Chapter 9

MICROSCOPIC RESIDUE ANALYSIS OF STONE TOOLS FROM THE MIDDLE PALEOLITHIC SITE OF STAROSELE

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INTRODUCTION

Prehistoric stone tools offer some of the best potential for reconstructing past human behavior, yet their function is not well understood. Traditional inferences of tool function from ethnographic analogy, and experimental replication and use of tools can do little more than help define the possible range of tool uses. Use-wear analysis can give evidence of use-action (slicing, incising, whittling, scraping, etc.) and relative hardness of the use-material. Microscopic residue analysis, the technique used in the current study, can allow identification of use-action and the specific material on which a tool was used (use-material). This technique relies on microscopic identification of actual traces of the use-material which adhere to the tool surface (Anderson 1980; Anderson-Gerfaud 1981, 1986, 1990; Briuer 1976; Fullagar and Field 1997; Gorski 1997; Hardy 1994; Hardy and Garufi 1998; Hurcombe 1992; Jahren et al. 1997; Loy 1983, 1985, 1986, 1987, 1993; Loy and Nelson 1987; Loy and Wood 1990; Loy and Hardy 1992; Loy et al. 1992; Shafer and Holloway 1979; Sobolik 1996). This chapter will discuss the results of microscopic residue analyses of stone tools from the Middle Paleolithic site of Starosele, Crimea. A portion of these tools was also examined for use-wear traces by a separate investigator (see Chapter 8).

Residues identified microscopically are typically divided into broad categories of plant and animal. Specific identification of plant residues relies on the presence of diagnostic morphological features that can be compared to modern and published materials. Plant residues that have been previously identified on archeological tools include wood fragments, root and tuber remains, starch grains, raphides, phytoliths, and nonspecific plant tissues. Wood fragments are recognized by the presence of diagnostic anatomy including specific vessel elements (e.g., tracheids), pitting, and tyloses. Depending on the anatomical parts visible, wood residues are potentially identifiable to species (Hoadley 1990; Hardy 1994; Hardy and Garufi 1998).

Root and tuber tissues from archeological contexts are typically identifiable to a specific taxon when viewed with a scanning electron microscope (Hather 1993; Mason et al. 1994). However, these starchy storage organs also contain inclusions within their cells which are more readily identifiable, namely starch grains, various calcium oxalate crystals, and phytoliths. Starch grains are visible under light microscopy as highly reflected particles which can be distinguished from sediment particles through examination under cross-polarized light (Banks 1975; Loy et al. 1992). Cross-polarization produces a characteristic extinction cross which resembles a Maltese cross. When one of the polarizing filters is rotated, the arms of the cross rotate. Size and morphology of the grains can sometimes be diagnostic of species of origin (Banks 1975). Starch grains are found in various parts of plants, but are often concentrated in storage organs such as roots or tubers (Fahn 1982). Raphides, needle-like calcium oxalate crystals, and other calcium oxalate druses form in the storage organs of some plants (Fahn 1982) and are sometimes found in association with starch grains on tool surfaces. Phytoliths, commonly used to aid in paleoenvironmental reconstruction, can be used to identify specific plants based on shape (e.g., Pearsall 1989). All of these plant parts have been used to help more specifically identify plant remains found on tool surfaces (Briuer 1976; Shafer and Holloway 1979; Loy et al. 1992; Jahren 1996; Sobolik 1996). While specific diagnostic features described above are not always visible, residues are identifiable as plant based on the appearance of cells and the presence of cell walls. The general term "plant tissue" refers to residues with recognizable cellular structure. Species of origin for these tissues is often unknown, but the presence of other plant materials, such as starch grains and raphides, provides additional evidence as to their possible origin. While specific identification may be difficult or impossible, the identification of residue as plant nonetheless provides valuable archeological information.

Animal residues, including blood, hair, feathers, collagen, bone, and antler, are somewhat less commonly identified on stone tools, at least microscopically. Blood is one of the most frequently identified residues, although it is often detected immunologically (e.g., Newman 1996; but see Eisele 1995 for potential problems). While blood residues can be identified microscopically (Briuer 1976; Hardy 1994; Loy 1993; Loy and Dixon 1998; Loy and Hardy 1992), their morphology varies greatly. Depending on the thickness of the residue, blood stains on stone tools can range in color from clear to yellow to red to black. Typically, the blood residue will appear as thin overlapping plates that get darker as the residue gets thicker with occasional drying cracks similar to cracks formed in drying mud. It is also possible to observe intact red blood cells on some tools (e.g., Loy and Dixon 1998). Overall, however, blood is difficult to recognize since mineral deposits and certain types of sediment can be mistaken for blood residues. Because of this widely varied morphology and the potential to mistake other residues for blood, microscopic identification of blood residues is best strengthened by corroborating evidence such as the presence of animal fibers or the use of a confirmatory chemical technique such as immunology or DNA analysis (e.g., Hardy et al. 1997; Loy and Dixon 1998; Newman 1996).

Animal fibers include hair, feathers, and fragments of bone or antler. Hairs are distinguishable from other fibers by the presence of overlapping scales on the cuticle, the outermost layer of the hair (Brunner and Koman 1974). Scale patterns differ between species and can have diagnostic value, but they vary on different parts of the body and even on different parts of an individual hair (from root to tip). Furthermore, closely related species do not share similar scale patterns, making it difficult to determine higher taxonomic levels, such as Family, without species identification.

The downy barbules of feathers—thin, birefringent fibers under reflected light microscopy—can survive and be detected on stone tool surfaces. The barbules are characterized by nodes and internodes similar in appearance to bamboo stems. Nodes of some feathers have prongs projecting from them, which, together with node shape, can be diagnostic to the Order level (Chandler 1916; Brom 1986).

