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THE PPNC BIFACIAL TOOL INDUSTRY FROM THE SUBMERGED SITE OF ATLIT-YAM, ISRAEL

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Abstract

Since the 1986 introduction of a new chrono-cultural Pre-Pottery Neolithic phase, the PPNC, few attempts have been made to define its lithic assemblages and to characterize the differences and/or similarities between PPNC lithics and the preceding PPNB and later Pottery Neolithic Yarmukian assemblages.

Here we present in detail the bifacial tool industry from Atlit-Yam, a single stratum submerged PPNC site at the Carmel coast, Israel. The large number of bifacial tools recovered from the site enable a thorough study of a PPNC bifacial tool industry. The Atlit-Yam bifacial tools are compared to bifacial tool assemblages from PPNB and Yarmukian sites in the southern Levant. We conclude that PPNC bifacial tools are very similar to those of the preceding Middle to Late PPNB.

INTRODUCTION

The PPNC site of Atlit-Yam (Fig. 1) is situated some 200–400 meters offshore, at a depth of 8–12 m, and covers an area of ca. 40,000 m^2. Radiocarbon dates for the site give a range of 8,180–7,550 yr B.P. (uncalibrated; Galili *et al.*, 1993, 1999). The architectural remains consist of stone-built water-wells (Galili and Nir, 1993; Galili and Sharvit, 1998), foundations of rectangular structures, a series of long, unconnected walls, ritual installations, and stone-paved areas (Galili *et al.*, 1993).

Sixty-five human skeletons were discovered, some of which were in primary burials while others were in secondary burials. Faunal remains included bones of wild and domestic sheep/goat, pig, cattle and dog, as well as more than 6,000 bones of marine fish. A majority of the fish bones were determined to be *Balistes carolinesis*, the gray trigger fish; but a few were also attributed to *Serranidae, Sparidae, Sciaenidae, Mugillidae*, and other families (Galili *et al.*, 1993; Zohar *et al.*, 1994, 2001).

Artifacts made of stone, bone, wood and flint (such as fishing net sinkers, knives) that may be associated with fishing activities, were also recovered, as well as large quantities of botanical remains, including seeds of domesticated wheat, barley, lentil, and flax (Galili *et al.*, 1993; Kislev *et al.*, 1996). The archaeological material indicates that the economy of the site was complex and based on the combined utilization of terrestrial and marine resources involving plant cultivation, livestock husbandry, hunting, gathering, and fishing.

Fourteen excavation seasons (1984–2000) were conducted on selected features revealed in the exposed areas of the seabed. In addition, rescue surveys during the winter served to document structures and installations, preserve and retrieve any occasionally exposed finds (human skeletons, artifacts and organic remains) facing an immediate threat of destruction. Digging was conducted manually with a dagger or using a dredging system operated by a water pump. A dredger removed loose sediments until the clay containing the archaeological material was reached. Then, the deposit was excavated in 10 cm spits in 0.5×0.5 m squares. The excavated material was collected in tagged plastic bags, marked with the square and layer, and transported to the shore laboratory for sieving. Small or

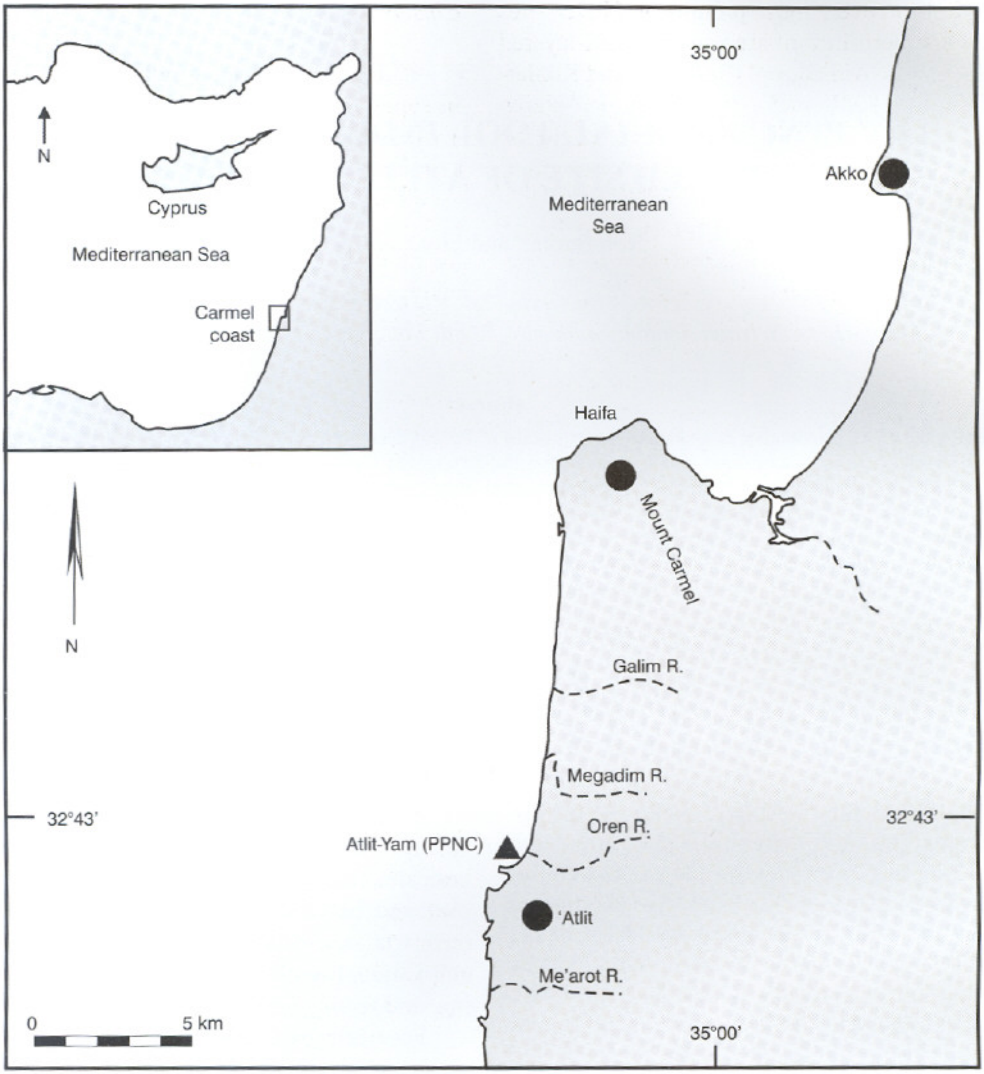

Fig. 1. Location map of the PPNC site of Atlit-Yam

fragile artifacts were collected in plastic jars and core samples of *in situ* clay were taken for pollen and sediment analysis.

FLINT BIFACIAL TOOLS FROM ATLIT-YAM

The flint assemblage of Atlit-Yam includes a relatively large group of bifacial tools (n=154) which enables a detailed technological and typological analysis based on both descriptive and quantitative grounds. These bifacial tools originate both from systematic excavation and salvage operations. The placement of Atlit-Yam within the PPNC time scale emphasizes the importance of such an analysis in order to clarify the similarities and/or differences between the Atlit-Yam bifacial tools and earlier (PPNB) and later (Yarmukian) bifacial tools. As for now, the technological and typological characteristics of the PPNC lithic industry are very roughly outlined (e.g. Rollefson, 1990; Rollefson and Köhler-Rollefson, 1993) and no attention whatsoever was paid to the bifacial tool assemblages from this period. Moreover, most prominent PPNC sites in the southern Levant are usually multi-layered sites (such as 'Ain Ghazal [Rollefson and Köhler-Rollefson, 1993] and Hagoshrim [Khalaily, 1999]). Therefore their assemblages could be contaminated by mixture of human or natural agencies. Being a single-layered PPNC site, Atlit-Yam offers an unusual opportunity for defining the techno-typological characteristics of the PPNC flint industry and the study of the bifacial tools is the first step towards this end.

The goal of the present paper is to present a comprehensive study of the PPNC bifacial tools from Atlit-Yam, in an attempt to understand the possible changes in these tool types during the transition from the Pre-Pottery Neolithic to the Pottery Neolithic Period.

The 154 bifacial tools were subjected to a detailed attribute analysis, including both qualitative and quantitative observations and measurements. The relevant results are presented in order to provide data for discussion and interpretation. It should be mentioned that the bifacial tool category includes three polished stone axes (made of basalt, limestone and greenstone) which were not included in the following analysis.

Bifacial tool types

The 151 flint bifacial tools in this assemblage were divided into several categories according to the following definitions (Barkai, 2002):

Axe

Axes were shaped by bifacial flaking and have a lenticular cross section. Their cutting edges are shaped by bifacial flaking, transversal blow or polish and are wider than 2 cm. In many cases the cutting edge is slightly round (n=79, 53 percent of the bifacial tools, Figs 2, 3, 4, 5, 6, 7, 8: 1, 9: 1, 10: 2).

Roughout (Preform)

Rough and coarse bifacial tools, most often only partially worked by bifacial flaking. The cutting edge is either shaped or not and most of these tools seems to have been discarded before the production process was completed (n=22, 14.5 percent of the bifacial tools, Figs 9: 2, 12).

