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Microwear analysis of early Neolithic (PPNA) axes and bifacial tools from Netiv Hagdud in the Jordan Valley, Israel

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Abstract

A sample of 76 bifacial lithic artifacts from the Sultanian assemblage at the Netiv Hagdud site (9900–9600 BP; American School of Prehistoric Research Bulletin 43, 1997) was examined for microwear and technological traces in order to determine the function of ground and flaked bifacial tools used during the PPNA period. Standardized axe types (flint tranchet axes and polished stone axes made of coarser-grained materials) are among the technological, typological, and functional innovations of the Sultanian culture. The ground stone celts do not seem to have been used as tools, but 78% of the flaked bifacial tools and 27% of the tranchet axe spalls in the microwear sample were used. Most (85%) of the utilized bifacial tools in the sample were used to work wood, and 91% of the utilized axe spalls had woodworking traces. In this article, methods of distinguishing woodworking tools from chipped stone hoes and scrapers are presented, and the significance of the evidence for light woodworking or carpentry at Netiv Hagdud and early Neolithic sites in the Levant is discussed.

Keywords: Microwear; PPNA; Sultanian; Netiv Hagdud; Tranchet axes; Neolithic crafts

1. Introduction

The appearance of standardized axe types is a technological, typological, and functional innovation of the Sultanian culture of the Pre-Pottery Neolithic A period in the southern Levant. Two major axe types are prominent in Sultanian assemblages—flint tranchet axes (shaped by transverse blows) and polished stone axes made of basalt, limestone, and other coarser-grained materials [6–8,11,13]. Tranchet axes are the dominant tool type in PPNA bifacial tool assemblages (almost 50% of the bifacial tools) [11]. Chisels are also present, but in much lower frequencies (about 15% of the bifacial tools) [11].

Sophisticated planning and highly developed technological skills were needed for the meticulous preparation of the tranchet axes by bifacial flaking and the successful execution of the transverse blow. It is no wonder, then, that workshops for the production and resharpening of tranchet axes appear in the PPNA [12]. Tranchet axes are usually made on blades of high quality, non-homogenous raw material and are usually very light (mean=37 g) and thin (mean=15 mm) [11]. The polished stone axes are larger and heavier. The stone axes from Netiv Hagdud weigh, on average, 191 g and are 31.5 mm thick [11].

The functions of these tools were investigated in a microwear analysis of 76 bifacial artifacts from the Sultanian lithic assemblage at the Netiv Hagdud site, a large (ca. 2.5 ha) deep (over 4 m) tell site located some 12 km north of Jericho in the Lower Jordan Valley [7,9]. Oval and rounded stone and mud brick structures were uncovered in all the layers of the tell. Rich assemblages of faunal, botanical, lithic, and human remains were retrieved; however, no domestic species were identified [7,8,28,40,63].

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Table 1
Netiv Hagdud (PPNA), summary of microwear and technological analysis

Item	Loci	No.	Artifact type	Flint color	Edge angle	Edge shape	G.L.	E.W. (mm)	Th.	Patina?	Edge fractures	Used	Motion	Worked material	Other notes
1	88	109	Tranchet axe	Light gray	55	Straight	74.0	50.0	13.8	No	Feathered	?	Plane/adze	Wood?	Edge rounded
2	40	21	Tranchet axe	Brown	70	Convex	78.4	30.0	11.5	Heavy	Feathered	?	Plane/adze	Wood?	Wavy edge, some damage
3	22	16	Tranchet axe	Mottled	45	Straight	82.7	25.0	12.0	Light	Step, feather	?	Plane/adze	Wood?	Some edge damage
4	48	23	Tranchet axe	Brown	70	Convex	106.0	53.0	15.0	Heavy	Hinge, step	X	Adze/chop	Wood?	Damage, haft traces
5	8a	50	Tranchet axe	Light gray	70	Straight	75.5	44.0	15.7	No	Feathered	X	Plane/adze	Wood	Coarse-grained
6	8b	119	Tranchet axe	Brown	70	Straight	86.5	35.6	14.0	Light	Feathered	X	Plane/adze	Wood	Edge grinding
7	10	4	Tranchet axe	Light gray	60	Straight	68.6	30.2	10.5	Light	Step, feather	?	Plane/adze?	Wood?	Right corner damaged
8	14	33	T-axe bit fragment	Mottled	65	Convex	47*	30.3	19.5	Light	Feathered	?	Plane/adze?	Wood?	Left corner battered
9	47	28	T-axe bit fragment	Brown	70	Convex	28*	30.6	15.0	Light	Step, feather				No visible wear traces
10	27	69	Large uniface	Brown	72	Straight	107.6	44.0	28.0	No	Battered				Unfinished? No wear
11	1014	110	Biface	Mottled	n/a	Convex	106.9	50.0	22.0	No	Large feather				Unfinished? no wear
12	18	30	Biface	Mottled	70	Convex	75.2	40.0	20.8	No	Battered				Cortex, unfinished?
13	21	107	Biface (small)	Brown	60	Convex	45.9	21.0	10.5	No	Feathered	X	Scrape	Hide	Light use
14	18	102	Biface	Light gray	n/a	n/a	58.8	n/a	19.0	no	Broken				Unfinished? No wear
15	13	31	Biface	Tan	60	Straight	75.5	17.0	21.5	No	Feathered	?	Plane/scrape	Wood/bone	Light use, abrasion
16	58	88	Biface	Light gray	n/a	Pointed	64.5	7.7	23.4	no	Feathered	?	Bore/ream	Hide/bone	Recycled as awl/borer
17	40	114	Biface fragment	Red brown	57	Convex	26*	33.0	20.5	Heavy	Battered	?	Scrape	Hide?	Lateral snap
18	18	90	Biface fragment	Light gray	n/a	Pointed	46.5*	9.2	17.4	Heavy			Borer?		No visible wear, patina
19	10	94	Biface (chisel?)	Brown	45	Straight	49.5	26.5	13.2	No	Feathered	X	Plane/scrape	Wood/bone	Cortex, red stains
20	40		Chisel	Light gray	65	Convex	89.6	14.0	13.8	Heavy	Step, feather				No visible wear
21	40	1	Chisel	Brown	65	Straight	75.4	15.5	12.8	Light	Step, feather	X	Plane/scrape	Wood	Edge grinding? Light use
22	1051	1	Chisel	Light gray	45	Straight	83.0	19.0	13.7	Heavy	Step, feather	X	Plane/scrape	Hide/wood	Edge grinding? Patina
23	21a	58	Chisel fragment	Tan	45	Convex	51*	20.0	14.0	Light	Battered	X	Plane/scrape	Wood/bone	Lateral snap
24	18	40	Chisel fragment	Tan	67	Convex	44.2*	21.2	14.0	No	Small feather	?	Plane/scrape	Wood/bone	Lateral snap, light use
25	21	62	Chisel fragment	Tan	55	Convex	38*	10.5	13.0	Light	Step, feather	?	Plane/scrape	Wood/bone	Lateral snap, light use
26	14	53	Chisel fragment	Mottled	60	Convex	52*	9.3	11.0	Light	Feathered	?	Plane/scrape	Wood/bone	Lateral snap, light use
27	14	45	Chisel fragment	Brown	60	Convex	45.8*	14.5	11.0	Heavy	Battered	X	Plane/scrape	Wood?	Lateral snap
28	18	354	Chisel	Light gray	55	Straight	74.3	18.0	12.5	Light	Step, feather	X	Plane/scrape	Wood/bone	Hard wood?
29	14	97	Axe spall	Light gray	75	Convex	27.8	61.3	9.2	No	Step, hinge				Some edge damage
30	18	103	Axe spall	Brown	55	Straight?	14.0	40.6	6.6	Heavy	Step, hinge				Lustrous, abrasion
31	34	88	Axe spall	White	60	Convex	18.6	39*	2.5	Heavy	Step, feather	X	Plane/adze	Wood	Macrosheen
32	14	85	Axe spall	Brown	65	Fragment	10.3*	28*	3.1	Light	Step, feather				Lustrous, abrasion
33	14	85	Axe spall	Beige	65	Convex	32.0	66.2	4.7	Light	Step, feather				Abrasion, coarse grain
34	14	85	Axe spall	Beige	55	Fragment	16.5*	30.5*	3.2	Light	Feathered				Abrasion, coarse grain
35	52	81	Axe spall	Banded	60	Convex	27.8	59.2	11.2	Light	Battered				Abrasion, coarse grain
36	27	109	Axe spall	Brown	70	Convex	16.0	30.0	5.8	Light	Feathered				Abrasion, edge damage
37	14	126	Axe spall	Beige	65	Convex	28.0	40.7	12.0	Light	Step, feather				Abrasion, crystalline
38	14	137	Axe spall	Brown	60	Convex	17.0	25*	4.4	Light	Step, feather	?	Plane/adze	Wood/bone	Very light use
39	26b	82	Axe spall	Pink	65	Convex	10.4	26.5	2.7	No	Feathered	X	Adze/chop	Wood	macrosheen, grinding?
40	21b	100	Axe spall	Beige	65	Pointed	21.5	27.5	7.4	Light	Feathered				Biface fragment?
41	21b	120	Axe spall	Beige	70	Convex	20.6	30.0	7.6	No	Step, feather				Coarse-grained flint
42	50	25	Axe spall	Beige	70	Straight?	20.4	64.0	7.3	Light	Feathered				Abrasion, crystalline
43	18	11	Axe spall	Beige	65	Convex	9.7	25.8	3.9	Light	Feathered				Abrasion, crystalline
44	18	14	Axe spall	Beige	75?	Convex	10.6	33.6	1.6	Light	Feathered	X	Cut/chop	Plant/wood	Macrosheen, abrasion