Bone and antler fragments are sometimes visible as long opaque fibers that are not highly birefringent. More typically, however, bone and antler fragments appear as masses of granular material. Diagnostic anatomy is usually lacking and identification is based primarily on comparison with modern materials (Hardy 1994).

Besides identifying the residues, analysts must attempt to show that the residues are use-related. The best way to do this is to examine the patterning of the residue on the surface of the tool. Residues which are concentrated along one edge or which are smeared back from an edge are likely to be use-related. Experiments with replicated tools on a variety of materials have been used to help establish typical patterns of residues associated with certain tasks and use-actions (Hardy 1994; Hardy and Garufi 1998). Terms for use-actions in this study follow widely accepted categories and include slicing, incising, scraping, planing, whittling, and boring (Hardy and Garufi 1998; Keeley 1980; Mansur-Franchomme 1982; see Table 9-1).

Further confidence that a residue is use-related can be established by comparing residue patterning with the distribution of use-wear. For example, a flake used to cut a groove in a piece of wood (use-action of slicing or incising) will typically have wood tissue confined in a zone along the working edge of the tool that penetrated the wood. This same area will often have striations running parallel to the working edge of the tool in the same area as the residue. How far this zone of residue and wear extends back from the edge of the tool will depend on how deeply the tool penetrated the material. In order to distinguish between slicing and incising, diagnostic wood anatomy would have to be preserved. Slicing involves moving the cutting tool perpendicular to the long-axis of the wood, thereby cutting a cross-section. An incising use-action moves the tool parallel to the long axis of the wood and typically cuts radial sections. If these sections are not visible, or if the wood has been cut obliquely, slicing and incising cannot be distinguished (Hardy and Garufi 1998).

By contrast, a flake used with a whittling motion (similar to using a pocket knife) will have wood residue smeared from the edge at an angle perpendicular or oblique to the tool edge on the surface in contact with the wood. The contact surface of the flake may also be characterized by polish and striations running roughly perpendicular to the working edge (Hardy and Garufi 1998). The upper surface will have more randomly distributed residue near the edge. Although the examples described here involve woodworking, the residue patterning from processing other materials with the same use-action is similar with some variation depending on hardness, duration of use, amount of water present, etc.

By using both use-wear and microscopic residue analysis, we can get a much clearer picture of prehistoric stone tool function. Both of these techniques were performed on a sample of tools from the Middle Paleolithic site of Starosele, Crimea, Ukraine (for use-wear results see Chapter 8), originally excavated between 1952 and 1956 by Alexander Formozov (1954, 1958). New excavations were conducted from 1993 to 1995 as part of the Joint Ukrainian/American Middle Paleolithic of Crimea project (Marks and Chabai 1998; Marks et al. 1997, 1998) which provided the sample for this analysis.

METHODS

A sample of 116 stone artifacts was examined for microscopic residues. All artifacts were placed unwashed in individual plastic bags as they were excavated until the time of analysis in order not to lose any possible residues. The artifacts came from Levels 1-4 and range in age from approximately 40,000-80,000 BP (Marks et al. 1998), with the majority from Level 3, approximately 50,000 BP. Each artifact was examined under reflected light at magnifications of 100 to 500 diameters for the presence of residues related to tool use. The location of residues was recorded on line drawings in order to facilitate recognition of any patterning in residue distribution and to aid in the prediction of use-actions. Residues were photographed and identified morphologically based on comparison with modern and published materials. In addition, sediments immediately surrounding the tool were examined for the presence of residues. If residues were found in the sediment as well as on a tool, they were not considered to be related to tool use. Only when residues were confined to a tool and were not present in the sediment were they interpreted as being use-related (Hardy 1994; Hardy et al. 1997; Hardy and Garufi 1998). Occasionally, residues were removed from the tool surface for examination under a scanning electron microscope to help confirm identification. After residue analysis was complete, 31 of the artifacts were sent to Marvin Kay of the University of Arkansas for thorough use-wear analysis (Chapter 8). The use of two different techniques of functional analysis performed by two independent researchers served to both cross-check the functional interpretations and increase the amount of

TABLE 9-1
Starosele, Use-actions and Residue Patterns

Use-Action	*Edge Morphology*	*Orientation*	*Motion*	*Result*	*Residue Pattern*
slicing/incising	unretouched	edge parallel to direction of movement, tool perpendicular to use-material	uni- or bidirectional	creates vertical cut in material	residue smeared along lines roughly parallel to tool edge; extent of residue varies depending on how deeply the tool penetrates use-material; patterning similar on dorsal and ventral surfaces
whittling	unretouched	working angle usually <60o	pushed or pulled along material	creates oblique cut in material	residue smeared along lines roughly perpendicular to edge on one surface; residue scattered near edge on other surface
planing	retouched	tool edge perpendicular to direction of motion, ventral surface toward material	pushed or pulled along material	retouched edge removes fragments of material	residue smeared along lines roughly perpendicular to tool edge on ventral surface, residue scattered on dorsal surface, often trapped in flake scars
scraping	retouched	same as planing, dorsal surface toward material	pushed or pulled along material	retouched edge removes fragments of material	residue smeared along lines roughly perpendicular to tool edge on dorsal surface with pockets of residue in flake scars; residue scattered on ventral surface confined near edge
boring	pointed, often retouched	point in contact with material	twisting	creates conical hole in material	residue smeared along lines perpendicular to long axis of point and confined near tip; extent of residue depends on how deeply tool penetrates material

functional information obtained (Chapter 10).