Chisels

Chisels were shaped by bifacial flaking, but in some cases more than two faces are shaped. Varied cross sections were indicated: lenticular, angular, plano-convex, triangular, trapezoidal or rhomboid. The cutting edges are mostly shaped by bifacial flaking, polish or transversal blows and their cutting edge width does not exceed 2 cm in width. Chisels are usually long and narrow (n=22, 14.5 percent of the bifacial tools, Figs 10: 1, 11).

Heavy Duty Tools

Large and massive bifacial tools shaped completely or partially by bifacial flaking. These tools are not standardized and do not resemble any other bifacial tool category or Paleolithic chopping tools in terms of shape or manufacturing technique. In some cases bifacial tools that were discarded during initial stages of manufacturing could be classified under this category (n=14, 9 percent of the bifacial tools).

Picks

Picks are mostly shaped by bifacial flaking on more than two facets of the tool (trihedral etc.). The working edge of the tool is pointed and relatively narrow while its base is wide and thick. The cross-section is usually triangular at the working edge and angular at the base. In some cases the bases were left unshaped (n=3, 2 percent of the bifacial tools).

Adze

Bifacially shaped tools with plano-convex cross-section. The ventral face is mostly flat and the dorsal face is curved, trapezoidal or triangular in section. Working edges are often shaped by bifacial flaking and polish, while the use of transversal blows appears in specific cases. Usually, cutting edge width of these tools exceeds 2 cm. In shape, most of the adzes were designed as long trapezes or triangles (n=2, 1.3 percent of the bifacial tools, Fig. 8: 2).

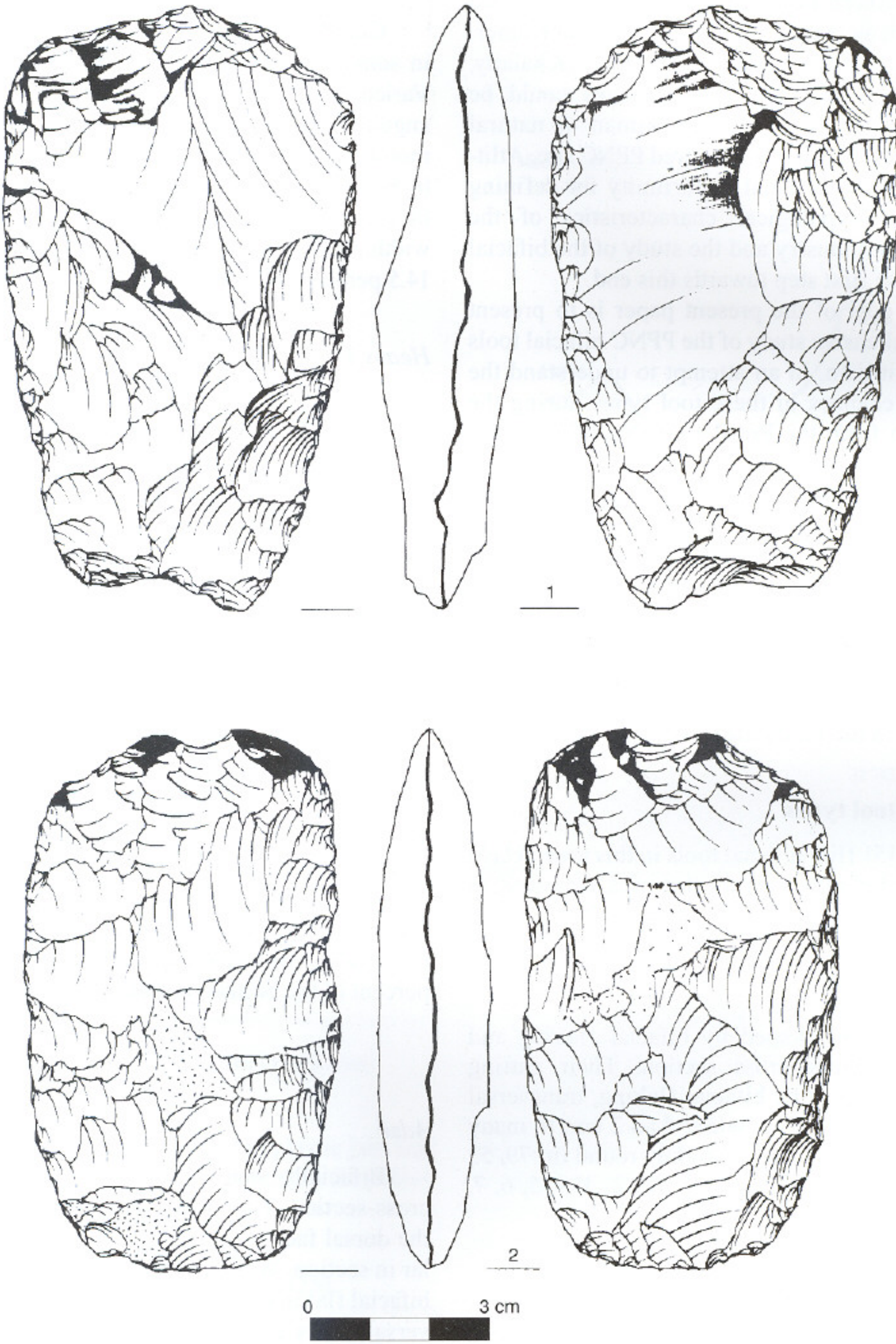

Fig. 2. Axes from Atlit-Yam

Fig. 3. Axes from Atlit-Yam

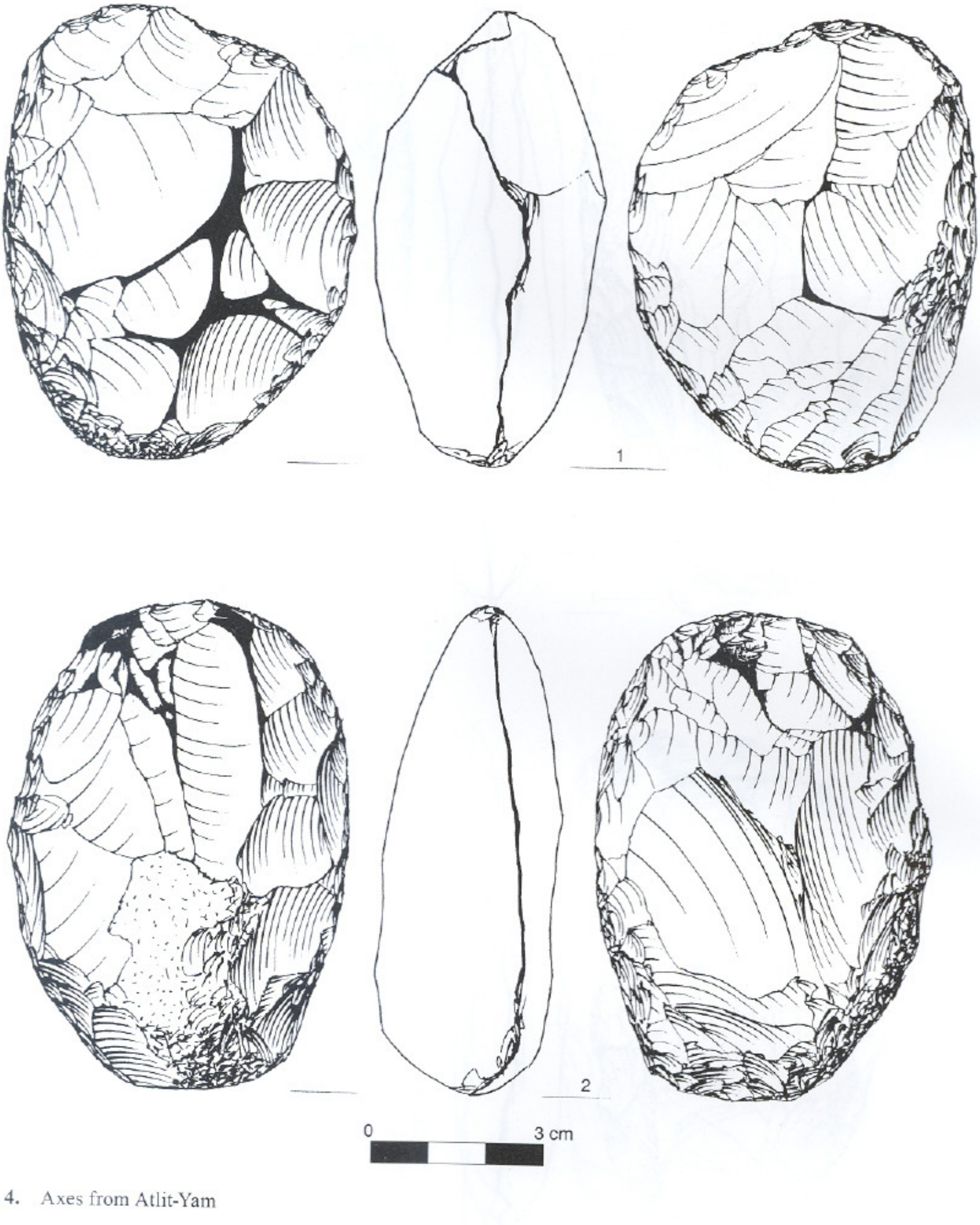

Fig. 4. Axes from Atlit-Yam

Other

Unclassified bifacial tools which do not fit any of the above categories (n=9, 6 percent of the bifacial tools).