Table 1 (*continued*)

Item	Loci	No.	Artifact type	Flint color	Edge angle	Edge shape	G.L.	E.W. (mm)	Th.	Patina?	Edge fractures	Used	Motion	Worked material	Other notes
45	50	2	Axe spall	Brown	70	Convex	13.6	42.0	4.9	Heavy	n/a				No visible wear
46	1014	98	Axe spall	Banded	45	Convex	17.5	45.0	9.5	Light	Battered				Abrasion, edge damage
47	18	15	Axe spall	Beige	65	Convex	14.5	31.5	3.8	Light	Step, feather				Abrasion, coarse grain
48	18	23	Axe spall	Brown	60	Convex	13.8	26.2	2.5	Light	Feathered				No visible wear
49	18	24	Axe spall	Brown	n/a	n/a	14.2	29.0	3.2	Light	n/a				Lustrous, abrasion
50	18	4	Axe spall	Brown	60	Convex	23.5	38.0	5.8	Heavy	Step, hinge				Abrasion, crystalline
51	18	2	Axe spall	Brown	65	Convex	12.8	28.8	6.6	Light	Feathered	X	Plane/adze	Wood	Macrosheen, striations
52	18	1	Axe spall	Banded	70	Convex	30.0	42*	5.0	Heavy	Battered				Cortex, abrasion
53		18	Axe spall	Brown	65	Straight?	33.0	43.5*	8.0	Light	Battered				Broken, abrasion
54	18	16	Axe spall	Beige	60	Convex	11.4	24.6	2.5	Light	Feathered				Abrasion
55	48	17	Axe spall	Banded	62	Convex	29.5	58.0	12.0	No	Step, feather				Blackened, burned?
56	26b	19	Axe spall	Light gray	50	Convex	14.6	37.8	4.4	Heavy	n/a				Crystalline
57	49	22	Axe spall	Brown	65	Convex	20.0	40.7	9.7	Heavy	Step, feather				Abrasion, crystalline
58	52	9	Axe spall	Brown	70	Convex	16.9	38.5*	7.2	Light	Feathered				Abrasion, crystalline
59	52	10	Axe spall	Brown	60	Convex	14.5	26.6	3.9	Light	Stepped	X	Adze/chop	Wood?	Macrosheen, abrasion
60	18	8	Axe spall	Brown	60	Straight?	18.0	40.5	2.8	No	Step, feather				Lustrous, abrasion
61	48	5	Axe spall	Beige	70	Convex	14.0	40.1	7.7	Light	Battered				Lustrous, abrasion
62	8b	20	Axe spall	Brown	45	Convex	15.8	43.0	5.5	Light	Feathered	X	Cut/scrape	Hide/meat?	Abrasion, light use
63	32	28	Axe spall	White	65	Convex	12.8	33.5	7.0	Heavy	Battered				Extremely heavy patina
64	32	20	Axe spall	Beige	65	Convex	11.5	31.0	5.0	Light	Step, feather				Abrasion, crystalline
65	18	12	Axe spall	Beige	70	Convex	25.5	33.0	6.0	Light	Step, feather	X	Adze/chop	Wood	Macrosheen, heavy use
66	18	26	Axe spall	Beige	70	Convex	13.8	36.0	5.0	No	Step, feather	X	Adze/chop	Wood	Macrosheen, striations
67	18	13	Axe spall	Light gray	60	Convex	12.3	32.3	4.0	Light	Feathered	X	Adze/chop	Wood	Macrosheen, heavy use
68	18	3	Axe spall	Brown	62	Convex	18.3	35.4	4.3	Light	Feathered				Abrasion, crystalline
76	21b	124	Axe spall	Beige	65	Straight?	10.5	43.0	4.0	Heavy	Step, feather	?	Adze/chop?	Wood?	Patina obscures wear

Note: Seven groundstone axes (numbered 69–75) were examined, but there were no visible wear traces.
Other notes: G.L., greatest length in mm; E.W., edge width in mm; Th., thickness in mm; edge fractures, type of flake scars along both faces of the working edge.
Used: there is microwear or macrowear evidence for utilization.
Motion: how the implement was used, e.g. as an axe, adze, chisel, knife, etc.
Material worked: the material that was modified with the implement.
Battered: there is extensive edge-damage, often in the form of hinge or step fractures.
Cortex: some of the original exterior surface of the rock can still be seen on the artifact.
Lateral snap: the tool may have snapped in half during use.
Recycled: appears to have broken and then been retouched and used for a different task.
Unfinished: tool may have broken during manufacturing.
Macrosheen: gloss or sheen is visible without magnification.
*broken, not full length; X, well-developed idenitifiable wear traces on edges; ?, less-developed wear traces, probably used.

The microwear sample included seven ground and polished celts and 69 bifacially flaked artifacts. The surfaces of the working edges of the celts were ground and weathered. Six were made of limestone, which becomes chalky when it is exposed to the elements. The seventh celt was made of basalt. There were no clear wear patterns visible on the edges of any of the celts. It does not appear that they were used as tools [13].

The wear traces on many of the 69 chipped stone bifacial artifacts were obscured by patina. Only 16 of the 69 artifacts (23%) in the sample were not patinated. However, wear traces were visible on the edges of 19 of the patinated tools (Table 1). Some of the heavily patinated tools had no visible wear traces. They may have been utilized, but post-depositional weathering and patination may have destroyed any wear traces that may have been present on their edges. The chipped stone artifacts in the microwear sample included seven tranchet axes, with cutting edges that were produced by the removal of a transverse flake [9,13,14,20,33,46]. Two tranchet axe fragments, and 41 spalls from tranchet axes were also examined for wear traces. Seven other bifaces, two biface fragments, four chisels, and five chisel fragments were examined, along with a single uniface (Table 1). While the ground stone celts in the sample do not seem to have been used as tools, most of the flaked bifacial tools were utilized.

2. Microwear analysis

The primary goal of the study was to determine the function of the bifaces. In the later Neolithic and Chalcolithic periods in the Levant, bifacial tools are believed to have been used as hoes, bone working, or woodworking tools [32,53,62]. Microwear analysis of bifacial tools from Pottery Neolithic and Chalcolithic sites [72,73] indicated that polished chipped stone axes, adzes, and chisels were part of a sophisticated woodworking kit that seemed to have developed as agricultural societies turned to carpentry to produce boards and furniture instead of logs [39]. Did these sophisticated woodworking techniques emerge during the early Neolithic, or were PPNA bifaces used for other tasks?

