An Experimental Study of Bone Artifacts from the Neolithic Site of Tell Abu Suwwan (PPNB-PN), Jordan

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Abstract: *A considerable number of Pre-Pottery Neolithic sites in the southern Levant have yielded worked bone artifacts, including ornaments and tools. Such artifacts are thought to have played an important role in the economy and in exchange at these sites. Although many bone artefacts have been recovered from these Neolithic sites, few technological or experimental studies have been done. Such studies are needed to understand the processes of production and distribution, and the relationship between the artefacts and the animals from which they were derived. This research used data from the Neolithic site of Tell Abu Suwwan in Jordan. Approximately 20,000 bone fragments have been analyzed from selected squares from Area B at the site. Fifty-eight worked bone artifacts were recovered from this sample. To attempt to identify the technologies used in bone fabrication at Tell Abu Suwwan during the Neolithic period, an experimental approach was undertaken that involved replication of bone artifacts using replicas of stone tools. The experiment helped to demonstrate the types of stone artifacts that could have been used to make the bone tools and the type of animal bones that were used in this manufacturing process.*

1. Introduction

A considerable number of Pre-Pottery Neolithic (PPN) sites in the southern Levant have yielded worked bone artifacts, including ornaments and tools. Among them are Nahal Issaron (Goring-Morris 1993), Abu Ghosh, Beisamoun (Lechevallier, cited in Wright 1978; Becker 1991) and Nahal Hemar (Schick 1988, Shimony & Jucha 1988) in Palestine. Such artifacts are thought to have played an important role in the economy and in exchange at these sites. Of the utilitarian artifacts awls, needles and spatulate objects are numerically predominant. Banning (1998: 212) suggested that notched or pierced bone tools were used for weaving and Kirkbride (1966) claimed that the iconic site of Beidha in southern Jordan produced the most convincing evidence for weaving in the entire region. She believed Beidha had specialized workshops for different kinds of craft activities during its PPNA and PPNB occupations (Banning 1998. Kirkbride 1966). Awls, spatulas, and needles were also found at Ba'ja, Basta and Ain Ghazal (Gebel et. al. 1988, Purschwitz & Kinzel 2007, Rollefson et al. 1992, Rollefson & Kohler-Rollefson 1992) whereas Ayn Abu Nukhayla (Henry et al. 2003) and Iraq ed-Dubb (Kujit 2004) offered different types of worked bone. Paralleled-sided spatulas and pointed tools such as awls and perforators were uncovered at Khirbet Hammam (Peterson 2004). Worked bone was exceptionally common at Shakarat al-Musay'id – 24 awls, 30 needles, 16 spatulas, 9 bone scrapers, and 43 miscellaneous pieces of unknown function (Jensen et al. 2005: 130). Although many bone artefacts have been recovered from these Neolithic sites, few technological or experimental studies have been done. Such studies are needed to understand the processes of production and distribution,

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and the relationship between the artefacts and the animals from which they were derived. We address these questions here using data from Tell Abu Suwwan (ASW), a large PPNB site located in the west Jordan highlands about 25 km north of Amman.

Approximately 20,000 bone fragments have been analyzed from selected squares from Area B at the site. Fifty-eight worked bone artifacts (~ 0.03%) were recovered from this sample and the technological procedures thought to have been used to make them assessed (Abuhelaleh 2011). The study suggested that different kinds of bone tools might be correlated with type, and size of species exploited as raw material. To assess the credibility of these proposed relationships we first classified the archaeological sample by type, size and raw material, and then attempted to manufacture replicas of the tools recording the number of production steps necessary to do so as well as the kinds of stone artifacts required to make them.

2. Tell Abu Suwwan

Tell Abu Suwwan is one of seven Neolithic 'megasites' in Jordan (Gebel 2004: 6, Simmons 2007: 125) and the only one north of the Zarqa River. Directed by the author, four field seasons (2005-8) were conducted under the auspices of the University of Jordan (al-Nahar 2013). Its architectural characteristics and the diagnostic lithic and bone artifacts, as well as 19 radiocarbon dates, suggest that it was occupied continually from the Middle Pre-Pottery Neolithic B (MPPNB) to the Yarmoukian (Pottery Neolithic) period (Table 1). The excavated part of the site was divided into Areas A and B. This study pertains only to Area B.