The Atlit-Yam bifacial tool category is clearly dominated by axes and axe roughouts, since most of the bifacial tool preforms represents primary stages of axe production. Therefore, more than

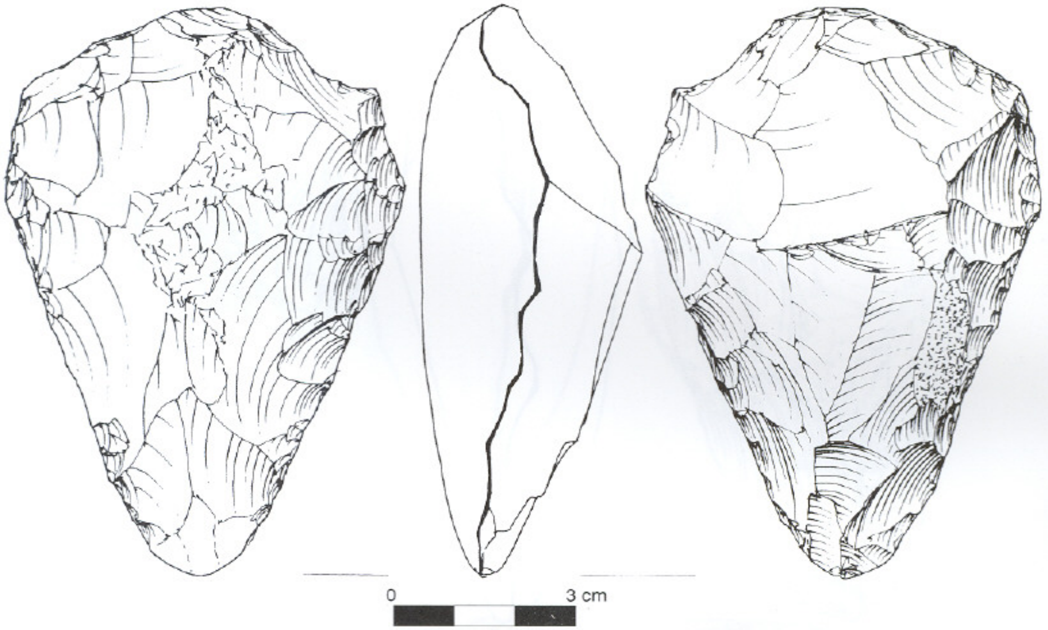

Fig. 6. Axe from Atlit-Yam

two-thirds of the Atlit-Yam bifacial tools are axes or axe roughouts (67.5 percent altogether), and this dominant category is accompanied by a much smaller group of chisels. Only two adzes were found at Atlit-Yam. We argue that the concepts and standards of later (Pottery Neolithic and Chalcolithic) adze shaping were not yet applied at the PPNC and these two specimens could be regarded as "accidental" adze-like bifacial tools rather than true adzes. The techno-typological analysis presented below will focus on the three prominent bifacial tool types in this assemblage: axes; axe roughouts and chisels.

TECHNOLOGICAL AND TYPOLOGICAL ANALYSIS OF THE ATLIT-YAM BIFACIAL TOOLS

Axes, axe roughouts and chisels were subjected to a detailed technological study aimed at establishing clear grounds for characterizing each type and understanding its manufacturing process and the standards of production, use and maintenance.

Blanks of bifacial tools

The blank type of half of the axes (51 percent) and most of the chisels could not be determined because of extensive bifacial flaking that removed the blank characteristics (e.g. Figs 2, 3, 6, 7). The rest of the chisels (23 percent) were made of nodules and blades (Fig. 11) while axes were made of flakes (29 percent, Figs 1: 1, 5: 1) and nodules (19 percent, Fig. 1: 2). The blank type of only a third of the axe roughouts could not be determined, while the two other thirds were made on nodules (36 percent, Fig. 12) and flakes (32 percent). It could be argued that nodules and flakes were almost equally prefered for axe production. Among the axes, one can observe a slight preference towards flakes, while almost no preference between flakes and nodules could be identified among the axe roughouts. It could be argued that since success rates of axes produced on flakes were higher than those made on nodules, more completed axes were eventually made on flake blanks. In any case, generally large, thick, flakes and thin nodules were selected for

