Chapter 8

STAROSELE STONE TOOL USE-WEAR ANALYSIS

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INTRODUCTION

Stone tool use-wear is straightforward and simple. Telltale signs of wear, such as microscopic use scratches, are taken as clues of tool use and of the material against which a tool edge or surface came into contact. This chapter describes the results of a use-wear analysis performed on a sample of tools from the Middle Paleolithic site of Starosele, and addresses these questions: How does tool function compare to form? How were stone tools used, and for what activities? Does the range of activities vary over time? Do conceptual differences exist in how stone tools were made, used, and maintained?

SAMPLES AND SAMPLING

A sample of 102 chipped stone artifacts from the recent excavations at Starosele (Marks et al. 1998) were analyzed. These artifacts were produced on mostly non-local, fine-grained, dark flints from western Crimea. They are ideal for a use-wear study and the photomicrographs of wear traces are truly spectacular in detail and clarity. The sample is an opportunistic one of mostly retouched artifacts, or "tools" (Table 8-1). The nonrandom selection deliberately reflects technological variability across and within the four occupation levels at Starosele, and allows for robust inferences about the artifacts.

The sample comes from four stratified Middle Paleolithic cultural levels (Marks et al. 1998). The uppermost, Level 1, dates by ESR (Rink et al. 1998) and radiocarbon methods (Hedges et al. 1996) to about 41,000 years ago, which correlates with the Hengelo Interstadial. Level 2 falls within the Hengelo or the Moershoofd interstadial. Level 3 occurred during relatively dry stadial conditions of the beginning of the Pleniglacial, which is consistent with its U-Series date of about 67,500 BP. Level 4 falls within the Amersfoort-Brörup or Odderade Interstadial and has a U-series date of >80,000 years old (see Chapter 11, this volume).

Of the artifacts, 34 were excavated in 1995 and 68 in the preceding years. The vast majority of the specimens (from the 1993-94 excavations) were already cleaned of matrix and often labeled before being examined. These specimens were, however, only slightly more likely to have pseudo-wear (13 to 10), whether by metal implements or stone-to-stone contact from field and laboratory settings than the ones that were not cleaned. Pseudo-wear is a serious problem for most archeological collections. Twenty-three of the 102 specimens (22.5%) had pseudo-wear, of which 10 were not retouched (58.82% of 17) and 13 were retouched (15.29% of 85).

MICROWEAR METHODOLOGY

Use-wear analysis is an unequivocal way to evaluate stone tool function and related issues. Microscopic wear traces, scratches for instance, are taken as signs of use and their nature permits inferences about the materials against which the tool edge was in contact. In this context, "contact" or "worked" material refer to both the intended or accidental object of tool use, or that which grips or holds the tool.

The microscopic use-wear analysis used by the author follows the logic and many of the criteria of Semenov's traceological approach, but is neither bound by it, nor by the low-power Keeley method (Semenov 1964, Keeley 1980). A legitimate difference with Semenov's classic study and the author's writings (Kay 1996) is the recognition of additive, soluble, inorganic residues, as expected by Keeley-method analysts. Photomicrographs of additive residues were taken in the 1980s, but they were neither recognized as such, nor their significance appreciated, until the Starosele study began in 1994.

Earlier studies by the author (Kay 1977, 1996, 1997) describe realistic experimental stone tool analogues, appropriate microscopic approaches, and use of ancient stone artifacts. These are, however, an inadequate statement of the use-wear methodology employed for Starosele and Crimea. Starosele has a greater number and complexity of artifacts than any of the author's earlier studies. Its analysis entailed additional experimental controls; a new suite of analytical observations about additive use-wear formation; and wear trace criteria in relation to contact materials, tool use, optional maintenance, and natural wear traces or pseudo-wear. The analysis was staggered over several years.

Confirmation of some of the results of the use-wear study at Starosele was provided by the independent residue analysis undertaken by Bruce L. Hardy (Chapter 9). The 1995 sample destined for specialist analysis was individually packaged in polyethylene plastic bags when excavated, neither cleaned nor further touched, and sent to Hardy. After microscopically examining the adherent matrix and the uncleaned artifact surfaces for organic residues, Hardy forwarded the artifacts to this author, but without providing information of his procedures or results. We later compared our results and realized that we had similarly recorded microscopic evaluations and had complementary findings. Our collaboration results in an especially robust assessment of the use of hand-held and hafted tools, and the recognition of contact materials that would not have been possible otherwise. The results of this collaboration are presented in Chapter 10 of this volume.

Each artifact was assigned an individual specimen number, weighed, measured, and logged into a computerized relational database. After being coated with water-soluble ammonium chloride to enhance flaking and surface details, they were photographed. Ultrasonic cleaning in an ammonium based detergent and water solution then removed the remaining, easily dislodged sediment and any oils that obscured microscopic details. Additional chemical treatment, as recommended by Keeley (1980: 11), was occasionally done after an initial inspection, as needed. The microscopic examination was mostly on the more-or-less flat ventral surface and all edges, but often also included both faces of an artifact. For flakes and other unifacial artifacts, the examination always began with the ventral surface. As this surface represents the side of final detachment from the core, its use-wear reflects that of the tool, whereas the dorsal side, in theory, could reflect activity prior to the flake's detachment.

A differential-interference binocular microscope with polarized light Nomarski optics (see Hoffman and Gross 1970 for a general discussion) was used at magnifications of 100 to 400 diameters. This microscope provides a high resolution, three-dimensional image for microtopography. Most scans for polishes, residues, and striae employed a systematic series of overlapping transects done at 100 diameters. Further evaluations were made at either 200 or 400 diameters, and details photomicrographed, as needed. Microscopic evaluations were also made, as appropriate, at lesser magnifications (10-40X), primarily to observe gross details of edge damage, crushing, and rounding.

The approximate locations of microscopic details and photomicrograph orientation were noted on specimen photographs or schematic illustrations. Photomicrograph illustrations are designed to express the range in wear trace variability, their location, and orientation. For the most part, wear traces are not continuous, and are distributed either along a tool edge or at a high spot on a tool surface.

The overall approach allows for quantitative evaluations of wear traces. The most important, albeit preliminary, are the orientation, number, width, and sequencing of use-wear striae; striae cross-sectional shape; the area or width of a tool edge contact zone (the portion of the edge in direct contact with a worked material); and shape, size, and number of abrasive particles. These data are obtained mostly from observation of photomicrographs.

USE-WEAR FORMATION

Use-wear is a response to micro-chemical and physical environments under which stone tool edges and surfaces contact a worked material. Tool and contact material hardness, moisture, the tool edge's plan and cross-sectional shape, and the direction and amount of applied force are all prime factors that affect tool use. These may result in use-wear. Other, secondary factors are likely to affect tool efficiency and use-wear, too. Among the most important would be abrasive particles; brittleness, malleability, and ductility of either contact material or tool; and dynamic changes in tool edge plan or cross-sectional shape as a tool is used, dulled, and resharpened. Use-wear is likely to be indicative of one or more primary and secondary factors. Abrasive use-wear is a by-product mostly of the manner and amount of applied force and frictional resistance offered by a contact material or introduced abrasives, and the length of time of tool use. For the formation of additive use-wear, or soluble residues, moisture must be added. Undoubtedly, other factors still unknown also must affect formation of soluble residues.

Additive residues also commonly form during stone tool use due to hafting or prehension. These wear traces permanently bond to an artifact surface. Clearly denoting the orientation and direction of their formation are the in-filling of striae, crystallization on the trailing edge of the residue, and, to a lesser degree, desiccation cracking. What goes into solution, or becomes a soluble gel, is probably mostly silica, assuming an X-ray probe of one soluble residue is representative (Kay 1997: 658-660; see also Keeley 1980; Mansur 1982; Vaughan 1985).

Strictly abrasive wear traces tend to smooth and polish, and ultimately lead to a nearly featureless, optically reflective surface. Their range of expression is from a mere scratch, or striation; to heavily striated, well developed polishes; and lastly to other polishes in which the striae are faint and have almost a vestigial appearance. Soluble residues contrast from abrasive polishes, although they invariably are optically reflective. They coat a surface, have a bumpy, textured appearance, and directional flow characteristics. Their deposition is clearly as a liquid, or gel. Exactly how long it takes for the gel to bond and harden onto a tool surface is uncertain. From experiments, hardening must have occurred in minutes, seconds, or even less. It seems likely, too, that hardening is differential and occurs progressively across a still-in-use tool edge.

As determined from experiments, abrasive use-wear also may occur alone, precede the accumulation of soluble residues, continue during the latter's deposition, or be masked by it. Abrasion of a soluble residue relates to the frictional properties of the residue itself, and occurs while it is soluble but viscous. The frictional coefficient of still-soluble residues must be significantly less than either the contact material or a tool surface and edge. When soluble, the residue acts as a lubricant. Yet, as it dries, the residue bonds to the tool surface or edge, and forms thin layers ("microplating"). This residue builds up microscopically, alters the edge, and ultimately reduces tool efficiency because it changes the geometry of the cutting edge.

Contact Materials

Conspicuous microscopic changes to a tool edge and adjacent surfaces occur during use. If only to a degree, these microscopic alterations relate to and are caused by contact materials. This relation is, of course, central to stone tool use-wear studies.

The wear trace criteria used here to differentiate contact materials contrast somewhat from other types of studies for reasons of optics and microscopy. Use-wear evaluations are microscope-dependent. The clearer the image, the more likely one will make meaningful comparisons and set analytical standards. The differential-interference microscope with polarized light Nomarski optics substantially improves the image over that of a reflected light binocular scope, and is similar in its depth-of-field characteristics to a scanning electron microscope at the same magnification range. For all microscopes, depth of field is reduced as magnification increases. For the differential-interference microscope, the resolution increases along with magnification, which is similar to a scanning electron microscope. The Nomarski optics afford an exceptionally detailed, three-dimensional image. It is important to note that the wear traces in question are often significantly smaller than, and may be independent of, edge damage that is either macroscopic or easily observed at magnifications less than 100 diameters. Whether abrasive or additive, these wear traces are readily observed at magnifications at or greater than 100 diameters on stone tool edges and surfaces of all kinds.

Based on experimental evidence, there are wear trace differences due to the relative hardness, malleability of contact materials, and the manner of tool use. These are stronger when moisture is present during tool use and soluble residues form. They also apply when only, or mostly, abrasive wear traces occur.

