coinman, N., 2004. Emergence of the Levantine Upper Paleolithic. In: Brantingham, P., Kuhn, S., Kerry, K. (Eds.), The Early Upper Paleolithic beyond western Europe. University of California Press, Berkley, pp. 97–112.

Fu, Q., Li, H., Moorjani, P., Jay, F., Slepchenko, S.M., Bondarev, A.A., Johnson, P.L.F., Aximu-Petri, A., Prüfer, K., de Filippo, C., Meyer, M., Zwyns, N., Salazar-García, D.C., Kuzmin, Y.V., Keates, S.G., Kosintsev, P.A., Razhev, D.I., Richards, M.P., Peristov, N.V., Lachmann, M., Douka, K., Higham, T.F.G., Slatkin, M., Hublin, J.-J., Reich, D., Kelso, J., Viola, T.B., Pääbo, S., 2014. Genome sequence of a 45,000-year-old modern human from western Siberia. Nature 514, 445–

449.
Garrod, D.A.E., 1951. A transitional industry from the base of the Upper Palaeolithic in Palestine and Syria. The Journal of the Royal Anthropological Institute of Great Britain and Ireland 81, 121–130.
Garrod, D.A.E., 1955. The Mugharet el-Emireh in Lower Galilee: type-station of the Emiran industry. The Journal of the Royal Anthropological Institute of Great Britain and Ireland 85, 141–162.
Gilead, I., 1981. Upper Palaeolithic tool assemblages from the Negev and Sinai. In: Cauvin, J., Sanlaville, P. (Eds.), Préhistoire du Levant. Centre National de la Recherche Scientifique, Paris, pp. 331–342.
Gilead, I., 1983. Upper Palaeolithic occurrences in Sinai and the transition to the Epi-Palaeolithic in the southern Levant. Paléorient 9 (1), 39–53.
Gilead, I., 1991. The Upper Paleolithic period in the Levant. Journal of World Prehistory 5 (2) 105–154.
Gilead, I., Bar-Yosef, O., 1993. Early Upper Paleolithic sites in the Qadesh Barnea area, NE Sinai. Journal of Field Archaeology 20, 265–280.
Goder-Goldberger, M., Crouvi, O., Caracuta, V., Horwitz, L.K., Neumann, F.H., Porat, N., Scott, L., Shavit, R., Jacoby-Glass, Y., Zilberman, T., Boaretto, E., 2020. The Middle to Upper Paleolithic transition in the southern Levant: New insights from the late Middle Paleolithic site of Far in II, Israel. Quaternary Science Review 237, 106304.
Goring-Morris, A.N., Belfer-Cohen, A. (Eds.), 2003. More than meets the eye: studies on Upper Palaeolithic diversity in the Near East. Oxbow Books, Oxford.
Goring-Morris, A.N., Belfer-Cohen, A., 2018. The Ahmarian in the context of the earlier Upper Palaeolithic in the Near East. In: Nishiaki, Y., Akazawa, T. (Eds.), The Middle and Upper Paleolithic of the Levant and beyond. Springer Nature, Singapore, pp. 87–104.
Goring-Morris, A.N., Belfer-Cohen, A., in press. Noisy beginnings: the initial Upper Palaeolithic in Southwest Asia. Quaternary International, https://doi.org/10.1016/j.quaint.2020.01.017
Goring-Morris, A.N., Davidzon, A., 2006. Straight to the point: Upper Paleolithic Ahmarian lithic technology in the Levant. Anthropologie XLIV/1, 93–111.
Groucutt, H.S., Scerri, E.M.L., Stringer, C., Petraglia, M.D., 2019. Skhul lithic technology and the dispersal of *Homo sapiens* into southwest Asia. Quaternary International 515, 30–52.
Hauck, T.C., 2015. Dynamics of culture change at the beginning of the Near Eastern Upper Paleolithic. In: Schyle, D., Richter, J. (Eds.), Pleistocene archaeology of the Petra area in Jordan. Verlag Marie Leidorf GmbH, Rahden/Westf., pp. 407–419.
Henry, D.O., 1994. Prehistoric cultural ecology in southern Jordan. Science 265, 336–341.
Henry, D.O., 1995. Prehistoric cultural ecology and evolution. Plenum Press, New York.
Henry, D.O. (Ed.), 2003. Neanderthal in the Levant: behavioral organization and the beginnings of human modernity. Continuum, London.
Henry, D.O., 2017a. The Middle Palaeolithic of southern Jordan. In: Enzel, Y., Bar-Yosef, O. (Eds.), Quaternary of the Levant: environments, climate change, and humans. Cambridge University Press, Cambridge, pp. 585–591.
Henry, D.O., 2017b. The Upper and Epipalaeolithic of southern Jordan. In: Enzel, Y., Bar-Yosef, O. (Eds.), Quaternary of the Levant: environments, climate change, and humans. Cambridge University Press, Cambridge, pp. 659–667.
Henry, D.O., Belmaker, M., Bergin, S., 2017. The effect of terrain on Neanderthal ecology in the Levant. Quaternary International 435, 94–105.
Henry, D.O., Mraz, V., 2020. Lithic economy and prehistoric human behavioral ecology viewed from southern Jordan. Journal of Archaeological Science: Reports 29, 102089.
Hiscock, P., Clarkson, C., MacKay, A., 2011. Big debates over little tools: ongoing disputes over microliths on three continents. World Archaeology 43, 653–664.
Hoggard, C.S., Stade, C.M., 2018. The efficiency of Middle Palaeolithic technological blade strategies: an experimental investigation. Lithics 39, 52–67.
Hovers, E. 1998 The lithic assemblages of Amud Cave: implications for understanding the end of the Mousterian in the Levant. In: Akazawa, T., Aoki, K., Bar-Yosef, O. (Eds.), Neandertals and

modern humans in western Asia. Plenum Press, New York, pp 143–163.

Hovers, E., 2009. The lithic assemblages of Qafzeh Cave. Oxford University Press, Oxford.

Hovers, E., Belfer-Cohen, A., 2013. On variability and complexity: Lessons from the Levantine Middle Paleolithic record. Current Anthropology 54, Supplement 8, S337–S357.

Hovers, E., Malinsky-Buller, A., Goder-Goldberger, M., Ekshtain, R., 2011. Capturing a moment: identifying short-lived activity locations in Amud Cave, Israel. In: Le Tensorer, J.-M., Jagher, R., Otte, M. (Eds.), The Lower and Middle Palaeolithic in the Middle East and neighbouring regions, ERAUL 126. Liège, pp. 101–114.

Hublin, J.-J., 2015. The modern human colonization of western Eurasia: when and where? Quaternary Science Reviews 118, 194–210.

Hublin, J.-J., Sirakov, N., Aldeias, V., Bailey, S., Bard, E., Delvigne, V., Endarova, E., Fagault, Y., Fewlass, H., Hajdinjak, M., Kromer, B., Krumov, I., Marreiros, J., Martisius, N.L., Paskulin, L., Sinet-Mathiot, V., Meyer, M., Pääbo, S., Popov, V., Rezek, Z., Sirakova, S., Skinner, M.M., Smith, G.M., Spasov, R., Talamo, S., Tuna, T., Wacker, L., Welker, F., Wilcke, A., Zahariev, N., McPherron, S.P., Tsanova1, T., 2020. Initial Upper Palaeolithic *Homo sapiens* from Bacho Kiro Cave, Bulgaria. Nature 581, 299–302.