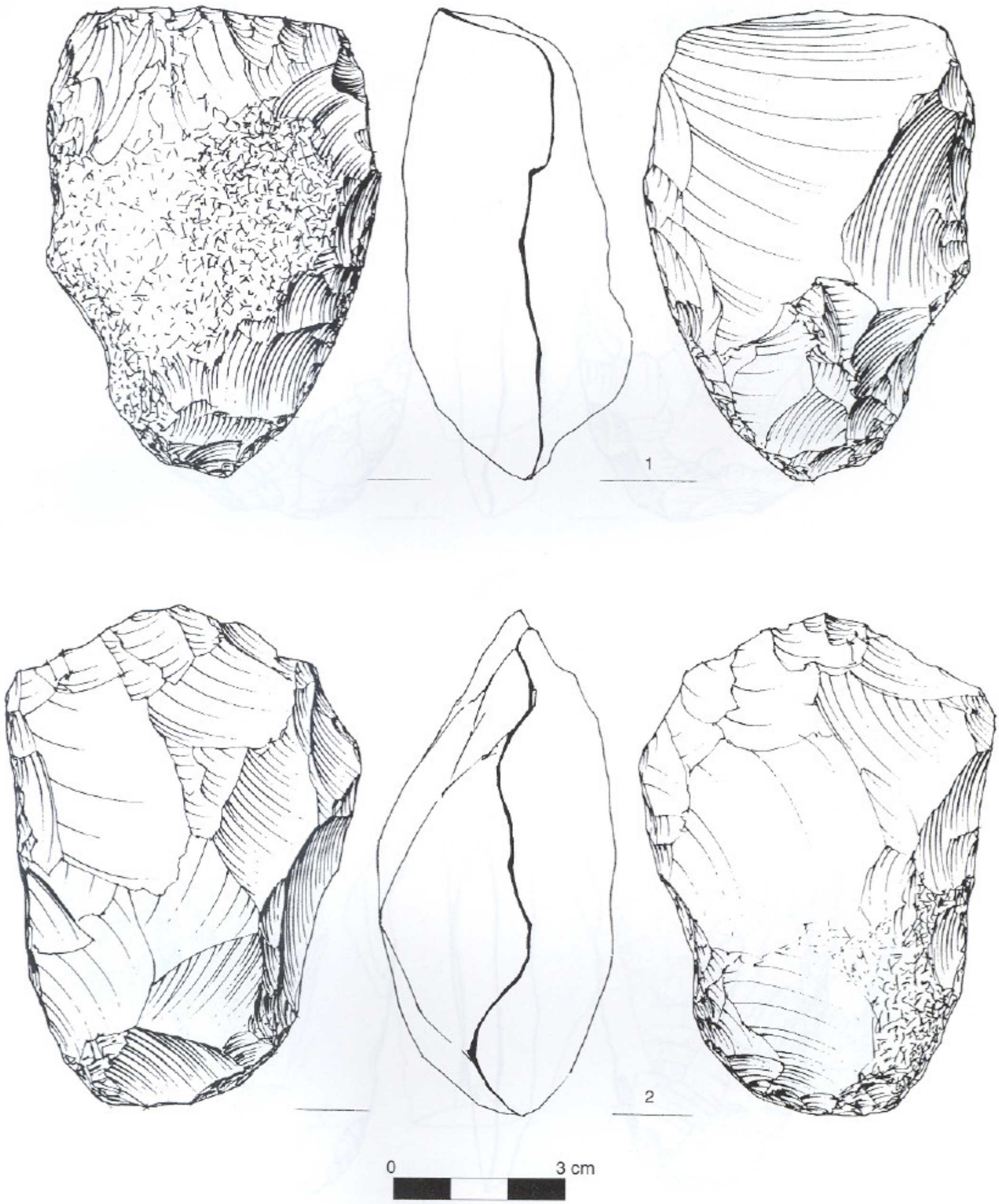

Fig. 7. Axes from Atlit-Yam

Fig. 8. Axe and adze from Atlit-Yam

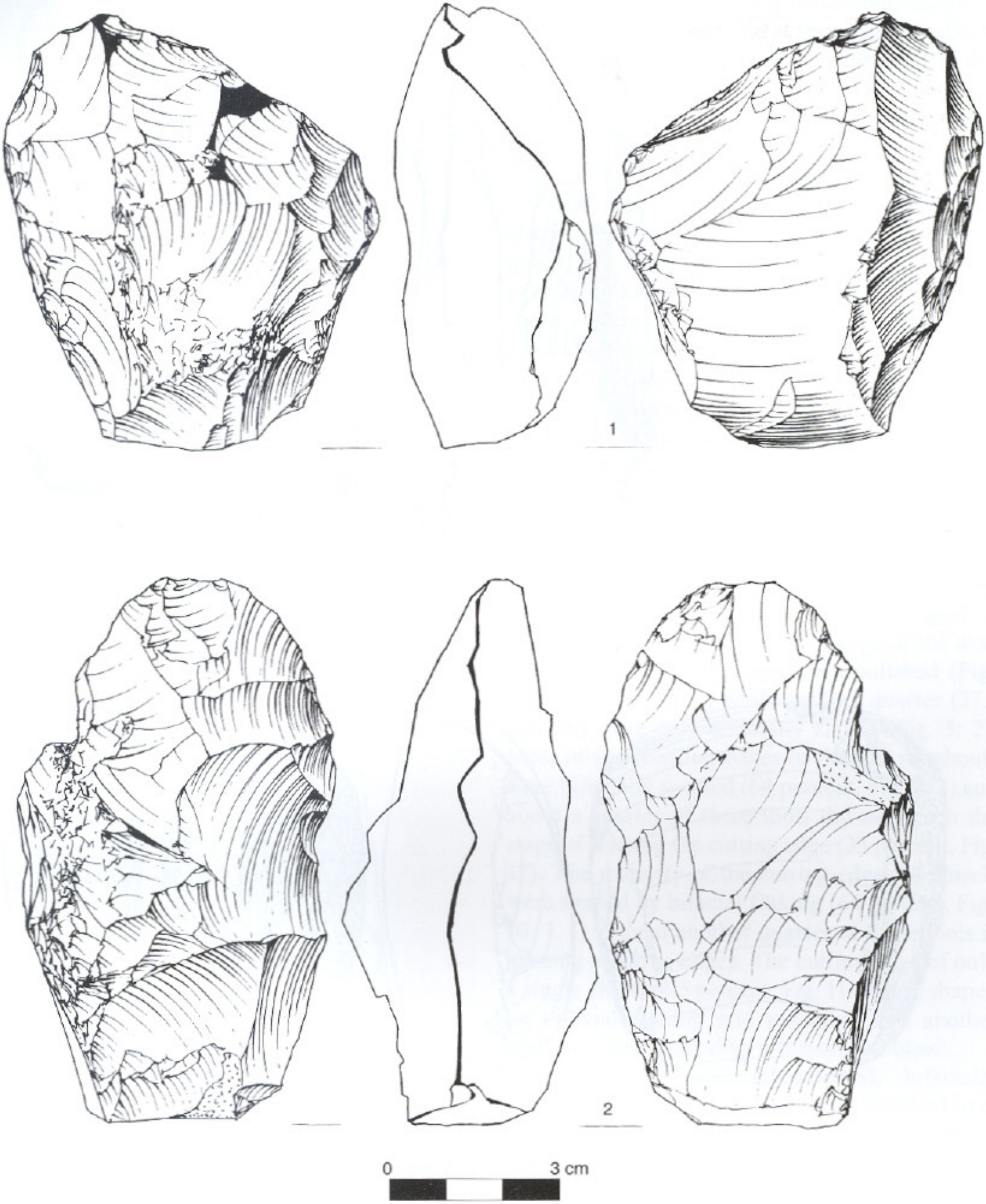

Fig. 9. Axe and roughout from Atlit-Yam

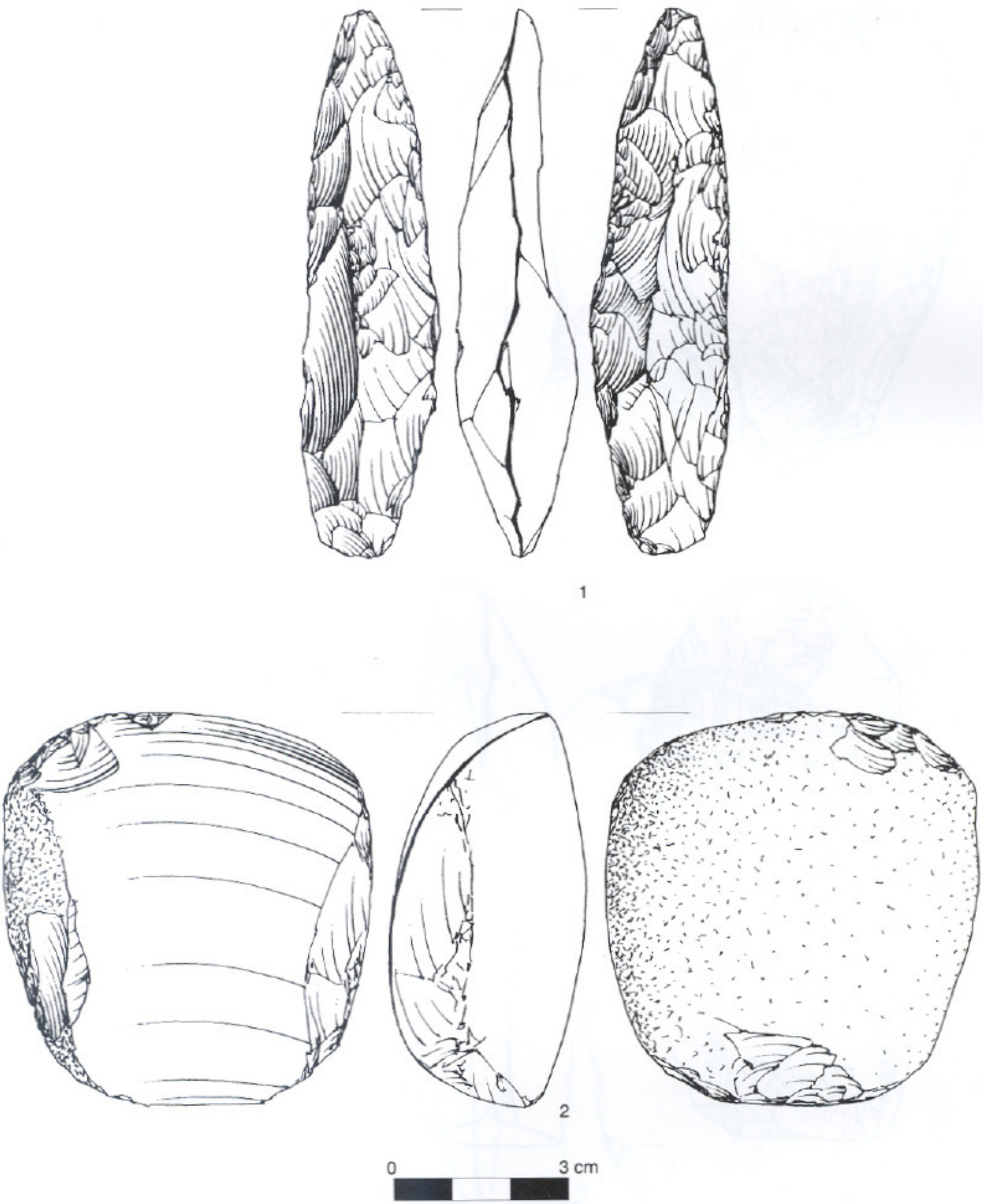

Fig. 10. Chisel and axe from Atlit-Yam

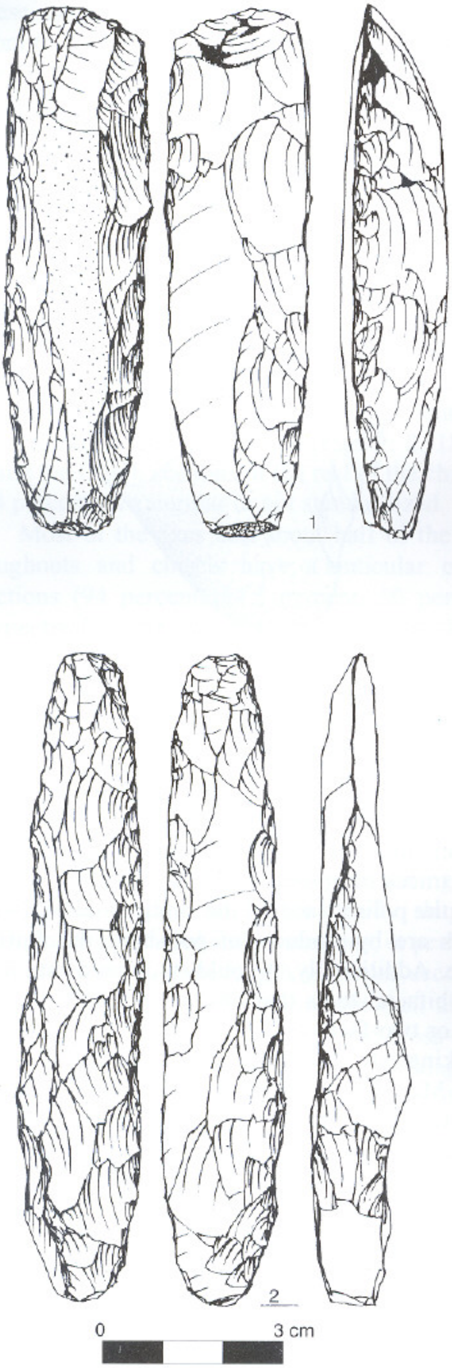

Fig. 11. Chisels from Atlit-Yam

axe production. It is much more complicated to define chisels blanks, but it seems reasonable to suggest that nodular pieces were prefered in this case.

Raw material quality of bifacial tools

Most of the axes, axe roughouts and chisels are made of homogeneous, high to medium quality flint with no inclusions (59.5 percent, 77 percent and 68 percent respectively). The rest of these bifacial tools are made of non-homogeneous, high to medium quality flint with inclusions. Seemingly homogeneous raw material without inclusions, even if not of the finest quality, was prefered over non-homogeneous superior flint for bifacial tool manufacture.