RESULTS

Residue Types Observed: Plants

Plant tissue was found on 35% of the tools examined from Starosele and included several different types of tissue. Starch grains were visible both scattered on tool surfaces and within cells of plant tissue adhering to tool surfaces. Although the plants of origin have not been identified, the presence of large numbers of starch grains suggests that they may derive from starchy storage organs such as roots or tubers. Raphides were found in association with some of the starch residues and also lend support to the idea that these residues come from starchy storage organs. Two patterns of residue characterized starch grains on the Starosele tools. In one pattern, starch grains are smeared in lines that form approximately a 60-90° angle with the edge of the tool. This type of patterning is consistent with a whittling (if the edge is unretouched) or scraping/planing (if the edge is retouched) use-action as seen in woodworking experiments (Hardy and Garufi 1998; and see Table 9-1). Applying these use-actions to tubers would suggest that tools were being used to remove cortical tissue. In a second pattern, starch grains and other plant tissues are scattered across both the dorsal and ventral surfaces of a tool but confined to one end or area. Taken together with use-wear observations, this pattern suggests that the starchy material may be related to a binding or mastic used in hafting (see below and Chapter 8).

Further evidence of hafting is found on one tool in the form of a possible mastic (STR95-26). This pointed flake has patches of a highly reflective black substance scattered over the proximal half of its dorsal and ventral surfaces. Morphologically, this substance resembles resin or bitumen observed on hafted tools from a variety of time periods (Collins 1981; Tankersley 1994; Hardy, personal observation), including Middle Paleolithic sites (Boëda et al. 1996). Chemical analysis, such as gas chromatography/mass spectrometry would be necessary to confirm this identification.

Residue Types Observed: Animal

Animal residues occur on 3.5% of the tools from Starosele and include hair fragments and feather barbules. Hair fragments are present on one scraper, one pointed piece, and two chips. The fragments on the scraper and pointed piece have scale patterns visible and therefore may be identifiable to species. However, as mentioned above, the identification of isolated hair fragments is difficult due to variations in scale patterns on different parts of the body and different parts of an individual hair. At present, specific identifications have not been possible although the hairs are not human in origin.

Feathers occur on two tools and have been preliminarily identified to the Order level. Feather fragments on both tools, a scraper (STR95-3) and a point (STR95-6), have heart shaped nodes with no projections and are identified as Order Anseriformes which include swans, geese, and ducks (Brom 1986). The point also has feather barbules with one projecting prong at each node indicative of the Order Falconiformes, raptors (Brom 1986). Although bird bones are present at the site, including partridge (Order Galliformes), choughs, jackdaws (both Order Piciformes), and swifts (Order Apodiformes), Anseriform and Falconiform bones are lacking (Chapter 1). Nevertheless, the feather fragments on the tools suggest that the inhabitants of Starosele were exploiting avian resources.

Results by Tool Type

The broad categories of tool types examined include scrapers, denticulates, points, blades, cores, flakes, and chips (<3 cm). Because typological categories often suggest function by their names (e.g., scrapers) and because tool types are traditionally used to divide up lithic samples, it is useful to examine the residue analysis results by tool type (Table 9-2).

TABLE 9-2
Starosele, Summary of Tool Function by Type and Level

	Residues		*Hafted*	*Use-Action*						
Tool Type	*Plant*	*Animal*		*Scraping*	*Planing*	*Slicing/Incising*	*Whittling*	*Boring*	*Indeterminate*	*Total Examined*
Levels 1, 2										
Scraper	5	1	2	2	1	1	–	–	1	5
Bifacial point	1	–	1	–	–	–	–	–	1	1
Level 3										
Scraper	8	–	3	2	1	–	–	–	9	12
Denticulate	3	1	2	–	1	–	–	–	3	4
Point	1	1	1	–	–	1	–	–	–	1
Core	–	–	–	–	–	1	–	–	–	1
Flake	11	–	1	–	–	2	2	–	11	15
Chip	10	–	–	–	–	–	–	–	71	71
Level 4										
Point	1	–	1	–	–	–	–	–	1	1
Scraper	1	1	1	2	–	–	–	–	2	3

Scrapers

A total of 20 scrapers were examined (Table 9-2). Fourteen (70%) had some form of plant residue, two (10%) had animal residues, and four (20%) had no visible residues. Plant residues consisted of various types of plant tissue, starch grains, and raphides. Animal residues include both hair and feather fragments. Patterning of residues and interpretation of use-actions are illustrated in the following examples.

STR95-16, simple convex sidescraper (fig. 9-1). This artifact has small fragments of plant residue adhering to its surface. Plant cells are cut longitudinally into thin sections, several of which start at the retouched edge and run toward the center of the tool. The thinness of the sections of the plant tissue suggests that it is related to the use of the tool. If the residues were modern contaminants, one would expect to find the outer cortex of the plant tissue or part visible and a thicker fragment with more cell types represented, as in the case of a root growing over a tool. Specific identification of the plant tissue has not been possible, but the patterning on the tool clearly suggests that it was used in either in processing plant material or as part of a haft. Use-wear suggests that the plant tissue is related to a binding or mastic, or perhaps even remains of the haft itself (Chapter 10).

