Journal of Archaeological Science 69 (2016) 130–142

Contents lists available at ScienceDirect

Journal of Archaeological Science

journal homepage: http://www.elsevier.com/locate/jas

Reconstructing projectile technology during the Pre-Pottery Neolithic B in the Levant: An integrated approach to large tanged points from Halula

Ferran Borrell [a, *], Denis Štefanisko [b]

[a] Instituto Internacional de Investigaciones Prehistóricas de Cantabria, Universidad de Cantabria, Edificio Interfacultativo, Avenida de los Castros s/n, 39005, Santander, Spain
[b] Department of Archaeology and Museology, Masaryk University, A. Nováka 1, 602 00, Brno, Czech Republic

ARTICLE INFO

Article history:
Received 17 September 2015
Received in revised form
20 March 2016
Accepted 1 April 2016

Keywords:
Neolithic
Levant
Pre-Pottery Neolithic B
Projectile technology
Tanged points

ABSTRACT

Large tanged points made on bidirectional blades constitute the most characteristic tool type during the Pre-Pottery Neolithic B in the Levant. Studies on projectile typology and on bidirectional technology have revealed important stylistic differences reflecting chronological and geographical patterning, contributing significantly to the understanding of early farming communities in the Near East. However, the reconstruction of the weapons these large tanged points were part of has not received the same attention. This investigation aims to fully characterize stone point production at Halula, a PPNB settlement in the middle Euphrates valley, and reconstruct the type of weapons and delivery mechanisms used. Our study also includes the analysis of various ballistic attributes using a series of recent morphometric methods and comparison with ethnographic and experimental data about projectiles of known use. Results indicate that Byblos points might have been used as dart-points propelled with the help of spear-throwers, indicating a shift –from bow to spear-thrower– in projectile technology associated with the appearance and expansion of bidirectional blade technology during the PPNB in the Levant and synchronous with the consolidation of agricultural systems in the region.

© 2016 Elsevier Ltd. All rights reserved.

1. Introduction

Large tanged projectiles made on flint blades are a characteristic feature of lithic assemblages found in the western wing of the Fertile Crescent (Fig. 1) in the Pre-Pottery Neolithic B period (PPNB). They were made using a distinctive bidirectional blade technology that originated in the middle Euphrates valley around the mid-9th millennium cal BC, at the beginning of the Early PPNB (Abbès, 2003). This technology rapidly diffused throughout the Levant during the 8th millennium cal BC, being strongly associated with the emergence and consolidation of village farming in the region. However, little is known about the weapons (spears, darts or arrows) the manufactured stone points were part of. This study is based on a large assemblage of points from Halula (Syria), a large PPNB settlement in the middle Euphrates valley, and seeks to reconstruct the type of weapons and delivery systems used at the site.

Many studies have proved that bidirectional technology was oriented to producing large, robust, straight and naturally pointed central blades (e.g. Abbès, 2003; Barzilai, 2010; Borrell, 2011a; Nishiaki, 2000 and Quintero, 2010). Such targeted blades were used to produce a range of tools (e.g. sickle blades, scrapers, knives, etc.) but most of them were transformed into large, tanged projectile points (mostly of Byblos type but also Amuq, Ugarit, Jericho and other types). In this sense, large tanged projectiles are so abundant and specific to PPNB contexts that the term Big Arrowhead Industries (BAI) techno-complex was tentatively proposed as a chrono-cultural period instead of PPNB (Kozłowski, 1999).

Lithic studies focused on bidirectional technology have permitted the reconstruction of the reduction sequences and the technological skills and behavioural patterns of its users, identifying different chronological and regional variants across the Levant during the PPNB (e.g. Barzilai, 2010; Borrell, 2011b and Nishiaki, 2000). Intensive research has also contributed to a better understanding of different cultural attributes of the first farming communities in the Levant, such as social complexity, inter-site and

* Corresponding author.
E-mail address: silmarils1000@hotmail.com (F. Borrell).

http://dx.doi.org/10.1016/j.jas.2016.04.005
0305-4403/© 2016 Elsevier Ltd. All rights reserved.

Fig. 1. Location of Halula and other key Neolithic sites in the Levant and approximate geographical expansion (red dotted line) of bidirectional blade technology during the PPNB. (For interpretation of the references to colour in this figure caption, the reader is referred to the web version of this article.)

intra-site social interactions, knowledge transfer, exchange networks and product circulation (e.g. Barzilai, 2010; Borrell and Molist, 2014; Quintero and Wilke, 1995 and Quintero, 2010). The points themselves have also been the object of specific typological and technological studies (e.g. Bar-Yosef, 1981; Borrell and Molist, 2007; Cauvin, 1974; Gopher, 1994; Kozłowski and Aurenche, 2005; Roodenberg, 1986; Schmidt and Beile-Bohn, 1996 and Shea, 2013). Such studies have provided abundant data related to projectile production, created different typologies (Byblos, Amuq, Ugarit, Jericho, etc), and indicated regional and chronological differences. Use-wear analyses are scarce and the total number of artefacts analyzed is small (e.g. Moss, 1983 and Coşkunsu and Lemorini, 2001). In general terms, these studies confirm that large points were used as projectiles, even though in some cases they were also used for other purposes (boring, cutting, etc.) mostly once they had been rejected as projectiles, but they have not provided evidence of the different weapons used during the Pre-Pottery Neolithic.

In sum, there is little doubt about the economic significance of bidirectional technology and of the large quantities of tanged projectiles produced in Neolithic settlements during the emergence and consolidation of agricultural systems in the Levant. However little is known about the weapons (spears, darts or arrows) that the large stone tips were part of or the delivery mechanisms used (bow, spear-thrower). Specific morpho-metric analyses devoted to such topics are abundant in other parts of the world where large projectiles dominate lithic assemblages (e.g. Shea, 2006; Shott, 1997 and Riede, 2009) but, in contrast, they are almost absent, though there is one notable exception (Roodenberg, 1986), in the archaeological literature of the Levant.

Our research is aimed at filling this gap by reconstructing the type of weapons and delivery mechanisms used during the PPNB at Halula. Our multi-disciplinary study integrates a techno-typological approach to the production of tanged points at Halula, evidence from hafting techniques at the site, and the analysis of various ballistic attributes using recent morpho-metric methods, which compare archaeological data with available ethnographic and experimental data. The investigation is based on a large assemblage of points from Halula (Syria), a large PPNB settlement in the middle Euphrates valley. The results constitute a preliminary but reliable approach to weaponry during the PPNB as a first step to 1) reconstructing hunting and/or warfare technologies during the Pre-Pottery Neolithic and 2) evaluating the socio-economic significance of bidirectional technology and of the massive production of

large tanged points in the context of the first consolidated farming communities in the Levant.

2. Projectile technology in the Levant

The earliest documented evidence for the production and use of projectiles in the Levant is dated to the early Upper Palaeolithic layers at Ksar Akil in the Lebanon (Levels 9–24) (Shea, 2006). Experimental tests using replicas of retouched pointed artefacts from this site have concluded that the original artefacts could have served as armatures for projectile weapons, possibly as arrows or more probably as darts (Bergman and Newcomer, 1983, 238 and Shea, 2006). Other plausible projectile points dated to the Upper Palaeolithic are those found at Emireh (Israel) and Üçağızlı (Turkey), and El-Wad points (Israel). The detailed analysis of scalene triangle and Kebara point types from Ohalo II (Israel) has concluded that they were used as side elements of complex projectiles (Yaroshevich et al., 2013). During the Epipalaeolithic no symmetric points are well attested in the Levant while microliths predominate. Experimental studies interpret them as elements of composite projectiles, proposing the appearance of bow and arrow technology in the Levant during this period (Yaroshevich et al., 2010).

The advent of the Neolithic represents a shift in projectile technology and typology in the Levant. Projectile points represent the most common and representative formal tool for the period, becoming the focus of many studies due, in good part, to their potential use as chronological markers (Gopher, 1994). During the PPNA Khiam points predominate and lunates are rare and not found at every site. Helwan points appear in the middle Euphrates valley (Gopher, 1994) and become widespread during the early stages of the PPNB. These points, which can be found both in the southern and northern Levant, are made from relatively small blades with a small tangs or a straight/concave base and usually display lateral notches. According to Aurenche and Kozłowski (1999) Helwan points are a "logical" development of Khiam points and perhaps embryonic tanged points. The most significant changes in the morphology and size of projectile points occur well into the PPNB period, especially in the northern Levant, with the advent and diffusion of large tanged projectiles (e.g. Byblos, Amuq and Jericho points). Despite the remarkable increase in size (up to 15 cm long) during the Middle and Late PPNB, such projectiles have frequently been described as arrowheads –which implies the use of bow and arrow technology– (Gopher, 1994, Kozłowski, 1999) or *flèches* (Cauvin, 1974), without any further attention being paid to the issue of size as the aim of those studies was mainly to seriate and chronologize the different type of points and not to reconstruct the weapons. More recently, the use of both large and small reinforced bows during the PPNB has been proposed, while larger projectiles have been interpreted as javelins or knives (Abbès, 2003, 154), as previously suggested by Cauvin (1968, 66–69) and Roodenberg (1986, 44). In all these cases, spears and javelins have been interpreted as weapons thrown by hand. These interpretations contrast with others who suggest that spear-throwers were used during the Middle PPNB, for example at Ain Ghazal in Jordan, whereas in the PPNC and PN bows and arrows would have been virtually exclusively used (Eighmey, 1992 in Rollefson, 1998), as indicated by a substantial decrease in size and the appearance of new types of smaller projectile points (e.g. Ha-Parsa, Nizzanim and Herzliya points).