Everything else being equal, a change in worked material hardness should be inversely proportional to contact with a tool edge. This prediction may be verified by experiments in which the width of a contact zone on a tool edge or surface is compared to worked material hardness and malleability. Generally speaking, as hardness increases, malleability decreases, and the contact zone narrows. So, if one knows or can calculate hardness and malleability of a contact material, one can also predict a tool's contact zone width and other systemic responses to a worked material. This prediction would work best for the theoretical-and-never-realized situation of comparable tool edges used in an identical manner with the same amount of applied force. Yet, it works reasonably well when virtually none of these conditions is met, which is the norm for stone tools. Although the contact zone width can be measured accurately from a photomicrograph, doing so is neither essential in the initial microscopic inspection, nor absolutely needed even later. More important are ordinal scale measures of the contact zone width, along with observations of other contact zone attributes.

We may infer gross differences in contact material from two wear trace criteria: tool edge rounding with a broad contact zone equates well with soft contact materials, while an absence of tool edge rounding over a more restricted contact zone represents harder contact materials. Further distinctions also can be made for either softer or harder contact materials, and these require inspections at magnifications generally greater than 200 diameters. These are based, in their order of importance, on (1) the occurrence, placement and frequency of striae and abrasive particles; (2) micro-edge cross-sectional shapes; (3) invasive wear traces; (4) the manner of deposition of soluble residues; and (5) wear trace sequencing.

Almost exclusively kinematic features include the above first three groups of attributes. *Striae and abrasive particles:* their occurrence is a direct measure of the overall extent of tool contact with a worked material. Their placement and orientation are evidence that a point or tool edge was used and indicate the direction and type of tool stroke. Their frequency (optimally expressed as number per unit area, or density) tends to increase with the relative hardness of the contact material. For example, relatively few striae occur during hide scraping, depending on the presence of abrasive particles, of course. The reverse is true of herbaceous plants, which often are associated with an almost limitless number of striae. Opal phytoliths, or cellular silica bodies, produced by the plant are probably the source of the abrasive materials. Working deciduous hardwoods may result in few striae. More dense contact materials such as bone, antler, or ivory produce heavily striated tool edges and surfaces.

Micro-edge cross-sectional shapes: these respond to and are responsible for certain kinds of tool strokes indicative either directly or indirectly of contact material hardness and malleability. Soft, highly malleable materials such as leather, animal hide, or herbaceous plants produce extensive tool edge rounding. Working deciduous hardwoods may result in little perceptible alteration of a tool edge. More dense contact materials such as bone, antler, or ivory are more likely to damage an acute angle edge, less so on a right or slightly obtuse angle edge.

Invasive wear traces: whenever the contact material envelops and touches the tool edge, or the tool deeply penetrates, the wear traces are invasive and often extend from a tool edge across its surface. Invasive wear traces keyed to tool use are preferentially distributed in a directional way on the leading side (i.e., the side facing the contact material) of higher microtopography, and rarely are continuous. When compared to the first two attribute groups, they provide substantiating evidence about the lateral or areal extent of contact with a worked material and its likely hardness.

Time/duration of tool use, optional maintenance, and recycling are addressed by the final two groups of attributes; these also bear on the kinematic features. *Soluble residue deposition:* first and foremost is the relation to micro-chemical environments affected by the tool and a worked material. The differential build up of soluble residues, their drying and cracking, provide insight into tool edge dulling and needed maintenance. *Wear trace sequencing*: the prime explanatory potential is in establishing a minimum number of observed tool uses, plus the likelihood a tool was maintained further or recycled.

Tool Stroke

Striae, abrasive particles, and soluble residue attributes all provide direct information about tool stroke. The most important soluble residue attribute is crystallization on the trailing edge or side; that is, on the side opposite the point or edge of contact between a tool and a worked material. Crystallization is useful in three general ways: to confirm a single tool stroke direction in which crystallization is only on one side of the contact zone; to identify a bidirectional tool stroke in which crystallization occurs on both sides of the contact zone, or a multidirectional tool stroke in which crystallization occurs on several sides of the contact zone; and, finally, to recognize a rotary tool stroke in which crystallization occurs in a circular pattern about the contact zone and may be seen to radiate from a central point. Abrasive particles are similar in their usefulness, as they tend to stop at the end of a striation, opposite the direction of force and tool motion. Striae provide a clear view of tool stroke orientation and are often complemented by abrasive particles or crystallization. Viewing these lines of evidence, as a whole, the direction, or directions, and orientation of different tool strokes may be defined. Although simplified here, these patterns reflect the observed use-wear evidence.

Although there are a large number of possible specific motions that can be defined through use-wear studies, the following discussion is limited to those actually seen in the Starosele sample.

Cutting

Striae derived from cutting are variable in orientation, and may result from single, bidirectional, and multiple-directional strokes. They also vary with the relative hardness of the contact material. Invasive cutting strokes are more likely with soft (e.g., hide, meat, and herbaceous plants) to medium hard (e.g., deciduous and coniferous wood) contact materials. In cutting, the tool edge acts as a simple wedge to split or cleave through a worked material. If the tool edge is held perpendicular to the surface of a worked material, striae and other wear traces will be at the tool edge itself and both adjacent surfaces. This is most common with biconvex tool edge cross-sections and when the tool edge angle is acute (between 45 and 60 degrees). Tool edges with planoconvex cross-sections where the tool edge angle is greater than 45 but less than 90 degrees almost invariably have evidence of cutting strokes on the flat side. The flat side adjacent to the working edge is the leading surface, the one most in contact with a worked material. For either type of tool edge cross-sectional shape, cutting striae and related wear traces should originate at the edge, and may parallel it, in which case the cutting stroke could be either a single or bidirectional, depending on the placement of abrasive particles and crystallization. The cutting stroke may also be obliquely or transversely oriented to the edge, or a combination of parallel, oblique, and transverse motions. The wear traces, again with priority given to striae, should clearly identify the orientation and direction of the cutting stroke.

Scraping

The predominant orientation of striae and related wear traces due to scraping should be transverse to the tool edge, clearly originate at this edge and should display either a uni- or bidirectional motion. For planoconvex tool edges, the leading surface is the convex one adjacent to the edge. The contact zone usually extends onto the flat side, as well, but is mostly limited to the edge itself. For biconvex tool edges and unretouched near-right-angle and obtuse angle edges, the edge itself is often the prime contact zone, and should display the same wear traces as do planoconvex tool edges.

Planing

Planing is a variation of scraping, with the same general orientation and directionality of wear traces. With a planoconvex cross-section, the leading surface is the ventral surface of the tool edge. The wear traces are invasive. Worked materials which are hard may result in substantial damage to tool edges; soft contact material results in tool edge rounding, which shows mainly on the dorsal surface of the edge itself.

Gouging

Gouging is a variation of scraping peculiar to near-right-angle edges and is usually found on tools with obtusely angled working edges. They will exhibit the same general orientation and directionality of wear traces as those used for scraping. The contact zone is almost invariably limited to the immediate, exceedingly narrow edge, and is usually correlated with hard contact material. The wear traces are not invasive.

Wedging

Wear traces derived from wedging are normally at the edge and invasive on both adjacent faces. Wear traces tend to be localized to the flake arêtes closest to the tool edge. The side opposite the wedge edge often shows hammer pitting. Bifacial flake scars on both the wedge edge and the opposite side are common, use-related, and are largely parallel to the orientation of the microscopic use-wear.

Engraving

Wear traces due to engraving originate at a point and extend back from it along the edge or surface in contact with a worked material. Working within a groove or slot may result in either bidirectional or multidirectional wear traces, as the tool edge is pushed or pulled along the slot. Wear traces generally are limited to the point, adjacent tool edge, or surface and are limited to a narrow contact zone. Invasive wear traces, however, may occur when the slot or groove being made is of sufficient magnitude that contact between it and the tool surfaces occurs. When invasive, the tool motion is often bidirectional, parallels the working edge when the edge is within the groove, or originates at the tip and is perpendicular to the tool's longitudinal axis.

Drilling and Perforating

Although of similar function, a drill and a perforator contrast in tool motion. Rotary motion applied at the tip is typical of a drill. A perforator would be plunged into or through a worked material, creating a conical hole by the wedging action of the tip and the tool shaft. Tool forms should differ, too. The drill form should allow for rotary contact of its tip with a worked material, but ideally, not its shaft. A perforator should have the almost opposite design elements: because its tip initiates an opening that is further wedged by frictional contact with its shaft, the conical shaft should end in a needle-like tip. Because both tools must be extracted from the hole, comparable wear may occur on the shafts of both.

Impact and Penetration

Projectile point use (or simple penetration) result in unidirectional wear traces that originate at the tip, parallel the longitudinal axis of the tool, and are invasive on both faces. The leading surfaces face the tip. It is difficult to distinguish between wear traces resulting from thrown—as opposed to thrusted—actions in killing big game (Kay 1996). A variety of macroscopic damage to the tip, faces, and base of projectile points is also common and impact-related (Witthoft 1968; Ahler 1971; Frison 1977). These consist of simple tip fractures on a needle-like tip, to impact fractures (burin-like facets) on the edges and surfaces, to failure and radical breakage of the tool.

Hafting and Prehension

Hafting allows for an application of greater force directed against a worked material and, thus, has a mechanical advantage over the hand-held employment of a similar tool. It does not necessarily assure the absolute stability of the hafted portion within the haft during tool use, however. Microscopic effects of friction due to haft binding and use-related movement are readily observable (Kay 1996). These afford unambiguous use-wear criteria to differentiate hand-held from hafted tools. Among the more important are the nonrandom placement, orientation, extent, and organization of striae and related wear traces typical of hafted but not of hand-held tool use.

Invasive wear traces due to prehension include abrasive wear traces—principally striae that fan out in a seemingly random fashion from a common surface area—and associated soluble residues that occasionally merge as rounded patches.

Pseudo-Wear

Pseudo-wear of a natural or taphonomic origin includes the effects of wind abrasion, trampling damage, post-excavation transport and stone-to-stone contact, and metal or graphite streaking.

The origin of natural striae should not relate to a tool edge, and should be independent of it, unless edge damage is responsible for the introduction of abrasive particles that are then swept across a surface. Instances where ambiguous wear traces are present are likely to have resulted from wind abrasion, trampling damage, post-excavation transport, and stone-to-stone contact. Wind abrasion results in abundant, highly directional striae and aerosol abrasive particles that parallel one another or form crossbeds. Wind abrasion may be superimposed on and obscure use-wear, or confused with it. Trampling damage, post-excavation transport, and stone-to-stone contact are likely to cause random striae that could be confused with prehension wear traces.

Metal and graphite streaking are common pseudo-wear features, and ones easily identified by their brightness and surface texture. They indicate damage to artifact surfaces and edges produced during or after excavation, or, more broadly, within the historic period. Unless the evidence is equally clear and convincing, striae near to metal or graphite streaks should be discounted, because they may well be caused by the streak but not have the metallic residue.