Inizan, M.-L., Reduron-Ballinger, M., Roche, H., Tixier, J., 1999. Technology and terminology of knapped stone. CREP, Nanderre.

Jelinek, A.J., 1982. The Tabūn Cave and Paleolithic man in the Levant. Science 216, 1369–1375.

Jones, M., Marks, A.E., Kaufman, D., 1983. Boker: the artifacts. In: Marks, A.E. (Ed.), Prehistory and Paleoenvironments in the Central Negev, Israel, Volume III: The Avdat/Aqev Area, Part 3. Southern Methodist University, Dallas, pp. 283–329.

Kadowaki, S., 2013. Issues of chronological and geographical distributions of Middle and Upper Palaeolithic cultural variability in the Levant and implications for the learning behavior of Neanderthals and *Homo sapiens*. In: Akazawa, T., Nishiaki, Y., Aoki, K. (Eds.), Dynamics of learning in Neanderthals and modern humans Vol. 1: cultural perspectives. Springer, New York, pp. 59–91.

Kadowaki, S., 2017. Technology of striking platform preparation on lithic debitage from Wadi Aghar, southern Jordan, and its relevance to the Initial Upper Palaeolithic technology in the Levant. Al-Rāfidān 38, 23–32.

Kadowaki, S., Henry, D.O., 2019. Renewed investigation of the Middle and Upper Paleolithic sites in the Jebel Qalkha area, southern Jordan. In: Nakamura, S., Adachi, T., Abe, M., (Eds.), Decades in deserts: essays on western Asian archaeology in honor of Sumio Fujii. Rokuichi Shobo, Japan, pp. 23–41.

Kadowaki, S., Kurozumi, T., Henry, D. O., 2019a. Marine shells from Tor Fawaz, southern Jordan, and their implications for behavioral changes from the Middle to Upper Paleolithic in the Levant. In: Nishiaki, Y., Joris, O. (Eds.), Learning Among Neanderthals and Palaeolithic Modern Humans. Springer Nature, Singapore, pp. 161–178.

Kadowaki, S., Omori, T., Nishiaki, Y., 2015. Variability in Early Ahmarian lithic technology and its implications for the model of a Levantine origin of the Protoaurignacian. Journal of Human Evolution 82, 67–87.

Kadowaki, S., Tamura, T., Sano, K., Kurozumi, T., Maher, L.A., Wakano, J.Y., Omori, T., Kida, R., Hirose, M., Massadeh, S., Henry, D.O., 2019b. Lithic technology, chronology, and marine shells from Wadi Aghar, southern Jordan, and Initial Upper Paleolithic behaviors in the southern inland Levant. Journal of Human Evolution 135, 102646.

Kaifu, Y., Izuho, M., Goebel, T., Sato, H., Ono, A. (Eds.), 2015. Emergence and diversity of modern human behavior in Paleolithic Asia. Texas A&M University Press, College Station.

Kerry, K.W., Henry, D.O., 2003. Tor Fawaz (J403): An Upper Paleolithic occupation in the Jebel Qalkha Area, southwest Jordan. In: Goring-Morris, A.N., Belfer-Cohen, A. (Eds), More than meets the eye: Studies on Upper Palaeolithic diversity in the Near East. Oxbow, Oxford, pp 171–184

Kuhn, S.L., 2002. Pioneers of microlithization: the “proto-Aurignacian” of southern Europe. In: Elston, R.G., Kuhn, S.L. (Eds.), Thinking small: global perspectives on microlithization, (Archaeological Papers of the American Anthropological Association12). American

Anthropological Association, Arlington, pp. 83–93.

Kuhn, S.L., 2003. In what sense is the Levantine Initial Upper Paleolithic a “transitional” industry? In: Zilhão, J., d’Errico, F. (Eds.), The chronology of the Aurignacian and of the transitional technocomplexes: dating, stratigraphies, cultural implications. Instituto Português de Arqueologia, Lisbon, pp. 61–70.

Kuhn, S.L., 2004. Upper Paleolithic raw material economies at Ücağızlı cave, Turkey. Journal of Anthropological Archaeology 23, 431–448.

Kuhn, S., Stiner, M.C., Güleç, E., Özer, I., Yılmaz, H., Baykara, I., Ayşen, A., Goldberg, P., Martínez, Molina, K., Ünay. E., Suata-Alpaslan, F., 2009. The early Upper Paleolithic occupations at Ücağızlı Cave (Hatay, Turkey). Journal of Human Evolution 56, 87–113.

Kuhn, S.L., Zwyns, N., 2014. Rethinking the initial Upper Paleolithic. Quaternary International 347, 29–38.

Leder, D., 2014. Technological and typological change at the Middle to Upper Palaeolithic boundary in Lebanon. Verlag Dr. Rudolf Habelt GmbH, Bonn.

Leder, D., 2016. Core reduction strategies at the Initial Upper Palaeolithic sites Ksar Akil and Abou Halka in Lebanon. Lithics 37, 33–54.

Leder, D., 2018. Lithic variability and techno-economy of the Initial Upper Palaeolithic in the Levant. International Journal of Archaeology 6 (1) 23–36.

Lycett, S.J., Norton, C.J., 2010. A demographic model for Palaeolithic technological evolution: the case of East Asia and the Movius Line. Quaternary International 211, 55–65.

Malinsky-Buller et, A., Ekshtain, R., Hovers, E., 2014. Organization of lithic technology at ‘Ein Qashish, a late Middle Paleolithic open-air site in Israel. Quaternary International 331, 234‑247.

Marks, A.E., 1976. Glossary. In: Marks, A.E. (Ed.), Prehistory and Paleoenvironments in the Central Negev, Israel, Volume III: The Avdat/Aqev Area, Part 1. Southern Methodist University, Dallas, pp. 371–383.

Marks, A.E., 1981. The Upper Paleolithic of the Negev. In: Cauvin, J., Sanlaville, P. (Eds.), Préhistoire du Levant. Centre National de la Recherche Scientifique, Paris, pp. 299–304.

Marks, A.E., 1983. The Middle to Upper Paleolithic transition in the Levant. In: Wendorf, F., Close, A.E. (Eds.), Advances in world archaeology volume 2. Academic Press, New York, pp. 51–98.

Marks, A.E., 1993. The Early Upper Paleolithic: The view from the Levant. In: Knecht, H., Pike-Tay, A., White, R. (Eds.), Before Lascaux: The complex record of the Early Upper Paleolithic. CRC Press, pp. 5–21.

Marks, A.E., Ferring, C.R., 1988. The Early Upper Palaeolithic of the Levant. In: Hoffecker, J.E., Wolf, C.A. (Eds.), The Early Upper Palaeolithic: evidence from Europe and the Near East, BAR International Series 437. B.A.R., Oxford, pp. 43–72.

Marks, A.E., Freidel, D.A., 1977. Prehistoric settlement patterns in the Avdat/Aqev area. In: Marks, A.E. (Ed.), Prehistory and paleoenvironments in the central Negev, Israel: the Avdat/Aqev area, Part 2. Southern Methodist University, Dallas, pp. 131–158.

Marks, A., Kaufman, D., 1983. Boker Tachtit: the artifacts. In: Marks, A. (Ed.), Prehistory and paleoenvironments in the central Negev, Israel: the Avdat/Aqev area, Part 3. Southern Methodist University, Dallas, pp. 69–125.