The edges of many of the tranchet axes in the microwear sample were lustrous, and eight of the axe spalls were covered with a 'macrosheen' or gloss that was visible without magnification (this is not patina, see Table 1). The sheen resembles the 'sickle gloss' or 'corn gloss' that is found on the edges of chipped stone reaping tools. However, high-power microwear studies have revealed that other activities besides harvesting cereals can produce a similar-looking macrosheen or gloss. These activities include: (1) cutting and splitting canes, reeds, and the stems of other plants, (2) digging through sod with a chipped stone hoe, or cutting the sod with an ardshare, (3) using chipped stone blades or flakes as the 'teeth' on threshing sledges, (4) scraping clay with stone tools during the process of manufacturing ceramics, and (5) woodworking [1,2,25,35,53,66,74,75].

A macrosheen can also be produced when flint tools are ground and polished. It is believed that stone axes, adzes, and chisels were ground to strengthen their edges and to reduce friction during use [15,23,29,30,43,47–50,65]. However, while the limestone and basalt celts from Netiv Hagdud were ground, the chipped flint bifaces were not.

Many activities can produce gloss on the edges of stone tools, and the different activities that produced them can only be identified if they are examined under an incident light microscope at magnifications of $50\times$ or higher [3,27,37,55,71]. The functions of the artifacts were determined by matching the observed microwear traces with the use-wear patterns found on experimental chipped stone tools contained in a reference collection of over 160 experimental tools made of several different flint types at Ohio State University (including many heat-treated replicas). For this study, Albert M. Pecora made some replicas of chipped stone chisels, axes, and adzes. Pecora ground the edges with sand and water (see Fig. 1) following procedures described in the ethnographic literature, and Yerkes used the tools to chop and plane wood.

2.1. Distinguishing woodworking tools from hoes and scrapers

It would require many days of chopping and smoothing wood or cultivating the soil to replicate the intense wear traces that produce the macrosheens observed on ancient stone tools. The microwear traces illustrated in Figs. 1 and 2 show the bright, smooth, domed features of the wood polish that formed on an experimental chisel used to plane wood (Fig. 1) and a flake tool (Fig. 2) used to 'girdle' a small tree. Similar traces were formed on the edges of the experimental axes and adzes, but these wood-chopping tools had more edge damage. The plant polish that formed on another flake tool that was used to cut grass for an hour is shown in Fig. 3. These traces show the early stages in the development of wood and plant microwear. To observe the advanced and developed stages of plant and woodworking traces, four artifacts from pre-historic North American sites were examined. The distinctive, flat, fluted polish with numerous comet-shaped pits shown in Fig. 4 formed on the end of a Mississippian chipped stone hoe from Perry County, MO (USA). These microwear features are not present on experimental stone tools that were used on plants or wood [24,25,71,74]. Many archaeologists have assumed that these tools were used to till the soil and cultivate crops, but some have suggested that they were probably also used to dig pits, wall trenches, and other features [18].

Fig. 1. Experimental chisel with edge-grinding traces running lengthwise (←) and smooth, domed wood polish and striations normal (↑) to the edge, used for approximately 3 h (100 ×, width of the figure is approximately 650 μm).

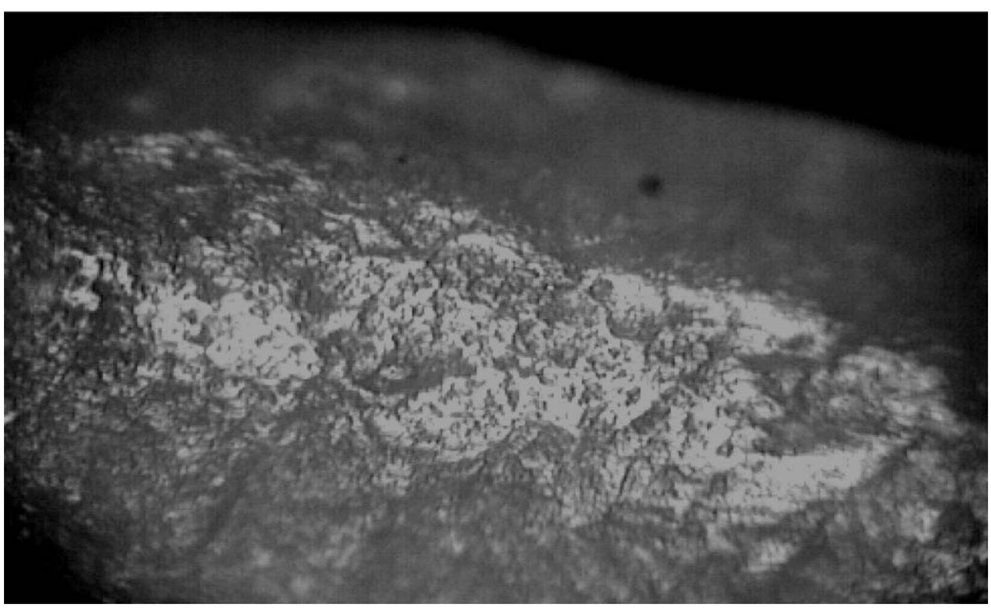

Fig. 2. Experimental flake used to cut soft (green) wood. Notice the smooth, domed appearance of the polish away from the edge of the flake, used for approximately 1 h (100 ×, width of the figure is approximately 650 μm).

Bright, flat polish with comet-shaped pits has also been seen on pre-historic sickle blades and threshing sledge flints, but fluting is only found on tools that were used as hoes or spades. Also, the orientation of the fluting, striations, and comet-shaped pits on chipped stone hoes is normal to the edge, while the wear traces on sickles and sledge flints are roughly parallel, or at a low angle to the cutting edge [4,17,19,27,35–37,60,61,75]. The plant polishes found on hoes, sickles, and sledge flints are similar, but they are quite different from the wear traces produced by working bone (Fig. 5) and hide (Fig. 6). Bright polish forms on the edges of experimental tools that were used to scrape bone, but the polish is confined to small areas at the edge, and does

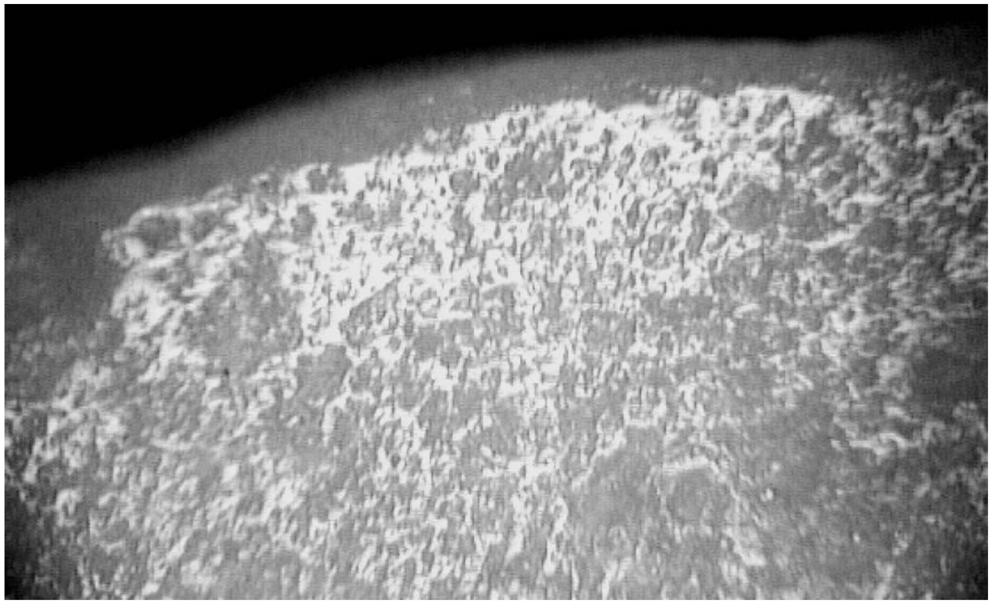

Fig. 3. Experimental flake used to cut grass. Notice the extensive, smooth, domed appearance of the polish and lack of striations. Used for approximately 1 h (100×, width of the figure is approximately 650 μm).