FUNCTIONAL CLASSIFICATION OF ARTIFACTS

A combination of microscopic and macroscopic information to assign stone artifacts to functional categories was used. Using wear trace evidence, the most basic question is whether the artifact was used. If not, the artifact is classed initially as a non-tool. If intentional and patterned retouch is present, it is further identified as a tool preform; without such retouch, it is classified as debitage. An artifact that displays tool use-wear is classed as a tool; one for which wear traces are inconclusive and/or are pseudo-wear is assigned as unknown.

TABLE 8-1
Starosele, Total Formal Tool Types *(N)* and Use-Wear Samples *(S)* by Level

	Level 1		*Level 2*		*Level 3*		*Level 4*	
Tool Class	*N*	*S*	*N*	*S*	*N*	*S*	*N*	*S*
Scrapers	72	26	15	5	59	14	9	6
Retouched Pieces	35	3	1	–	37	2	3	–
Points	21	13	–	–	5	4	1	1
Pièces Esquillées	2	1	–	–	–	–	–	–
Denticulates/Notches	17	1	4	–	37	7	–	–
Bifacial Tools	13	10	1	1	–	–	–	–
Other	1	–	–	–	2	8	–	–
Total	161	54	21	6	140	35	13	7

For specific tool types, or type subdivisions, additional criteria apply. The leading aspect (surface and/or edge) of the tool during use, the orientation, type, and relative invasiveness of the tool stroke are prime criteria for assigning tool function. Wear trace sequences indicate either repetitive use or tool recycling; wear traces only at a tool edge or on a leading surface indicate optional maintenance and discard. Worked material, when part of tool functional classification, is inferred by the tool contact zone width, edge rounding, or other types of microscopic alteration (edge faceting, damage, etc.), striae, and abrasive particle density. Wear traces for either prehension or hafting further divide tools into two major categories, hand-held or hafted. Macroscopic tool edge cross-sectional shape, curvature, pointedness, symmetry, and overall measures of mass and size are considered.

Starosele Stone Tool Functional Types

Not all morphological tool classes from Starosele were examined, since emphasis was placed on the more heavily retouched tools, scrapers, points, and bifacial foliates (Table 8-1). For those classes, however, a significant sample of each level was studied, ranging from 77%

TABLE 8-2
Starosele, Use-Wear Categories

Function	*Uncertain*	*Unknown*	*Hand-held*	*Hafted*	*Total*
Level 1					
Cut/Scrape	–	–	10	2	12
Wedge	–	–	4	–	4
Burin	–	–	2	6	8
Unifacial Point	3	–	–	8	11
Bifacial Point	1	–	–	8	9
Unifacial Scraper	–	4	–	1	5
Debitage	–	4	–	–	4
Drill	–	–	–	1	1
Level 2					
Unifacial Point	–	–	–	1	1
Bifacial Point	–	–	–	1	1
Cut/Scrape	–	–	2	1	3
Debitage	–	1	–	–	1
Level 3					
Unifacial Point	–	–	–	7	7
Burin	–	–	–	3	3
Cut/Scrape	–	–	10	5	15
Scraper	–	–	–	1	1
Wedge	–	–	4	–	4
Spokeshave	–	–	1	–	1
Debitage	–	4	–	–	4
Level 4					
Unifacial Point	–	–	–	1	1
Burin	–	–	–	2	2
Cut/Scrape	–	–	–	4	4
Total	4	13	33	52	102

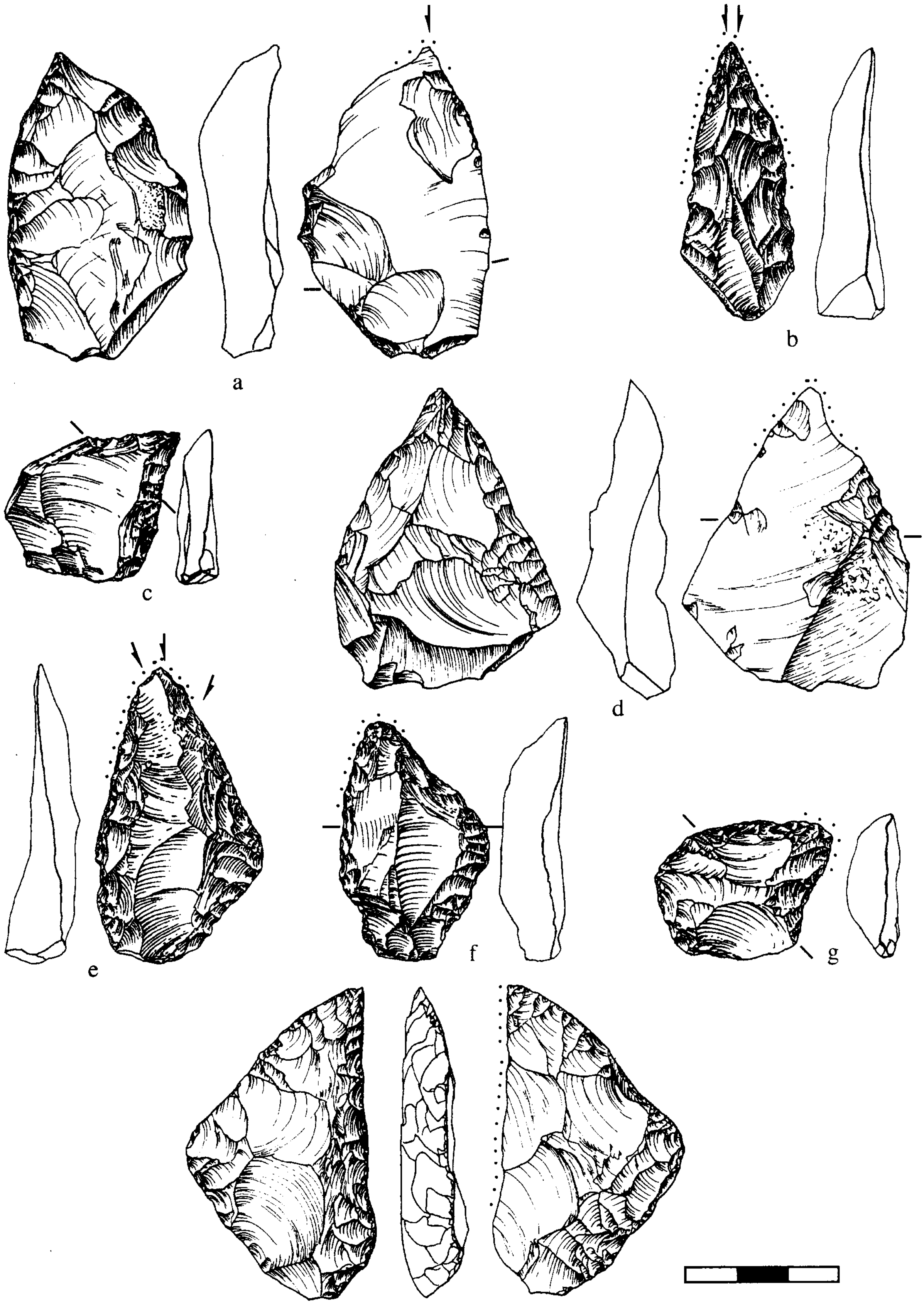


Fig. 8-1—Starosele, functional types, Level 1: *a-f*–unifacial points; *g*–hafted drill; h–bifacial knife. Stippling indicates the tool edge; dashes indicate the extent of the haft element.

of the bifacial tools in Level 1 to 25% of the scrapers in Level 3. As expected, the correlation between morphological types and functional types depends upon the degree to which the morphology determines the way a tool can be used. This rarely is a one to one correlation and, so, it is not surprising that a sample drawn from a morphological class, such as scrapers, will break down into a number of different functional groups.

This study recognizes seven functional groups of tools, based upon the purpose for which they were used. They are defined only briefly below because there is usually a high correlation between a functional type (e.g., knife) and the kind of tool stroke used (e.g., cutting) and these have been described above. The functional types recognized here are drill, spokeshave, wedge, burin, knife, scraper, and point (Table 8-2). Among the latter three cases, individual items functionally may fall into more than one group. For instance, an artifact may be used initially as a knife and then as a scraper, or vice versa. Of these functional groups, five might be thought of as being associated with maintenance classes, while the other two, knives and points, might be more related to extractive activities (Binford and Binford 1966). On the other hand, since numerous items in this study exhibit use for both cutting and scraping, such a clear-cut distinction may not be warranted.

Drill

A drill is used in a rotary motion tool stroke. The one example found was used against a hard contact material. The tool is a Level 1 hafted uniface whose sides converge in a nearly symmetrical way to the rounded but still pointed tip (fig. 8-1g). Only rotary wear traces of crystallization filaments about the heavily microplated and faceted tip can be seen.

Spokeshave

The morphological equivalent of the functional spokeshave type is a notch. Functionally, it is used to scrape or plane; the notch may be deliberately prepared or unprepared. Use-wear shows striae transverse and parallel to the edge, but mainly within the notch. Only a single example was recognized, which is a hand-held, unifacially notched tool from Level 3. In this case, the notch and the edge adjacent to it exhibits minor rounding and abrasive polishing, which suggest a medium hard material, probably wood.

Wedge

The morphological equivalent to the wedge is the pièce esquillée, which is recognized primarily from formal criteria and clear evidence of edge damage. The wedges from Starosele are expedient tools and, aside from the two pièces esquillées recognized from Level 1, all others were formally classed as other types of tools, such as denticulates, notches, and scrapers (fig. 8-2). These wedges were used for splitting relatively hard substances such as wood, bone, or antler. Wedges are distinguished by invasive abrasive polishes and striated soluble residues, as defined above. Among the more important clues for the recognition of wedging, regardless of gross morphology, are bipolar flake scarring of one or both surfaces, hammer-caused pitting, step fracturing, and failure of the edge opposite the wedge edge.

Burin

Burin edges may be produced a number of ways, as in Crabtree's (1977: 48) experiments in which a slightly obtuse extremely tough tool edge was created by radial fracture, by a percussion blow directed perpendicular to the surface, or by burin faceting (see Barton et al.