STR95-10, double convex sidescraper (fig. 9-2). This scraper, despite its large size (approximately 13 cm in length) and uniform unifacial retouch, preserves little functional

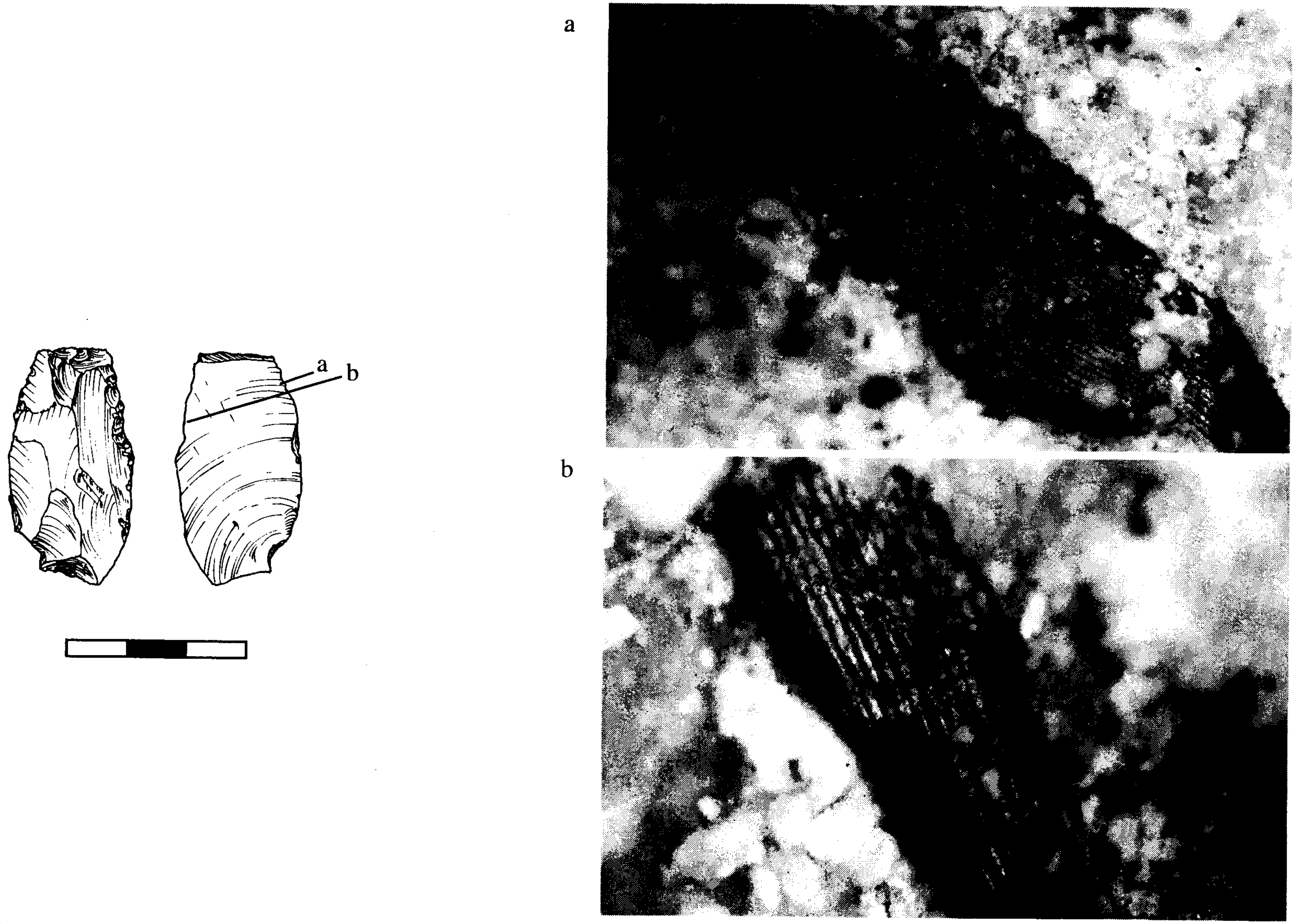


Fig. 9-1—Starosele Level 3 (STR95-16), simple sidescraper: *a*–thin section of plant tissue adhering to edge of tool (original magnification 100x); *b*–another fragment of the same plant tissue (original magnification 200x).