Excavations in Area B yielded a complex square or rectangular structure (12.5 x 11m) sub-divided internally by parallel walls resulting in 5 narrow rectangular spaces (Fig. 2). The structure is similar to the 'grill buildings' at Çayönü, an early Neolithic site in Anatolia (Özdoğan 1999). Because of the density and kinds of artifacts

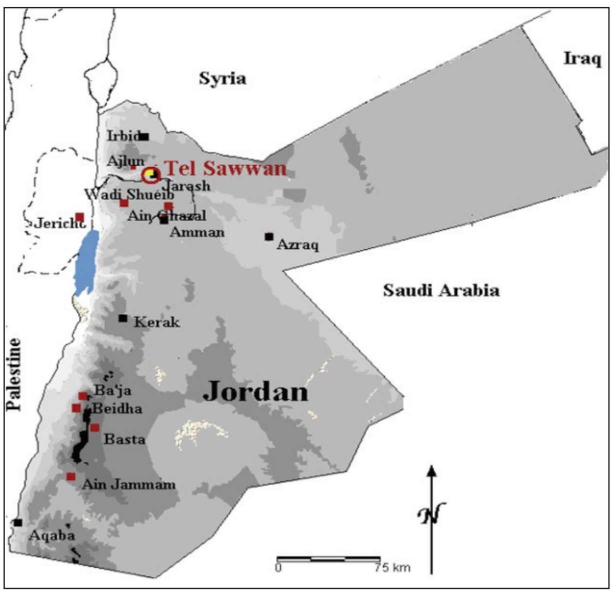

Fig. 1. Pre-Pottery Neolithic B Sites in Jordan.

Fig. 2. Tell Abu Suwwan – Aerial Photo of Area B.

ASW YR	AREA	SQ	LOC	LEVEL	^{14}C BP non-calibrated	^{14}C BC calibrated	Period
2006	A	D5	23	510.89	8410 ± 56	7469 ± 68	LPPNB
2006	B	K6	3	515.39	8259 ± 49	7306 ± 100	LPPNB
2008	B	K6	27	514.16	8440 ± 120	7453 ± 118	LPPNB
2008	B	F8	6	513.99	8310 ± 50	7380 ± 76	LPPNB
2006	A	D4	6		8140 ± 100	7141 ± 157	LPPNB
2005	A	E2	6	510.97	8380 ± 56	7446 ± 68	M/LPPNB
2008	B	K6	24	514.31	8484 ± 55	7547 ± 29	M/LPPNB
2008	B	K6	29	514.14	8570 ± 51	7596 ± 31	M/LPPNB
2006	A	V3	4	510.75	8931 ± 58	8109 ± 108	MPPNB
2006	B	W3	5	511.11	9048 ± 59	8267 ± 32	MPPNB
2008	B	G7/F7	17	514.61	8699 ± 84	7777 ± 133	MPPNB
2008	B	K6	38	513.64	8680 ± 60	7710 ± 81	MPPNB
2006	A	D5	23	510.60	7975 ± 62	6888 ± 116	PPNC
2005	B	J6	10		7870 ± 50	6755 ± 87	PPNC
2008	A	D5	39	512.47	7760 ± 120	6659 ± 153	PPNC/Yarm
2008	B	0A	2	515.34	7713 ± 79	6558 ± 68	PPNC/Yarm
2006	A	D4	7		7630 ± 50	6498 ± 47	PPNC/Yarm
2008	B	F8	3	514.84	7422 ± 74	6304 ± 74	Yarmoukian
2008	B	CD		514.54	7304 ± 97	6192 ± 107	Yarmoukian

Table 1: Tell Abu Suwwan chronology (al Nahar 2013).

found there, the external space or courtyard in front of the eastern entrance has been interpreted as a processing area or courtyard, variously subdivided, and with several stratified floors made from very small stones, pebbles, and fine gravels (al-Nahar 2009).

Tell Abu Suwwan has also yielded a large amount of chipped stone dominated by Neolithic diagnostics, and many grinding stones. Even though the lithic analysis is still incomplete, all stages of lithic production appear to be present. Débitage includes a large number of flakes, blades, bladelets, and a diverse collection of different types of cores (e.g., naviform blade cores, multiple platform, opposed platform, etc.). Moreover, the retouched component of the lithic assemblage included a large number of diagnostic artifacts such as arrowheads (several types), sickle blades, truncations, notches, denticulates, bifacial knives, and several scraper types including many tanged circular scrapers of different sizes. Additionally, a new scraper type was recognized at ASW, called the Jarash

Fig. 3. Tanged scrapers from Area B at Tell Abu Suwwan.

Fig. 4. Borers, sickle blades, backed and truncated pieces and serrated pieces made on small blades and bladelets – Tell Abu Suwwan, Area B.

scraper after the spectacular Roman city nearby (Figs. 3, 4) (al-Nahar 2006, 2010, 2009, 2013).

Although archaeozoological studies are still incomplete, around 20,000 bones, teeth and horn core fragments have been analyzed from selected squares at the site. The domesticated component is dominated by sheep (Ovis sp.) and goat (Capra sp.). Wild animals are also present, indicating a certain emphasis on hunting (e.g., Gazella sp., Bos primigenius, Sus scrofa, Ovis sp., Lepus sp., Lynx sp.) (Abuhelaleh 2011).