Fig. 4. Smooth, fluted polish with comet-shaped pits on Mississippian chipped stone hoe from Perry County, MO, USA. Distal edge is at top, flutes and 'comet' pits show that the hoe was used to cut through sod (50×, width of the photomicrograph is approximately 1300 μm).

not extend back from the edge like the plant polishes. Also, there are no comet-shaped pits, or flutes in the bone polish (Fig. 5, [27,37,71]).

The 'greasy' looking polish shown in Fig. 6 formed on the edge of a pre-historic end-scraper from a Middle Woodland (Hopewellian, 2000–1650 BP) site in Fulton County, IL (USA). This artifact shows well-developed hide working traces. Microwear on hide working tools is duller than plant and wood polish, and the edges of hide scrapers become very rounded during use [27,37,71]. The microwear on bone and hide working tools is distinctive enough to separate them from plant and woodworking tools, but is the wear on woodworking tools different than the wear that is found on chipped stone hoes and spades?

The illustrations in Figs. 7 and 8 show well-developed woodworking traces on two pre-historic Dalton adzes from St. Clair County, IL. These distinctive artifacts are associated with an initial Holocene (10,700–10,000 BP) hunter–gatherer complex that is now recognized over

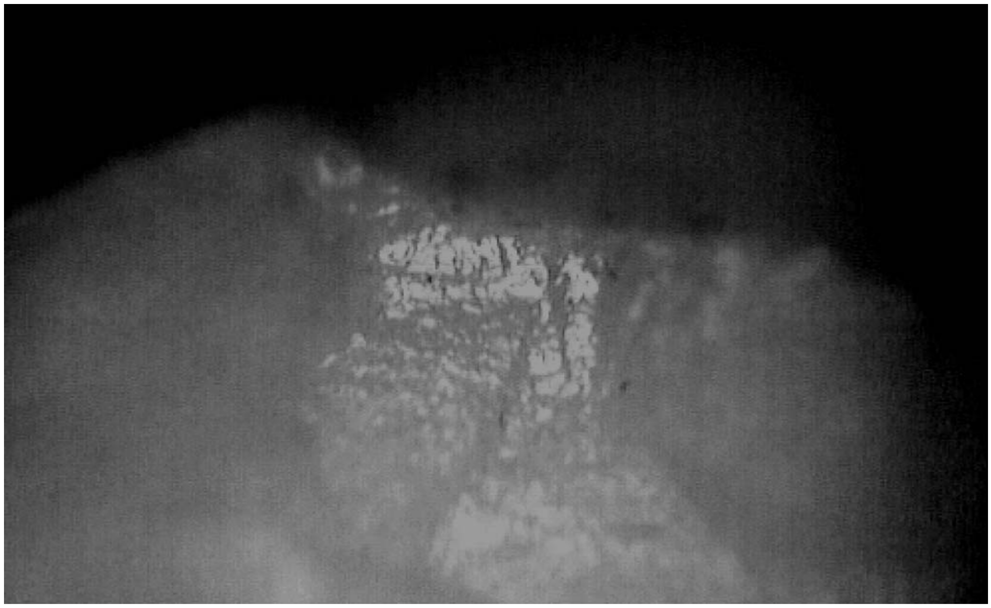

Fig. 5. Experimental flake used to scrape fresh bone. Notice the bright appearance of the polish and the build-up of the wear on a small portion of the edge of the flake (100×, width of the photo is approximately 650 μm).

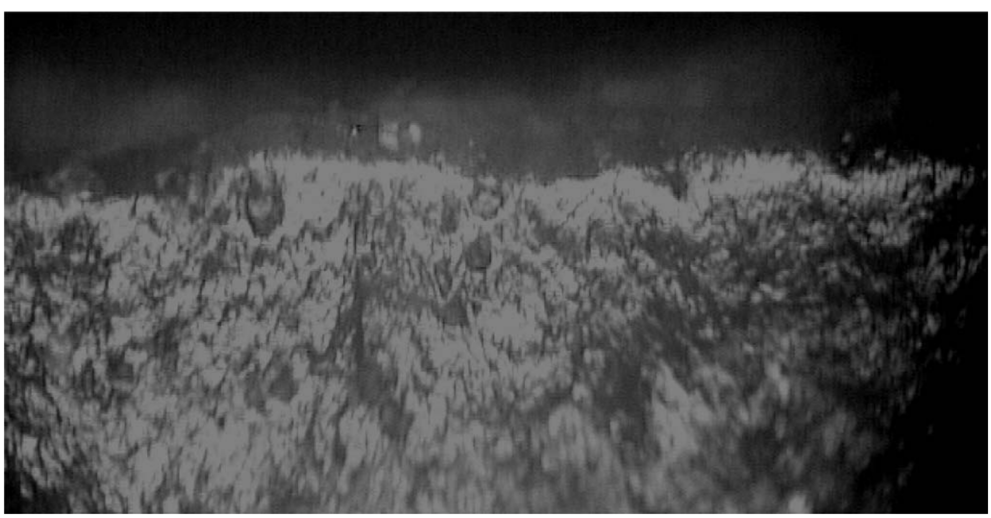

Fig. 6. Unifacial end scraper from Middle Woodland site in Fulton County, IL, USA (2000–1650 BP). Well-rounded edge and 'greasy' appearance of polish are typical of hide scraping tools (100×, width of the figure is approximately 650 μm).

much of the southeastern United States [44]. Dalton adzes look like hoes, but they date to a period long before there is any evidence for plant cultivation in eastern North America [54].

Dan Morse recognized that Dalton adzes were probably woodworking tools. He suggested that the adzes were used to manufacture dugout canoes and wooden utensils in addition to felling trees [45]. His hypotheses were confirmed in a microwear analysis of 15 Dalton Adzes from sites in northeast Arkansas (USA) conducted by Gaertner [24,25]. A macrowear sheen that looks like corn gloss or hoe polish is visible on these Dalton adzes, but microscopic examination showed that they were not used as cultivating tools. Under incident light magnification of 50× and higher, no flutes or comet-shaped pits were observed, instead, the adzes exhibit bright, domed polish with many striations. The striations are usually parallel and normal to the edge as seen in Fig. 8, but sometimes striations are oriented in many directions (Fig. 7) [24,25,74].

A comparison of the wear traces suggests that the following characteristics can be used to distinguish bifacial woodworking tools from hoes, sickles, and sledge flints: (1) chipped stone hoes develop a smooth, bright

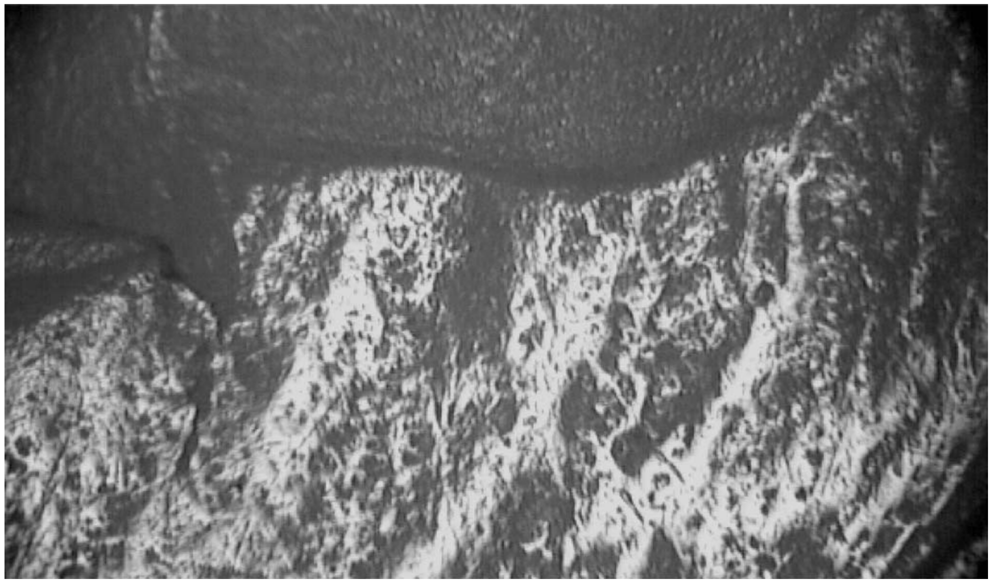

Fig. 7. Smooth, domed wood polish on distal edge of a chipped stone Dalton adze from St. Clair County, IL, USA (approximately 10,700–10,000 BP). Note the striations running several directions (50 ×, width of the photomicrograph is approximately 1300 μm).