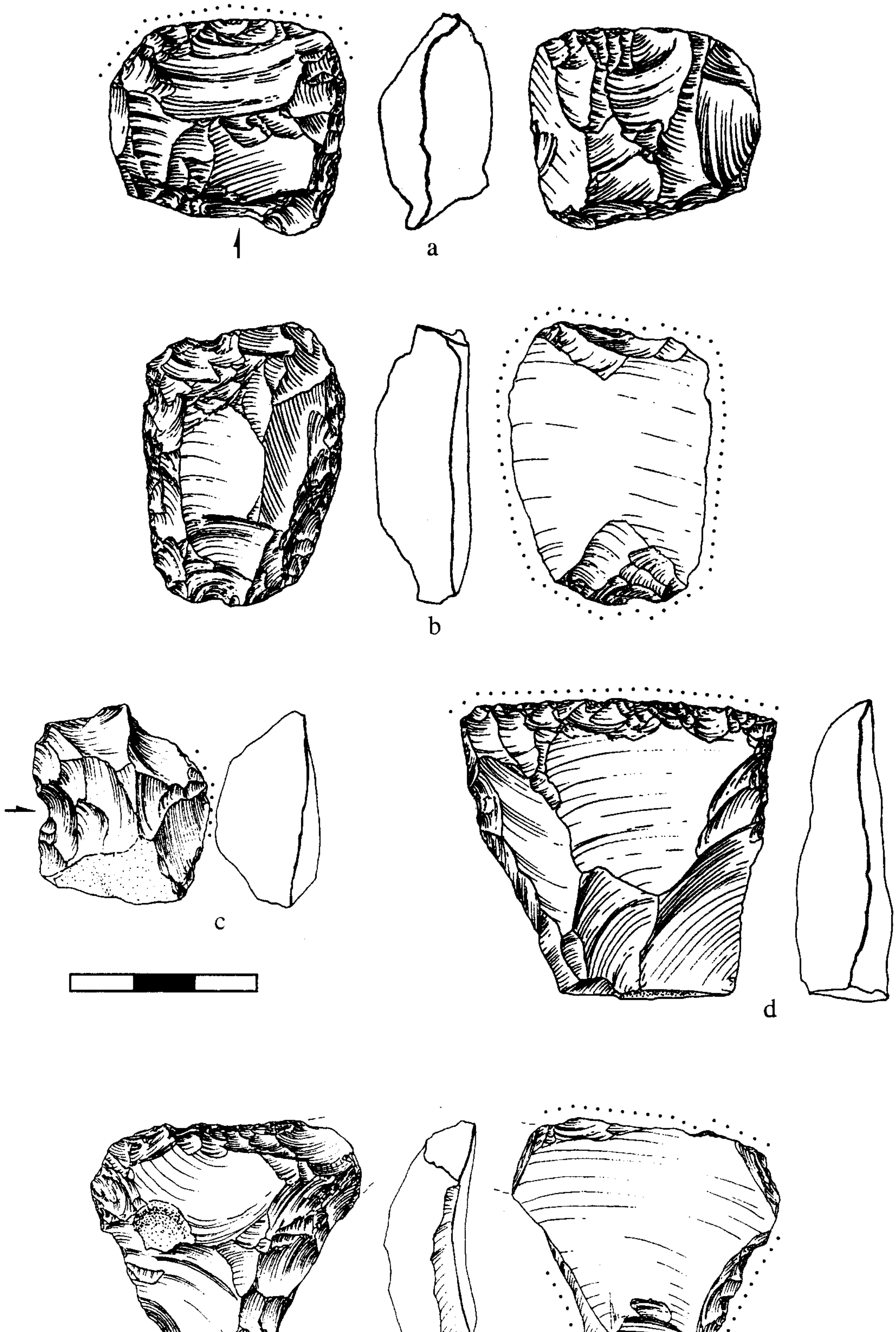


Fig. 8-2—Starosele, functional types, Level 1 *(a-f)* and Level 3 *(c-e)*: wedges. Stippling indicates the tool edge.

1996 for a literature review). The working edge is a near right angle or slightly obtuse angle. These are relatively thick and may be pointed at one end, side, or edge. Functionally, it matters not how these edges are created, only that they exist. From experiments and archeological examples, burins are first and foremost heavy duty fabricating tools used to slot, split, wedge, or engrave medium hard to hard material. The most critical wear traces include a consistently very narrow contact zone, no edge rounding, per se, but often significant edge damage or densely striated edge faceting. All burins at Starosele involved gouging in which the striae are primarily perpendicular to the edge and are consistent with a scraping motion. Although a number of functional burins were recognized, none was morphologically a burin, but ranged (typologically) from broken scrapers and points to denticulates (e.g., figs. 8-4, 8-9). In this sense, they differ from their Upper Paleolithic counterparts, but they are no less burins functionally than are Upper Paleolithic ones.

Knife

In the pure sense, knives are used only for cutting, with the criteria defined above for a cutting motion. On the other hand, many of these pieces show multiple uses, often a combination of cutting and scraping.

Scraper

This functional scraper group, as the group knife above, tends to have examples that have been used in conjunction with cutting, sometimes seemingly as part of the same activity. The use-wear criteria have been described above.

Since these knives and scrapers and their combinations represent a significant sample, it is useful to examine the relationship between these functions and the degree to which they were hafted or hand held. It is noteworthy that those tools used strictly as scrapers were all hafted, while less than half of the pieces used for both scraping and cutting were hafted (Table 8-2).

Point

Points include tools used mostly to penetrate with a straight motion into the contact material. Wear traces are consistent primarily with impact and penetration motions, and these are usually associated with additional wear traces indicating tool hafting. Those tools that display use-wear sequences of impact and penetration followed by cutting were most likely used as points first, either thrust or thrown; those with a reverse use-wear sequence may have been knives first.

Use-Wear Examples

Since space limitations preclude detailed descriptions of each and every artifact studied, a few examples are included here and in Chapter 10 to convey a sense of the study details.

A Level 4 sub-trapezoidal scraper illustrates a variety of ventral surface wear traces. The randomly oriented striae (fig. 8-3a) are experimentally linked to prehension. On the interior (fig. 8-3b) and on the retouched edges (fig. 8-3c, d) there are striated soluble residues perpendicular to the edge (a scraper diagnostic) which carry across the flat ventral surface in a deeply invasive scraping stroke. Cutting followed. Its use-wear striae are parallel to and at the retouched edge (see fig. 8-3c, d and fig. 8-8a) that truncates the scraping striae. Abrasive particles and crystallization filaments have complementary orientations, due to a single direction of the cutting stroke. The cutting edge was drawn back toward the user. Scraping

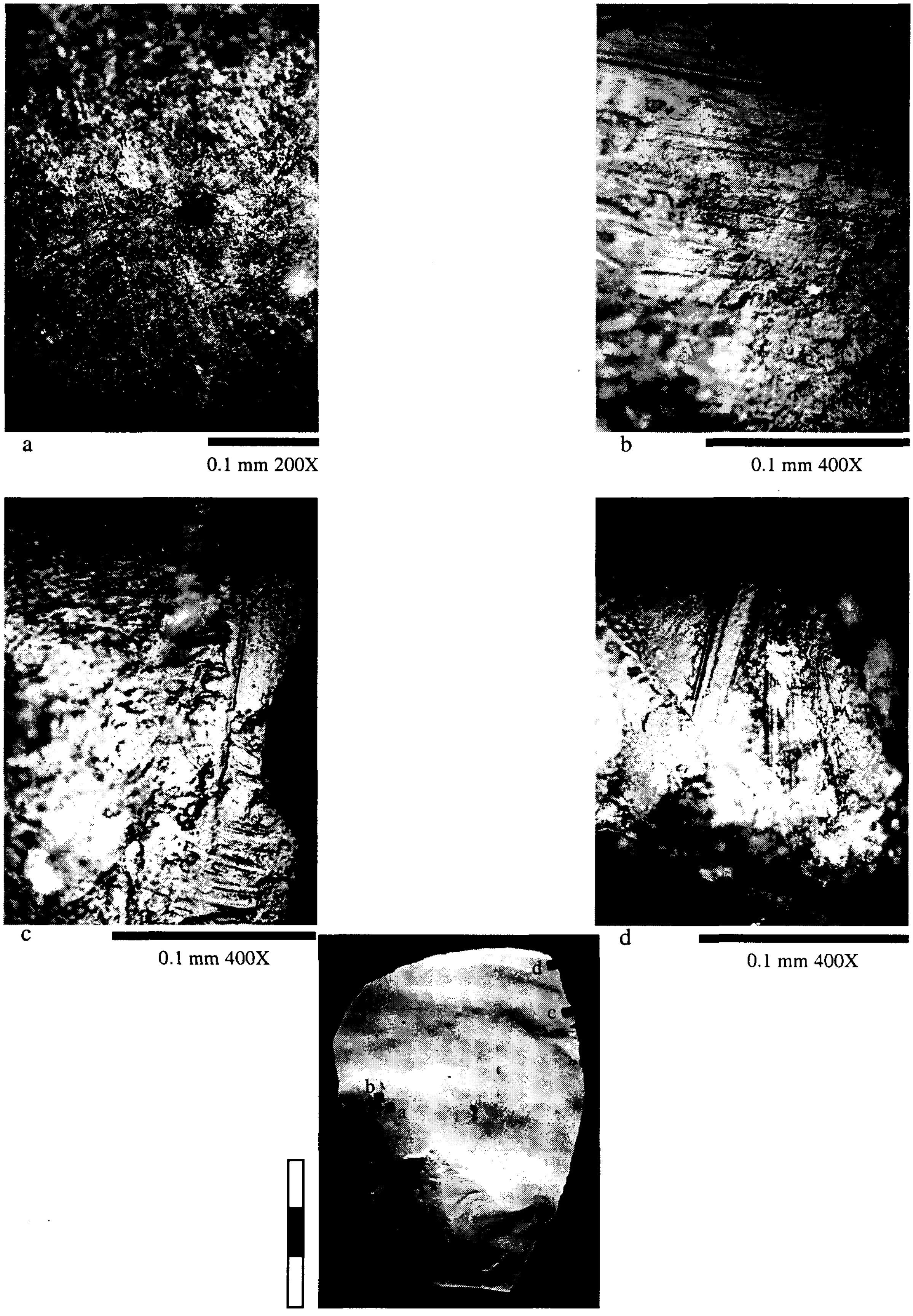
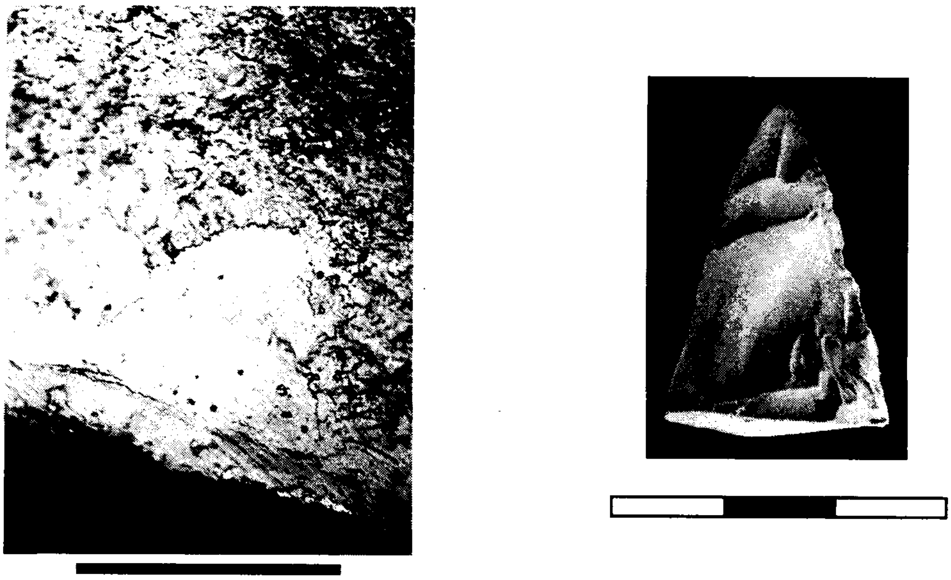
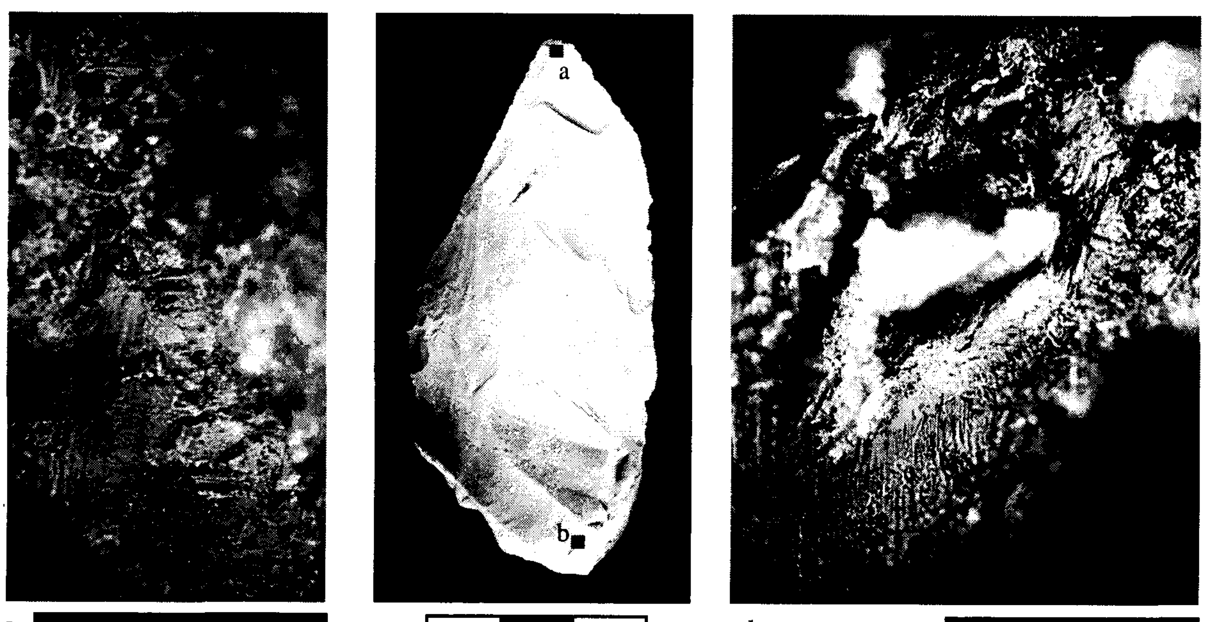