3. The Data & Comparative Studies

Fifty-eight (0.3%) worked bone objects were recovered during the faunal analysis of the site. These bone tools were the subject of a specialized analysis to differentiate them morphologically and to describe the technologies used in their fabrication (Abuhelaleh 2011). The occupants of ASW were clearly aware of the various characteristics regarded as desirable or essential to manufacture bone tools (Newcomer 1974). The source of the raw material, size, shape and density, anatomical parts, and the use for which the objects were intended were the main criteria selected for bone tool manufacturing (Choyke & Schibler 2007). Regarding selection for particular bones, Camps-Fabrer (1990) identified the technologies used to make bone tools from Chalcolithic and Bronze Age sites in Spain. Metapodials were most commonly used. Garfinkel and Horwitz (1988) studied the PPNB bone industry from Yiftahel and have proposed

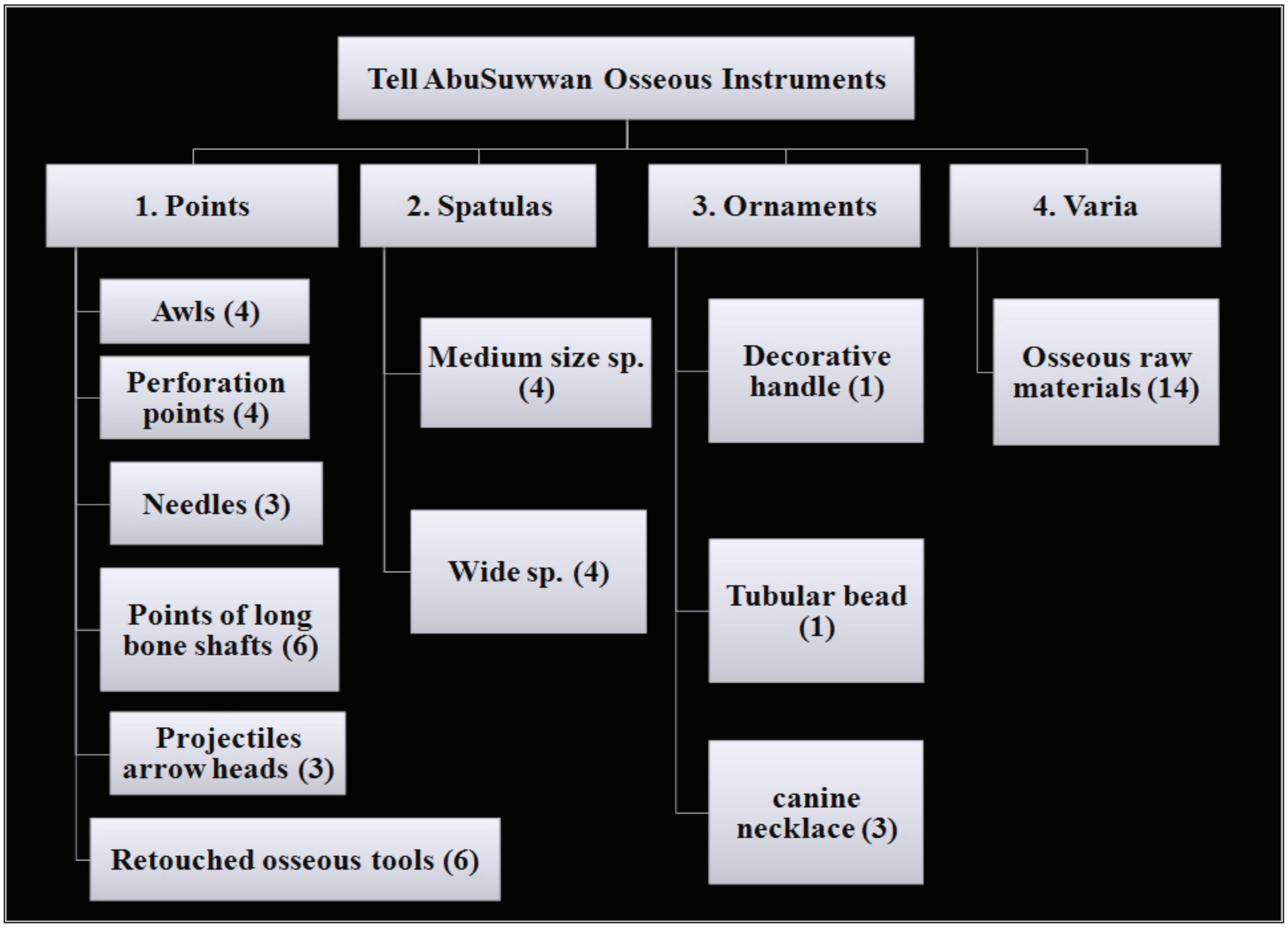

Fig. 5. Typological scheme of Tell Abu Suwwan worked bone artifacts. (n) represents the number of remains for each category.