Meignen, L., 2012. Levantine perspectives on the Middle to Upper Paleolithic “transition”. Archaeology Ethnology & Anthropology of Eurasia 40 (3) 12–21.

Meignen, L., 2019. The Mousterian lithic assemblages from Kebara Cave. In: Meignen, L., Bar-Yosef, O. (Eds.), Kebara Cave, Mt. Carmel, Israel: The Middle and Upper Paleolithic archaeology Part II. Peabody Museum of Archaeology and Ethnology, Harvard University, Massachusetts, pp. 1–147.

Meignen, L., Bar-Yosef, O., Speth, J.D., Stiner, M.C., 2006. Middle Paleolithic settlement patterns in the Levant. In: Hovers, E., Kuhn, S. (Eds.), Transitions before the transition: Evolution and stability in the Middle Paleolithic and Middle Stone Age. Springer, New York, pp. 149–169.

Mellars, P. (Ed.), 1990. The emergence of modern humans: an archaeological perspective. Edinburgh University Press, Edinburgh.

Mellars, P., 2006. Going east: new genetic and archaeological perspectives on the modern human colonization of Eurasia. Science 313, 796–800.

Mellars, P., Boyle, K., Bar-Yosef, O., Stringer, C. (Eds.), 2007. Rethinking the human revolution. University of Cambridge, Cambridge.

Muller, A., Clarkson, C., 2016. Identifying major transitions in the evolution of lithic cutting edge production rates. PLoS ONE 11(12) e0167244.

Neely, M.P., 2002. Going microlithic: a Levantine perspective on the adoption of microlithic technologies. In: Elston, R.G., Kuhn, S.L. (Eds.), Thinking small: Global perspectives on microlithization. Archeological papers of the American Anthropological Association Number 12, pp. 45–56.

Nelson, M.C., 1991. The study of technological organization. Archaeological Method and Theory 3, 57–100.

Neuville, R., 1951. Le Paléolithique et le Mésolithique du Désert de Judée. Archives l'Institut de PaléontologieHumaine, Paris.

Nishiaki, Y., 1985. Truncated-faceted flakes from Levantine Mousterian assemblages. Bulletin of Department of Archaeology, the University of Tokyo 4, 215–226.

Nishiaki, Y., 2018. Initial Upper Paleolithic elements of the Keoue cave, Lebanon. In: Nishiaki, Y., Akazawa, T. (Eds.), The Middle and Upper Paleolithic of the Levant and beyond. Springer Nature, Singapore, pp. 71–86.

Nitecki, M.H., Nitecki, D.V. (Eds.), 1994. Origins of anatomically modern humans. Plenum Press, New York and London.

O'Connor, S., 2015. Crossing the Wallace Line: the maritime skills of the earliest colonists in the Wallacean Archipelago. In: Kaifu, Y., Izuho, M., Goebel, T., Sato, H., Ono, A. (Eds.), Emergence and diversity of modern human behavior in Paleolithic Asia. Texas A&M University Press, College Station, pp. 214–224.

Ohnuma, K., 1988. Ksar 'Akil, Lebanon: a technological study of the earlier Upper Palaeolithic levels of Ksar 'Akil, vol. III. Levels XXV-XIV. BAR International Series 426. B.A.R., Oxford.

Ohnuma, K., Bergman, C.A., 1990. A technological analysis of the Upper Palaeolithic levels (XXV–VI) of Ksar Akil, Lebanon. In: Mellars, P. (Ed.), The emergence of modern humans: an archaeological perspective. Edinburgh University, Edinburgh, pp. 91–138.

Ohnuma, K., Bergman, C.A., 2013. Technological notes concerning "partially faceted butt" on débitage from the Initial and Early Upper Palaeolithic levels of Ksar Akil, Lebanon. Iranian Archaeology 4, 7–14.

Rabb'a, I., 1987. Geological Map Sheet, 1:50000, Al Quwayra (3049 I). Hashemite Kingdom of Jordan, Ministry of Energy and Mineral Resources, National Resource Authority, Geology Directorate, Amman.

Roberts, P., Amano, N., 2019. Plastic pioneers: Hominin biogeography east of the Movius Line during the Pleistocene. Archaeological Research in Asia 17, 181–192.

Rose, J.I., Marks, A.E., 2014. "Out of Arabia" and the Middle-Upper Palaeolithic transition in the southern Levant. Quartär 61, 49–85.

Shea, J., 2003. The Middle Paleolithic of the east Mediterranean Levant. Journal of World Prehistory 17 (4) 313–394.

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

Shea, J., 2007. Behavioral differences between Middle and Upper Paleolithic *Homo sapiens* in the East Mediterranean Levant: the roles of intraspecific competition and dispersal from Africa. Journal of Anthropological Research 63 (4) 449–488.

Shea, J., 2013. Stone tools in the Paleolithic and Neolithic Near East: a guide. Cambridge University Press, Cambridge.

Shea, J., Stutz, A.J., Nilsson-Stutz, L., 2019. An Early Upper Palaeolithic stone tool assemblage from Mughr El-Hamamah, Jordan: An interim report. Journal of Field Archaeology 44 (7) 420–439.

Solecki, R.L., Solecki, R.S., 1970. A new secondary flaking technique at the Nahr Ibrahim Cave site (Lebanon). Bulletin Musée de Beyrouth 23, 1377uave

Stiner, M.C., 2014. Finding a common bandwidth: causes of convergence and diversity in Paleolithic beads. Biological Theory 9 (1) 51–64.

Stringer, C., 2012. Lone survivors: how we came to be the only humans on earth. Times Books, New York.
Stutz, A.J., Shea, J.J., Rech, J.A., Pigati, J.S., Wilson, J., Belmaker, M., Albert, R.M., Arpin, T., Cabanes, D., Clark, J.L., Hartman, G., Hourani, F., White, C.E., Stutz, L.N., 2015. Early Upper Paleolithic chronology in the Levant: new ABOx-SC accelerator mass spectrometry results from the Mughr el-Hamamah Site, Jordan. Journal of Human Evolution 85, 157–173.
Tixier, J., 1963. Typologie de I'Epipaléolithique du Maghreb. Mémoires du Centre de Recherches Anthropologiques, Préhistoriques et Ethnographiques 2. Paris, Arts et Métiers Graphiques.
Torrence, R., 1989. Retooling: toward a behavioral theory of stone tools. In: Torrence, R. (Ed.), Time, energy and stone tools. Cambridge University Press, Cambridge, pp. 57–66.
Torrence, R., 2002. Thinking big about small tools. In: Elston, R.G., Kuhn, S.L. (Eds.), Thinking small: Global perspectives on microlithization. Archeological papers of the American Anthropological Association Number 12, pp. 179–189.
Villa, P., Roebroeks, W., 2014. Neandertal demise: an archaeological analysis of the modern human superiority complex. PLoS ONE 9 (4), e96424.
Wakano, J.Y., Gilpin, W., Kadowaki, S., Feldman, M.W., Aoki, K., 2018. Ecocultural range-expansion scenarios for the replacement or assimilation of Neanderthals by modern humans. Theoretical Population Biology 119, 3–14.
Wiseman, M.F., 1993. Lithic blade elements from the southern Levant: A diachronic view of changing technology and design process. Mitekufat Haeven—Journal of the Israel Prehistoric Society 25, 13–102.
Zwyns, N., Rybin, E.P., Hublin, J.-J., Derevianko, A.P., 2012. Burin-core technology and laminar reduction sequences in the initial Upper Paleolithic from Kara-Bom (Gorny-Altai, Siberia). Quaternary International 259, 33–47.