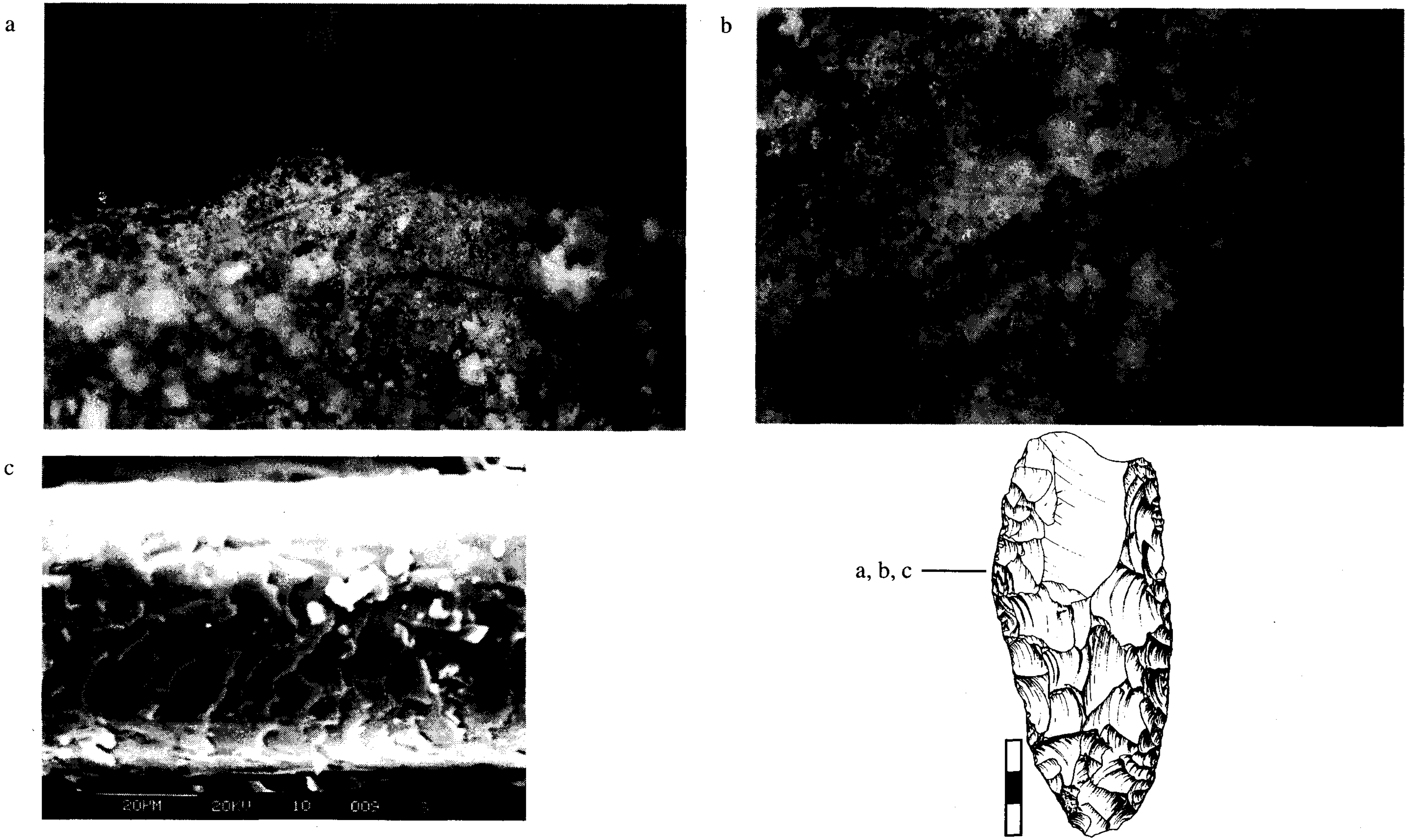


Fig. 9-2—Starosele Level 4 (STR95-10), double convex sidescraper: *a*–hair fragment on tool edge, note that hair is partially trapped under tool matrix (original magnification 50x); *b*–same hair fragment with medulla visible (original magnification 100x); *c*–scanning electron photomicrograph of another hair fragment from the same tool with scales clearly visible.

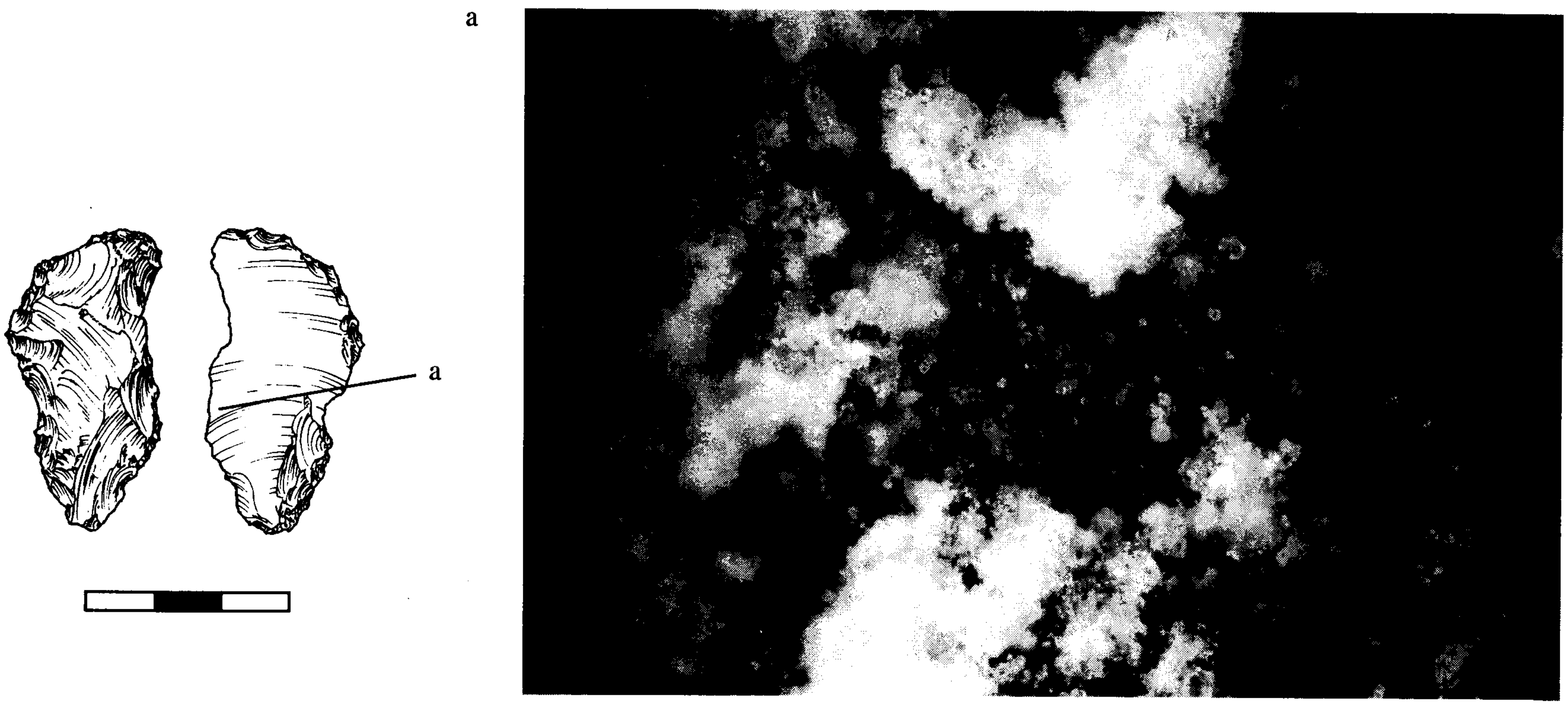


Fig. 9-3—Starosele Level 3 (STR95-23), denticulate: *a*–mass of starch grains viewed under cross-polarized light, note extinction crosses (original magnification 500x).