Cutting edge shaping of bifacial tools

Most of the axes were found broken, lacking their working edges (38.5 percent, e.g. Figs 4: 1, 6, 7). About third of the cutting edge of the axes were bifacially worked and then polished (Figs 2, 3, 4: 2, 5: 1, 8: 1) while another quarter (27.5 percent) were only bifacially flaked (Fig. 5: 2). Most of the working edges of the axe roughouts were bifacially worked (64 percent, Fig. 9: 2) and about a quarter of these tools did not reach the stage of shaping the cutting edge (23 percent, Fig. 12). The majority of the cutting edges of chisels were shaped by bifacial flaking (64 percent, Figs 10: 1, 11: 2) and another quarter of these tools is missing working edges. The cutting edge of only a single chisel (4.5 percent, Fig. 11: 1) was shaped by bifacial flaking and polishing and another specimen was shaped by a transversal blow.

The prominence of polished, bifacially worked, working edges among the finished axes and the almost total absence of the use of polish in chisel shaping are two clear characteristics of the bifacial tool category. Bifacial flaking was the major strategy selected for working edge shaping, while many of the axe roughouts were discarded before that stage. It seems likely that the working edge of bifacial tools was shaped at the later stage of the manufacturing process, only after the whole tool was bifacially flaked successfully. Bifacially worked axes were polished as an intentional finishing process and later stages of

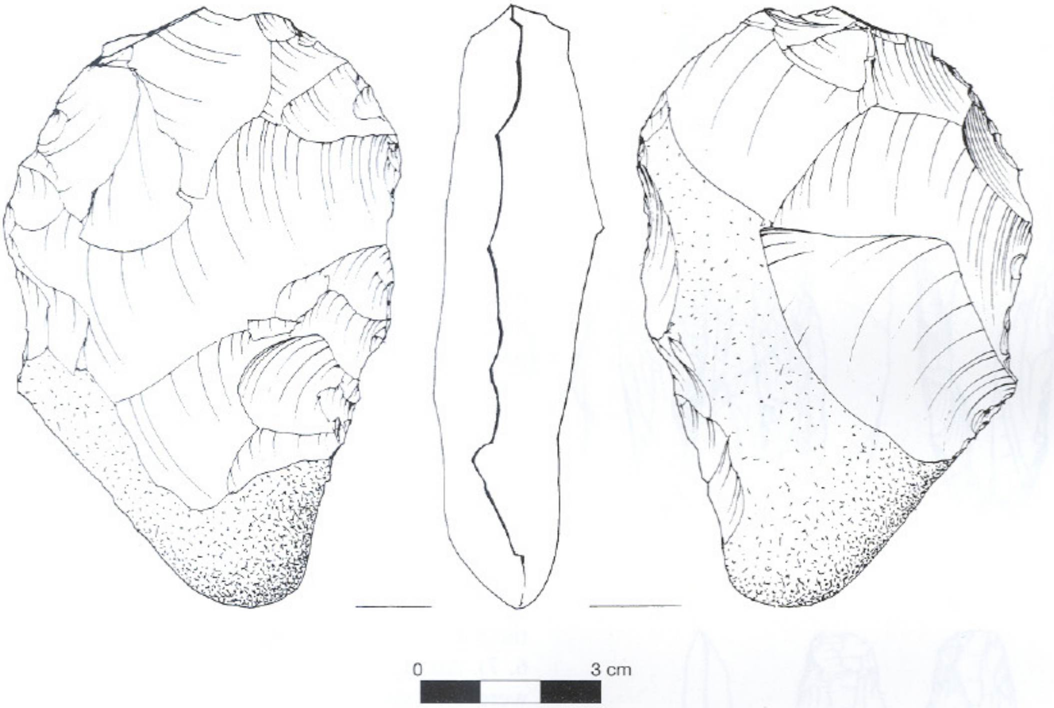

Fig. 12. Axe roughout from Atlit-Yam

resharpening sometimes removed parts of the polished surfaces. However we do not claim that only polished bifacial tools were actually used. It is most likely that polish was applied according to specific needs, while in other cases unpolished tools were used.

Body shaping of bifacial tools

Most of the axes, axe roughouts and chisels were shaped by overall bifacial flaking (63 percent, 59 percent and 95 percent respectively, e.g. Figs 2: 2, 3, 6, 7: 10, 11, 12). One quarter of the axes (26 percent) were bifacially flaked and polished (Figs 2: 1, 4, 5: 1), as well as one of the chisels (4.5 percent, Fig. 11: 1). Many of the axe roughouts (41 percent, Figs 9: 2, 12), as well as some of the axes (9 percent), were only partially bifacially worked. It appears that overall bifacial flaking was the prefered strategy for bifacial tool shaping. Most of the axes that have a polished cutting edge have traces of polish on one or two faces of the tool as well. Thus the correlation between a polished working edge and traces of polish on the tool's body suggests that the polish trace on the ventral and/or dorsal faces are by-products of polishing the cutting edge. Additionally, it could be argued that broken bifacial tools that do have polish traces on one or two faces did have, originally, a polished working edge even if the bit is currently missing. Many of the axe roughouts were discarded before the tool's body was completely shaped by bifacial flaking and it seems that these tools were abandoned during a relatively early stage in the manufacturing process.

Shape of bifacial tools

Most of the axes and axe roughouts are trapezoid (47 percent, 45.5 percent respectively, e.g. Figs 2: 1, 3: 1) or triangular (23 percent, 18 percent, Figs 5: 2, 6) in shape. The rest are ovaloid or sub-rectangular (22 percent and 27 percent respectively, Figs 2: 2, 3: 2, 8: 1) while the shape of other axes and axe roughouts could not be classified into these categories. Chisels are different in shape from the axe and axe roughouts, since all chisels are long and narrow, usually with a pointed (77 percent) or straight (23 percent) working edges.

Cross section and length section of bifacial tools

Most of the axes, axe roughouts and chisels are lenticular (convex-convex) in length section (99 percent, 77 percent, 73 percent, e.g. Figs 2, 3, 5, 10, 12). The length sections of the rest of the axe roughouts (23 percent) and of some of the chisels (13 percent) are a combination of lenticular and plano-convex sections (Figs 9: 2, 11: 2) while the length sections of the rest of the chisels (14 percent) are angular or not standardized.

Most of the axes and about half of the axe roughouts and chisels have a lenticular cross sections (94 percent, 54.5 percent, 50 percent respectively). The rest of the axe roughouts have a lenticular/plano-convex (28 percent) or angular (14 percent) cross-sections. The rest of the chisels have angular (36 percent) or rectangular-triangular (9 percent) cross sections.

It appears that axes cross and length sections were strictly lenticular, and the same could be said about most of the axe roughouts. Many of the axe roughouts were discarded during the manufacturing process, before finally shaping the volume of the tool and its sections, or perhaps a failure in shaping the length and cross-sections of these preforms was the reason for their abandonment. The fact that the length and cross-sections of most of the chisels in this assemblage is lenticular as well could suggest that chisel shaping conventions were influenced by the way the most dominant tool types at Atlit-Yam, the axes, were shaped.

Bifacial ridge (lateral edge) shaping

About half of the bifacial ridges of the axes and chisels are straight and were meticulously shaped (56 percent and 45 percent respectively, Figs 2: 2, 3, 5: 2). The bifacial ridges of the rest of the axes and chisels are partially twisted (Figs 2: 1, 5: 1, 6). Only few of the axe roughouts' bifacial ridges are straight (9 percent) while the rest are straight-twisted (59 percent, Figs 9, 12), or completely twisted (32 percent). It seems that while many of the axes and chisels were carefully shaped according to strict standards and most of the axe preforms were discarded before reaching the stage of shaping the bifacial ridges. By the same token, it could be suggested that these preforms were abandoned because of a failure in shaping the ridges.

Bifacial tool preservation

Half of the axes were found complete (51 percent, Figs 2, 3: 1, 4: 2, 5, 8: 1) while the other half is represented by basal and medial fragments (45 percent, Figs 6, 9: 1) and by only few cutting edge fragments (5 percent). Almost all of the axe roughouts (91 percent) and most of the chisels (73 percent) were found complete (Figs 9: 2, 11, 12). The number of complete bifacial tools is relatively high in comparison to other Neolithic sites and could attest to certain selectivity during the recovery process or to some specific characteristics of the site.

Discard patterns of complete bifacial tools

Since large percentages of the Atlit-Yam bifacial tools are complete, and assuming that breakage was the reason for discarding the rest of the bifacial tools, it seems essential to investigate the main reasons for the discard of complete tools.