Table 1: General inventories of chipped stone artifacts from Tor Faraj, Wadi Aghar, Tor Fawaz, and Tor Hamar in the Jebel Qalkha area, southern Jordan

Cultural entities	Late Middle Paleolithic	Initial Upper Paleolithic	Initial Upper Paleolithic	Ahmarian
Site	Tor Faraj	Wadi Aghar	Tor Fawaz	Tor Hamar
Excavation areas (Units)	A4, B2, B3, B4	100, 101, C, D, 83-1, 83-2	6, 7, 8, 9, 10	9, 10
Layers	E	C–D1	Surface, B2, C	F, G
Retouched tools	23	29	187	91
Levallois points (unretouched points)	7	0	5 (Levallois-like and other large points)	0
Levallois blades	15	0	7	0
Levallois flakes	40	0	0	0
Blades	43	57	541	175
Bladelets	21	14	162	407
Partially cortical blades	5	11	156	37
Partially cortical bladelets	2	1	5	25
Cortical blades	2	2	25	7
Flakes	197	95	933	452
Partially cortical flakes	67	40	511	140
Cortical flakes	21	19	309	53
Core trimming elements	23	10	65	35
Spalls	5	1	19	33
Cores	10	9	82	43
Chips	567	214	3303	2690
Chunks	3	3	42	16
TOTAL	1051	505	6352	4204
References	Kadowaki and Henry 2019	Kadowaki et al., 2019b	Kadowaki et al., 2019a	Kadowaki and Henry 2019

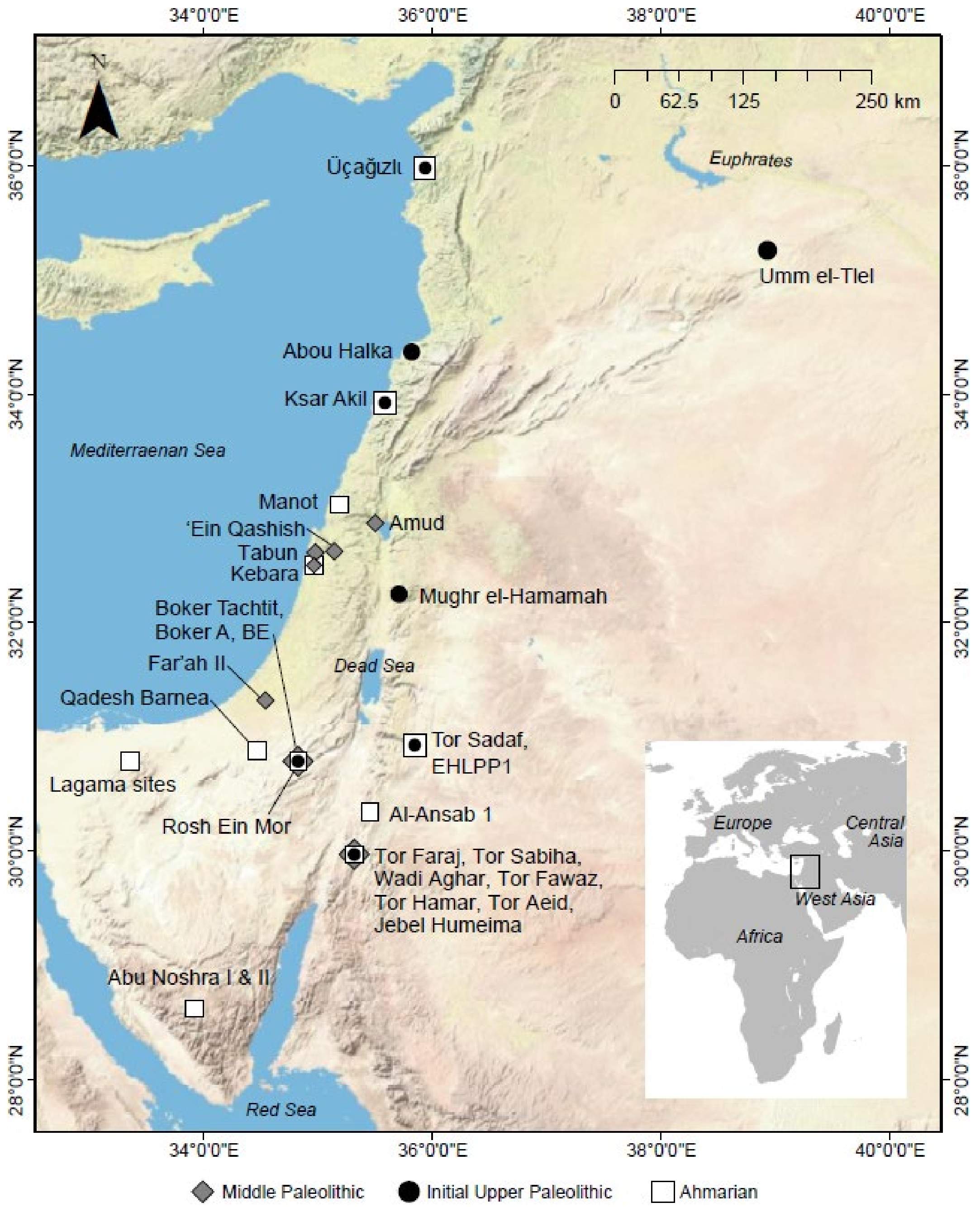

Fig. 1: Map of the Levant, showing the locations of archaeological sites mentioned in the text. Designation of chrono-cultural entities (Middle Paleolithic, Initial Upper Paleolithic, and Ahmarian) are based on the lithic assemblages mentioned in the paper.

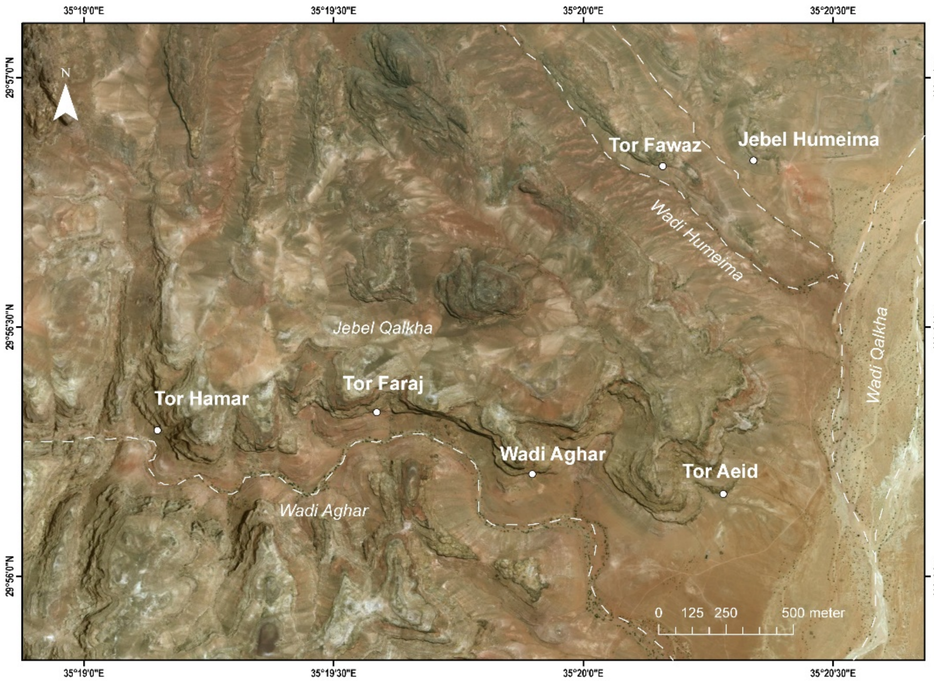

Fig. 2: Satellite image of the Jebel Qalkha area, showing the locations of sites studied in the paper. Tor Faraj (LMP), Wadi Aghar (IUP), Tor Fawaz (IUP), Tor Hamar (Ahmarian), Jebel Humeima (Ahmarian), Tor Aeid (Ahmarian).