In summary, interpretations of projectile use during the PPNB in the Levant are contradictory and somewhat speculative as researchers do not take into account the analysis of diverse ballistic and morpho-metric features of the projectile heads, which has been addressed in other parts of the world (e.g. Hildebrant and King, 2010; Hughes, 1998; Riede, 2009; Sisk and Shea, 2011 and Shott, 1997). Finally, it has to be noted that however they were used, large points from PPNB sites have generally been associated with hunting (e.g. Abbès, 2003; Gopher, 1994 and Nishiaki, 2000), and their marked decrease during the PPNB-PN transition is seen as an indicator of the decline in hunting (Nishiaki, 2000) and/or a marked shift towards different game. However it is interesting to note that alternative interpretations suggest that one of the potential causes that originated the massive production of large projectiles during the PPNB might have been related to an increase of warfare (Bar-Yosef, 2014, 75), although the author himself admits the difficulty in identifying this in the archaeological record.

3. Materials and methods

3.1. The site and the assemblage

Halula is located on the right bank of the Euphrates River. The dimensions of the tell are about 300 m from north-west to south-east by 150 m north-east to south-west, covering an area of over eight hectares. The depth of the archaeological deposits is almost 8 m. The chronological sequence includes a long series of occupational phases belonging to the Pre-Pottery Neolithic (end of Middle PPNB and Late PPNB) and to the Pottery Neolithic (Pre-Halaf and Halaf) (Molist, 2013). The chipped stone assemblage discussed in this paper belongs to the Pre-Pottery Neolithic occupational phases 5 to 19 –Phase 1 corresponds to the foundation of the Neolithic settlement and Phase 20 to the first Pottery Neolithic occupation of the site-in Sector 4, dated from *ca.* 7700 to 7100/7000 cal. BC. The excavated area covers a surface of about 600 m^2. PPNB architecture in this sector is characterized by the construction (and reconstruction) of rectangular residential buildings. Long-term excavation of the site has provided an important corpus of new data about the communities that settled the Euphrates valley at the end of the Pre-Pottery. Due to its size and continued occupation, Halula can be included within a series of large settlements that played a significant role in the region (e.g. Akarçay, Bouqras and Abu Hureyra) and which provide an excellent framework within which to analyse projectile technology in established farming communities of the Levant. The total number of flint artefacts studied from these occupational phases at Halula is 9637 including 603 projectile points, which represent up to 6.25% of the total assemblage.

Projectile points represent the most abundant tool type, ranging between 15 and 35% of the retouched tools during the different occupational phases, with a clear decrease at the end of the PPNB sequence (*ca.* 7100 cal. BC) which also corresponds to the decline of bidirectional technology throughout the sequence. The large number of projectiles analyzed represents the biggest collection ever studied from well-dated and reliable archaeological contexts for this period in the northern Levant.

4. Results

4.1. Production of lithic projectile points at Halula

All except one of the 603 stone points studied are made on blades, and the vast majority were made using bidirectional blades (506, 84%). The rest were made on unidirectional blades (23, 3.8%) and blades of indeterminate type (74, 12.2%). Within the group of projectile points made on bidirectional blades, full measurement has been possible in 170 cases, showing a clear preference for the targeted naturally pointed central blades (136, 80%).

Different varieties of both local and non-local flint were used to produce projectiles at Halula although Eocene dark brown fine-

grained variety was preferred (436, 72.3%). A good number of projectiles (131, 21.7%) were made of multi-coloured fine-grained flint varieties that can be easily found on the river terraces as mainly medium-sized (15–35 cm) globular and spherical nodules. A small number (20, 3.3%) were made from non-local fine-grained reddish/pink flint from unlocated primary outcrops. The rest of the points were made from coarse-grained flint varieties -white to light grey in colour-transported by the river in large quantities (5, 0.9%), other local varieties that are not commonly found in the river (8, 1.3%), or were burnt and could not be identified (3, 0.5%).

The vast majority of the projectile points analyzed correspond to the Byblos type (559, 92.7%). The rest of the assemblage consists of Amuq points (8, 1.3%) –most of them corresponding to the last Late PPNB occupational phases of the sequence in Square 2G– and other undefined projectile types (15, 2.5%). Indeterminate broken fragments represent only 3.5% (21) of the total. With respect to the Byblos type projectile points from Halula, it is important to note that as well as the most characteristic features that define this type –point fashioned on a blade, with tang set off from the body by two shoulders, with abrupt or semi-abrupt retouch on the tang and sparsely regular or semi-abrupt retouch on the body of the point (Cauvin, 1968; Gopher, 1994)– they display other specific features (Fig. 2). These are related to the particular bidirectional blade reduction sequence found at Halula and other sites in the northern Levant during the second half of the 8th millennium cal BC (Borrell, 2011a, Borrell, 2011b). They need to be taken into consideration because they affect the final morphology of the points and, thus, their ballistic attributes.

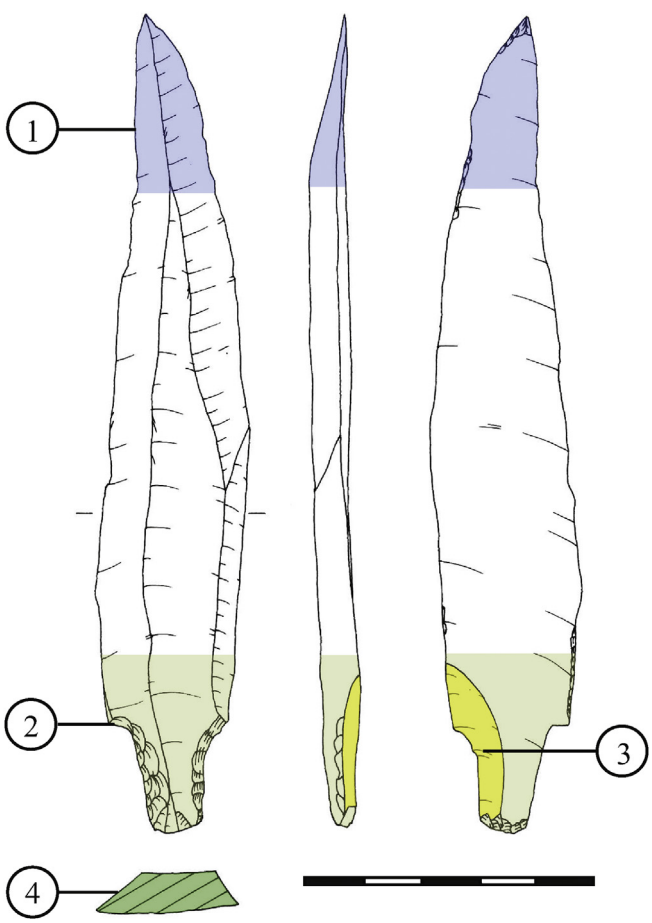

Fig. 2. The main characteristic morphological traits identified in central bidirectional blades used for manufacturing Byblos points at Halula (for details see Borrell, 2011b). Note the slight curvature to the left of the distal end of the blade (1); the twisted longitudinal profile especially noticeable on the proximal part (2); the S-shaped delineation is partially corrected with a burin-like ventral removal (3); and the asymmetric trapezoidal cross-section (4), where the right side of the trapeze is almost always the shortest.

The remarkable homogeneity and standardization observed both in the blade type and the final configuration of the points contrasts with the variability observed in both their length and weight. Byblos points from Halula range from 36 to 141 mm in length, 10–30 mm in width, and 4–13 mm thick (Fig. 3). This remarkable variability in the length of the points is the result of two factors. The first is that flint knappers from Halula used any kind of central blade obtained throughout the reduction sequence of the core to manufacture Byblos points, from the large initial ones to the last shorter blades obtained before abandoning the exhausted cores. The standardized morphology of the blades was deliberately chosen but the differing lengths was not a constraint. The second factor is that a good number of points show evidence of having been reused and re-retouched several times, thus gradually decreasing the total length of the point, though this barely affected the width and thickness of the points. Some of the points display different types of impact fracture (Fig. 4).

4.2. Hafting technologies

A wide range of adhesives are known to have been used worldwide for hafting, with some of the best known being bitumen (e.g. Boëda et al., 1999), birch bark tar (Pawlik and Thissen, 2011), amber (Tankersley, 1994) and various conifer resins (Helwig et al., 2014). In Halula, a careful macroscopic screening of the surfaces before the points were washed has allowed the identification of lime plaster remains on the tang of at least a dozen points, as well as a tang completely covered with plaster and a proximal/medial fragment of a point with its tang covered with lime plaster (Fig. 5). Not a single trace of bitumen has been found on any of the studied points. However preservation of bitumen is well attested at the site as it can be identified on almost half of the sickle elements in the assemblage. This leads us to conclude that in Halula lime plaster was the only adhesive compound used for fixing the stone tip to the rest of the projectile (shaft or foreshaft).

Detailed examination of the distribution of lime plaster remains still attached to the tang indicate that lime plaster covered the totality of the tang and part of the proximal part of the point, including part of the shoulders. One intriguing aspect is that in the two best preserved examples lime plaster seems to be in direct contact with the stone, apparently leaving no place for any kind of string or cord to attach the stone tip to the shaft before applying the lime plaster covering. Another remarkable aspect is that in both these cases the external surface of the lime plaster exhibits a series of more or less parallel incised longitudinal marks (Fig. 5B and E). Their interpretation is difficult though they could have been caused by the lime plaster being wrapped in some kind of textile or inserted into a hollowed out handle made of wood or horn. Another possible interpretation is that these incisions were produced while sticking and modelling the lime plaster on both the shaft and stone tip, maybe using some kind of tool to eliminate/remove the excess of material. Whatever the purpose, the use of lime plaster would have certainly added considerable weight to the tip of the projectile –whether it was an arrow point, a dart or a spear– a feature that will be taken into consideration when analyzing and interpreting the weight of the stone tips.