Fig. 8-3—Starosele, functional types, Level 4: oriented photomicrographs of a cut/scrape tool: *a*–random abrasion probably due to prehension; *b-d*–striated soluble residues, crystallization, adhering abrasive particles due to sequential use as a scraper and then as a knife.



0.1 mm 400X

Fig. 8-4—Starosele Level 1: oriented photomicrograph of plano-convex bifacial point tip recycled as a hafted burin.



a 0.1 mm 400X b 0.1 mm 400X

Fig. 8-5—Starosele Level 1: oriented photomicrographs of an asymmetrical plano-convex bifacial point used to cut then pierce game. Note haft wear details in *(b)* and soluble residue use sequence of cutting striae intersected by impact, or penetration, striae.

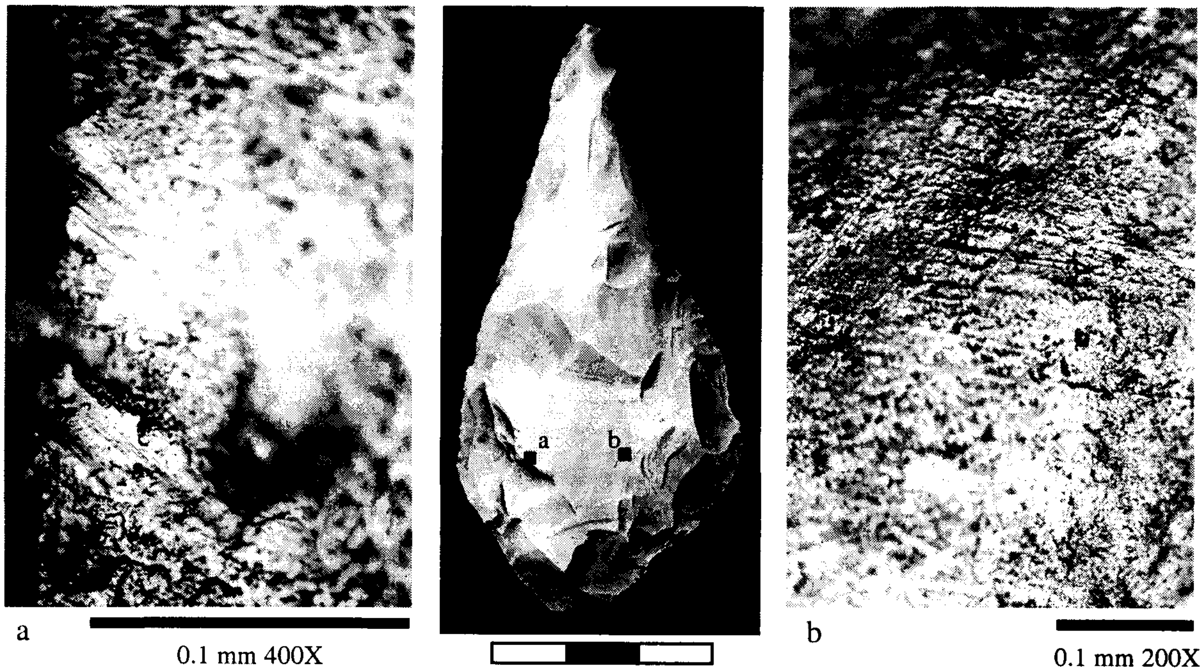


Fig. 8-6—Starosele Level 1: oriented photomicrographs of haft wear details on a symmetrical plano-convex bifacial point.

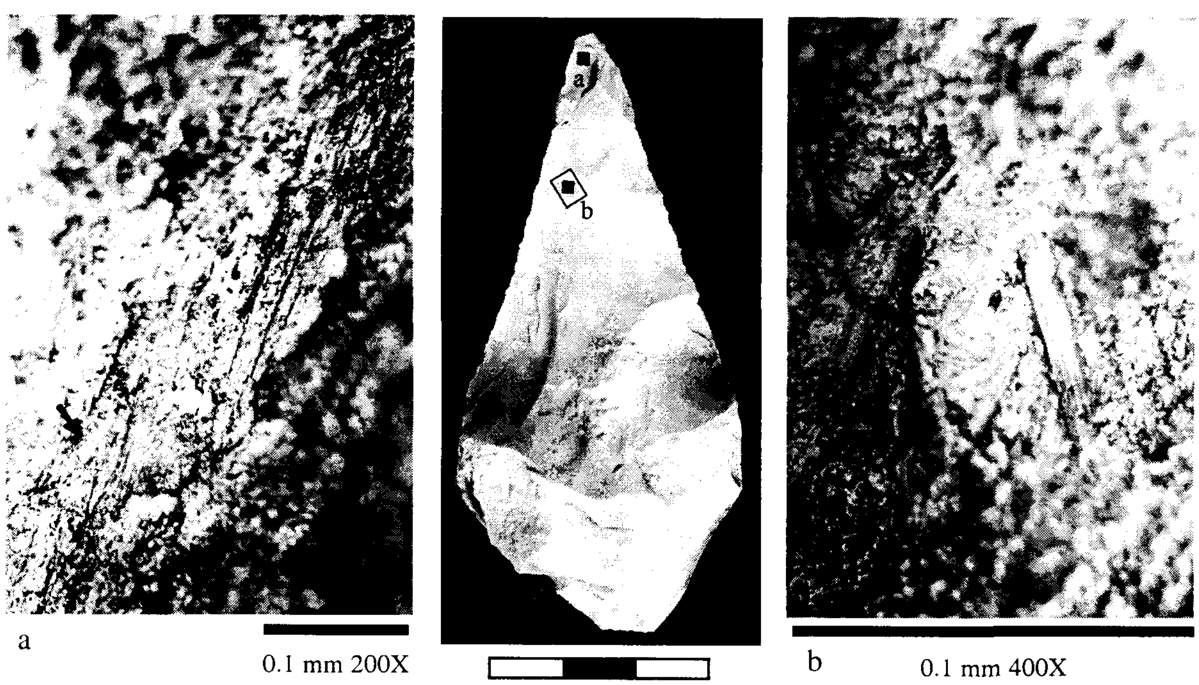


Fig. 8-7—Starosele Level 1: oriented photomicrographs of a symmetrical plano-convex bifacial point (ventral surface of fig. 8-6): *a*–impact striae that originate at the tip, the arrow points to overlying cutting striae; *b*–series of cutting striae nearly identical to those in photomicrograph *(a)*. Note orientation of photomicrograph *(b)* to tool.

and then cutting a medium hard material is likely—perhaps wood, as the striae are generally back from the edge and low in density. Insofar as the wear traces are both at the tool edges and invasive, it is clear the tool was not further maintained, or resharpened.

There is a hafted burin recycled from a broken bifacial planoconvex foliate point tip (fig. 8-4) from Level 1 which is similar to virtually all other functional burins from Starosele in lacking the classic prepared burin facets common to Upper Paleolithic technology. Instead, it has a slightly obtuse extremely tough tool edge created by a bending fracture.