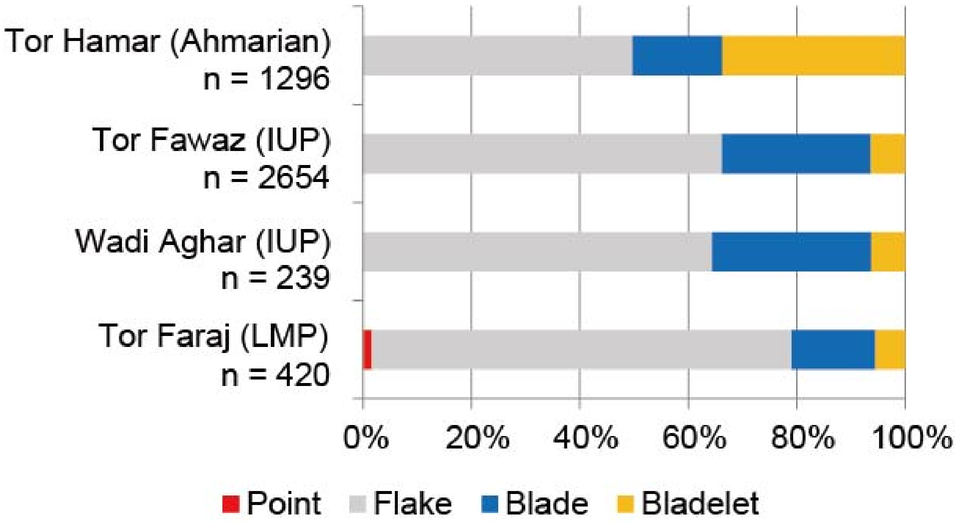

Fig. 3: Relative frequencies of four morphological groups of debitage from Tor Faraj, Wadi Aghar, Tor Fawaz, and Tor Hamar in the Jebel Qalkha area. See text for details of the morphological groups.

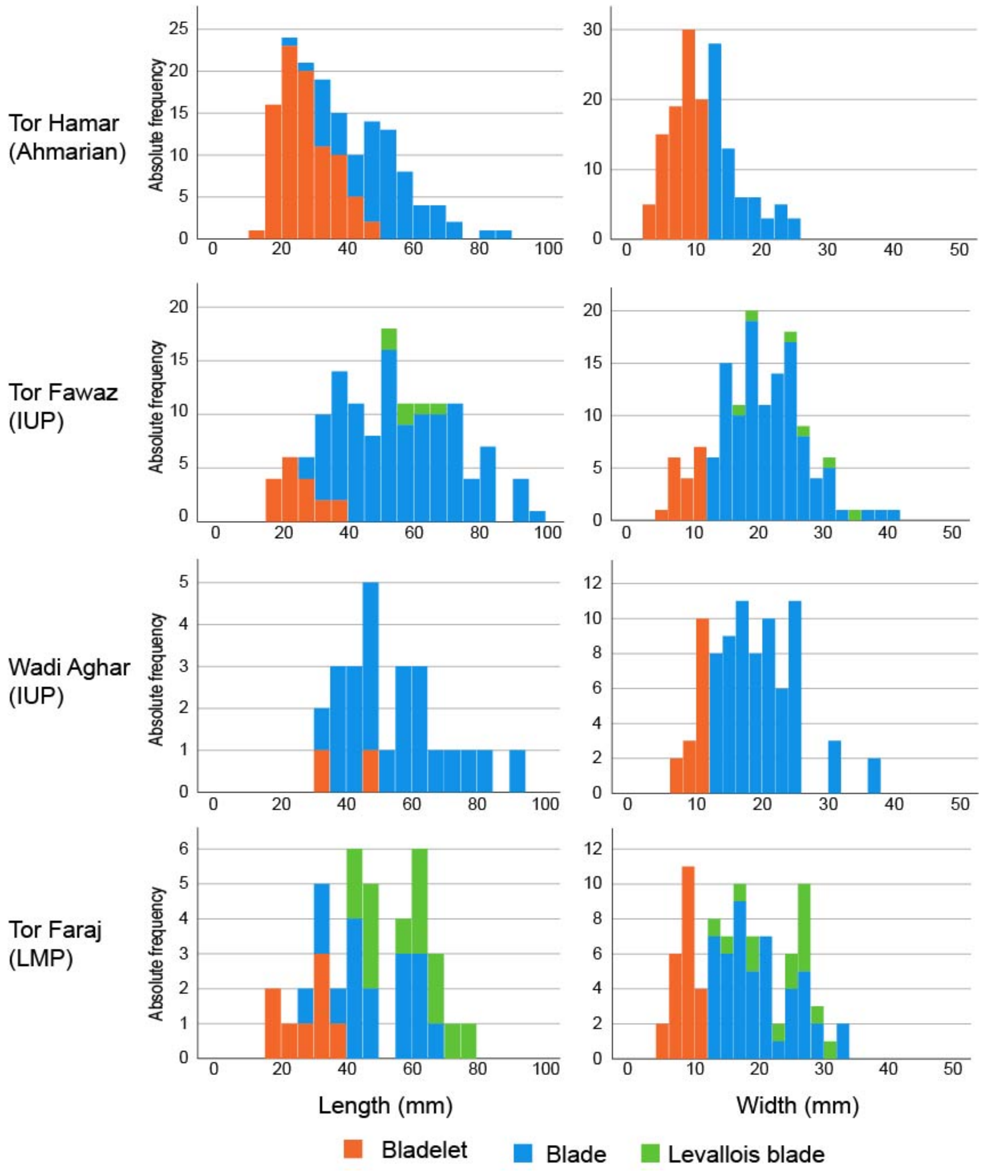

Fig. 4: Histograms of length and width of blades/bladelets from Tor Faraj, Wadi Aghar, Tor Fawaz, and Tor Hamar.