Bone tools categories	Typology	Osseous raw materials	Retouched blade (1) & Sickle blade (2)	Abrading	Utilization traces remarks	Mesurments* (MM) Length/Largness/thickness	Preservation of the points
Pointed bone tools	Awls (4)	Femore+Tibia	1+2	Yes	Yes	100.0 /20.0/5.0m	1 Instrument
	Perforation points (4)	Metapodiale Medium size	1+2	Yes	Yes	50.0/11.0/ 2.0	1 Instrument
	Needles (3)	Fragment long bone	2	YES	YES	41.6/ 15.0-2 .0/ 3.0-2 .0	1 Instrument
	Projectiles (3)	Metapodiale Long bone Medium size	1+2	YES	NO	35.3-46.4/ 6.4-2.2/2	1 Instrument
	Points of long bone shafts (6)	Metapodial Medium size	1+2	Yes	Yes	40.0/8.0/5.0	1 Instrument
	Retouched osseous tools: Horn (2)	Goat/Sheep	-	Yes	Yes	92.0/38.0/10.0	1 Instrument
	Retouched osseous tools: Long bone (4)	Long bone Medium size	1+2	Yes	Yes	54.0/14.0/5.0	2 Instruments
Spatula	Medium size spatula (4)	Costola Medium size	1+2	No	Yes	61.0/14.0/2.3	2 Instruments
	wide spatula (4)	Costola (Aurochs)	1+2	Yes	Yes	136.0/24.2/8.4	1 Instrument

Table 2. Worked bone sample from ASW cross-classified by typology, anatomical part, abrasion, utilization, measurements and preservation.

a typology for the osseous industry at that site based only on size and shape. This was a strictly morphological study. No behavior chain was identified that might have indicated criteria for bone selection, how bones were prepared, fabricated, modified or used. Clutton-Brock (1979) studied the bone tools from PPN Jericho, targeting provenience and the anatomical parts used in tool fabrication. Cristiani's research on the osseous industries from Dalmeri rockshelter in Italy is another example (2008).

Fig. 6. ASW 1 – (A) distal portion of an arrowhead, (B) grooves to shape it so that it can be hafted to the arrow shaft.

Although there are many studies of bone tool manufacture, few of them attempt an experimental approach like the one described below. It is important to keep in mind that there was almost certainly variation in how prehistoric peoples produced these instruments. Not only were there different trajectories to the

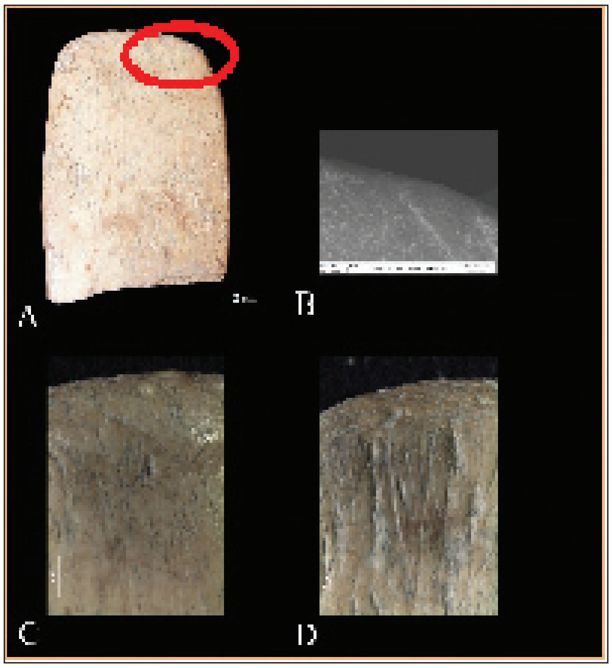

Figure 7. ASW 16 – (A) ventral surface of the proximal end of a wide spatula, (B) use wear traces (SEM Image), (C) manufacturing marks on the ventral surface (stereomicrograph), (D) manufacturing marks on the lateral edge (stereomicrograph).

production of similar tools, similar tools could have been made and used for different purposes. Since the archaeological record is silent on the subject, only through modern-day replication of these artifacts can we really understand how they were made and used.

4. An Experimental Approach

To attempt to identify the technologies used in bone fabrication at ASW, an experimental approach was undertaken that involved replication of bone artifacts using modern material. The first step was to identify the modifications applied to the unaltered bones prior to shaping. Source material (species, anatomical parts) and use were taken into account, use being determined by the overall intended shape of the tool. Stereoscopic and electron scanning microscopes (ESM) were used to identify manufacturing processes and subsequent use and wear patterns. The ASW bone tools were compared with those from K'sar Akil in Lebanon (Newcomer 1974) and Yiftahel in Palestine (Garfinkel & Horwitz 1988).

4.1. Bone Tool Types

The main typological categories of worked bone artifacts from ASW are given in Figure 5. These are pointed tools, spatula, ornaments and varia. Type frequencies and other metric data are given in Table 2. Micrographs of awls, arrowheads, spatulas and decorated instruments are shown in Figs 6-8.

5. Experimental Methodology

1. A production step database was set up to register all data during the experiment, including estimates of time expended for each step. The scheme contains the names of object use and their typology. To proceed in

Fig. 8. ASW 36 – Awl on a right femur of a wild boar.

this method it was important to establish the type(s) of stone tool(s) used to make each category of bone artifact.