The burin edge is the blunt, thick, transversely broken end opposite the tip, which was stuck into a handle. The use-wear is a textbook example of a densely striated soluble residue and of edge faceting. There is overlapping of the soluble residue indicating two distinct episodes of use, each bordered by its own desiccation crack. The sequence of desiccation cracks is consistent with drying farthest from the tool edge, and then proceeding to the edge during use. Burin use was as a chisel to slot or groove an extremely hard material. The primary direction of movement was at a slightly oblique angle to the tool edge. The burin stroke was bidirectional because the abrasive particles are at opposite ends and across the soluble residue. Final crystallization also occurred at the immediate tool edge, consistent with the placement of the abrasive particles.

A final set of examples is armatures and technologically related knives from Level 1. Level 1 has distinctive planoconvex bifacial foliates and unifacial points of similar cross-sectional shape. These were probably were probably hafted in "V"-shaped split sockets to accommodate similarly shaped, thick butts. The bifacial implements are mostly larger and exhibit a great deal more care in their manufacture than do the unifacial points. Marks and Monigal (1998) regard these bifacial foliates as most likely to have been thrust, due to their larger size and weight. From a wear trace perspective, these could have been attached to a thrusting spear or one that was thrown, or even used as hafted knives, since use-wear of penetration all looks the same, whether from having been thrown or stabbed into a contact material.

TABLE 8-3
Starosele, Formal Tool Types and Prehension

Tool Class	*Sample N*	*Uncertain*	*Unknown*	*Hand-held*	*Hafted*
Scrapers	51	1	10	21	19
Points	18	2	–	3	13
Retouched Pieces	5	–	1	2	2
Pièce Esquillée	1	–	–	1	–
Denticulates/Notches	8	–	–	5	3
Bifacial Tools	11	1	–	1	9
Other	8	–	2	5	1
Total	102	4	13	38	47

Hafting use-wear for this group, as a whole, and for the two illustrated bifacial examples (figs. 8-5–8-7) is consistent in several respects. There is evidence for flat surface-to-surface contact with the handle. Haft binding can be seen by both perpendicular and obliquely oriented striae to the tool's longitudinal axis.

Use-wear on the two bifacial foliates comes from tool use and they exhibit complex use histories. These bifacial foliates may be interpreted as having been used to pierce a carcass

TABLE 8-4
Starosele, Formal Tool Types and Tool Motion

Use-Wear Motion	*Scrapers*	*Points*	*Retouched Pieces*	*Pièces Esquillées*	*Denticulate/ Notch*	*Bifacial*	*Other*	*Total*
Cutting	7	2	2	–	1	3	3	18
Scraping	10	–	–	–	3	–	–	13
Cut/Scrape	6	2	–	–	–	–	2	10
Scrape–>Cut	1	–	–	–	–	–	–	1
Planing	–	–	–	–	–	–	1	1
Gouging	3	1	–	–	–	–	–	4
Wedging	3	–	1	1	3	–	–	8
Engraving	4	3	–	–	1	1	–	9
Rotary	1	–	–	–	–	–	–	1
Impact	5	8	1	–	–	6	–	20
Pseudo Wear only	6	2	1	–	–	–	1	10
Unused	5	–	–	–	–	1	1	7
Total	51	18	5	1	8	11	8	102

and also to butcher it. There is also unambiguous sequencing of use-wear on the pieces. The asymmetric bifacial foliate (fig. 8-5) has a clear sequence of invasive cutting use-wear transverse to the tool edges followed by tip impact-related penetration; the reverse of this sequence is true for the symmetric bifacial point (figs. 8-7 and 8-10b). They also differ from the cut/scrape tool and the chisel burin in that the wear traces are not directly on the tool edges but on the leading surfaces facing the edges and tip. The implication is they both had rejuvenated edges.

TOOL FORM AND FUNCTION

While it long has been recognized that there is no predictably positive correlation between form and function (Bordes 1961), except when necessitated by extremes (e.g., one cannot cut with a rounded edge), most of traditional typological nomenclature has a functional connotation, even if such is explicitly rejected. Thus, the relationship between morphological forms and how they were used is of some interest. For instance, Binford and Binford (1966) assumed such relationships, even adding unretouched blades to Bordes' classes because they seemed to be functionally for cutting. In addition, the distinction between "formal" and "ad hoc" tools has been used to imply differences in "curational" behavior, with the implicit view that the more heavily retouched the tool, the more it was desired and the longer it was used. All of these concerns can be approached from a fresh perspective using use-wear studies.

Form and Hafting

Using the morphological classes described in Marks and Monigal (1998) for Starosele, but combining all four assemblages, it is clear that the most heavily retouched tools—the bifacial foliates—exhibit the highest percentage of hafting: 90%. This is followed by points and then by scrapers. The less heavily retouched tools—denticulates, notches, retouched pieces—show much lower occurrences of hafting, while almost 20% of the scrapers did not have clear enough use-wear patterns to make a determination (Table 8-3). In short, it would appear that hafting tends to be associated with heavily retouched, often rejuvenated tools, which therefore may be considered "curated."

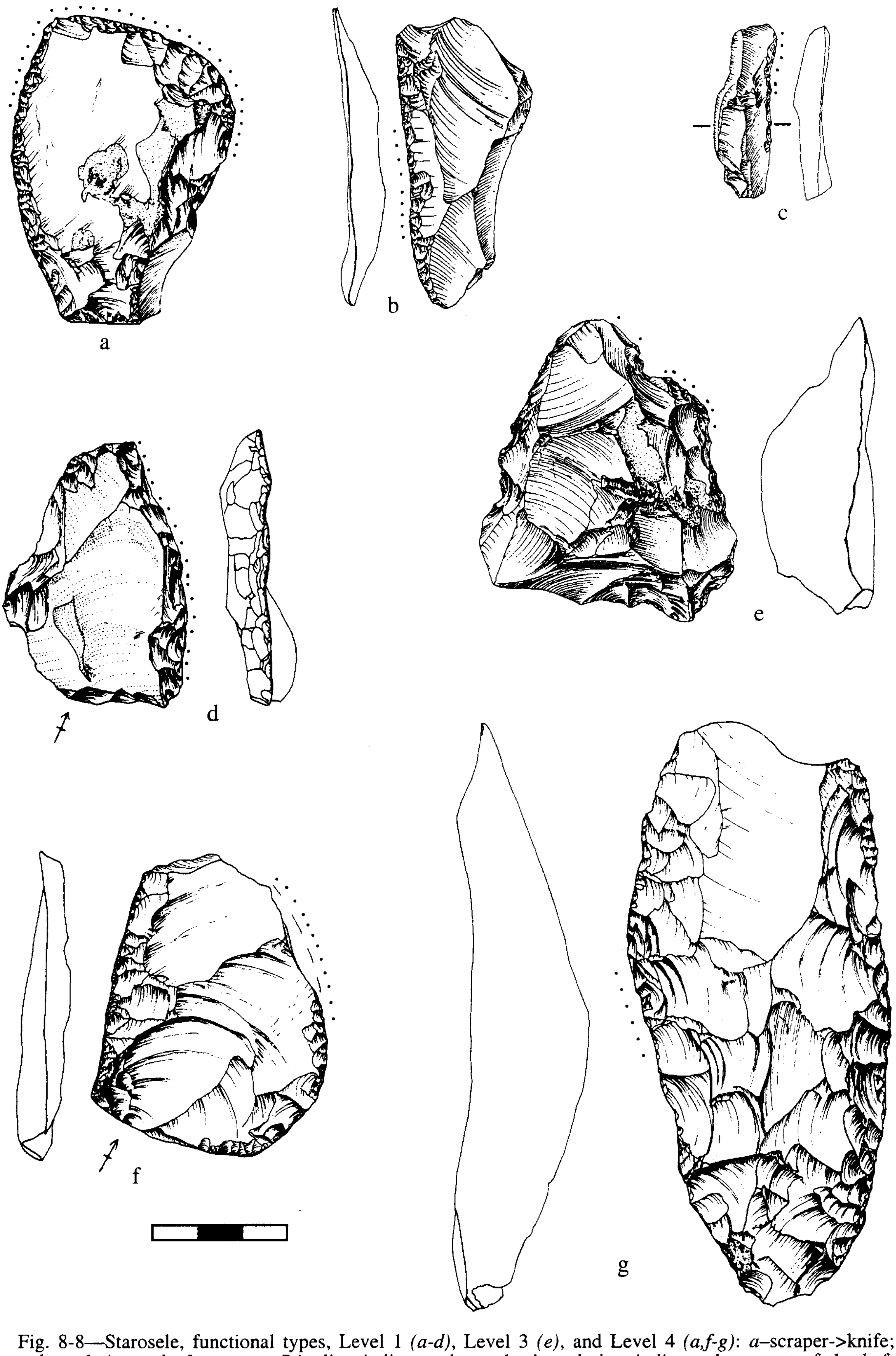


Fig. 8-8—Starosele, functional types, Level 1 *(a-d)*, Level 3 *(e)*, and Level 4 *(a,f-g)*: *a*–scraper->knife; *b,c,g*–knives; *d,e,f*–scrapers. Stippling indicates the tool edge; dashes indicate the extent of the haft element.