In summary, the examples provide evidence for well-developed hafting technologies Halula and confirm our first observations about the differential use of lime plaster and bitumen as adhesive compounds at the site (Borrell and Molist, 2007). Bitumen –a

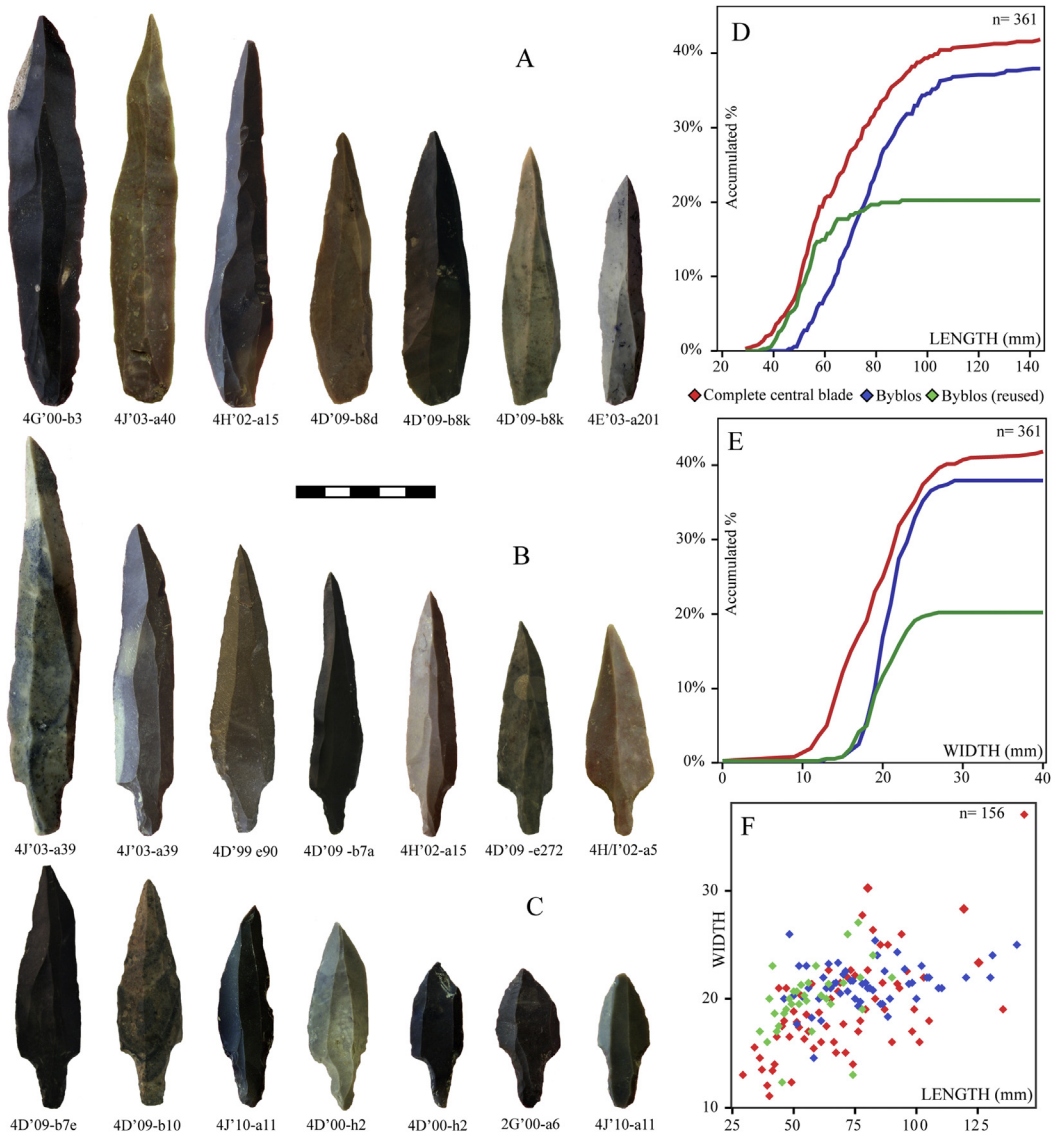

Fig. 3. Examples of the decreasing length of the central blades as the reduction sequence progressed (A), of non re-used projectiles (B) and of projectiles with clear signs of having been reused and retouched several times (C). Graphs comparing the length and width measurements of the complete Byblos points analyzed with the complete central blades (D, E and F). Note the agreement between the maximum length of the larger points and the complete central blades.

material that was not locally available— was used for fixing sickle elements to their shaft —facilitating their immediate *in situ* replacement during the harvest- and for waterproofing/coating basketry. In contrast, lime plaster was used for hafting the large stone points to the rest of the projectile, a duality that represents a unique pattern in the Levant.

Finally, use of lime plaster as an adhesive compound in the region has been reported at earlier sites in the southern Levant such as Ohalo II where it was identified as white calcareous adhesive (Yaroshevich et al., 2013), Saflulim (Goring-Morris, 1999) and Lagama (Kingery et al., 1988) but always to fix small stone tips and in most cases microliths. For the later periods Miller (1983, 187–190) reported the use of gypsum plaster for hafting an arrowhead. In the case of Halula, our interpretation is that using lime plaster —easy to produce, hard and relatively light and fragile— did not represent a handicap to the effectiveness of the projectile. On the contrary, if we consider that the shaft of a projectile could be the most valuable part, it would be advantageous if the lime were to crack/break off when the projectile struck home, leaving the stone point inside the prey and releasing the handle, avoiding its breakage or loss in the case of the animal's escape.

4.3. Morpho-metric analyses

Morpho-metric analyses can be useful for distinguishing between different weapon types as each weapon (spear, dart and arrow) requires stone tips with different attributes and metrics. Such analyses have been widely used in North American prehistory (e.g. Christenson, 1986; Hildebrant and King, 2010; Hughes, 1998; Shott, 1997 and Thomas, 1978), but less frequently in Europe and other parts of the world (e.g. Roodenberg, 1986; Shea, 2006; Sisk and Shea, 2011 and Yaroshevich et al., 2013).

The earliest approaches using morpho-metric studies began with a series of heated exchanges (e.g. Browne, 1940 and Kidder, 1938) leading to disappointing conclusions, which were partially corrected later on when some authors noted that what is experimentally proven as possible today speaks little of the actual manner of use of projectile points in Prehistory (Christenson, 1986, 114 and

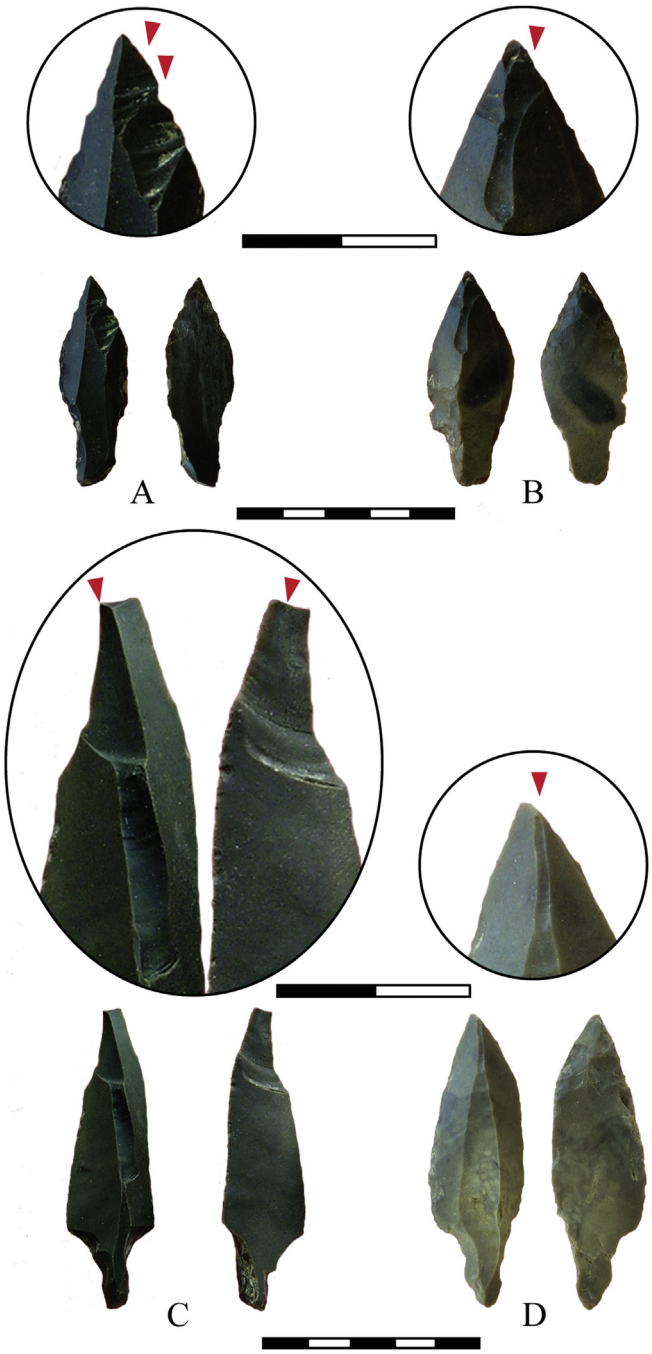

Fig. 4. Some examples of different impact fracture types on complete Byblos points from Halula. Note the intensive reutilization of points A and B.