evidence. The only residues present are several hair fragments which are found on both the dorsal and ventral surfaces on the edge of the tool. The hair is partially trapped underneath the matrix adhering to the tool (fig. 9-2a,b) and has a visible medulla and scale pattern. No other functional evidence is present on the tool except for a few striations that are located in approximately the same area as the hairs (Chapter 8). As mentioned previously, the identification of isolated hair fragments is often difficult due to variations in scale pattern across the body and on different portions of the hair (Brunner and Koman 1974). In an attempt to better discern the scale pattern, one of the hair fragments was removed from the tool and examined with scanning electron microscopy (fig. 9-2c). At present, the exact species has not been identified, although it is possible to rule out humans (the most likely contaminant). The presence of only a few hairs on a tool does not provide good patterning with which to interpret function. Nevertheless, the placement of hair fragments on an edge and on both sides of the tool in the same location suggests that the residue is related to use. It is not possible based on this evidence, however, to attribute a specific task to this tool.

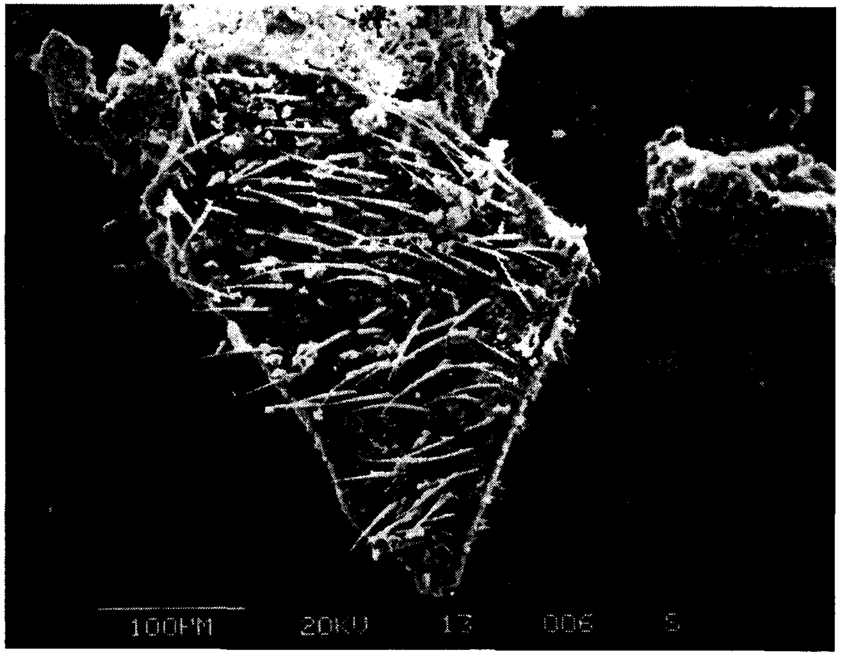
Denticulates

Four denticulates are included in the sample, three of which had plant residues on their surfaces. All three of these had starch grains concentrated in one area. STR95-23, for example, has large amounts of starch along one edge (fig. 9-3) in a pattern similar to that produced by a scraping use-action in modern experiments (Hardy and Garufi 1998). The same pattern appears on another denticulate and suggests that these tools may have been used to scrape a starchy substance, possibly some kind of root or tuber based on the large amount of starch present. Alternatively, the starch may be part of a binding or mastic to aid in hafting (Chapter 10). If this is the case, the denticulate edges may have been under the haft and were not necessarily working edges. Once again, a clearer picture comes when residue and use-wear techniques are combined. Given the use-wear evidence for these tools, the residues are most likely related to hafting. The fourth example (STR95-13), which also appears to have been hafted, has two types of animal residue. One is a degraded hair fragment with a scale pattern visible, while the other is a small fragment of insect exoskeleton (fig. 9-4). Although it would be tempting to conclude that this tool was used in the processing of mammals as well as insects, both residues are isolated and not covered by matrix, making it impossible to confidently attribute them to tool use.

Pointed Pieces

Three artifacts in the sample have convergent retouched edges and could be classified as either points or convergent scrapers. They are referred to here as points based on the combination of residue and use-wear evidence, which suggests that these tools may have been hafted. Residue evidence for hafting comes from two sources: the distribution of starch grains and plant tissue on the proximal one-half to two-thirds of the tool and possible mastic residue on one tool. Two of the pointed pieces have starch and plant tissue concentrated on the proximal portion of the tool in the same area where use-wear (striations) indicates hafting. The third pointed artifact (STR95-26) has an unidentified substance, which morphologically resembles a resinous mastic (fig. 9-5). It, too, is confined to the proximal one-half of the tool. The patterning and appearance of this residue are suggestive of a mastic based on comparisons with experimental and published materials (Boëda et al. 1996). However, this identification remains tentative in the absence of chemical analysis to confirm its origin. In addition to possible hafting residues, one point (STR95-6) also has feather barbule fragments on its tip that appears to be use-related (see Chapter 10 for a full description).