Most of the complete axes were discarded because of unsuccessful repair, mainly failed attempts at resharpening the working edge or at reshaping the tool itself by bifacial flaking (80 percent, Figs 2: 1, 3: 1, 8: 1). The rest of the complete axes (7.5 percent) were discarded due to cutting edge damage (unintentional flaking, battering and minor fractures, Figs 2: 2, 4: 2, 5: 1). Only two complete axes were discarded because of unknown reasons (5 percent). Most of the complete axe roughouts were discarded because of unsuccessful shaping (70 percent), mainly due to failing bifacial blows which resulted in hinge or step fractures (Fig. 9: 2). The rest of the complete axe roughouts were discarded because of unknown reasons (20 percent, Fig. 12), unsuccessful repair (5 percent) or raw material defects (5 percent). Complete chisels were discarded because of unsuccessful repair (67 percent, Figs 10:

1, 11: 1), unknown reasons (20 percent, Fig. 11: 2) and raw material defects (14 percent). A clear difference between the discard patterns of complete axes and axe roughouts could be indicated. Most of the complete axes were discarded due to failing resharpening and reshaping attempts, aimed at restoring the tool's effectiveness after it has been damaged during use. Numerous cutting edges of these axes show impact fractures and minute flaking negatives that removed parts of the polished bit and/or dulled the original working edge (Galili *et al.,* 1993 fig. 12: 7; 13). The cutting edge damage does not seem to be the major or sole reason for discarding these tools, since it appears that they were severely malformed by use and needed repair and maintenance. In many cases repair attempts failed and the bifacial blows did not reshape or resharpen the tool properly and therefore the tool was discarded. Other complete axes were clearly discarded due to working edge damage, without any attempt to mend them. Only two apparently complete and perfect axes, showing no damage, were discarded for reasons that were not obvious (henceforth complete and perfect axes).

Most of the axe roughouts were discarded during the manufacturing process due to unsuccessful bifacial blows and in cases where the preforms did not meet production standards. It is clear that the axe roughouts were not used as working tools and were abandoned before the manufacturing process ended. Some of the preforms were discarded for reasons that could not be related to any functional, stylistic or mechanical factor.

The analysis of the complete bifacial tools discard pattern reveal that most of these tools at Atlit-Yam (apart from roughouts) were used as working tools and were discarded after at least one stage of use, usually following failing attempts to fix and reshape the tool. Most of the axes and chisels were actually used, damaged and later were put through stages of maintenance and repair, while only small numbers of complete axes and chisels were discarded as "usable" or "perfect" tools. It could be argued that most of the bifacial tools from Atlit-Yam were in continuous and intensive use. The discarded axe roughouts indicate relatively high production standards. Bifacial preforms that did not meet production standards were almost immediately discarded, without trying to overcome the manufacturing defects. The Atlit-Yam flintknappers maintained strict production standards that could have been the result of abundant flint sources at their disposal, probably located in the vicinity of the Carmel mountain ridge. This enabled them to reject less than perfect preforms and move on to the next blank. The complete bifacial tool production process took place at Atlit-Yam, starting from shaping the raw material blanks, continuing through shaping, sharpening, polishing, repairing and reshaping the tools and ending at discarding the worn out, exhausted, damaged and non-reparable bifacial tools.

Table 1 presents the measurable parameters of the three major bifacial tools in the Atlit-Yam assemblage.

MEASURABLE PARAMETERS

The relatively large number of complete bifacial tools at Atlit-Yam enables a detailed analysis of dimensions and weight. The mean length of the different bifacial tool types is quite similar, in the range of 81–84 mm. The axes are only slightly longer then the axe roughouts and chisels and it seems that the length standard of the Atlit-Yam bifacial tools was about 80 mm.

In thickness, the axes and chisels (as completed working tools) are very similar, as opposed to the uncompleted axe roughouts that were discarded during the manufacturing process. The working edges of axe and chisels are mostly thinner than 5 mm, while most of the axe roughout bits are thicker than 5 mm. The mid thickness of more than half of the axes and chisels does not exceed 20 mm, as opposed to only one quarter of the axe roughouts. Chisel bases are relatively quite thin, axe bases are a bit thicker but roughouts bases are significantly thicker than axes and chisels. The thickness figures of bifacial tools indicate uniformity in shaping the completed tools, while the unfinished preforms are much thicker. It could be argued that axe roughouts were discarded before reducing their thickness, or perhaps unsuccessful thinning was one of the major reasons for discarding these tools.

The similarity in axe and chisels thickness emphasizes the differences in width measure-

Table 1

The measurable parameters of the three major bifacial tools in the Atlit-Yam assemblage

Measurable parameters	Axe (n=79)	Axe roughout (n=22)	Chisel (n=22)
Length of complete tools (mm.)	up to 70 (15%) 71-100 (72.5%) 101-120 (12.5%)	up to 70 (30%) 71-100 (55%) 101-120 (15%)	up to 70 (19%) 71-100 (75%) 101-120 (6%)
Mean length of complete tools (mm.)	83.88 (n=40)	81 (n=20)	82.2 (n=16)
Cutting edge thickness (mm.)	up to 5 (90%) above 5 (10%)	up to 5 (38%) above 5 (62%)	up to 5 (76.5%) above 5 (23.5%)
Mid thickness (mm.)	11-20 (51%) 21-30 (30%) 31-40 (16%) above 40 (3%)	11-20 (27%) 21-30 (36%) 31-40 (18%) above 40 (18%)	11-20 (58%) 21-30 (37%) 31-40 (5%)
Mean mid thickness (mm.)	22.9 (n=74)	28.2 (n=22)	19.2 (n=19)
Base thickness (mm.)	6-10 921%) 11-15 (43%) above 15 (36%)	6-10 (9%) 11-15 (23%) above 15 (68%)	6-10 (67%) 11-15 (24%) above 15 (9.5%)
Cutting edge width (mm.)	26-30 (12%) 31-40 (22%) 41-60 (57%) 61-70 (8%)	31-40 (33%) 41-60 (52%) 61-70 (15%)	above 10 (17%) 11-15 (22%) 15-17 (28%) 20-21 (17%) 21-24 (17%)
Mean cutting edge width (mm.)	45.5 (n=39)	47.4 (n=20)	15.5 (n=16)
Mid width (mm.)	26-40 (11%) 41-60 (69%) 61-75 (20%)	26-40 (4.5%) 41-60 (77%) 61-75 (18%)	21-30 (68%) 31-40 (32%)
Base width (mm.)	11-20 (19%) 21-30 (23.5%) 31-40 (37%) above 40 (20.5%)	21-30 (38%) 31-40 (33%) above 40 (29%)	Up to 10 (19%) 11-20 (67%) 21-30 (14%)
Length/ cutting edge width ratio	1.8:1	1.7:1	5.3:1
Cutting edge width/ mid thickness ratio	1.9:1	1.6:1	0.85:1
Measurable parameters	Axe (n=79)	Axe roughout (n=22)	Chisel (n=22)
Number of bifacial flakings on complete tools	21-40 (28%) 41-60 (38%) 61-80 (26%) above 80 (8%)	21-40 (70%) 41-60 (20%) 61-80 (10%)	21-40 (19%) 41-60 (50%) 61-80 (31%)
Number of cross-flakings on complete tools	2-5 (3%) 6-10 (45%) above 10 (53%)	6-10 (74%) above 10 (26%)	6-10 (73%) above 10 (27%)
Number of hinge flakings on complete tools	up to 5 (5%) 6-10 (46%) 11-15 (33%) above 15 (15%)	up to 5 (42%) 6-10 (21%) 11-15 (265) above 15 (10%)	up to 5 (12%) 6-10 (44%) 11-15 (44%)
Cutting edge angle (in dgree)	up to 35 (78%) 40-55 (22%)	up to 35 (35%) 40-45 (40%) above 60 (25%)	up to 35 (75%) 40-55 (25%)
Weight of complete tools (grams)	51-70 (2.5%) 71-100 (27.5%) 101-200 (52.5%) 200 (17.5%)	31-50 (5%) 51-70 (10%) 71-100 (15%) 101-200 (25%) above 200 (45%)	31-50 (50%) 51-70 (19%) 71-100 (12.5%) 101-200 (19%)
Mean weight of complete tools (grams)	132 (n=40)	171.5 (n=20)	60.8 (n=16)

ments between these bifacial tool types. The mean cutting edge width of axes is 45.5 mm, as opposed to 15.5 mm for chisels. The difference in width between axes and chisels is even reinforced by the fact that non of the axe bits is narrower than 26 mm while two-thirds of the chisels cutting edges does not exceed 17 mm. It should be mentioned that some bifacial tools were classified as chisels despite of the fact that their working edges are a slightly wider than 20 mm, based on length/cutting edge width ratios, and therefore it is argued that in the case of Atlit-Yam some of the chisel bits are wider than the common standard of up to 20 mm, but still belong to this category. Nevertheless, most of the chisels and all the axes follow the traditional cutting edge width classifications and only a small group of chisels fall out of this standard. The classification of axes and chisels according to the working edge width seems to be correct when one examines the ratio between the tool's length and cutting edge width, among the two "traditional" tool types. Axes show ratio of 1.8 : 1 while for chisels this ratio is three times larger, 5.3 : 1. These figures emphasize the morphological differences between the two tool types and demonstrate that axes are wide and squat as opposed to the long and narrow chisels. The ratio between the tool's cutting edge width and mid thickness indicates as well that the traditional classification does work.

Among the axes, this ratio shows 1.9 : 1 and clearly stands for tools that are twice as wide than thick, while for chisels this ratio shows 0.85 : 1 and thus reflects narrow and thick tools. The width differences between axe and chisel are very pronounced as well when one compares the mid and base width of these tool types.