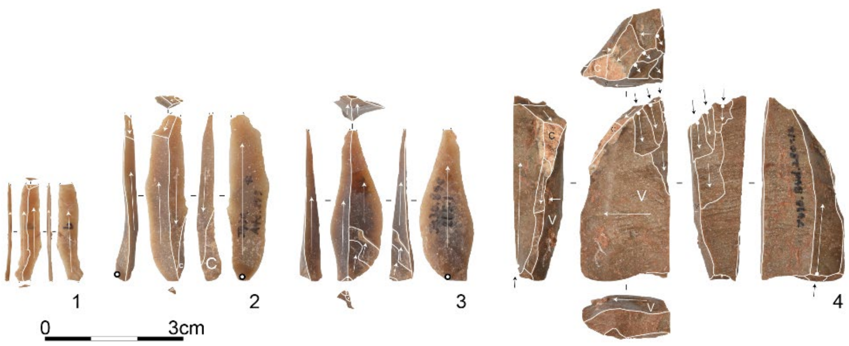

Fig. 5: Bladelets (1–3) and a burin with bladelet scars (4) from Tor Faraj Layer E. Arrows on flaking scars (outlined) show flaking directions. ‘C’ indicates cortex. ‘V’ means a ventral face of a blank.

Fig. 6: Bladelets (1–4) and bladelet cores (5: Burin-core on blade, 6: Volumetric convergent core) from Wadi Aghar. Arrows on flaking scars (outlined) show flaking directions. ‘C’ indicates cortex.

Fig. 7: Bladelets (1–9) and bladelet cores (10–11: Burin-cores on flakes, 12: Single platform volumetric parallel core on block) from Tor Fawaz. Arrows on flaking scars (outlined) show flaking directions. ‘C’ indicates cortex. ‘V’ means a ventral face of a blank.

Fig. 8: El-Wad points made on bladelets (1–5) and single platform bladelet cores (6: Core-on-flake, 7: Core-on-cobble, 8: Incipient stage of core-on-flake with a narrow working surface, 9: Core-on-cobble with a narrow working surface) from Tor Hamar Layers F and G. Arrows on flaking scars (outlined) show flaking directions. 'C' indicates cortex. 'V' means a ventral face of a blank.

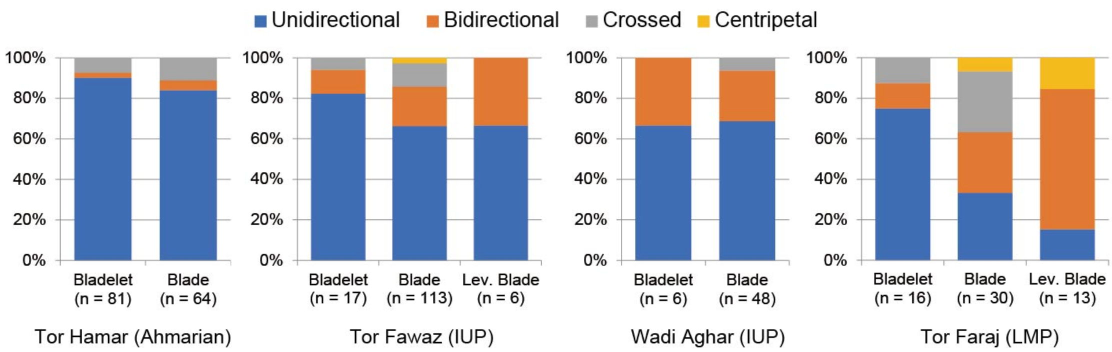

Fig. 9: Relative frequencies of dorsal scar patterns on blades/bladelets and Levallois blades from Tor Faraj, Wadi Aghar, Tor Fawaz, and Tor Hamar.

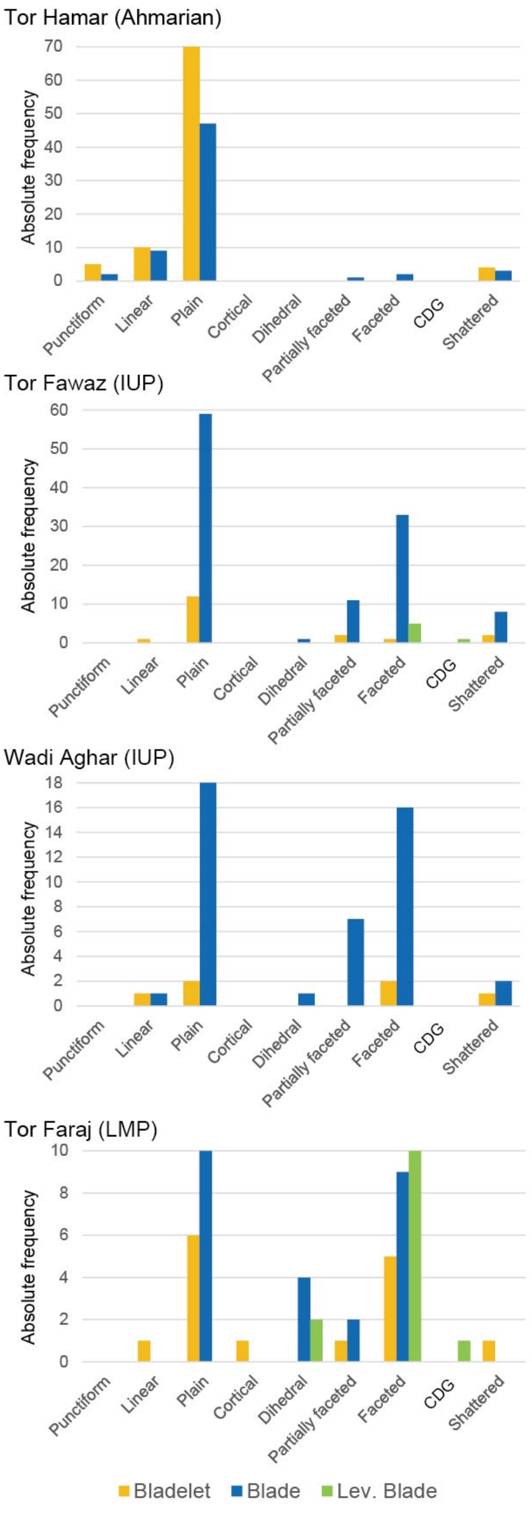

Fig. 10: Frequencies of platform types of blades/bladelets and Levallois blades from Tor Faraj, Wadi Aghar, Tor Fawaz, and Tor Hamar. CDG = *Chapeau de gendarme*