2. Following the archaeological classification of the ASW bone artifact types given above, tool replicas were prepared experimentally. During fabrication, each stone tool replica was used on a different type of bone to produce a bone artifact replica. The pointed osseous tools and spatulas were the most commonly found tools at the site. The experiment concentrated on producing replicas of them.
3. A sheep carcass and cow ribs were the primary source of raw material. Different portions of the sheep carcass were used in this experiment. Metapodials, ulnae and femora were used to produce the different pointed tool categories. The cow ribs were used to replicate the wide spatula.
4. The modern replicas were then examined under the stereomicroscope and the ESM to analyze the marks related to the manufacturing and utilization processes on both the bone and the stone tools surfaces.

5.1. Bone and Lithic Artifact Replicas:

The experiment helped to demonstrate the types of stone artifacts that could have been used to make the bone tools. The final products of the experiment in relation to the stone tools used are given in Table 3. These results confirm our hypothesis of the production steps involved in making bone artifacts at Tell Abu Suwwan.

5.1.2 Replicated Lithic Artifacts

A pre-defined set of lithic tool replicants were made and used in the experiment, selected on the basis of the most common lithic types found at ASW and in other PPNB sites in the west-central highlands (Rollefson et al. 1992, Simmons et al. 2001, al-Nahar 2010). The experimental results suggest that the best candidates that were used to make the bone industry are endscrapers, sidescrapers, burins, retouched blades, denticulates, truncated pieces, and borers. Unretouched blades and flakes might have been used as well. There is considerable variation in lithic raw material types at Tell Abu Suwwan and it was not possible to source, hence match, the raw material types found in the site. Therefore, a very fine-grained,

Bone Tool Categories	Typology	Osseous Raw Material	Stone Implement: retouched (1) unretouched (2)	Abrasion
Pointed Bone Tools	awl (1)	sheep ulna (left)	1+2	yes
	perforated points (2)	metatarsal	2	yes
	needle (1)	metatarsal	2	
	projectiles (2)	metatarsal	2	Yes
	points of long bone shaft (1)	sheep femur (right)	2	No
Spatulae	wide spatula (1)	large cow ribs	1+2	Yes

Table 3. Typological scheme of experimentally manufactured bone artifacts.

homogeneous red flint collected near a single outcrop in central Italy was selected to hold constant the variability and the homogeneity of the rock texture. While we are aware of the bias introduced by performing experiments using a different raw material, we tried to minimize it in the functional analyses by adopting a series of sampling procedures.

Blades were selected to make the stone tools for the replication experiment because of overall standardized shape and to maximize the length of sharp edges. The blades were struck from cores with one or two opposed striking platforms. Soft hammer percussion (bone, wood) was used for knapping. The blades were retouched using both direct percussion and bone/antler pressure flaking.

5.1.3. Replicated Bone Artifacts

Throughout the experiment any alteration of the surface of the bone was recorded. This included marks caused by either butchering of the carcasses or instruments used for preparation of the tools themselves. This helped us to understand the kind and sequence of traces that accumulated at each step on each individual piece. The replication experiment produced a needle, a wide spatula, five different points, and an awl. In each case the replicated tools were