a



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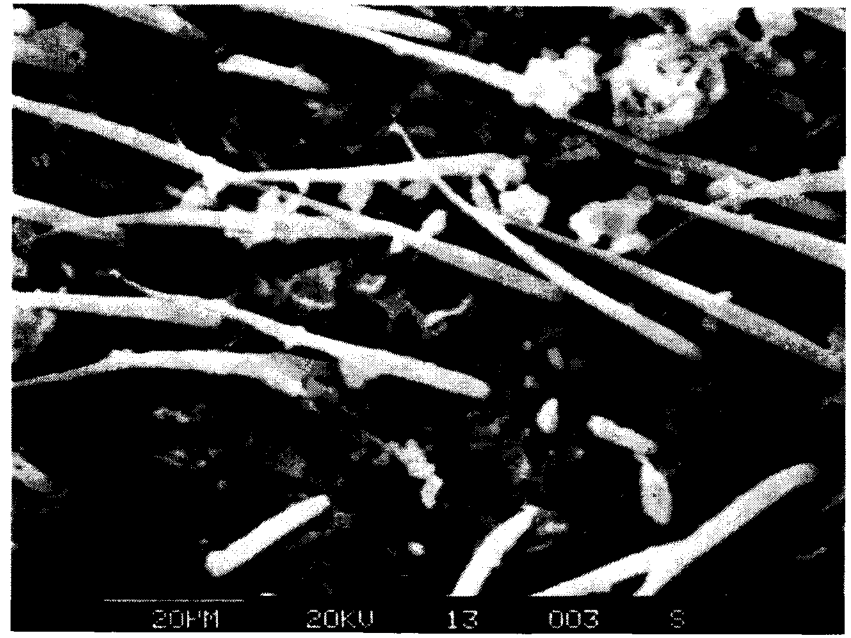

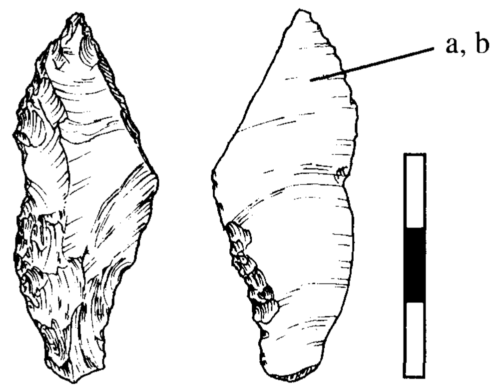

Fig. 9-4—Starosele Level 3 (STR95-13), simple convex sidescraper with inverse retouch: *a*–scanning electron photomicrograph of insect exoskeleton fragment; *b*–same fragment at higher magnification.

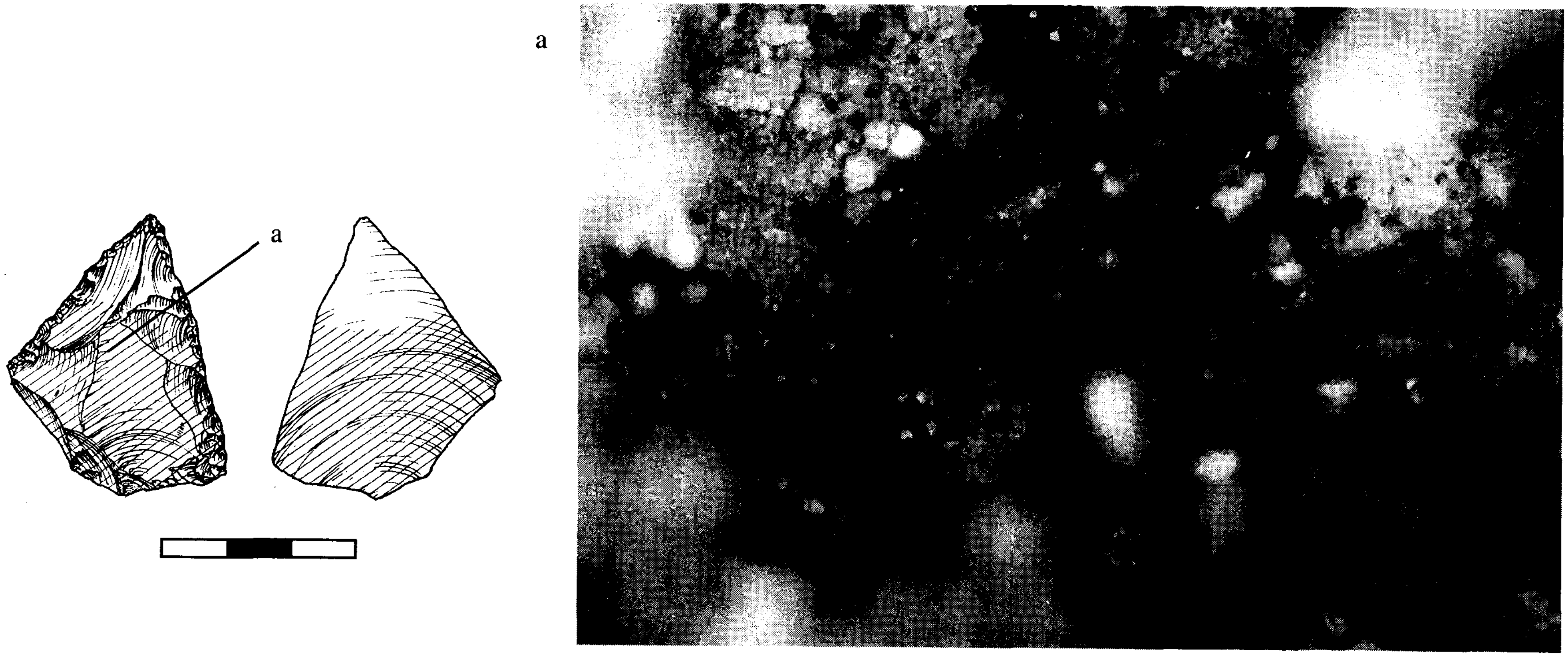

Fig. 9-5—Starosele Level 4 (STR95-26), sub-trapezoidal point: *a*–possible mastic (original magnification 100x).