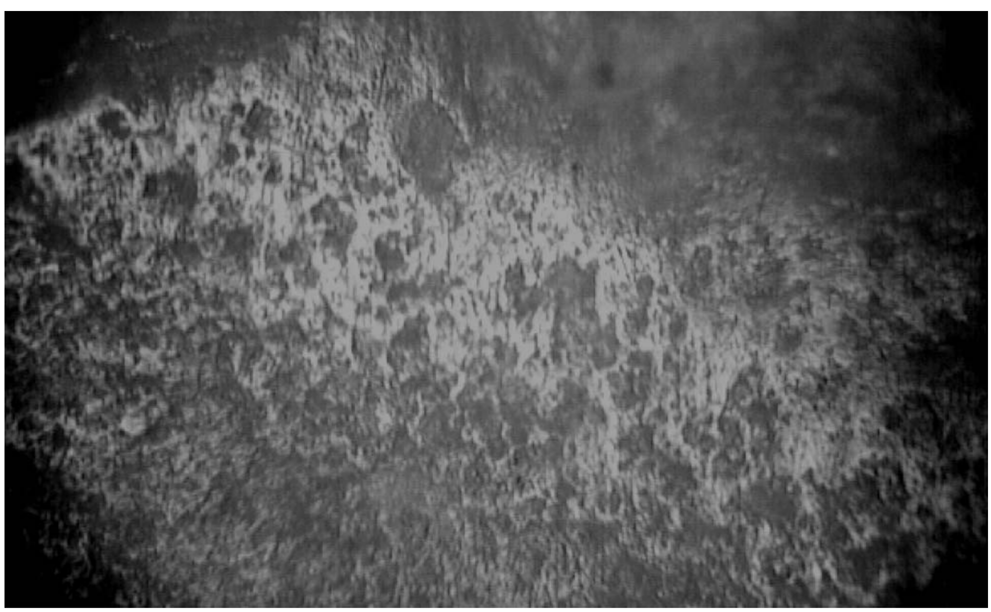

Fig. 8. Smooth, 'flat' wood polish on distal edge of another Dalton adze from St. Clair County, IL, USA. Note the many parallel striations (100 ×, width of the figure is approximately 650 μm).

polish with comet-shaped pits and flutes oriented normal to the cutting edge. Striations on the edges of hoes may become 'filled in' as the plant polish builds up [69]; (2) Similar plant traces form on sickles and sledge flints, but without the fluting. The striations and comet-shaped pits on sickles are not normal to the cutting edge, but are nearly parallel or at a low angle. This shows that sickles and sledge flints were used to cut plants, but not to chop them; (3) Woodworking tools develop wear traces that lack the comet-shaped pits and flutes. Striations are more common and prominent on axes, adzes, and chisels. They are often oriented perpendicular, or at a high angle to the cutting edge. The wood polish can extend back well beyond the edge of the tool, and can be domed and flat.

These microwear features were used in the analysis of the bifaces and axe spalls from Netiv Hagdud. It should be stated that a program of long-term, detailed replication experiments is needed to confirm the observations. The authors plan to make copies of Levantine

Neolithic tools and to use them to cut down trees, plane wood, make wooden objects, prepare and cultivate fields, and harvest cereals under controlled conditions in the Levant.

3. Results of the microwear analysis

A summary of the results of the microwear analysis is presented in Table 1. Discussion of the wear traces and technological features follows for each class of artifacts.

3.1. Tranchet flint axes

Seven of these distinctive bifaces were examined. All were made by removing transverse (tranchet) flakes from the dorsal and ventral faces of their distal ends. The result is a very sharp and 'smooth' cutting edge. In the latter Neolithic and Chalcolithic periods, chipped bifacial axes and adzes had their edges ground to produce smooth bits [6,10,11]. Two tranchet axe bit fragments were also included in the microwear sample.

The tranchet technique was developed independently by several different pre-historic groups. It was used in the Middle Pleistocene by African and Near Eastern hunter–gatherers to make cleavers and resharpen handaxes [14,52,59,68]. In Europe, late Mesolithic foragers and early Neolithic farmers made tranchet tools [5,22,26,51], and mobile hunters of the late Pre-historic period on the southern Plains of the USA made tranchet unifacial tools [56]. Early agriculturalists produced tranchet axes and adzes in the Nile Valley [31] and in the Levant [9,12,13,21,46], and similar-looking tranchet adzes and axes were produced by lithic craft specialists in workshops during the Pre-classic and Classic periods in the Maya lowlands [42,56,57,58].

It has been assumed that these tranchet tools were used to work wood, but some of the results of limited replication experiments and use-wear analyses have been ambiguous. Mayan oval bifaces, tranchet tools, and axe spalls (a.k.a. 'orange peel' flakes) were examined with hand-lenses by McAnany [42] and under a low-power (10–40 ×) binocular microscope by Shafer [56,57]. McAnany [42] described a dull, lightly striated polish on the oval 'general utility' bifaces that she attributes to their use as hoes or cultivating tools. She did not describe the wear on the few tranchet-bit tools recovered at Pulltrouser Swamp. Shafer found some edge battering, smoothing, and rounding on Mayan tranchet tools from several lowland sites, as well as point initiation fractures (step and hinge), and dull and bright polishes with perpendicular scratches and striations [56]. He thought that the variation in the low-power use-wear traces on the tranchet tools was the result of their being used on a 'wide range of contact materials' [56], but he concluded that most of the tools were hafted like small axes or hatchets and used to cut woody vegetation [56]. The variation in wear patterns on these Mayan axes and adzes may reflect the length of time for which each tool was used to work wood, rather than its use on different materials. Aldenderfer et al. [1] examined the wear traces on several oval 'general utility' bifaces from lowland Mayan sites and found that these were not general-purpose tools. They were either used to work wood or to till the soil. None of the bifaces showed any signs of multiple uses. A high-power examination of the Maya tranchet tools is needed to determine if they were also used just for working wood or for multiple tasks, but it should be noted that the traces Shafer observed under low power were also seen on the experimental woodworking tools that were examined in this study.

Holmes [31] had suggested that the tranchet axes and axe preparation flakes (e.g. axe spalls) from Naqada, Egypt exhibited woodworking use-wear traces, but she found that post-depositional surface modification obscured most of the wear traces. She withdrew her earlier interpretation and concluded that the function of the Naqada tools is still unknown. Keeley [38] examined two Sultanian tranchet adzes from Jericho. He noted a macrosheen on one of the adzes that was visible to the naked eye. Under 200 × magnification, he noted bright, smooth wood polish with many striations oriented normal to the cutting edge. The extent of the wear was asymmetrical, suggesting use as an adze [55]. The second, smaller 'tranchet adze' from Jericho that Keeley examined also had asymmetrical woodworking traces. He suggested that it might be a chisel rather than an adze since it had parallel sides and a narrow cutting edge. There were fewer striations on this 'chisel'.

3.2. Tranchet-bit tools at the Netiv Hagdud site

In a recent study, Yamada [70] examined three tranchet axes and two tranchet chisels from Netiv Hagdud as part of a high-power microwear study included in his dissertation on Neolithic tool use-wear patterns in the southern Levant. Nadel [46] classified 27 of the bifacial tools from Netiv Hagdud as tranchet axes and 16 others as tranchet chisels. Yamada found that heavy patina on these implements restricted his sample to only five that were suitable for microwear (12% of the total number of tranchet-bit tools). The tranchet tool sample from Netiv Hagdud was expanded to nine implements (21%) for this study, but the patina on the surface of the tools obscured many of the wear traces. We agree with Yamada that even the tools without patina from Netiv Hagdud are difficult to interpret, but we believe that it is possible to interpret the function of these tools. Yamada [70] also examined 23 (15%) of the total of 149 axe spalls from the Sultanian assemblage at Netiv Hagdud. The sample of tranchet axe spalls was increased to 41 (26%) for this study. Yamada found wear traces on five of the spalls in his high-power microwear sample.