Fenenga, 1953, 319). More solid groundwork based rather on empiric knowledge gained from ethnographic projectile points of known function, has been published since the late 1970s (e.g. Hildebrant and King, 2010; Hughes, 1998; Shea et al., 2001; Shea, 2006; Shott, 1997; Thomas, 1978; Sisk and Shea, 2011), followed by a series of papers that also point out the weak points of such approaches (e.g. Erlandson et al., 2014 and Newman and Moore, 2013). In the Levant, the only morpho-metric approach to large tanged Neolithic points has been carried out by Roodenberg (1986).

At Halula, the best preserved Byblos points (463) were measured to perform the following morpho-metric analyses: Shott's Discriminant Analysis, Dart and Arrow Index (DAI), Tip Mass, Tip Cross-Sectional Area (TCSA) and Tip Cross-Sectional Perimeter (TCSP), which are described below. The results of the TCSA, TCSP and Tip Mass analyses were then been compared with ethnographic projectile points of known function and with experimental projectile points. For the calculation of the TCSA, TCSP and DAI, neck-width was estimated using a method described by Andrefsky (2005, 186), modified for tanged projectile points where the neck width of this type of projectile corresponds to its shoulder width, which is the maximum width of the projectile.

4.3.1. Discriminant analysis

Thomas (1978) was the first to propose a verifiable formula to differentiate between various types of projectile weapons using four variables (neck width, maximum width, length and thickness of the point). The method was improved by Shott (1997) who increased the database of indigenous darts with a known function, but also established a more accurate approach to the identification of archaeological projectiles. In his opinion in Thomas's approach some of the measurements –for example length attribute-might be biased by maintenance and reuse of broken/damaged points, something which was also observed at Halula. He thus proposed a single-variable analysis using point width at shoulder [Dart discriminant: 1.40*(shoulder width) − 16.85; Arrow (D-discriminant): 0.89*(shoulder width) − 7.22] an approach that proved successful in distinguishing over 85% of the arrowheads and more than 75% of the darts in his sample. Using Shott's (1997) formula the arrow and dart discriminants of 463 projectile points from Halula have been calculated (Fig. 6A); the results show that most of the projectiles fall within the range of darts.

4.3.2. Dart and Arrow Index (DAI)

Differences between arrowheads and dart-points have recently been studied by Hildebrant and King (2010). The Dart and Arrow Index (DAI) is a method developed to better accommodate the fragmentary nature of the stone projectile points found in archaeological excavations. The DAI method is based on two parameters (neck width and maximum thickness) which usually remain unchanged despite the projectile being broken or modified for re-use, and they are therefore deemed to be reliable indicators of the original functional identity of a tool. The results using Hildebrant and King (2010) DAI analysis of 463 Byblos points from Halula also indicate that all projectiles were used as darts (Fig. 6B).

4.3.3. Tip mass

The method of using tip mass as a discriminant for distinguishing between different weapon types has been used by archaeologists since the second half of the 20th century (e.g. Fenenga, 1953; Korfmann, 1974 and Rausing, 1967). The most debated point is difference between the maximum weight of an arrowhead, compared to a dart-point. Rausing (1967) stated that anything weighing more than 13 g, including the material used to attach the stone tip to shaft, should not be accepted as an arrowhead. Others, like Korfmann (1974), suggested that an arrowhead weighing less than 7 g would be more reliable and accurate, whereas heavier points would be remarkably less accurate. Roodenberg (1986) concluded that 10 g would be the limit between arrowheads and javelin points. More recently Hughes (1998, 374) fixed the maximum possible weight of an arrowhead at 11 g. However, the maximum weight of an arrowhead also depends on the bow type, material and size all of which have an effect on the draw weight. Unfortunately bows are rarely preserved in prehistory and the Levant is no exception, which that does not help to solve the issue. In general terms, and despite the different opinions, there is certain agreement that the maximum weight of the arrowhead and the adhesive should fall between 11 and 13 g, although for some

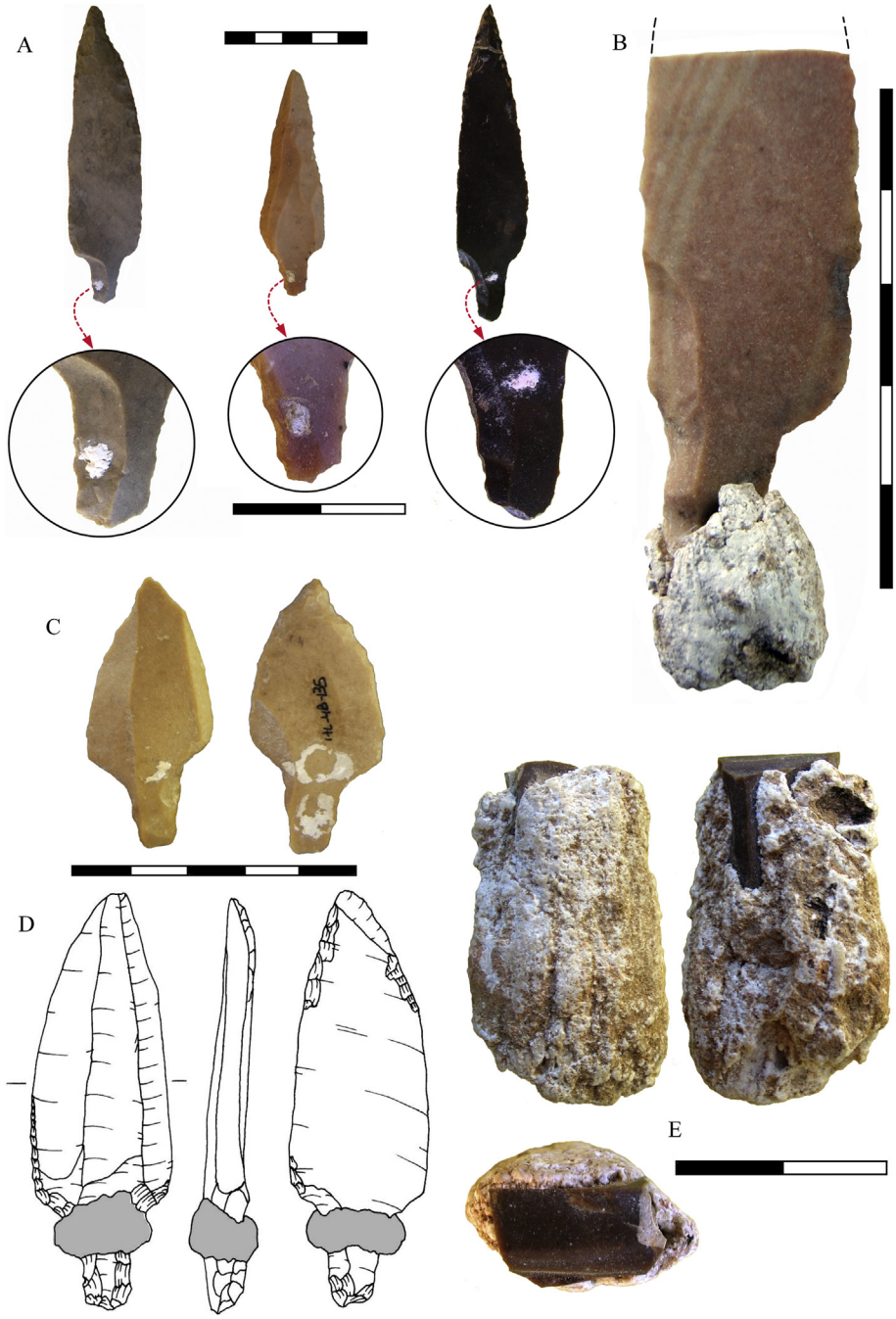

Fig. 5. Multiple evidence of the use of plaster as adhesive for hafting Byblos points at Halula during the Pre-Pottery Neolithic.

authors arrowheads of this weight are not considered to be very accurate.

Complete Byblos points from Halula display great variability in mass, ranging from 5 to 23 g (Figs. 7 and 8). This variability in the weight is clearly related to the marked variability in the length of the projectiles, which is the result of two factors. First, almost half of the 223 complete projectiles studied show clear evidence of intensive rejuvenation/repair gradually decreasing both the total length and weight of the original point (Figs. 3 and 7). The second factor affecting the total length, and thus the weight, of the stone points from Halula is that Byblos points were made using central blades of different sizes – ranging from 12 to 14 cm for the initial blades to 7 cm long, which is the average length of the last negative removals of central blades observed in bidirectional cores from Halula. However, these differences do not seem to have been a constraint as long as the blades were robust with a straight longitudinal section and a naturally-pointed distal end.