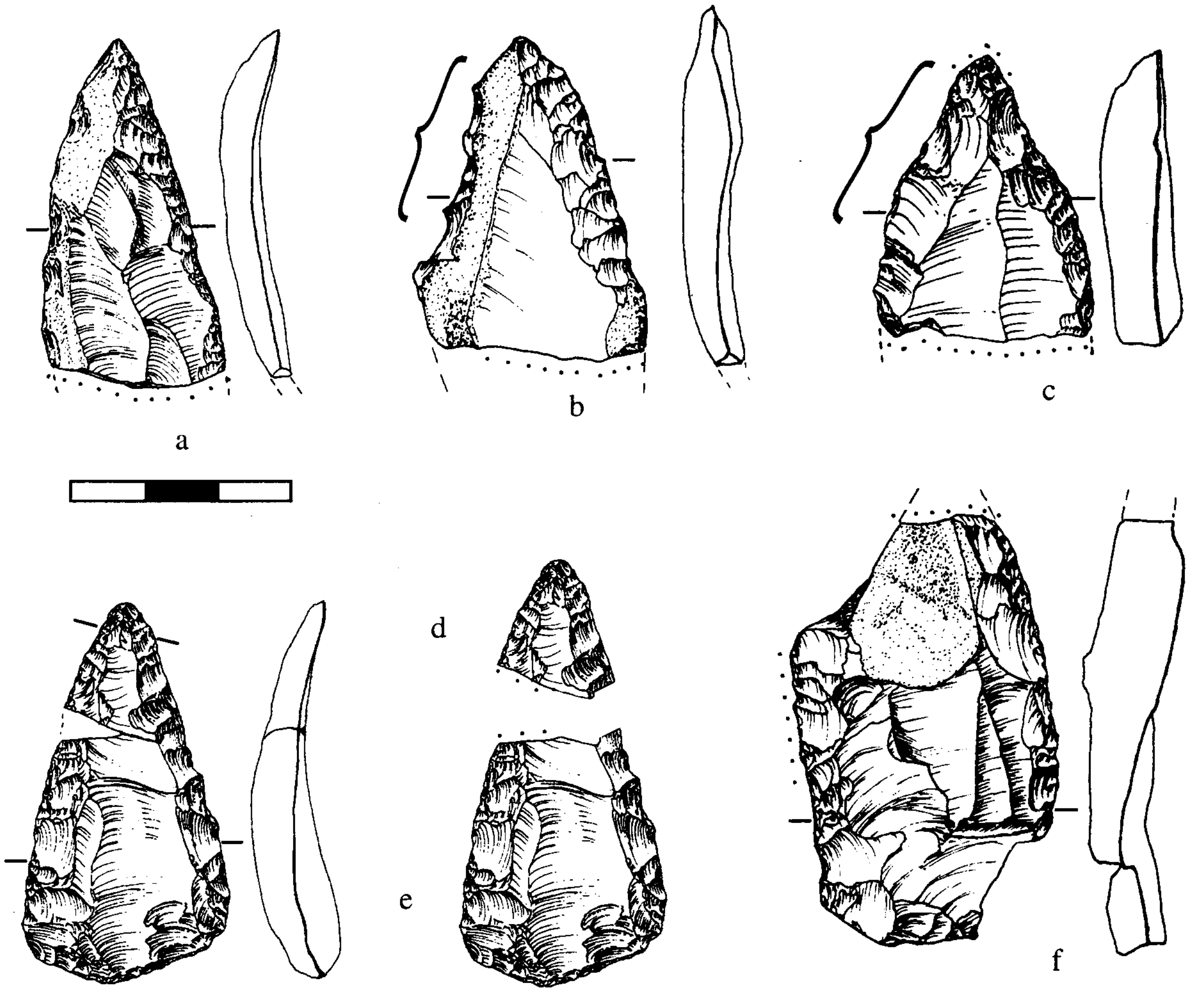


Fig. 8-9—Starosele, functional types, Level 1 *(a-c,e)* and Level 4 *(b,f)*: hafted burins. Stippling indicates the tool edge; dashes indicate the extent of the haft element; brackets indicate portion of tool that was hafted.

Form and Function

How does tool function compare to form? At times, it matches well, but at other times, it does not even come close. On one level, the pieces with edges used as burins were never recognized as burins, per se, but when the form of the working edge is considered, all functional burins have very similar working edges. In this case, however, the working edge is so small, relative to the whole piece—and is often the result of a break or snap—that morphologically, the piece tends to be dominated by other attributes. This is seen very clearly in that the functional burins were typed morphologically as scrapers, points, denticulates, and bifacial foliates (Table 8-4).

Morphological scrapers are a different problem. Of the 51 scrapers studied from all levels, 11 showed no use. Of the remainder, 17 (42.5%) were used for scraping or a combination of scraping and cutting, only 7 (17.5%) were used only for cutting, while 5 (12.5%) were used for both penetration and cutting (functional points). The remaining 11 (27.5%) exhibited other uses, quite apart from what their morphology might predict. Thus, while there is some positive link between the implied function of the nomenclature and actual function, it is not

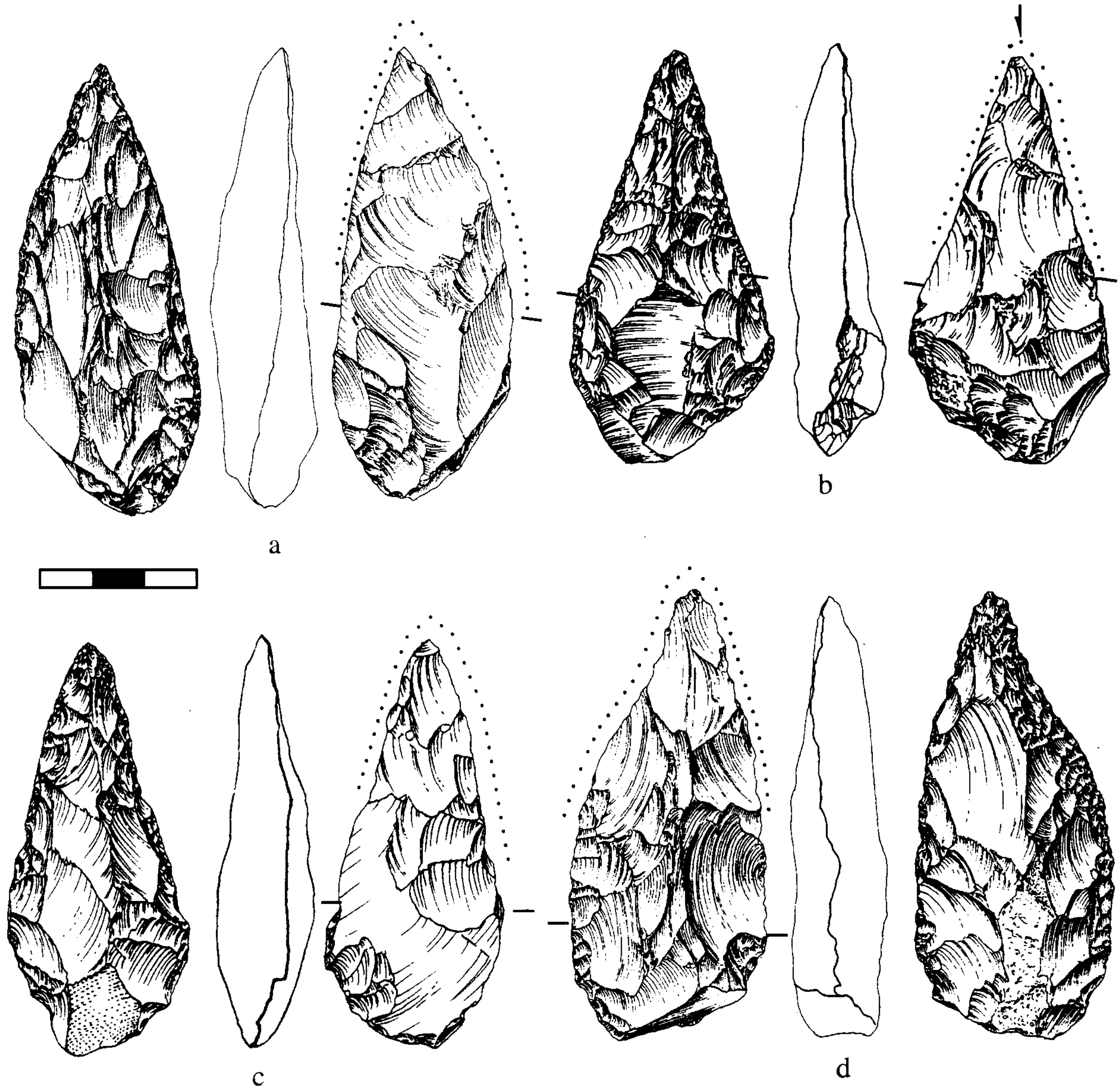


Fig. 8-10—Starosele, functional types, Level 1: bifacial points. Stippling indicates the tool edge; dashes indicate the extent of the haft element.

even 50%. If, however, cutting and scraping are combined, since they often are interrelated motions, then over 70% of the morphological scrapers might be considered correctly identified.

Morphological points, not surprisingly, are somewhat better correlated with actual function than the scrapers. Of the morphological points with wear-traces, a full 50% shows penetration as the initial use. It is important, however, to realize that almost all of these were further used for cutting; this is also true for the bifacial foliates. Thus, a functional distinction between a "projectile" and a knife may not be meaningful in this context. It is hardly likely that the high level of combined use is a coincidence. Rather, it appears that such dual use was a normal, habitual pattern in the Middle Paleolithic at Starosele.

It is the other morphological tool types that suggest a wide range of actual use, relative to their morphological class. This is seen very clearly for the denticulates, no more than 37.5% of which were used the same way. While other types have small samples, they too suggest a