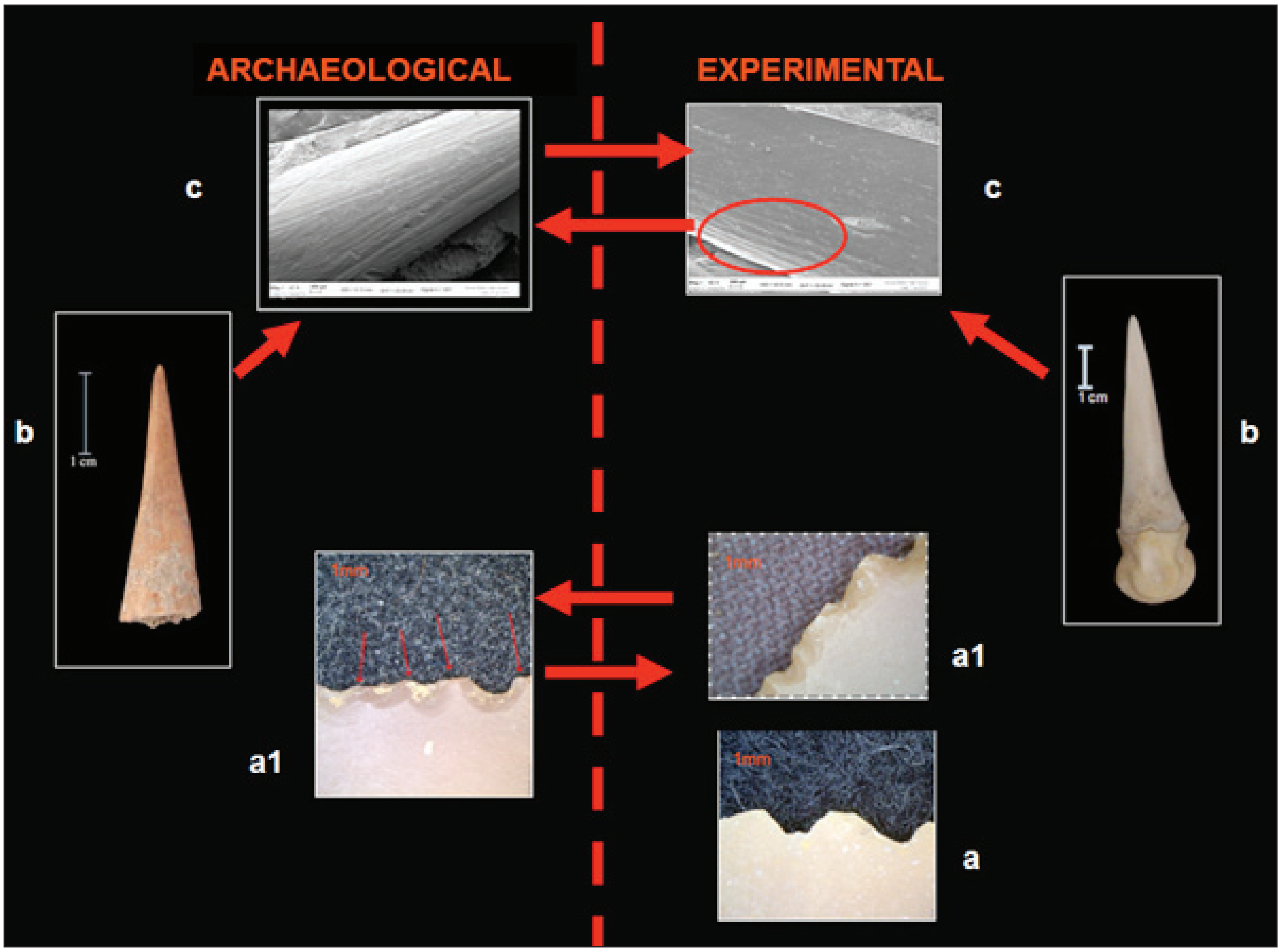

Fig. 9. Results of the comparative analysis between the ASW collection and the experimental work. (a) sickle blade edge before use, (a1) sickle blade edge showing traces related to bone working, (b) proximal end of a bone awl (ASW.10) (left), experimental awl (right), (c) processing traces left by the use of a sickle blade on the awl surface.

made from anatomical parts similar to those found at Tell Abu Suwwan.

Table 3 summarizes the main characteristics of the bone tools produced in the experiment and the replicated stone artifacts with which they were made. Additional surface wear traces were recognized during the butchering processes of the carcasses. Stereomicroscopic studies have been applied to distinguish all modifications on the surfaces during the work. Additionally, ESM analysis was done to assess differences between the experimental bone tools and original ones from Tell Abu Suwwan.

5.2 Microscopic Analysis & Comparison of Replicated & Original Stone & Bone Tools

The edges of the experimental stone tools were examined at each stage in the behavior chain (Schiffer 1976) in order to assess the degree of use-wear. By doing so we can measure their effectiveness during the experimental operations (Semenov 1954, Korobova 2008, Beyries et al. 2008). Use-wear traces on the replicas were then compared with the use-wear traces on the original lithic tools from Tell Abu Suwwan. The experiment confirmed the kinds of stone tools that proved to be most efficient (e.g., retouched blades, sickle blades) as the experimental tools produced the same type of traces that appeared on the originals (Fig. 9).

The functional analysis of the stone tools integrated the low (LPA) and high (HPA) magnification approaches (Beyries 1987, Christensen 1996, Keeley 1980, Odell 2000, Plisson 1985,2001, Semenov 1954). The LPA analysis was made with a stereomicroscope (Seben Incognita 3-10-80x) and a digital microscope (Dinolight Am413T-5-230x) while the HPA study used a metallographic microscope (AmScope ME300T-M -40-640x) equipped with a camera (AmScope MD600).