When comparing the selected assemblage from Halula with projectile points of known function (arrowheads, darts and spears) it is clear that most of the points from Halula fall closer to ethnographic darts than to arrowheads and in an intermediate position between dart-points and spears (Fig. 8). If we restrict the analysis to complete points with no evidence of being reused, which range in length from 7 to 14 cm (the last central blades documented in cores at Halula measured no more than 7 cm), it is possible to estimate that the original weight of the points when they were produced

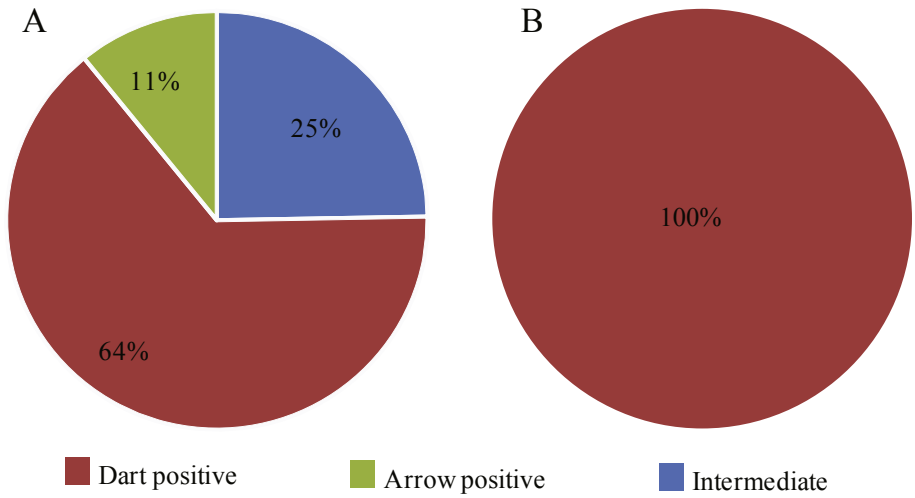

Fig. 6. Results using Shott's (1997) Dart and Arrow discriminant (A) and DAI analysis (Hildebrant and King, 2010) (B) of Byblos points from Halula. Note that in order to be as accurate as possible in our analyses, when applying Shott's discriminant analysis we adopted Tarabek (2013) intermediate category for those projectiles displaying values which are less than 0.5 from the discriminant values.

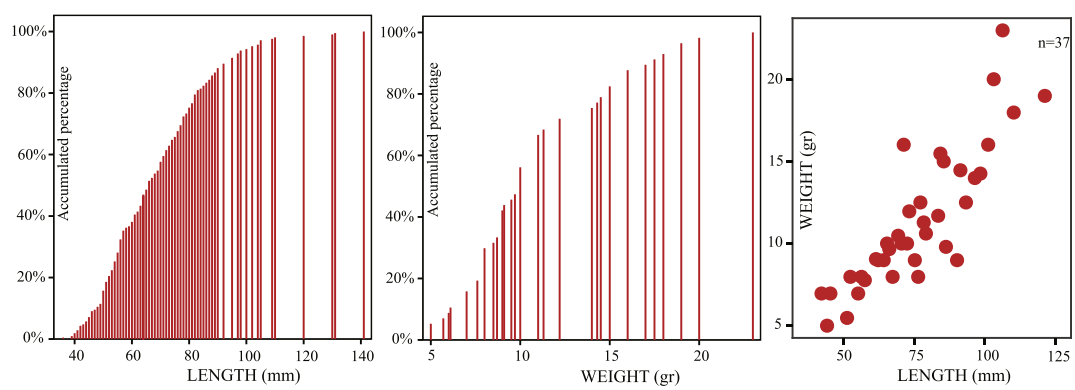

Fig. 7. Length and weight of the complete Byblos points analyzed. Note that the weight could only be measured in 37 artefacts.

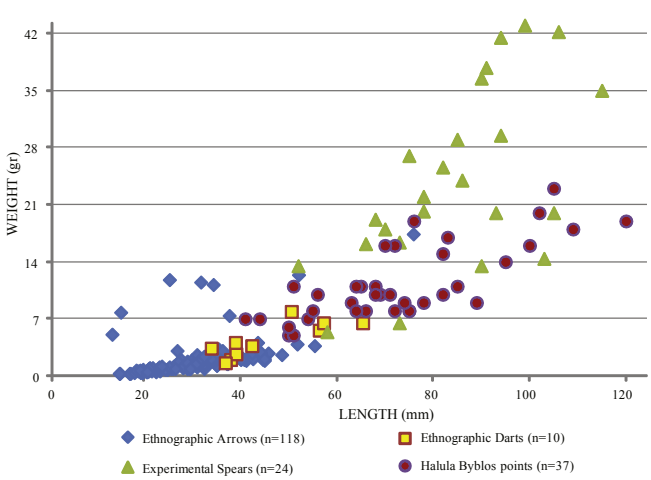

Fig. 8. Comparison of the length and mass of the Byblos points from Halula with the experimental and ethnographic projectile points (Shea et al., 2001, 807–816, Shott, 1997, 86–102 and Thomas, 1978, 461–472).

ranged from 9 to 19 g before the adhesive was applied which remarkably increased even more the total mass/weight of the tip of the projectile.

In summary, if initial results of tip mass analyses might be a little ambiguous and suggest a potential co-existence of different weaponry, the particular features of the assemblage studied (intensive reutilization of the projectiles and the use of lime plaster as adhesive) indicate that the total tip mass of the original/new (complete and hafted) projectiles might have been considerably higher, in agreement with those reported in ethnographic darts.

4.3.4. Tip Cross-Sectional Area (TCSA) and Tip Cross-Sectional Perimeter (TCSP)

TCSA and TCSP are calculations of projectile tip cross-section area and tip cross-section perimeter respectively (Fig. 9), which has to be calculated at the point of maximum width and thickness of the point (Friis-Hansen, 1990, Hughes, 1998, 354, Shea, 2006, 824 and Sisk and Shea, 2011, 3); for the Byblos points analyzed that is next to the shoulders. Unlike the mass and length of the projectile points analyzed from Halula, TCSA and TCSP attributes are barely affected by extensive maintenance and reuse of the projectiles. For this study the TCSP has been analyzed using an updated formula (Sisk and Shea, 2011) (Fig. 9B) adapted for unifacial points (asymmetric cross-section) which makes it more suitable for analyzing the Byblos points (which have a trapezoidal cross-section).

The average, minimal, maximum and standard deviation of TCSP and TCSA of 463 Byblos points from Halula have been calculated, showing a remarkably limited variation despite the large sample

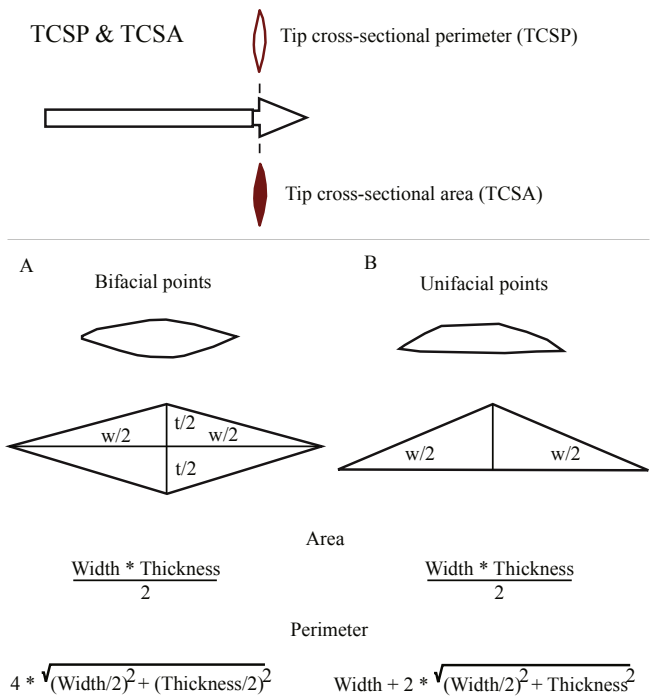

Fig. 9. Ballistic attributes of a projectile (modified after Friis-Hansen, 1990) (above) and equations used for calculating the TCSA and TSCP of rhomboid/bifacial (A) and unifacial points (B) (after Sisk and Shea, 2011, 3) (below).

analyzed. These values have been compared to those of a series of ethnographic and experimental points of known use (Figs. 10 and 11; Tables 1 and 2). Note that TCSA and TCSP at Byblos and other unifacial indigenous projectiles (macroblade dart points and macroblade knives) have been calculated using Sisk and Shea's (2011) formula.

The TCSA and TCSP analyses indicate a clear overlap of Byblos points from Halula with the North American indigenous dart-points and Australian Kimberly points (darts). As already pointed out by other researchers (Sisk and Shea, 2011), the results indicate that TCSP seems to be a more useful measurement than TCSA to discriminate the use of darts and arrows. At the same time, it is also possible to observe difficulties of both methods for determining the use of Australian macroblade points, which some authors consider rather anomalous from the ballistics point of view (Newman and Moore, 2013).

5. Discussion: did darts coexist with bows and spears?

The results of the morpho-metric analysis using Shott's discriminant formulas, DAI, TCSA and TCSP of the Byblos points from Halula have repeatedly generated values that fall well within the ranges obtained for ethnographic and experimental darts. These results differ from Shea's (2006, 826) who, using Gopher's (1994) data, calculated the TCSA of a series of Neolithic points from Israel (including Byblos, Amuq and Jericho types) and interpreted them as arrowheads. In our opinion, such disagreement makes clear the importance of combining different methods of analysis. Secondly, Shea's results might have been affected by two regional phenomena. Byblos points in the southern Levant are, in general terms (A. Gopher, personal communication), smaller than in the northern Levant. Secondly, during the PPNB there is clear trend in the southern Levant towards producing smaller projectiles, a phenomenon that culminated during the Pottery Neolithic with the appearance of the smaller Nizzanim, Herzilya and Ha-Parsa types. These two aspects and the fact that Gopher's data base includes specimens from distant regions of the southern Levant and from fairly different time periods, increases the total number of smaller specimens of Byblos points, thus subsequently producing lower TCSA mean values.

The coincident results of the different morpho-metric analyses performed and the high level of standardization observed in the production and hafting of a single type of point at Halula –the Byblos type, whether long or short– suggests the use of only one type of weapon (darts) at Halula during the Late PPNB. Differences observed in length and weight –overlapping with values attributed to arrowheads in some cases and spears in others– is more likely to reflect 1) the intensive reuse of damaged points and 2) the use of different kinds of dart-points according to prey size, technique (long-range vs. short-range hunting), or use/activity (hunting, warfare or ceremonial) rather than indicate the coexistence of different types of weaponry (bow and arrow, spear-thrower and spear) at the site. However, the issue deserves to be discussed in detail as it has to be admitted that it is difficult to be totally conclusive in this matter.