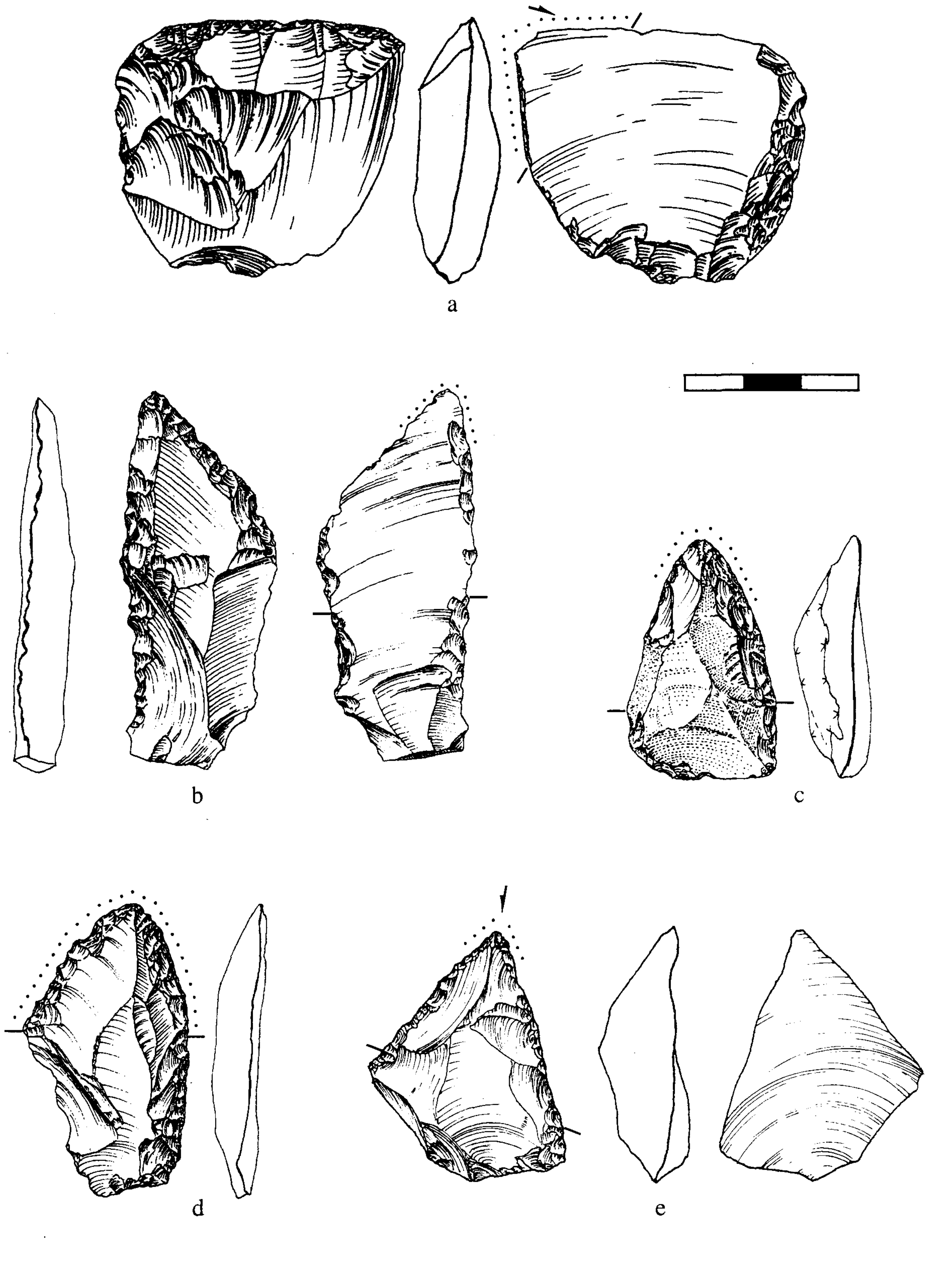


Fig. 8-11—Starosele, functional types, Level 1 *(a)*, Level 3 *(b-d)*, and Level 4 *(e)*: unifacial points. Stippling indicates the tool edge; dashes indicate the extent of the haft element.

wide range of uses. In addition, contrary to morphological typology, not all retouch relates to a tool edge. For instance, a retouched edge of a Level 4 "scraper" was instead apparently an intentional backing for prehension (fig. 8-8a). Opposite is the actual, unretouched tool edge with wear traces indicating hide scraping. In a like manner, virtually all of the retouch on the hafted burins merely facilitated the hafting (fig. 8-9).

Curation

Curated tools (and technology) should have an intrinsically greater worth than ones not curated (Shott 1989). Their recognition may depend as much on cultural systemic context as it does on form. For Starosele, however, it would be difficult to regard any contextual relations as especially noteworthy. Starosele technology also is strictly utilitarian. If there is a difference in intrinsic value, it is one expressed by aspects of manufacture, and use-life. The former is ably covered by Marks and Monigal (1998), as are some details of use-life, especially resharpening of bifacial foliates. From a use-wear perspective, the bifacial foliates also can be readily demonstrated to have had a greater value than the unifacial tools. Greater emphasis was placed in their manufacture and optional maintenance. They had extended use-lives that often ended with the recycling of fragmented pieces.

By definition, stone tools from archeological sites represent a terminal state of use. They were either intentionally discarded or were lost. Intentional discard would imply, on the one hand, spent or exhausted items no longer suitable for either maintenance or recycling; that is, tools at the end of their use-life. Loss, on the other, implies that the tool was still serviceable. There may not be an easy way to distinguish intentional discard from loss; information about the state of tool use-life must be found elsewhere.

Sequential Tool Use

Wear trace use-life evaluations offer complementary and significant new information to that afforded by tool form. For Starosele unifacial tools, they are the prime means to this assessment; for the bifacial foliates, a more exact way. Yet, optional maintenance through resharpening tool edges may result in a loss of critical use-life information. This loss could be the case especially for hand-held tools used on hard contact materials, for which there is a narrow contact zone and no invasive wear traces. In contrast, a hafted tool without evidence of use (a Level 1 unifacial point) would indicate resharpening removed the telltale wear traces from the tool edge, masking a relatively long use-life. Theoretically, a hand-held tool edge could be replaced completely, leaving no evidence of prior use. For Starosele, however, this problem is either not serious, since only a single example is even possibly like this, or it pertains primarily to the 13 artifacts classed as unknowns, plus the four seemingly unused but well made ones. So the problem of optional maintenance confusion can be discounted or isolated to a maximum of 17 artifacts not classed in the use-wear analysis as tools but which were retouched.

For all tools, use-wear information on sequential use and recycling relate to use-life and the question of curation. For analytical purposes, those tools with evidence for resharpening, sequential use, or recycling are classed as curated. This definition, however, includes tools that may have undergone such modifications during a single episode of use, lasting no more than minutes.

Comparison of Results by Level

In Level 1, all examined tools appear to be formal rather than ad hoc. Of the sixteen hand-held examples, 30% of the cut/scrape tools appear to have been curated, but none of the hafted cut/scrape tools was. The curated, hafted tools include two burins (2 out of 6), of which one is recycled from a broken biface, and three points (3 out of 8). Overall, the percentages of curated unifacial tools for hand-held (18.75%) and hafted (23.5%) are not very different, but favor the hafted tools that relate to different functional groups. A dramatically different percentage exists for the other eight bifacial tools, of which six (75%) had been curated (figs. 8-1h; 8-10).

Maintenance of bifacial tool edges is the key to understanding the bifacial foliates. Conchoidal fracture creates razor sharp edges, even without further retouch. Retouch of any kind changes the geometry of the tool edge, but not necessarily its sharpness. Retouch extends the employed portion of the edge by simply creating more edge per unit length. Equally valuable, it allows for choice in the cross-sectional shape of the tool edge, so that functionally more desirable characteristics can be achieved and maintained through resharpening. The bifacial foliates are specialized tools, although not the only ones at Starosele. Where they differ in concept from the other tools is in their relative maintainability (see Bleed 1989); that is, they appear to have been intentionally designed for a longer use-life than a unifacial tool of similar function.

The Level 2 sample has three tools, all formal and unifacial, of which one was hand-held and two were hafted. Only a point was classified as curated, accounting for 50% of the hafted tools.

Of the thirty-one unifacial tools studied from Level 3, fifteen were hand-held and sixteen hafted. Some could be described as ad hoc, because there is little if any modification of the tool blank beyond what could be accounted for by use alone. The hand-held tools include only one curated item, a cut/scrape tool; none of the hafted ones with similar function were curated. Curated, hafted tools include one (1 of 3) burin and six (85.7%) points (fig. 8-11b-d). Two curated points on unmodified tool blanks are classed as ad hoc, and the remainder has the most minimal of edge preparation. Overall, curated tool percentages for hand-held (6.6%) and hafted (43.75%) differ substantially from the Level 1 unifacial tools, which generally have a more "finished" appearance but are less likely to be curated. The on-site production of tools, the greater diversity of raw material, and some reliance on local flints (Marks and Monigal 1998) all seem consistent with the high proportion of curated tools in Level 3.

Level 4 is similar to Level 2 in having a very small use-wear sample: seven, of which four were hand-held and three were hafted. One hand-held cut/scrape tool (fig. 8-8f) and one hafted burin were classified as curated.

Implications for Understanding Tool Use and Activities

With the possible exception of Level 2, for which we simply have too little data, the archeological levels have a nearly identical range of functional tool categories. Because the levels (other than Level 2) express approximately the same range of activities, a discussion of use-wear results for Starosele as a whole is appropriate. Hide working is present, along with the fabrication of wood and bone objects. Of the latter, some must have been handles. The killing and butchering of game is clearly evident, too.

A difference between the levels is most starkly drawn in the curated tools and their implications for understanding activity, in a comparison between Levels 1 and 3. As Marks and Monigal (1998) note, the technologies and their placement within a chaîne opératoire differ significantly. Level 1 exhibits post-production tool importation, tool maintenance, and recycling of secondary tool products. Raw material acquisition was off-site, although exactly how far is unknown (Marks and Monigal 1998). Nevertheless, the artifacts are carefully made and, especially the bifacial foliates, occasionally were curated. Level 3 differs in that, for at least part of the assemblage, all phases of tool manufacture, use, and maintenance are present. Yet, the assemblage is attenuated and haphazard in appearance. There was also a greater reliance on a wider range of flint resources, including some of poor quality locally available flint (Marks and Monigal 1998). The tools include at least some truly expedient ones. Most of the formal tools look not much better and display varying degrees of marginal retouch. Yet, relative to Level 1, there appears to be a much higher rate of tool curation.

CONCLUSIONS

When looking at a record of perhaps more than 40,000 years, it seems unreasonable to trace exact historical connections among Starosele's occupants. Different groups could and actually did solve at least some technological problems in the same, or nearly same, way at Starosele. From the use-wear evidence, it appears that the Level 3 tools parallel choices made before and after at Starosele. In this respect—and in spite of its many unique qualities—Level 3 is similar to the other cultural levels.

Middle Paleolithic studies, mostly in the absence of use-wear analysis, have wildly speculated on the subject of hand-held versus hafted tools (see Chase 1989: 332; Holdaway 1989). Microwear analysis is not just *a* way to evaluate tool hafting, but indeed is *the* preferred way to systematically make these evaluations (Anderson-Gerfaud and Helmer 1987; Beyries 1987a; Mellars 1989: 351; Shea 1988, 1990), because wear traces show general processes of use, prehension, and hafting. The use-wear evaluations at Starosele are especially robust. They are based first and foremost on experimental replicas that assuredly were attached to a handle or foreshaft and others that assuredly were not. The evidence in this study of hand-held and hafted tools is unambiguous and emphatic. Hafted tools are neither unique to Starosele nor did they begin late in its archaeological record. Instead, hafted technologies in Crimea would have had to precede the occupations at Starosele, as their use is consistent and equally well-developed throughout its archeological record. The question now becomes, what are the systematic differences between functional tool categories, some of which were hand-held and others hafted? Hand-held tools were mostly used on medium hard to hard materials (hard wood to bone, and antler) regardless of cultural level. From one cultural level to the next, hafted tools display greater variability in contact materials, but exhibit two maintenance tool clusters—hard contact material tools and soft contact material tools—plus projectile points for killing and butchering game and for defense.

This and the following two chapters are a further step—albeit a modest one—in understanding Middle Paleolithic behavior and decision making. Microscopic evidence of Starosele stone tool use convincingly expresses information about a wide range of technological and behavioral issues that would not otherwise be available. Although vital to this and other analyses, these issues extend beyond tool function and typological comparison. Perhaps foremost among these is the dichotomization of hand-held and hafted tools at Starosele. Evaluation of use-life and the likelihood of tool curation are other significant contributions. Along with the insights of tool function and activity, these lines of information provide a novel, if not unique, opportunity to recognize systematic cultural responses, and some aspects of cognition at Starosele.