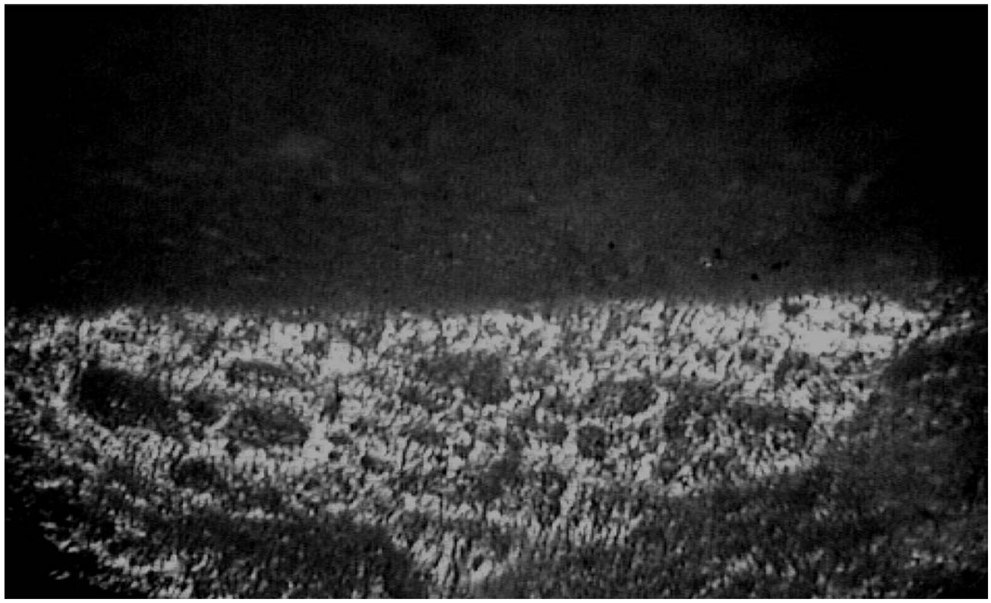

Fig. 9. Smooth, domed wood polish with many small striations on dorsal face of Tranchet axe from Netiv Hagdud (item 6; locus 8b, number 119) approximately 8 mm in from the distal edge. Compare with Figs. 7 and 8 (50 ×, length of the photomicrograph is approximately 1300 μm).

Yamada used a replica of a tranchet axe to chop wood, and another replica was used as a woodworking adze. The tools were used to fell trees, and 'work the trunk' of a eucalyptus tree [70]. He found some limited macroscopic edge damage traces similar to those described by Shafer [56,57] on his experimental tranchet axes and adze. The microscopic wear traces were weakly developed on the experimental tools [70], while other microwear analysts also reported weakly developed wear traces on experimental chipped stone axes and adzes [37,41,67], this may be due to the relative short duration of Yamada's wood-cutting experiments. Ancient axes and adzes (like the Dalton tools previously described) usually have more well-developed woodworking traces.

Yamada [70] noted that the wear traces on the axes, adzes, and axe spalls from Netiv Hagdud did not resemble 'classic' woodworking microwear. However, he recorded weakly developed polish at and near the cutting edges of some of the artifacts that he examined that is similar to the wear seen on the experimental woodworking tools used in this study (Fig. 1). Yamada also described developed polish with coarse striations on the tranchet tools from Netiv Hagdud that is identical to the microwear on the Dalton adzes from the USA (Figs. 7 and 8), and concluded that they were probably used to chop wood (and not to work hide or the soil) [70]. The variation in microwear traces on the tranchet axes and spalls from Netiv Hagdud that Yamada recorded may be due to their use both as wood chopping and carpentry tools. The extent and intensity of the microwear traces on the ancient tools would also depend on the length of the time for which each tool was used.

3.3. The wear traces on the tranchet tools from Netiv Hagdud that were examined in this study

Two of the seven tranchet axes examined in this study had well-developed woodworking use-wear traces, and the other five exhibited wear traces and edge damage that suggests that they also probably were used to work wood. One of the two tranchet axe fragments in the sample seems to have been used to work wood, but the other fragment had no visible wear traces (Table 1). Clear woodworking traces (Fig. 9) were seen on the dorsal face of a small, narrow tranchet axe from locus 8b (number 119, Fig. 10), and on another small tranchet axe from locus 8a (number 50), both seemed to have been used to plane wood (Table 1). Well-developed woodworking traces were also present on both faces of the distal edge of a larger tranchet axe from locus 48 (number 23, see Refs. [9,46]). Possible hafting traces were also present on the (ventral) right lateral edge of this axe near the butt. This larger axe seems to have been used for heavier chopping and adzing, possibly for felling trees. The wear traces on the other tranchet axes in the sample and the axe bit fragment from locus 14 (number 33) were not as distinctive, but they seemed to have been used for lighter woodworking (Table 1).

Only one of the tranchet axes had visible hafting traces, but the absence of microwear hafting traces does not mean that an implement was absolutely *not* hafted. Hafting traces result from the stone implement moving in the haft. A securely hafted tool would not move or rub against the binding, so there would be no visible

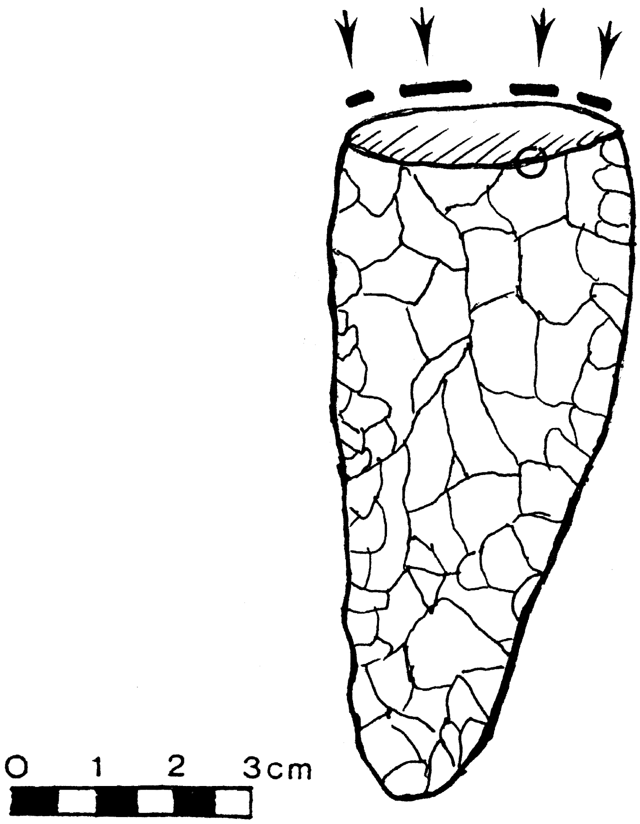

Fig. 10. Sketch of tranchet axe from Netiv Hagdud (item 6). Circle shows location of photomicrograph in Fig. 9, bold lines show locations of other microwear traces, arrows show orientation of wear traces.

hafting wear. Also, the patina on these implements may have obscured any hafting traces.

3.4. Microwear on the axe spalls that were examined in this study

Forty-one axe spalls were examined for microwear traces, and 11 of them (27%) had identifiable wear traces on their edges. The 30 axe spalls with no visible wear are listed in Table 1. Eight of the 11 spalls with visible wear had a macrosheen on their surface that could be seen without magnification. Ten of the spalls with wear traces seem to have been used on wood. Six of these seem to have come from tranchet axes that were used for heavier wood chopping, while four spalls had wear traces that seem to have been produced by lighter woodworking activities.