Concerning the hypothetical use of Byblos points as spearheads, it is important to keep in mind that lime plaster seems to have been the only adhesive used to haft Byblos points of all sizes at Halula, including potential spearheads. As a relatively fragile material it does not seem reasonable to assume that points hafted with lime plaster would be used as contact weapons designed for repeated thrusting attack rather than thrown. So, although the potential use of some Byblos points as spearheads cannot be ruled out, the evidence from hafting indicates that most might have been used as projectiles rather than as contact weapons. Even so, it is interesting to note that size, and thus mass, does not seem to have been a restriction for large ethnographic points which were used as darts as indicated by the high TCSA and TCSP values of Australian Kimberly points (darts) and especially Australian macroblade darts. Finally, the potential coexistence of arrowheads and javelins (spears) had already been proposed in the Levant at the PPNB/PN site of Bouqras (Roodenberg, 1986). The author used different parameters (length/thickness and length/weight of the stone point and thickness/width of the tang) to analyse the points from Bouqras (all types from both the PPNB and PN levels) and proposed the use of both arrows and javelins there.

Identifying the potential use of bows at Halula (for smaller Byblos points) is a rather challenging task but one that must also be taken in consideration because some of the Byblos points analyzed fall within the range of arrowheads and might apparently suggest the co-existence of two weapon types at Halula. There are remarkable differences in both the characteristics and use of arrows and darts, which could indicate diverse hunting techniques and organization or even specialization in different species of game. However, it is important to point out that tip mass variability at Halula is only related to changes in length and not in width or thickness, and not to any variation in the shape or typology of the point that might affect other ballistic attributes of the projectile. As mentioned in the tip mass analysis section, most Byblos points from Halula display values far beyond what is considered the maximum possible weight of an arrowhead (11–13 g including the material used to attach it to the shaft). The smaller of the Byblos points analyzed, weighing between 5 and 6 g (with an estimated weight around 9–11 g with the adhesive) could effectively work as arrowheads but these values are not higher than the smallest of the ethnographic darts, so they could also have been used as dart-points. According to Korfmann's (1974) parameters, a bow to shoot such arrows should be able to draw approximately 82 lbs. Bows do seem to have been used in the Levant during the Epipalaeolithic (Yaroshevich et al., 2010) and in central Anatolia during

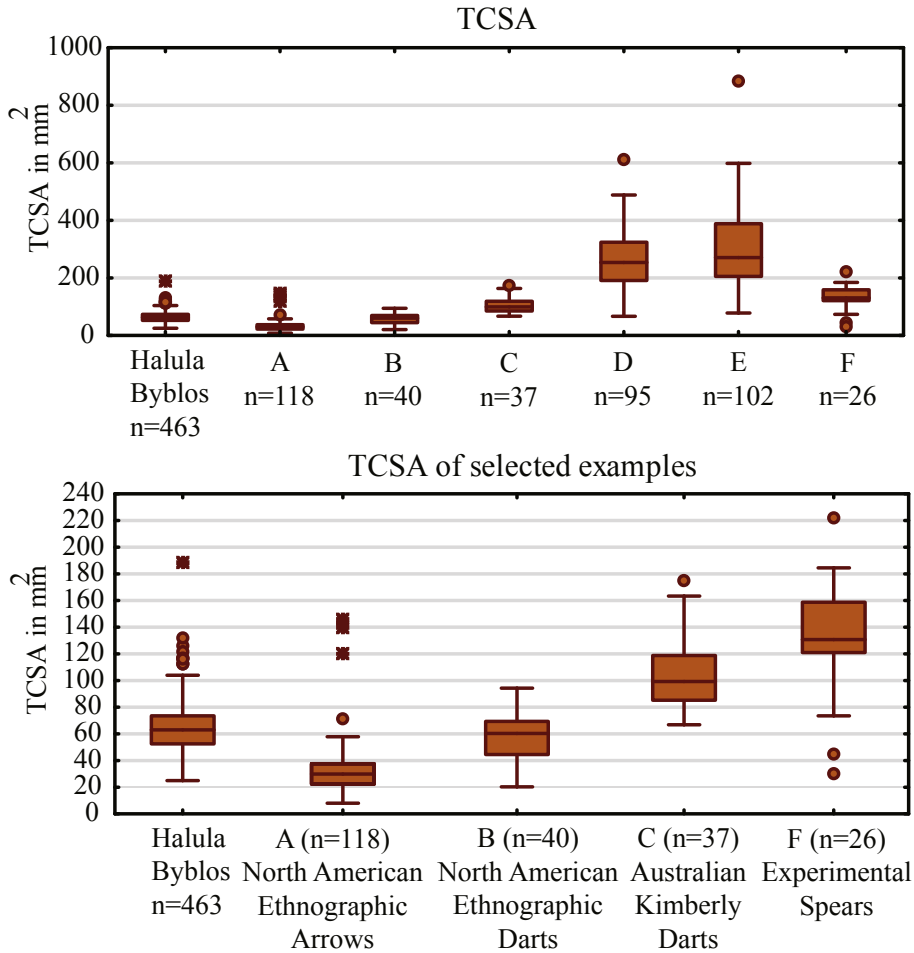

Fig. 10. Box and Whisker plots comparing the TCSA indexes of the Byblos points at Halula with those of indigenous and experimentally produced points (A: North American ethnographic arrows, B: North American ethnographic darts, C: Australian Kimberly darts, D: Australian macroblade darts, E: Australian macroblade knives, F: experimental spears). References used for the experimental and ethnographic examples are the following: Thomas (1978), Shott (1997) and Hughes (1998).

the Pottery Neolithic as observed in the frescoes of Çatal Höyuk representing deer hunting (Mellart, 1967) but there are no data about the weights potentially drawn by such bows. The small size of the microliths used in the Epipalaeolithic projectiles and the iconographic evidence from Çatal Höyük suggest that they were short self-bows, probably similar to the Neolithic bows documented in Swiss lakes with draw weights of around 35–67 lbs (Junkmanns, 2001). The oldest bow documented in the region is the complete wooden bow found in a burial cave (Cave 13 also known as the Cave of the Warrior) in Wadi el-Makkukh, near Jericho, together with several grave goods (McEwen, 1998). The bow, dated to the Chalcolithic period (ref. AA22234, 5120 ± 50 BP), is made from a single piece of olivewood; it measures 125.4 cm in total length and displays a double curvature in its limbs with the centre section curving towards the archer, in contrast to the Neolithic European bows which generally have simple curvatures. Reconstruction of the bow and arrows (no complete arrows were found only two foreshafts and pieces of reed) concluded that the bow was an effective and highly sophisticated hunting and fighting weapon with a draw weight of up to 44 lbs, shooting arrows with an average total length of ca. 60 cm weighing ca. 14 g (including the tip, the mastic and the shaft). Reconstruction of the projectiles included small tranchet arrowheads made of flint, similar to Predynastic and Dynastic Egyptian specimens associated with double curved bows. In summary, in the light of the meagre data available of Neolithic and the most sophisticated later (Chalcolithic) bows it seems fairly unlikely that even the smaller and lighter Byblos points found at Halula could have been used as arrowheads. Heavy Byblos points produced at Halula, with an asymmetric trapezoidal cross-section, seem better suited to be used in curved trajectory shots, typical of darts, rather than in flat trajectory shots.

6. Conclusions

Reconstruction of the projectile technology used at Halula has been characterized through a pioneering approach using both lithic technology and ballistics to what is the largest assemblage of stone points for the period in the northern Levant. It provides a solid base for future work and interpretation; it also indicates the suitability of morpho-metric studies as part of a comprehensive approach to stone tip use production – hitherto mainly applied in Palaeolithic contexts– for use in the Neolithic Levant. Our comprehensive approach to projectile production and use, from stone tip production and hafting to potential use determined through morphometric analyses, has revealed high levels of standardization during a long time span of around 500 years. Such standardization is in clear agreement with the high levels of intra-settlement social interaction, knowledge sharing and cultural homogeneity between households, observed at Halula around 7700–7100 cal BC (Borrell and Molist, 2014). The only remarkable variability observed is