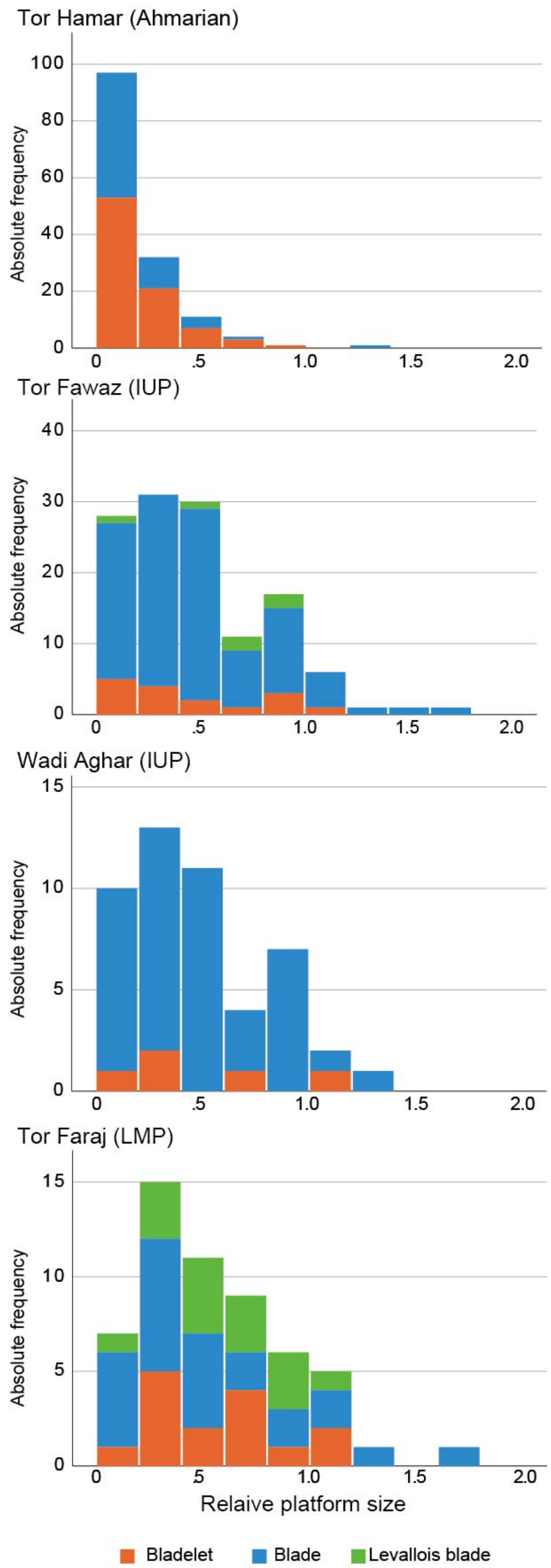

Fig. 11: Histogram of the relative platform size (see text for the definition) of blades/bladelets and Levallois blades from Tor Faraj, Wadi Aghar, Tor Fawaz, and Tor Hamar.

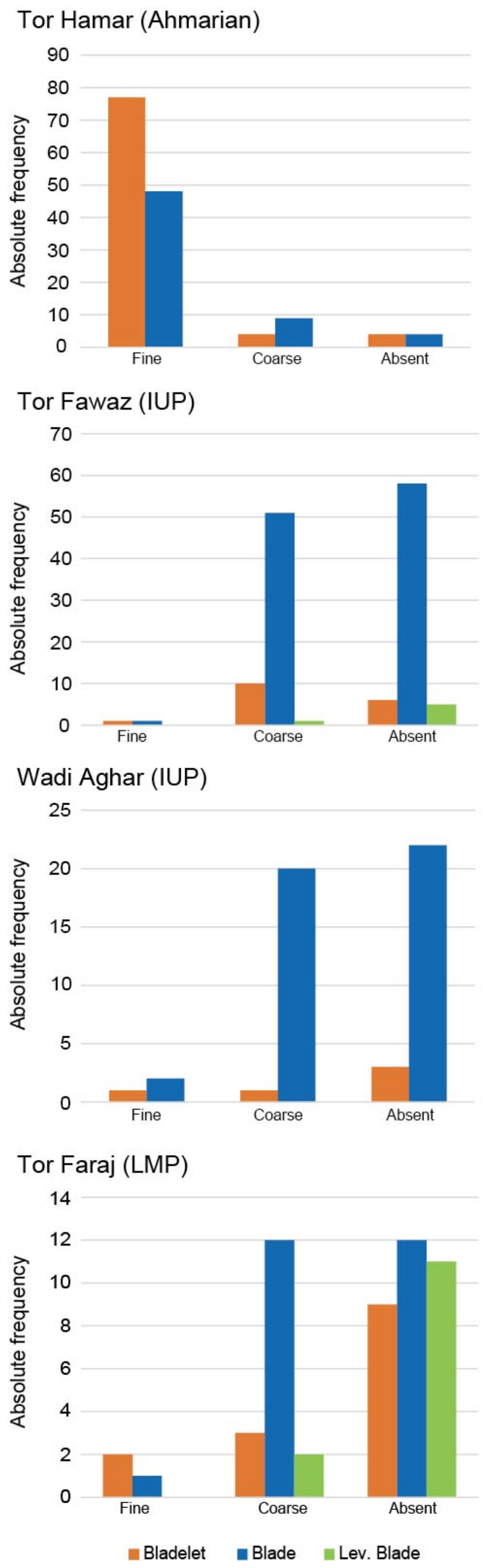

Fig. 12: Frequencies of overhang removals of blades/bladelets and Levallois blades from Tor Faraj, Wadi Aghar, Tor Fawaz, and Tor Hamar. Coarse = coarse flaking. Fine = fine flaking/abrasion.

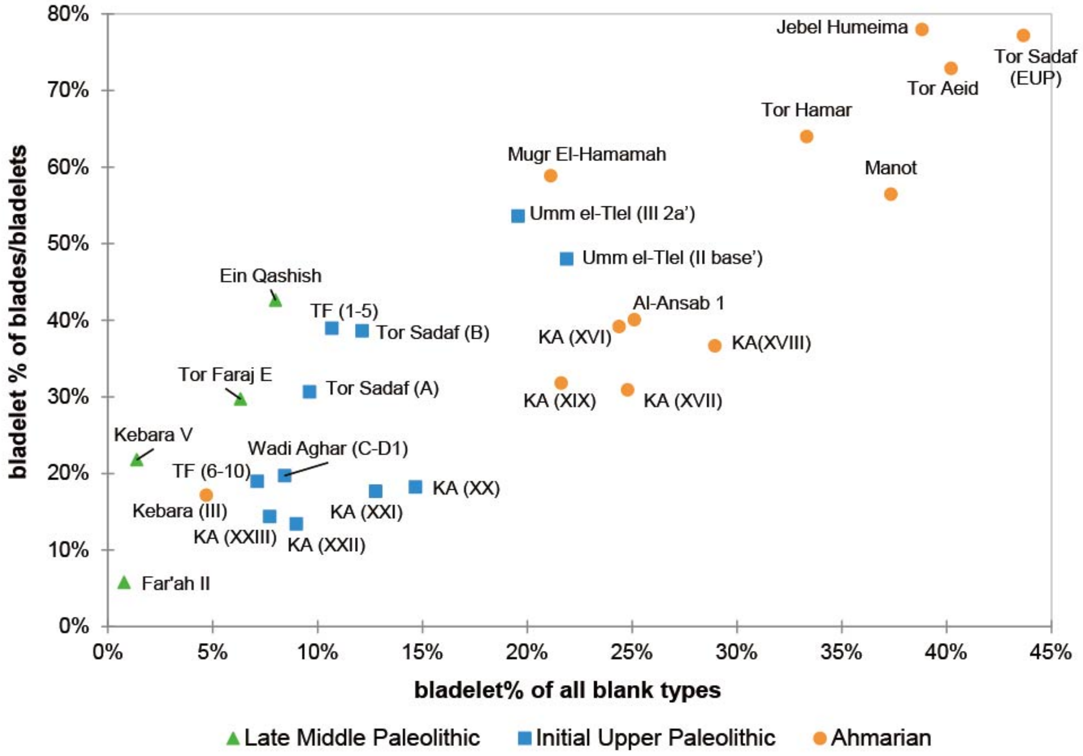

Fig. 13: Relative frequencies of bladelets in blades/bladelets and those in all blank types (see text for the definition) in LMP, IUP, and Ahmarian assemblages in the Levant. KA is Ksar Akil, and TF is Tor Fawaz. See SOM Table S2 for data sources.