As Yamada had found in his study (see previous discussion), the woodworking traces were clearer and more developed on the axes spalls than on the tranchet axes in the microwear sample. For example, extensive smooth polish with many striations (Fig. 11) was present on the edge of an axe spall from locus 26b (number 82, Fig. 12). Five axe spalls from locus 18 also had woodworking traces on their edges. Perhaps locus 18 included

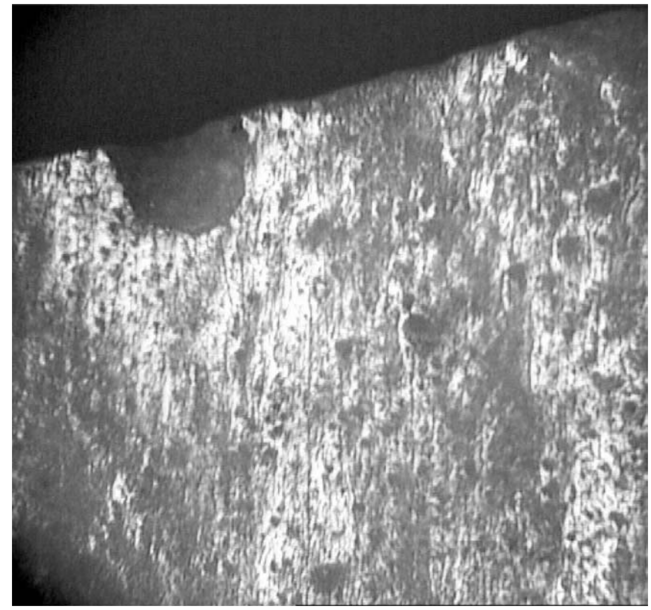

Fig. 11. Smooth polish with many striations on edge of spall (number 39) from axe used for wood chopping. Similar to wear on Dalton adze in Fig. 8 (50×).

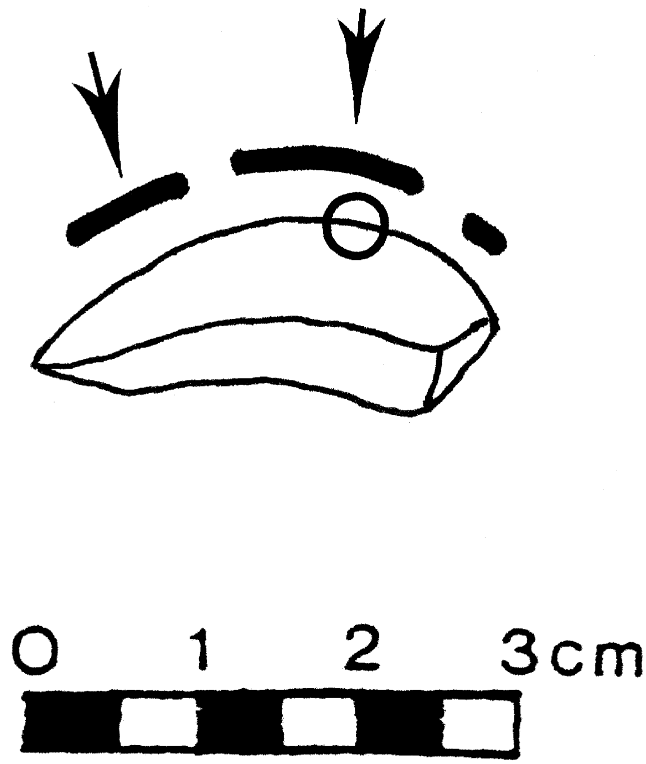

Fig. 12. Axe spall (item 39, locus 26b, number 82). Circle shows location of the photomicrograph in Fig. 11, bold lines the extent of microwear.

an area where tranchet axes that had become dull from use were being resharpened. One of these (number 12) is illustrated (Figs. 13 and 14), and has bright domed

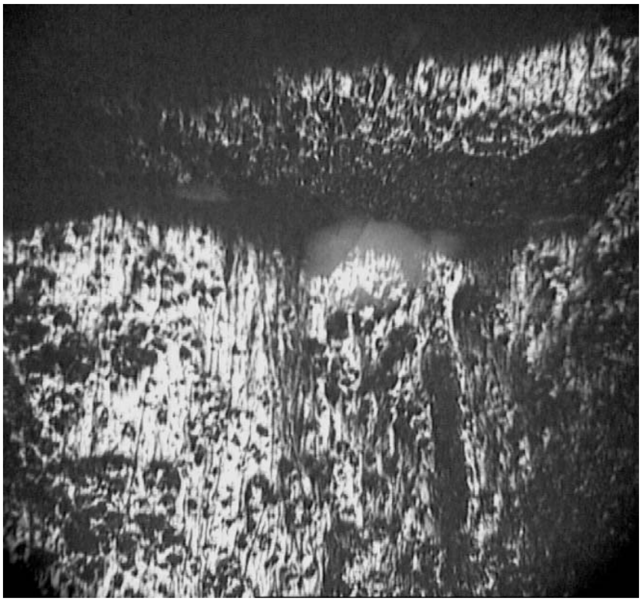

Fig. 13. Bright domed polish on axe spall (number 67). From axe that seems to have been used to chop or plane wood. Polish similar to wear traces on Dalton adze in Fig. 7 (50 ×, approximately 1300 μm wide).

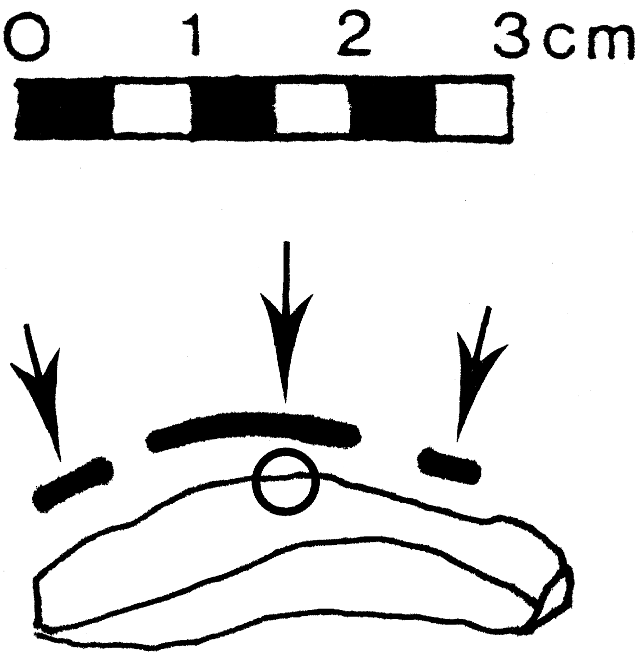

Fig. 14. Sketch of axe spall (item 67, locus 18, number 13). Circle locates the photomicrograph in Fig. 13, bold lines show extent of microwear traces, arrows show direction of use.

polish with many striations that is similar to the wear found on the Dalton adzes (see Fig. 7). This spall probably came from a tranchet axe that was used to chop wood. One of these spalls from locus 18 (number 14) was covered with patina, and a strange greasy polish was seen on its surface. There is some slight edge

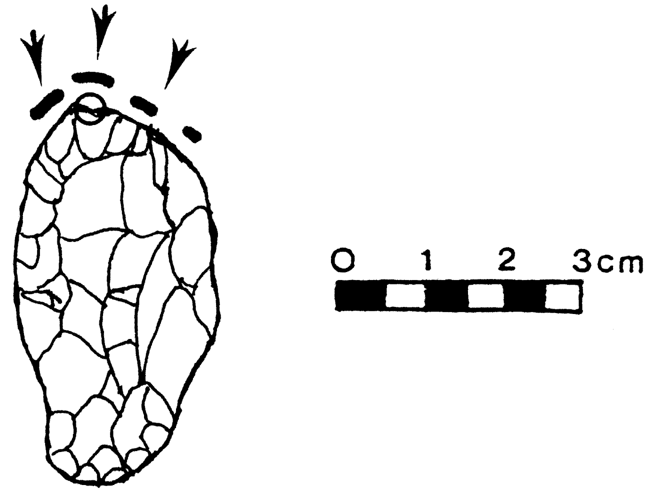

Fig. 15. Sketch of small biface from Netiv Hagdud (item 13, locus 21, number 107). Circle shows location of the photomicrograph in Fig. 16, lines and arrows show extent and direction of wear traces.

rounding, but the extent of the wear (a macrosheen was visible with the naked eye) suggests it that it was used on wood or plant material. The greasy appearance may be the result of the patina covering the microwear traces. Another of the five utilized spalls from locus 18 (number 2) had a very well-developed woodworking polish on its edge. However, in addition to striations running normal to the cutting edge, it also had several prominent striae running parallel to the edge. Perhaps these were made when the edge of the axe from which the spall was removed was abraded in an attempt to resharpen the tool.