6. Bone Fabrication Technology

The laboratory study of the various raw

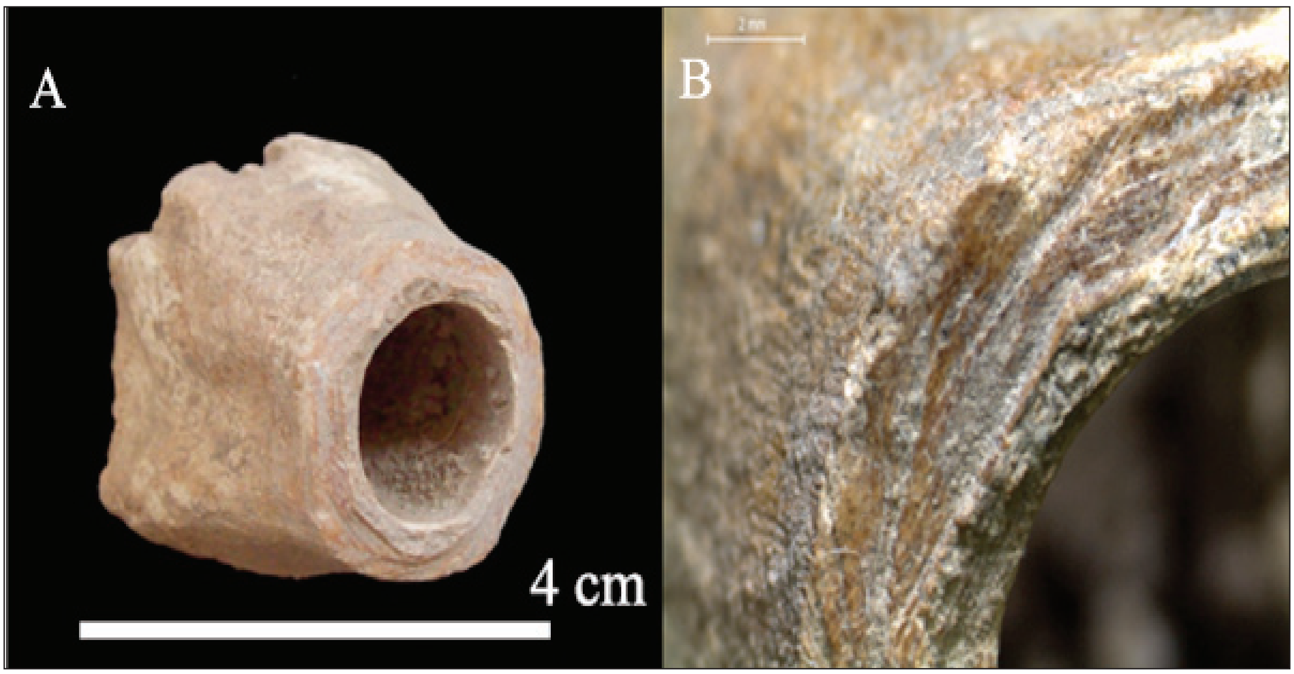

Fig. 10. ASW37 – (A) distal fragment of a goat tibia with grooving marks, (B) detail of the grooving by which the epiphyseal end is removed from the shaft (stereomicrograph).

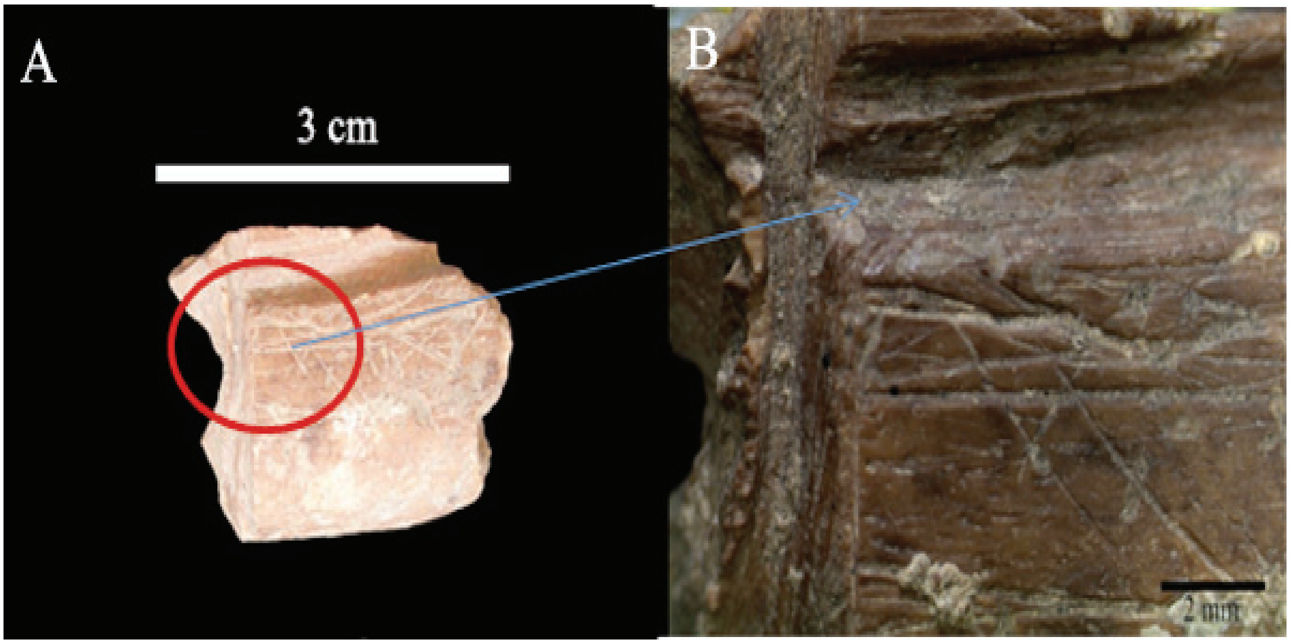

Fig. 11. Tell Abu Suwwan 40 – (A) raw bone fragment on a metapodial, (B) longitudinal and transverse grooves to cut the bone.

materials and bone tool making indicated different stages of fabrication. These stages have been confirmed by various modifications on the raw material and by studying the traces of manufacture on the surfaces of the bone. Two main technological classes of osseous industry can be proposed:

1. Implements made on intentionally broken bone fragments. In this category the maker takes advantage suitable fractures of a bone fragment to modify it either by abrasion and/or using retouched stone tools.
2. Implements planned and manufactured according to a mental template. Here the initial phases of the chaîne opératoire are followed in all cases while different techniques are utilized to finish the implement. Either abrasion or scraping with retouched tools are used to sharpen the piece.