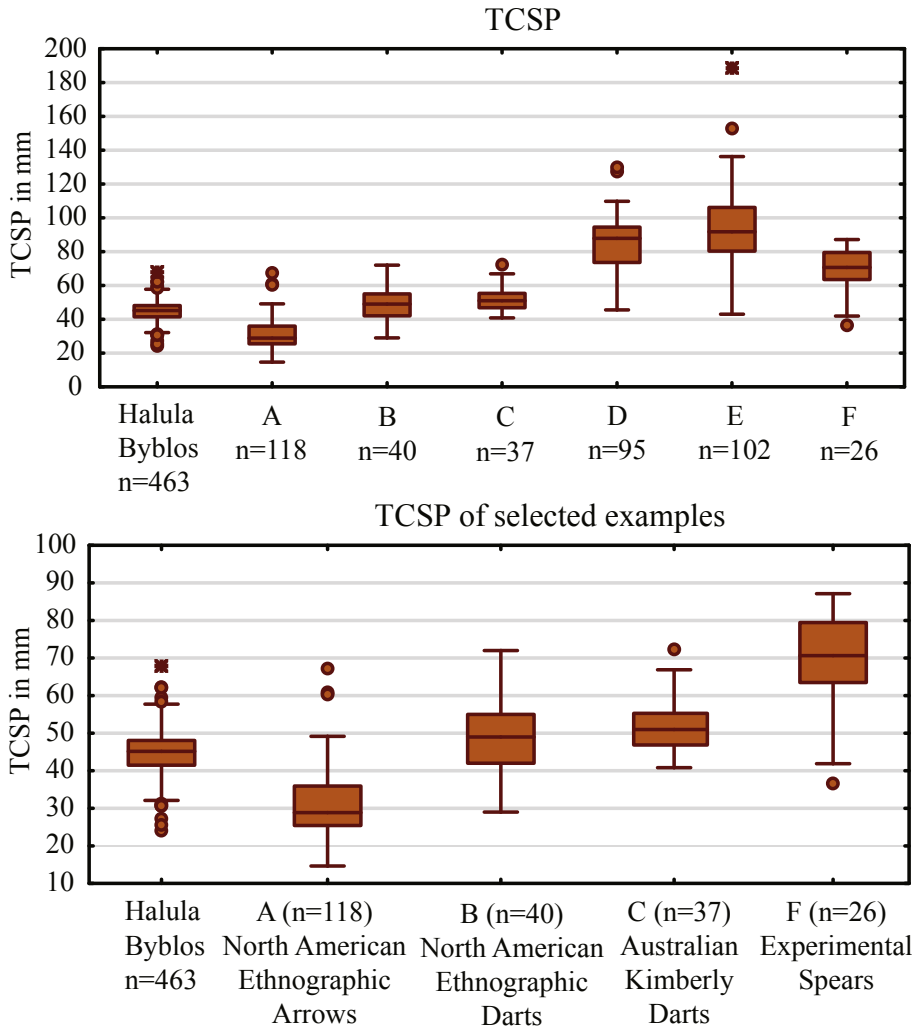

Fig. 11. Box and Whisker plots comparing the TCSP indexes of the Byblos points at Halula with those of indigenous and experimentally produced points (A: North American ethnographic arrows, B: North American ethnographic darts, C: Australian Kimberly darts, D: Australian macroblade darts, E: Australian macroblade knives, F: Experimental spears).

Table 1
Average, Minimal, Maximal and Standard Deviation of TCSA of projectile points used in the analysis (Halula n = 463).

TCSA	Average	Min	Max	Standard dev.
Halula	66.06	25.00	188.50	18.01
North American indigenous arrows	32.53	7.99	145.80	19.94
North American indigenous darts	57.95	20.30	94.32	17.80
Australian Kimberly points (darts)	103.14	66.88	174.82	24.69
Australian macroblades dart points	264.51	66.57	612.32	96.71
Australian macroblades knives	296.11	77.97	885.13	134.21
Experimentally produced spears	130.75	7.99	222.00	43.60

Table 2
Average, minimal, maximal and standard deviation of TCSP of projectile points used in the analysis.

TCSP	Average	Min	Max	Standard dev.
Halula	44.86	24.14	67.94	5.75
North American indigenous arrows	31.35	19.10	67.25	8.00
North American indigenous darts	49.63	29.00	72.00	10.03
Australian Kimberly points (darts)	52.10	40.82	72.26	6.80
Australian Macroblades dart points	85.59	45.53	129.80	15.02
Australian Macroblades knives	93.39	42.99	188.77	21.88
Experimentally produced spears	68.58	36.59	87.13	13.55

attested in the total length of the projectile points, and thus the tip mass, which seems to be the result of the successive reuse of the points, and also to the variability in length of the original bidirectional central blades used to produce Byblos points. Despite such variability, there is little doubt that all the blanks and points were produced within the same production process and the possibility of two or more alternative production processes aimed at producing different points can be discounted. Results also indicate that most, if not all, Byblos points from Halula were produced for use as dart-points. The variability observed in the size of both the stone tips and the projectiles might relate to the use of slightly different projectiles or even to the age of the hunter as attested in different ethnographic records (Ellis, 1997, Nishiaki, 2013). The potential coexistence of darts with other weapons, such as bows or spears, remains speculative.

This study thus represents a step forward in our knowledge of projectile technology during the Pre-Pottery Neolithic B indicating that darts were the principal weapon, whether for hunting or warfare use. This interpretation should not be automatically extrapolated to all Byblos points from other sites during the Pre-Pottery Neolithic B, as we consider that similar research should be undertaken elsewhere. However it is reasonable to assume that this could be the case in most of the northern Levantine PPNB

settlements, where Byblos points are, in general terms, larger and, thus, heavier than in the southern Levant. If this is so, the appearance and prevalence of large Byblos points, and the bidirectional blade technologies associated with their production in Pre-Pottery Neolithic assemblages indicate a significant shift in projectile technology. A shift that, from the point of view of projectile technology evolution, is not limited to a mere change in the morphology and size of the stone tips used in projectiles (from microliths or small points to large tanged points) but a critical change in the weapons used: from bow and arrow (Epipalaeolithic and PPNA) to darts (PPNB). This shift is aimed at increasing damage and penetration (darts) –and thus lethality- but sacrifices the versatility and accuracy of the bow, which is generally considered a superior technology; it is also contrary to the general replacement of spear and darts in favour of bow and arrow technology in most parts of the world, though coexistence is attested in certain areas such as in North America (Shott, 1997).

Interestingly, the expansion of spear-thrower use during the PPNB -in other words the loss and subsequent reintroduction of bow-and-arrow technology-cannot be associated with a reduction in typological and technological complexity, as seen in other parts of the world where the same phenomena has been observed (Riede, 2009). In clear contrast, the production of large Byblos points is associated with bidirectional blade technology, a relatively complex technology that requires remarkable practice and a good understanding of the whole reduction sequence to reach the required expertise. Secondly, it is interesting to note that the appearance and expansion of large points (used as dart-points) in the Levant occurred during the PPNB, a period characterized by rural village life during which agricultural and herding practices consolidated and intensified. However, it is noteworthy that the faunal remains from Halula indicate that combined exploitation of a relatively broad spectrum of species from varied biotopes such as bovids (*Bos primigenius*), equids (*Equus asinus/hemionus*), cervids (*Cervus/Dama*), suids (*Sus scropha*) and gazelle (*Gazella gazella*) played a notable role in the subsistence strategies of the community during most of the PPNB sequence (phases 1–16) and especially during the earlier occupations (phases 1–8) of the site (Saña and Tornero, 2013).

In summary, a shift (from bow to spear-thrower) in projectile technology, associated with the appearance and expansion of bidirectional blade technology during the PPNB in the Levant, is synchronous with the consolidation and expansion of agricultural systems in the region. Determining what drew PPNB communities to such an "irrational" shift in projectile technology involving larger projectiles at a transregional scale is a challenging quest that is beyond the scope of this paper. There is no doubt that the needs of PPNB communities changed, as is suggested by the change in type of weapon and the increase in the number of projectile points found in their settlements. However, different hypotheses can be put on the table. Was it the result of a shift toward hunting larger animals? A marked change in the organization of hunting (from individual trips towards group hunting or specialized seasonal mass killing events)? A transformation in the perception and value of hunting itself, from a subsistence activity towards a task with certain social status which would be manifest in the production and display of large projectiles? Or the direct effect of increasing inter-community competition, conflict and warfare? All are plausible, some even complementary, but testing or refuting each of these hypotheses constitutes a research line by itself requiring further interdisciplinary research both in the region and at a transregional scale.

Acknowledgements

We would like to express our gratitude to M. Molist for facilitating our research at Halula. We also acknowledge the comments and constructive criticism made by A. Gopher, I. Mateiciucová and E. Healey to the first draft of the manuscript. Comments and critics made by anonymous reviewers have also been of great value.