One axe spall from locus 8b (number 20) seems to have been finely retouched along its edge. Some very weakly developed wear traces on this edge *may* be the result of cutting hide or meat. However, the spall is patinated, and the wear traces were obscured. This may be an example of a 'recycled' axe spall. Shafer [56, pp. 63–64] also found several modified tranchet spalls that were used for other tasks, and Barkai [10] discussed the recycling of bifacial tools and axe resharpening flakes at later Neolithic and Chalolithic sites in the Levant. The PPNA inhabitants of Netiv Hagdud probably also reworked and recycled some the tranchet axe spalls.

4. Microwear traces on other bifacial and unifacial tools from Netiv Hagdud

4.1. Chisels

Eight of the nine chisels and chisel fragments in the microwear sample seem to have been utilized. Two were used to plane or scrape wood, five were used to scrape or plane wood and/or bone, and one seems to have been used to scrape wood and hide (Table 1). One chisel had

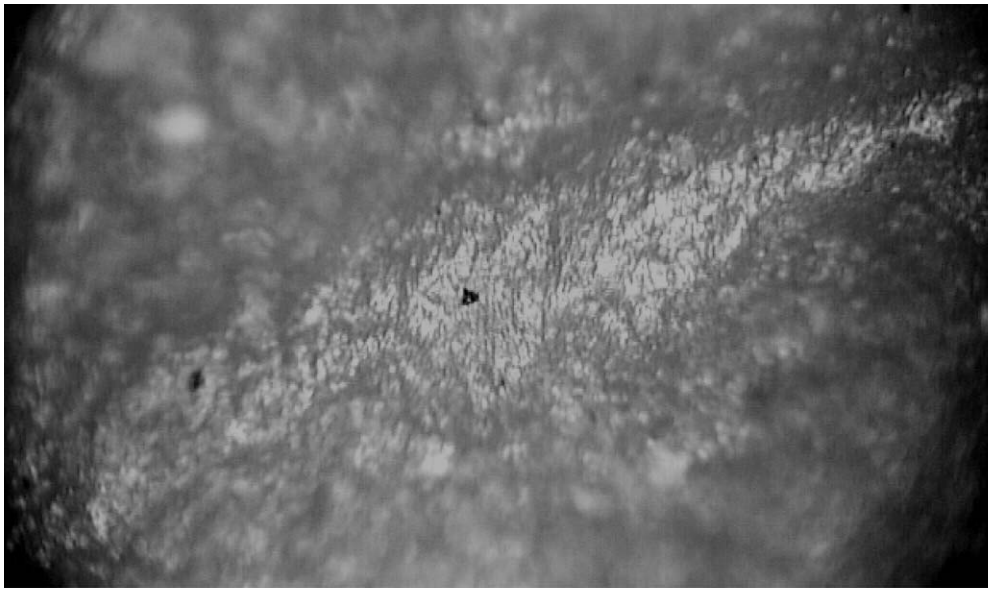

Fig. 16. Rounding and small striations on ventral face of distal edge of small biface (number 13) from Netiv Hagdud. Note 'greasy' appearance of polish. The biface seems to have been used to scrape hide. Compare with Fig. 6 (100×, width of the photomicrograph is approximately 650 μm).

no visible wear traces on its edge. One distal chisel fragment with a wider, rounded bit from locus 14 (number 45) had some extensive woodworking traces and exhibited a *lateral snap* or *bending fracture* [34,50,64]. The experimental chisel also broke with a lateral snap when it was hafted in a bone sleeve and struck with a hammerstone while it was being used to plane a piece of seasoned wood. The chisel fragments may have come from chisels that may have also broken when they were used in this fashion.

4.2. Other bifaces

Three of the nine bifaces in the sample may be unfinished (a large one from locus 1014 [number 110], and two smaller bifaces from locus 18 [numbers 30 and 102]). Cortex was still present on the dorsal face of number 30, and the others seemed to be in the early stages of biface production. There were no visible wear traces on these three artifacts (Table 1). Six of the bifaces seem to have been utilized. Two were used to scrape or plane wood or bone (one from locus 13 [number 31] and one from locus 10 [number 94]), and two were used to scrape hide (one from locus 21 [number 107, see Figs. 15 and 16] and one from locus 40 [number 114]). Some edge rounding and greasy use-wear traces are visible on the ventral face of the distal edges of these tools, but they appear to be lightly used. A biface from locus 58 (number 88) had some bright polish and striations at its tip that suggest that it may have been used to bore through bone, or pierce hide [16]. Another biface fragment from locus 18 (number 90) may have been used as a borer (Table 1.).

4.3. Large uniface

One large unifacial tool was examined. It was found in locus 27 (number 69). It is made of coarse-grained brown flint with some crystalline inclusions. Its distal edge is battered, but there were no visible use-wear traces.

5. Conclusions

The bifacial tools examined in this study were used to work wood, bone, hide, meat, and plant material. The tranchet axes and chisels seem to be designed for woodworking. However, while some of the larger tranchet axes may have been used to fell trees, many of these tools seem to have been used for 'light' woodworking, rather than heavy chopping. The edge damage on most of the tranchet axes is not extensive, and the large impact fractures and *point initiation* flake scars that are common on wood-chopping tools are only present on the larger axes [49,72]. This suggests that most of the axes and chisels were part of a 'carpentry' tool kit designed to make wooden utensils or smooth and plane wooden boards. There were no visible wear traces on the ground stone celts in the sample. While the flaked stone bifaces were used for woodworking and other tasks, the ground stone celts do not seem to have been used as tools.

In summary, the PPNA Sultanian lithic industry included two different bifacial tool classes, thin, light flint tranchet axes and chisels for light woodworking tasks, and heavy, large, polished stone axes that showed no evidence of use. It seems reasonable to argue that only large tranchet axes were used for felling or chopping trees, while most of the tranchet axes and chisels were used for lighter wood crafts.

The establishment of large villages and the construction of standardized dwellings probably brought about new needs and led to the development of new kinds of woodworking tools. The use of bifacial tools may also be an indication of greater manipulation of natural resources.

During the first phase of the Pre-Pottery Neolithic B period (EPPNB, after 9500 BP), a new axe type was introduced—the polished flint axe. For the first time flint axes are made by flaking and polishing their edges and surfaces. This resulted in the production of functional, heavy duty, woodworking tools. Tranchet flint axes appear in EPPNB contexts as well, alongside the new polished flint axes, but in much lower frequencies than in the PPNA. The replacement of light tranchet flint axes by heavier polished ones is complete by the end of the PPNB period.

The fact that no use-wear traces were found on the stone polished axes is significant. These distinctive tools must have played a role in a different arena of Neolithic life [11,12]. Bifacial tools were used by Neolithic people in order to manipulate nature and make efficient use of natural resources. Many of the innovative crafts and conceptions of semi-sedentary agricultural societies could not be implemented without bifacial tools.

The development of sophisticated woodworking seems to have originated during the early Neolithic period in the Levant. While the form of the flaked axes, adzes, and chisels undergoes changes during the later Neolithic and Chalcolithic periods, and the tranchet technique is abandoned as edge-ground bifaces become more common, woodworking seems to be a rather constant activity.

Some bifaces from Netiv Hagdud were also used for boring and scraping hide and bone. None of the bifaces in the sample were used as hoes. Future microwear studies should help us understand the full range activities that were conducted at the settlement. The microscopic examination of Neolithic tools must be complemented by ongoing replication experiments and ethnoarchaeological studies if we wish to reconstruct ancient human behavior in the Levant during the transition from foraging to food production.

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