The cutting edge width of axe roughouts is very similar to the completed axes and demonstrate the similarity between these two types. Roughouts cutting edge are slightly wider than these of the completed tools and thus it seems that working edge width was shaped during early stages of axe manufacture. This argument is supported as well by the width similarities between mid and base width of axes and axe roughouts.

The completed tools, both axes and chisels, were intensively flaked and most of these (64 percent and 81 percent respectively) were shaped using at least between 40 to 80 bifacial blows. Only one third of the axe roughouts, on the other hand, were shaped using more than 40 bifacial blows and it seems clear that these preforms were abandoned in an early stage of the production process. The fact that many of the axes and chisels were repaired and maintained during their use could contribute to the high number of bifacial blows. Axes and axe roughouts are clearly different in the number of cross-flakings (lateral intrusive) as well – more than half of the axes, as opposed to only one quarter of the preforms, demonstrate the use of more than ten such blows. It could be suggested that a successful shaping of bifacial tools was evaluated by the execution of the cross-flakings, which shaped the volume of the tool, and thus low numbers of perfectly performed cross-flakings resulted in discarding the preform. Additionally, the relatively high number of recorded cross-flakings and the fact that many roughouts were discarded because of unsuccessful execution of these blows indicate high production standards and strict expectations of the end product.

The number of hinge flakings is relatively high as well among the completed tools and could stand for frequent phases of resharpening and reshaping that resulted, in many cases, in hinged blows that frequently ended in these tools being discarded. The axe roughouts carry relatively low number of hinged flakings since these are knapping accidents that took place during early stages of production, and the preform was probably discarded shortly afterwards without any repair or maintenance attempts.

Cutting edge angles of the Atlit-Yam axes and chisels are quite similar and relatively sharp, mostly sharper than 35 degrees (78 percent and 75 percent respectively). This similarity between axes and chisels could indicate similarities in use, but in different modes of power and precision – axes were intended to perform massive tasks that demanded wide cutting edge while chisels were used in much delicate and precise crafts. Cutting edge angles of most of the axe preforms are blunt in comparison to the completed axes and thus it is clear that the preforms were discarded before the advanced stages of the working edge shaping.

The suggestion regarding task division between axes and chisels is supported by the weight differences between these two bifacial tool types – complete axes are relatively heavy and weigh, on average, 132 grams, more than twice the weight of an average complete chisel (61 grams). Axe roughouts are much heavier than the completed axes, basically because the preforms were discarded during early stages of production, in many cases due to failing attempts to shape the tool's volume by cross-flakings intended to reduce mass. The weight of axe roughouts may indicate the weight of the original blanks, most probably more than 200 grams.

It should be mentioned that four axes were broken in a very special pattern (Figs 7: 1, 9: 1, 10: 2), described as the "Hula break" (Barkai, 1999, fig. 4, 2000) and another four axes were transformed into cores after they ceased functioning as bifacial tools (Figs 4: 1, 6, 7: 2).

DISCUSSION

The large bifacial tool group from Atlit-Yam was divided into three major tool types: Axes, axe roughouts and chisels. Axes were usually made of high to medium homogeneous flint and the prefered blanks were mostly flakes and nodules. Many of the axe's working edges were originally polished, but post-polish flaking and cutting edge damage (battering, accidental flaking etc.) removed parts of the polished surfaces (see Figs 2: 2, 4, 9: 1). Generally, axes are wide and heavy and it seems clear that they were used in massive tasks with a remarkable energetic effort. The specific breakage pattern found on four axes, the Hula break, further supports the assumption that some of the axes were broken during use in tough, intense activities (see Barkai, 2000). Many of the axes are complete and most of these were discarded because of unsuccessful repair attempts. Axes were usually shaped as trapeze or triangle and their cross and length sections are almost always lenticular. Axe roughouts are quite similar to the completed axes in terms of length and width, but they are much heavier and thicker and thus it could be concluded that preforms were most probably discarded due to failing attempts to reduce the volume of the blank. Most of the axe roughouts were found complete and their discard pattern analysis revealed that these were abandoned mostly due to unsuccessful shaping, namely failure in cross-flaking execution and failing thinning attempts. There were no further attempts to shape the blank or correct the knapping errors and thus it seems that strict production standards were kept at Atlit-Yam. Chisels, like axes, were mainly made of high to medium quality homogeneous flint and the working edges were mostly bifacially flaked. The use of polish is almost altogether absent. Most of the chisels were found complete, and these were usually discarded due to unsuccessful repair. This implies frequent use and repair phases and a remarkable investment in maintaining these tools.

No further attempts to repair or remodel unsuccessfully reshaped axes were made, probably since such attempts would lead to a significant reduction in the tool's dimensions. The standardization in length, thickness and cutting edge angle reveals that axes and chisels were manufactured according to formal criteria and were fully-fitted for use. Clear similarities, as well of differences, could be indicated between axes and chisels. These tools are very similar in length, thickness and working edge angle but much different in working edge width and in weight.

The large number of axe roughouts and the high frequency of axe maintenance and repair indicate the presence of a workshop for axe production and repair at Atlit-Yam. The bifacial tool workshop was probably part of the larger Neolithic habitation complex of Atlit-Yam and represents one component of the technological activities carried out at the site.

The study of the large bifacial tool assemblage from Atlit-Yam revealed strict production and maintenance standards that resulted in very uniform axes and chisels.

A "workshop" locus was found at the site with large numbers of bifacial thinning flakes, some of which could represent axe manufacture while other could be related to the shaping of Naviform cores (authors' personal observation). The bifacial tools discard pattern could indicate relative abundance of raw material and/or easy access to flint sources in the immediate vicinity of the site. In general, the PPNC Atlit-Yam axes are relatively wide and thin with a wide, polished, working edge (e.g. Figs 2, 3, 8: 1). These large and heavy axes were most probably used in heavy woodworking activities (see Barkai, 2000).

The next step – after characterizing the PPNC Atlit-Yam bifacial tools – is to compare the data presented above to the preceding PPNB and later Yarmukian (Pottery Neolithic) bifacial tools in order to understand the placement of the PPNC bifacial tools within the larger framework of technological, typological and functional changes during the Neolithic period. Since this is the first detailed analysis of PPNC bifacial tools it might be possible to clarify whether these tools resemble the former PPNB standards or the later Pottery Neolithic conventions. Several distinctive differences between the lithic industries of PPNB-Yarmukian cultures are well pronounced (e.g. Gopher, 1994). The decline in Naviform blade production is evident at the end of the Pre Pottery Neolithic period, alongside a size reduction of arrowheads and the replacement of long, finely denticulated sickle blades by shorter, heavily denticulated, backed and truncated Yarmukian sickles (e.g. Gopher, 1994; Gopher and Gophna, 1993). Assuming that the technological and typological differences between the PPNB and the Pottery Neolithic lithic industries reflect some economical, social or conceptual innovative aspect, it should be interesting to see how the bifacial tool category fits the above framework.

Based on several PPNB and Yarmukian bifacial tool assemblages previously analyzed by one author (R. B.), the following comparison is intended to place the Atlit-Yam bifacial tools in the wider Neolithic context.

As stated earlier, the Atlit-Yam bifacial tool category is highly dominated by axes (53 percent) and axe roughouts (14.5 percent), together comprising over two-thirds of this category. On average, axes comprise more than half (52 percent) of the bifacial tool category at four PPBN sites studied in detail (Barkai, 2000). At the MPPNB sites of Yiftahel (Garfinkel, 1987; Khalaily *et al.*, 2000) and Kfar HaHoresh (Goring-Morris, 1991, 1994) axes are the most dominant bifacial tool types (31 percent and 50 percent respectively), accompanied by axes roughouts (24 percent and 19 percent respectively). At the PPNB (most probably LPPNB) site of Beisamoun (Lechevallier, 1978) 64 percent of the bifacial tools were classified as axes and another six percent as axe roughouts (Barkai, 2000). Thus it could be concluded that axes dominate the bifacial tool group of the PPNB, ranging between more than half to almost three-quarters of the bifacial tools, when taken together with the axe roughouts. At Yarmukian sites, axes are, on average, 40 percent of all bifacial tools (Barkai, 2000). At Sha'ar HaGolan (Garfinkel, 1998; Stekilis, 1966) 45 percent of the bifacial tools were classified as axes and another 6 percent as axe roughouts. At Hamadiya (Kaplan, 1965) axes comprise 42 percent of the bifacial tools and axe roughouts another 8 percent. At the Earlier Pottery Neolithic levels of Nahal Zehora II (Gopher forthcoming; Gopher and Orelle, 1991) axes are 39 percent of the bifacial tools and only 3 percent of this category were classified as roughouts, without further indication of the intended end product (Barkai, 2000). Thus Yarmukian axes and axe roughouts, taken together, never exceed 50 percent of the bifacial tool category. Since at Atlit-Yam 53 percent of the bifacial tools were classified as axes and another 14.5 percent as axe roughouts we would like to suggest that the composition of the bifacial tool category at PPNC Atlit-Yam is much closer to the PPNB tradition than to the Yarmukian new conventions. The decline in axe frequencies commenced at the beginning of Pottery Neolithic and further declined during the Wadi Raba culture of the later Pottery Neolithic, when axe frequencies decreased to an average of 10.5 percent of all bifacial tools. Thus it seems that the decline in axe dominance started only after the PPNC and reached an average of less than 5 percent of Chalcolithic assemblages (Barkai, 2000).