References

Abbès, F., 2003. Les outillages néolithiques en Syrie du Nord. Méthode de débitage et gestion laminaire durant le PPNB. BAR Int. S.1150, Oxford.
Andrefsky, W., 2005. Lithics: Macroscopic Approaches to Analysis, second ed. Cambridge University Press, Cambridge.
Aurenche, O., Kozłowski, S.K., 1999. La naissance du Néolithique au Proche-Orient. Éditions Errance, Paris.
Bar-Yosef, O., 1981. The pre-pottery neolithic period in the southern levant. In: Cauvin, J., Sanlaville, P. (Eds.), Prehistoire du Levant. CNRS, Paris, pp. 555–569.
Bar-Yosef, O., 2014. The homelands of the cyprus colonizers: selected comments. Eurasian Prehist. 10 (1–2), 67–82.
Barzilai, O., 2010. Social Complexity in the Southern Levantine PPNB as Reflected through Lithic Studies. BAR Int. S.2180, Oxford.
Bergman, C.A., Newcomer, M.H., 1983. Flint arrowhead breakage: examples from Ksar Akil. Leban. J. Field Archaeol. 10, 238–243.
Boëda, E., Geneste, J.M., Griggo, C., Mercier, N., Muhesen, S., Reyss, J.L., Taha, A., Valladas, H., 1999. A Levallois point embedded in the vertebra of a wild ass (Equus africanus): hafting, projectiles and Mousterian hunting weapons. Antiquity 73, 394–402.
Borrell, F., 2011a. Bi-directional blade technology in the northern levant during the 7-8th millennia CAL B.C: new insights from Mamarrul Nasr 2, Syria. J. Field Archaeol. 36/2, 132–150.
Borrell, F., 2011b. Knapping methods and techniques at Tell Halula (middle Euphrates valley), during the mid VIIIth millennium cal. B.C. In: Healey, E., Campbell, S., Maeda, O. (Eds.), The State of the Stone Terminologies, Continuities and Contexts in Near Eastern Lithics, SENEPSE 13. Ex Oriente, Berlin, pp. 291–303.
Borrell, F., Molist, M., 2007. Projectile points, sickle blades & glossed points: tools and hafting systems in Tell Halula (Syria) during the Mid VIIIth Millennium Cal. B.C. Paléorient 33 (2), 59–78.
Borrell, F., Molist, M., 2014. Social interaction at the end of the Pre-Pottery Neolithic B: an inter-site analysis in the Euphrates valley. Camb. Archaeol. J. 24/2, 215–232.
Browne, J., 1940. Projectile points. Am. Antiq. 5, 209–213.
Cauvin, J., 1968. Les Outillages Néolithiques de Byblos et du Littoral Libanais. Fouilles de Byblos (tome IV). Adrien Maisonneuve, Paris.
Cauvin, M.-C., 1974. Flèches à encoches de Syrie: essai de classification et d'interpretation culturelle. Paléorient 2/2, 311–322.
Christenson, A.L., 1986. Projectile point size and projectile aerodynamics: an exploratory study. Plain Anthropol. 31, 109–128.
Coşkunsu, G., Lemorini, C., 2001. The function of pre-pottery neolithic projectile points: the limits of morphological analogy. In: Caneva, I., Lemorini, C., Zampetti, D., Biaggi, P. (Eds.), Beyond Tools: Redefining the PPN Lithic Assemblages of the Levant, SENEPSE 9. Ex Oriente, Berlin, pp. 145–159.
Eighmey, J., 1992. A Functional Analysis of Projectile Points from the Neolithic Site of 'Ain Ghazal, Jordan. Unpublished Master thesis. San Diego University.
Ellis, C.J., 1997. Factors influencing the use of stone projectile tips: an ethnographic perspective. In: Knecht, H. (Ed.), Projectile Technology. Plenum, New York, pp. 37–68.
Erlandson, J.M., Watts, J.L., Jew, N.P., 2014. Darts, arrows, and archaeologist: distinguishing dart and arrow points in the archaeological record. Am. Antiq. 79, 162–169.
Fenenga, F., 1953. The weight of chipped stone points: a clue to their function. Southwest. J. Anthropol. 9, 309–323.
Friis-Hansen, J., 1990. Mesolithic cutting arrows: functional analysis of arrows used in the hunting of large game. Antiquity 64, 494–504.
Gopher, A., 1994. Arrowheads of the Neolithic Levant: a Seriation Analysis. Eisenbrauns, Winona Lake.
Goring-Morris, A.N., 1999. Saflulim: a late natufian base camp in the central neguev highlands. Isr. Palest. Explor. Q. 131, 36–64.
Helwig, K., Monahan, V., Poulin, J., Andrews, T.D., 2014. Ancient projectile weapons from ice patches in northwestern Canada: identification of resin and compound resin-ochre hafting adhesives. J. Archaeol. Sci. 41, 655–665.
Hildebrant, W.R., King, J.H., 2010. Distinguishing between darts and arrows in the archeological record: implications for technological change in the American west. Am. Antiq. 77, 789–799.
Hughes, S.S., 1998. Getting to the point: evolutionary change in prehistoric weaponry. J. Archaeol. Meth. Theory 5, 345–408.
Junkmanns, J., 2001. Arc et Flèche, fabrication et utilisation au Néolithique. Editions Musee Schwab, Bienne.
Kidder, A.V., 1938. Arrow-heads or dart points? Am. Antiq. 4, 156–157.
Kingery, W.D., Vandiver, P.B., Prickett, M., 1988. The beginnings of pyrotechnology, part II: production and use of lime and gypsum plaster in the Pre-Pottery

Neolithic near east. J. Field Archaeol. 15, 219–244.
Korfmann, M., 1974. Diskussion der Grundnomenklatur steinerner Pfeilköpfe. Archäographie 3, 59–67.
Kozłowski, S.K., 1999. The big arrowhead industries in the near east. Neo Lithics 2/99, 8–10.
Kozłowski, S.K., Aurenche, O., 2005. Territories, Boundaries and Cultures in the Neolithic Near East. BAR Int. S.1362, Oxford.
McEwen, E., 1998. The bow. In: Schick, T. (Ed.), The Cave of the Warrior. A Fourth Millennium Burial in the Judean Desert, Israel Antiquities Authority Reports 5. Israel Antiquities Authority, Jerusalem, pp. 45–53.
Mellart, J., 1967. Çatal Höyük a Neolithic Town in Anatolia. Thames and Hudson, London.
Miller, R., 1983. Chisel-ended arrowheads from tell Hadidi, Syria. Bull. Inst. Archaeol. Lon. 20, 187–190.
Molist, M. (Ed.), 2013. Tell Halula: un poblado de los primeros agricultores en el valle del Éufrates, Siria. Memoria Científica. Ministerio de Educación, Cultura y Deporte, Madrid.
Moss, E., 1983. A microwear analysis of burins and points from tell Abu Hureyra, (Syria). In: Cauvin, M.-C. (Ed.), Traces D'Utilisation sur les Outils Néolithiques du Proche Orient, Travaux de la Maison de L'Orient V. GIS-Maison de l'Orient, Paris, pp. 143–161.
Newman, K., Moore, M.W., 2013. Ballistically anomalous stone projectile points in Australia. J. Archaeol. Sci. 40, 2614–2620.
Nishiaki, Y., 2000. Lithic Technology of Neolithic Syria. BAR Int. S.840, Oxford.
Nishiaki, Y., 2013. "Gifting" as a means of cultural transmission: the archaeological implications of bow-and-arrow technology in Papua New Guinea. In: Akazawa, T., Nishiaki, Y., Aoki, K. (Eds.), Dynamics of Learning in Neanderthals and Modern Humans, Replacement of Neanderthals by Modern Humans Series, vol. 1. Springer, New York, pp. 173–185.
Pawlik, A.F., Thissen, J.P., 2011. Hafted armatures and multi-component tool design at the Micoquian site of Inden-Altdorf, Germany. J. Archaeol. Sci. 38, 1699–1708.
Quintero, L., 2010. Evolution of lithic economies in the levantine neolithic. In: Development and Demise of Naviform Core Technology as Seen at 'Ain Ghazal ('Ain Ghazal Excavation Reports, Volume 2). Bibliotheca neolithica Asiae meridionalis et occidentalis. Monograph of the Faculty of Archaeology and Anthropology. Ex Oriente, Berlin.
Quintero, L.A., Wilke, P.J., 1995. Evolution and economic significance of naviform core-and-blade technology in the southern levant. Paléorient 21/1, 17–33.
Rausing, G., 1967. The Bow: Some Notes on its Origin and Development. Gleerups, Lund.
Riede, F., 2009. The loss and re-introduction of bow-and-arrow technology: a case study from the Southern Scandinavian Late Palaeolithic. Lithic Technol. 34/1, 27–46.
Rollefson, G., 1998. The Aceramic neolithic of Jordan. In: Henry, D.O. (Ed.), The Prehistoric Archaeology of Jordan, pp. 102–126. BAR Int. S.705, Oxford.
Roodenberg, J.J., 1986. Le mobilier en Pierre de Bouqras. Utilisation de la Pierre dans un site néolithique sur le Moyen Euphrate (Syrie). Nederlands Historisch-Archaeologisch Instituut te Istanbul, Istanbul.
Saña, M., Tornero, C., 2013. La gestión de los recursos animales en Tell Halula: nuevas hipótesis y aproximaciones metodológicas para el estudio de la domesticación animal y producción ganadera. In: Molist, M. (Ed.), Tell Halula: un poblado de los primeros agricultores en el valle del Éufrates, Siria, vol. II. Ministerio de Educación, Cultura y Deporte, Madrid, pp. 277–332.
Schmidt, K., Beile-Bohn, M., 1996. A LPPNB variant of Byblos points from Gürcütepe II – palmyra points? Neo Lithics 96/2, 9–11.
Shea, J.J., 2006. The origins of lithic projectile points technology: evidence from Africa, the Levant and Europe. J. Archaeol. Sci. 33, 823–846.
Shea, J.J., 2013. Stone Tools in the Paleolithic and Neolithic of the Near East: a Guide. Cambridge University Press, New York.
Shea, J.J., Davis, Z., Brown, K., 2001. Experimental test of middle paleolithic spear points using a calibrated crossbow. J. Archaeol. Sci. 28, 807–816.
Shott, M.J., 1997. Stones and shafts redux: the metric discrimination of chipped stone dart and arrow point. Am. Antiq. 62, 86–102.
Sisk, M.L., Shea, J.J., 2011. The African origins of complex projectile technology: an analysis using tip cross-sectional area and perimeter. Int. J. Evol. Biol. 1–8.
Tankersley, K.B., 1994. Clovis mastic and its hafting implications. J. Archaeol. Sci. 21, 117–124.
Tarabek, J.E., 2013. What's the Point: the Transition from Dart to Bow in the Eastern Plains. Unpublished Master thesis. University of Kansas.
Thomas, D.H., 1978. Arrowheads and atlatl darts: how the stone got the shaft. Am. Antiq. 43, 461–472.
Yaroshevich, A., Kaufman, D., Nuzhnyy, D., Bar-Yosef, O., Weinstein-Evron, M., 2010. Design and performance of microlith implemented projectiles during the Middle and the Late Epipaleolithic of the Levant: experimental and archaeological evidence. J. Archaeol. Sci. 37, 368–388.
Yaroshevich, A., Nadel, D., Tsatskin, A., 2013. Composite projectiles and hafting technologies at Ohalo II (23ka, Israel): analyses of impact fracture, morphometric characteristics and adhesive remains on microlithic tools. J. Archaeol. Sci. 40, 4009–4023.