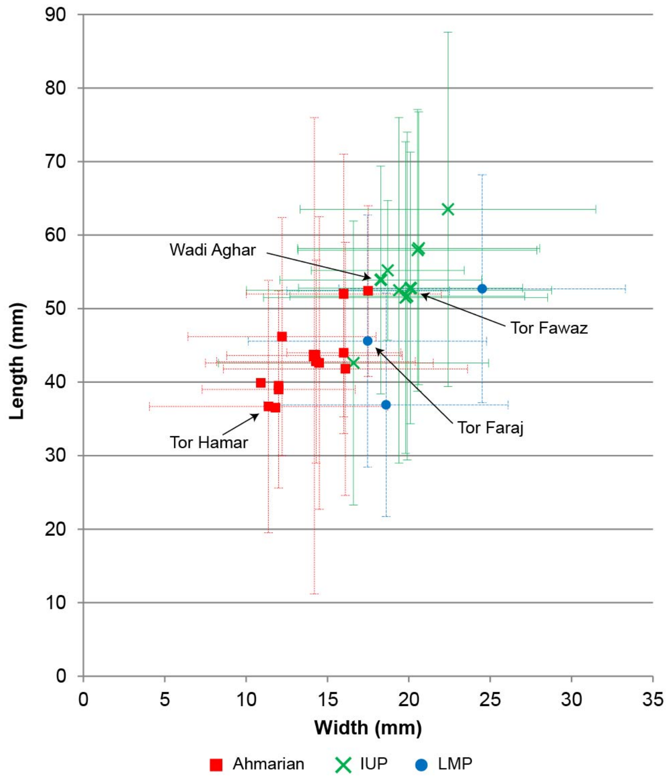

Fig. 14: Length and width statistics (mean and standard deviation) of blades/bladelets from LMP, IUP, and Ahmarian assemblages in the Levant. See SOM Table S3 for data sources.

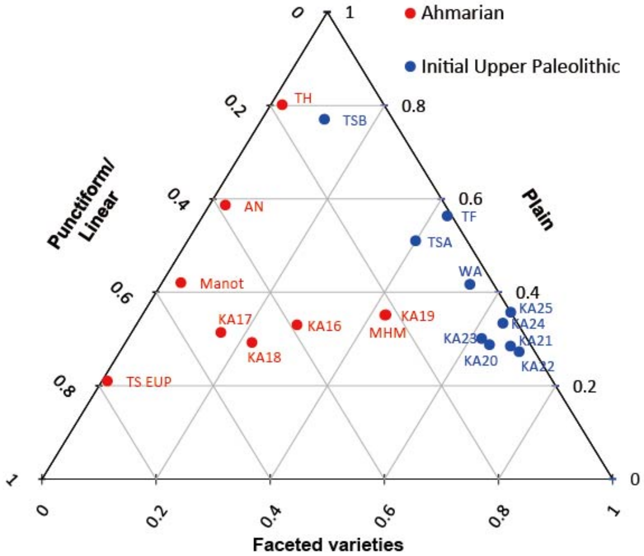

Fig. 15: Relative frequencies of platform types of blades/bladelets from IUP and Ahmarian assemblages in the Levant. See text for the definition of platform-type groups. See SOM Table S4 for data sources. Site names are abbreviated as AN (Al-Ansab 1), KA (Ksar Akil), MHM (Mugr El-Hamamah), TF (Tor Fawaz), TH (Tor Hamar), TS (Tor Sadaf), WA (Wadi Aghar).

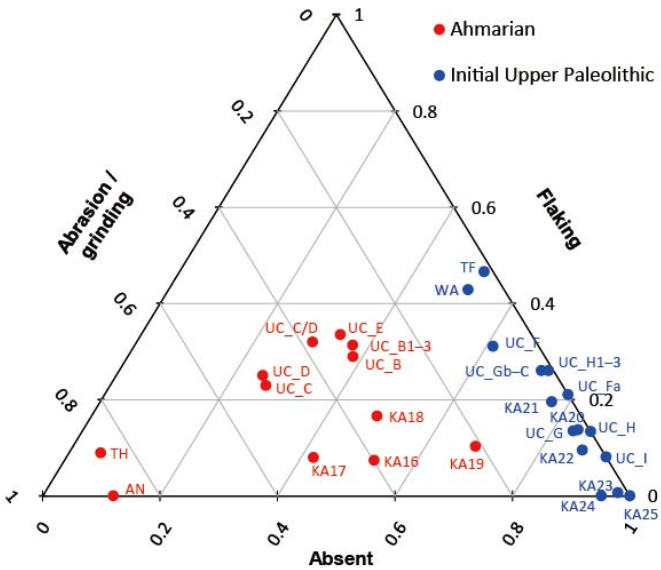

Fig. 16: Relative frequencies of overhang removals of blades/bladelets from IUP and Ahmarian assemblages in the

Levant. See SOM Table S5 data sources. Site names are abbreviated as AN (Al-Ansab 1), KA (Ksar Akil), TF (Tor Fawaz), TH (Tor Hamar), UC (Ücağızlı), WA (Wadi Aghar).

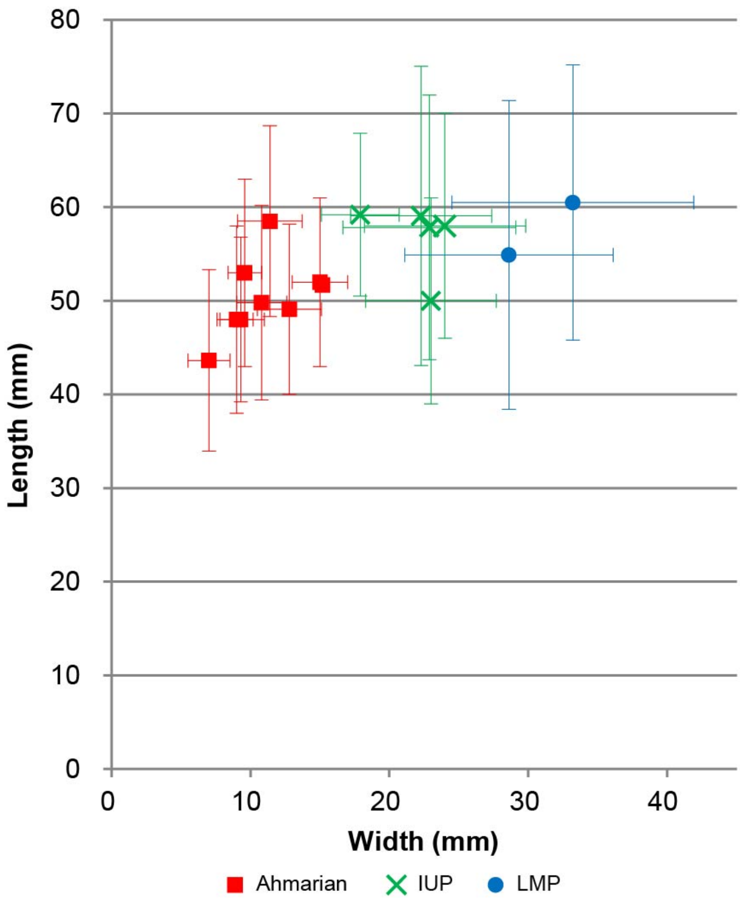

Fig. 17: Length and width statistics (mean and standard deviation) of points from LMP, IUP, and Ahmarian assemblages in the Levant. See SOM Table S6 for data sources.