The first phase is to prepare the bone surface, initially by smoothing it by scraping with different stone tools. This phase could be done either before or after cutting the epiphyses to prepare the shaft for the further processing. The preparation phase is marked by intensive longitudinal grooving on unaltered bone. Then the distal portion is removed by cutting it circumferentially in order to produce pointed implements for perforation.

A second way to do it is to cut off the epiphysis prior to the fabrication of the tool. This method was applied to various long bones from several species. In each case we found that the long bone shaft was cut perpendicularly to remove the epiphyses. This step in preparation results in intensive perpendicular grooving on the surface (Fig. 10).

A third way is to cut one or several longitudinal grooves in the workpiece. This resulted in the best (i.e., most efficient) exploitation of the raw material because more than one implement could be produced from the same bone fragment. Spiral cutting of the shaft has been observed and could be used to prepare the proximal end of an awl (Fig. 11).

The last technique is similar to the third one. However, in this case an inclined longitudinal cut (spiral cut) has been made that might have been used to prepare the point of a long awl.

We concluded from the experimental part of the study that the motions involved in cutting the bone resembled those found at ASW. Typically longitudinal cuts were made prior to cuts perpendicular to the long axis of the bone. The Neolithic occupants of Tell Abu Suwwan seem to have used the epiphyseal portions as handles to assist in longitudinal cutting. This also proved to the be the case with the experimental work. Keeping the epiphyseal portion stable was necessary in order to make the grooves. After that, longitudinal cuts were made by intensive grooving done from at least three distinct cutting angles.

Disarticulating (splitting the shaft into long, thin fragments) the epiphyses could be done with two methods: (1) by bashing the shaft with a hammer stone, indicated by the irregular fractures on the long bone surfaces; and (2) by inducing a longitudinal fracture by using indirect percussion with a sharp blade.

7. Conclusion

In an effort to identify the suite of technological behaviors used in the manufacture of 58 bone artifacts from the site of Tell Abu Suwwan, we replicated stone tools similar to those found archaeologically and used them to make modern copies of the bone objects recovered from the site. A comparison using both low- and high-resolution stereomicrographs of manufacturing traces was largely successful in reproducing the technologies used to make the prehistoric bone objects. Lower limb bones (tibiae and metapodials) of wild boar, goat, sheep and gazelle were used preferentially to make pointed implements whereas the ribs of medium and large animals (such as cattle ribs) were used to make spatulate objects. The surfaces of the bones were first prepared with retouched blades and scrapers, while grinding and polishing were utilized to finish the points. The variety of the implements recovered in Tell Abu Suwwan seems to indicate a certain amount of design specificity in the tools necessary for particular activities.

Few studies have been published about Neolithic bone tool production technologies in the southern Levant (e.g., K'sar Akil, Yiftahel), and Jordan in particular is still in great need of specialized research aimed at reconstructing these technologies. Although this is only a first step in that direction, the results of future work should confirm or reject the findings reported here. Organic technologies were as important in the Levantine Neolithic as they were earlier but it is only with the Neolithic that substantial amounts of organic material are preserved. We need to make use of these data to do more than erect morphological classifications of bone tools. We need to focus more intensively on the procedures by which these artifacts were made and used.

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ملخص: عُثر على الكثير من الأدوات العظمية في مواقع العصر الحجري الحديث في بلاد الشام، وقد لعبت هذه الأدوات دورا مهماً في اقتصاد هذه المرحلة؛ إلا أن الدراسات التجريبية على هذه الأدوات قليلة بشكل عام؛ فهذا النوع من الدراسات يساعد على فهم مراحل التصنيع ومدى انتشار هذه الأدوات وعلاقتها بالتبادل الاقتصادي بين مواقع هذه المرحلة. وللتوصل لهذه المعرفة، عُني البحث بدراسة الأدوات العظمية التي عُثر عليها في موقع تلّ أبوالصوّان، الذي يعود إلى العصر الحجري الحديث، ويقع شمالي الاردن. وقد عُثر في الموقع على عشرين ألف قطعة عظمية استُخرج منها ٥٨ قطعة عظمية مُصنّعة، وقد اهتمت هذه الدراسة بالتعرّف على نوع الأدوات الصوانية، ونوع العظام الحيوانية التي استُخدِمت في تصنيع تلك الأدوات، ومراحل تصنيعها؛ وذلك من خلال إجراء دراسة تجريبية استُخدِمت فيها أدوات صوّانية وعظمية، جرى تصنيعها من قِبل الباحثين لهذا الغرض.

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