Since chisels comprise, on average, 15–20 percent of both PPNB and Yarmukian assemblages, the Atlit-Yam chisels could not be used as an indicator for cultural comparisons (Barkai, 2000).

Only few adzes appear in PPNB assemblages (1 percent on average), while at Yarmukian assemblages these tools appear in much higher numbers and reach 10 percent of all the bifacial tools (Barkai, 2000). The two adzes found at Atlit-Yam (1.3 percent of the bifacial tools) point towards a resemblance to PPNB tool-kit composition.

In terms of raw material preferences, it seems clear that during the PPNB relatively high quality, homogenous flint was mostly used for axe production (36 percent of the axes, on average), while during Yarmukian times only 19 percent of all axes were made of such raw material (Barkai,

Table 2

Axe data

Period	Mean length (mm.) of complete axes	Mean mid thickness (mm.) of all axes	Mean cutting edge width (mm.) of complete axes	Mean weight (gram) of complete axes
PPNB	83.8 (n=41)	23 (n=68)	45.2 (n=41)	117.2 (n=41)
PPNC	83.9 (n=40)	22.9 (n=74)	45.5 (n=40)	132 (n=40)
Yarmukian	92 (n=38)	22 (n=94)	40 (n=38)	111 (n=38)

2000). At Atlit-Yam, 27 percent of the axes were made of high quality, homogenous flint and thus it could be argued that the tendency to select superior flint for axe production changed at the end of the PPN, towards a decline in the use of such raw material at the Pottery Neolithic.

Polished cutting edges appear both in PPNB and Yarmukian assemblages (43 percent and 31.5 percent respectively) and thus it seems possible, according to the percentage of polished bits at Atlit-Yam, that the assemblage resembles Yarmukian assemblages rather than those of the PPNB (Barkai, 2000). However, when looking at the details, it seems that the higher average proportion of PPNB polished cutting edges is influenced by their abundance at Beisamoun (86 percent of the axes) while at sites such as Yiftahel or Kfar HaHoresh they appear in much lower frequencies (31 percent at both sites) and thus it is concluded that in terms of the use of polished working edges no pronounced differences could be found between PPNB, PPNC and Yarmukian assemblages (Barkai, 2000).

Atlit-Yam is a unique site in terms of the number of complete axes discarded because of cutting edge damage (only 7.5 percent of the bifacial tools), in contrast to both PPNB and Yarmukian sites. At PPNB sites between one-quarter (Yiftahel and Kfar HaHoresh) to one-half (Beisamoun) of the bifacial tools were discarded because of cutting edge damage, while these frequencies are even higher in Yarmukian assemblages (83 percent at Sha'ar HaGolan; 75 percent at Hamadiya and 42 percent at Nahal Zehora II). These very low frequencies of damages axes at Atlit-Yam are hard to explain, and one possible explanation might be the very high frequencies of axe maintenance an repair practiced at the site (see below).

The bifacial tool category from Atlit-Yam is unique in terms of complete axes discarded because of unsuccessful repair as well. While at PPNB and Yarmukian sites only a relatively small number of axes were discarded because of unsuccessful repair (33 percent at Yiftahel; 16 percent at Kfar HaHoresh; 0 percent at Beisamoun; six percent at Sha'ar HaGolan; 0 percent at Hamadiya, and; 17 percent at Nahal Zehora II), most of Atlit-Yam complete axes (80 percent) were discarded for the same reason (Barkai, 2000). These very high proportions of discarded complete axes at Atlit-Yam due to unsuccessful repair does not seem exaggerated when compared to the same category of discarded complete axes at PPNA and PPNB axe workshops. At the PPNA axe workshop of Modi'in Shimshoni, 82 percent of the complete axes were discarded because of unsuccessful repair, 73 percent at the EPPNB axe workshop at Nahal Lavan 109, and 100 percent at the axe workshop of Mezad Mazal (data from Barkai, 2000). It seems that in terms of axe maintenance and repair Atlit-Yam resembles axe workshops rather than habitation sites where axe production and maintenance was only one of many activities carried out. This data supports the suggestion regarding an existence of bifacial tool workshop at Atlit-Yam and it seems that bifacial tools were frequently maintained at the site and discarded only when the repair was not successful. At habitation sites that did not include workshops for maintaining bifacial tools many axes were discarded when damages, sometimes without any repair or maintenance attempts.

Very small numbers of complete axes that were discarded because of unknown reasons were found at Atlit-Yam (5 percent), in contrast to much higher proportions at other PPNB sites (42 percent at Yiftahel; 53 percent at Kfar HaHoresh and 40 percent at Beisamoun). At Yarmukian sites, complete axes discarded for unknown reasons were less common than in the PPNB (6 percent at Sha'ar HaGolan; 25 percent at Hamadiya and; 17 percent at Nahal Zehora II) and thus it could appear that in terms of complete and perfect axes (no flaw or damage indicated) the assemblages of Atlit-Yam are much more similar to Yarmukian sites rather than PPNB assemblages. However, considering the similarity between Atlit-Yam and other axe workshops, it appears that complete and perfect axe frequencies at Atlit-Yam mostly match these workshop sites (0 percent at the PPNA axe workshop of Modi'in Shimshoni, 7 percent at the EPPNB axe workshop at Nahal Lavan 109 and 0 percent at the axe workshop of Mezad Mazal [data from Barkai, 2000]) and thus could not be used as chrono-cultural marker.

The following table demonstrates the mean length, mid thickness, cutting edge width and weight of bifacial tools at PPNB, PPNC and Yarmukian sites in order to clarify the similarities and differences in terms of metrics between each cultural phase (data from Barkai, 2000). It must be kept in mind that the PPNB data represent the mean of three different sites (Yiftahel, Kfar HaHoresh and Beisamoun), the PPNC data includes axes from a single site (Atlit-Yam), and the Yarmukian data represents the mean of three sites (Sha'ar HaGolan, Hamadiya and Nahal Zehora II).

The data is presented in Table 2, nevertheless there are some methodological difficulties with such a comparison and show that in terms of length, thickness and working edge width that PPNC axes are almost identical to PPNB axes, which are shorter and wider than the Yarmukian ones. The Atlit-Yam axes are heavier than the PPNB and Yarmukian axes and this could be attributed to some special characteristics of this specific site. In any case, the mean metric differences between PPNB and Yarmukian axes are not very pronounced and demonstrate a continuation in axe production from the mid-late Pre-Pottery Neolithic to the early phases of the Pottery Neolithic. Axe production standards change dramatically during later stages of the Pottery Neolithic (see Barkai, 2000) but this issue is beyond the scope of this paper. In any case, even within the PPN-PN continuum of axe production the PPNC axes fall very close to those of the PPNB rather than to their Yarmukian counterparts.

As a final note, it should be mentioned that among the Atlit-Yam axes a "special" axe type is prominent, perhaps representing specific preferences of the site's inhabitants. These are relatively wide and thin axes, made mostly on flakes and sometimes on flat nodules and usually have polished cutting edges (Figs 2, 3). The "flat" polished axes are found alongside other, much thicker axes (Figs 4, 5: 1, 6) and other axe sub-types (Fig. 7) and thus the "uniqueness" of the "flat" axes is blurred by combining the different axes into a single category.

CONCLUSIONS

In this paper the PPNC bifacial tools from the site of Atlit-Yam were presented in detail in order to characterize one aspect of the PPNC lithic industry and compare it to the preceding PPNB and the forthcoming Pottery Neolithic Yarmukian. Since the introduction of the PPNC as a cultural-chronological phase in 1986 following the excavation at the site of 'Ain Ghazal (Rollefson and Simmons, 1986, no detailed information was published regarding the bifacial tool industry of this phase (Rollefson and Köhler-Rollefson, 1993). We believe that the site of Atlit-Yam, being a single stratum site, provides an unusual opportunity to study the characteristics of PPNC assemblages with no earlier or later disturbances.

The analysis of the Atlit-Yam bifacial tool industry has revealed the dominance of axes among the different bifacial tool types at the site, accompanied by small number of chisels. This kind of tool-kit composition is typical of the preceding PPNB and is slightly different than Yarmukian standards (Barkai, 2000). The other attributes described above also indicate similarity between PPNB and PPNC bifacial tools. We may conclude that at least for the bifacial tool category, continuity from the PPNB to the PPNC is clearly indicated. Yarmukian standards of bifacial tool manufacture are slightly different than those of the preceding PPN and demonstrate a decline in axe dominance during the Pottery Neolithic and the rise of a new bifacial tools to dominate later – the adze.

The similarity between the PPNB and the PPNC bifacial tool industries is of importance regarding the differences between PPNB and PPNC in other lithic aspects (see Gopher, 1994). This study indicates the importance of studying similarities and differences between PPNB and PPNC other tool types, such as arrowheads and sickle blades in order to better understand the technological, typological and cultural processes involved in the transition from the Pre-Pottery Neolithic period. We hope that further studies of the Atlit-Yam assemblages, as well as studies of other PPNC assemblages, will help understanding the termination of the PPN system and the transition to the Pottery Neolithic.

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