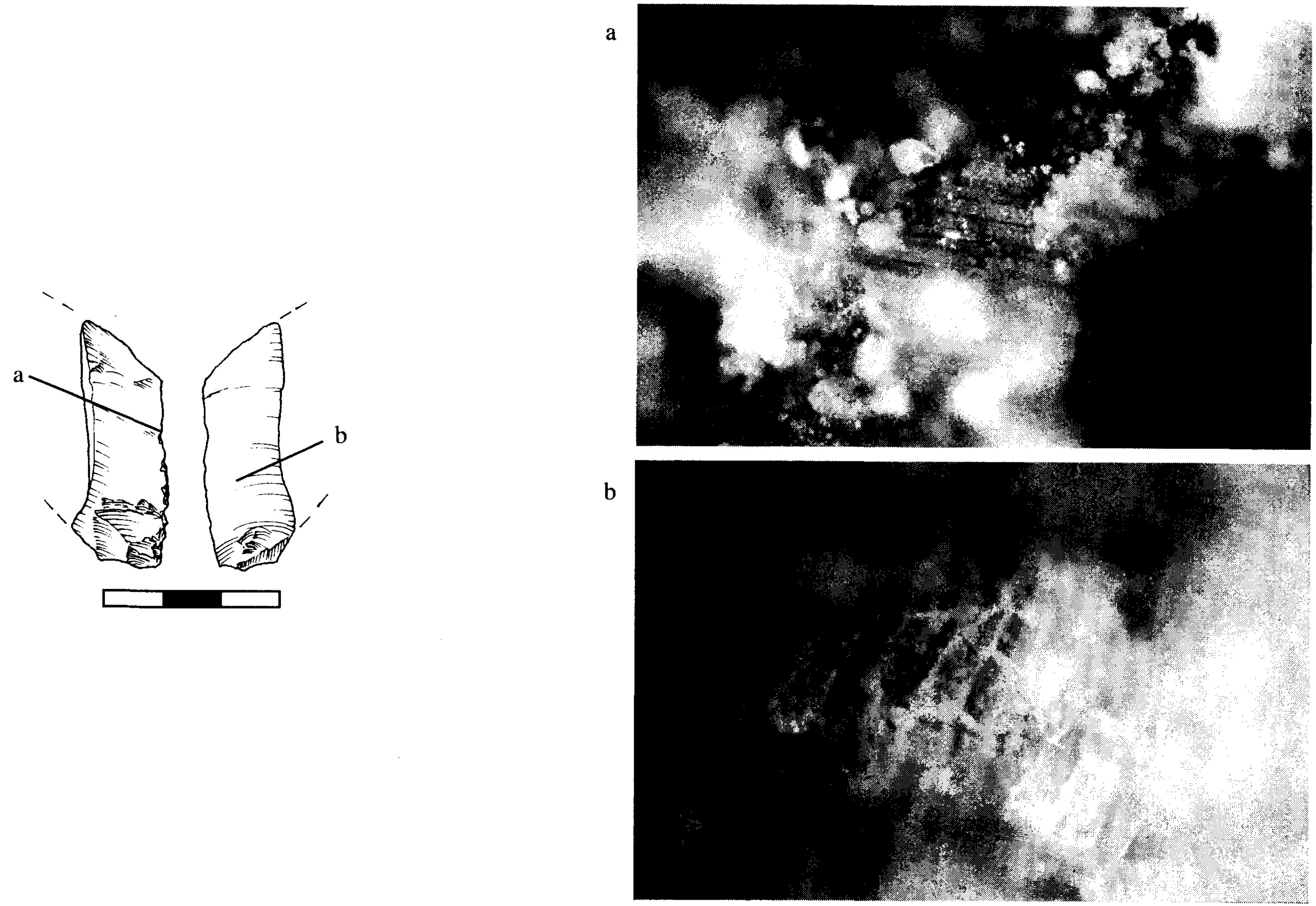

Fig. 9-6—Starosele Level 3 (STR95-27), use-retouched blade: *a*–striations on tool edge, bright particles within striations are starch grains (original magnification 500x); *b*–plant tissue (original magnification 500x).

Core

One unifacial, discoidal core was examined. This core has some scattered, isolated plant fragments with visible cellular structure that do not appear to be patterned. No starch grains or raphides are present.

Retouched Blade

A blade with unifacial retouch along one edge again shows evidence for the processing of starchy plants. Plant tissue and starch grains are smeared back from the retouched edge (fig. 9-6). Their distribution, particularly starch grains located within striations, suggests that the tool was used to scrape a relatively hard starchy substance.

Flakes

A total of 14 unmodified flakes were examined for residues. As with other artifact types, the majority of them show evidence of plant material. Eleven of the fifteen (73.3%) have some type of plant residue, either starch grains or plant tissue. The residue is typically patterned to indicate a slicing type of use-action. A slicing use-action will usually produce residues in lines roughly parallel to the edge of the tool and will often be accompanied by striations, particularly if the use-material is hard. How far the residue extends away from the edge of the tool will depend on how deeply the tool cuts in to the use-material (Hardy and Garufi 1998; and see Table 9-1). No animal residues are present and only one flake has possible hafting evidence.

Chips (<3 cm)

Seventy-one small flakes classified as chips or debitage were included in the residue analysis. The majority of these (61 of 71) did not have any residues. Eight had plant fragments in the form of starch grains or plant tissue and one had an isolated degraded hair fragment. Those chips that do have residues may be flakes from resharpening episodes during the use-life of a tool.

TABLE 9-3
Possible Roots and Tubers Exploited at Starosele

Pastinaca sativa (wild parsnip)
Daucus carota (wild carrot)
Beta vulgaris (sugar beet)
Raphinus sativa (fodder radish)
Tragopogon porrifolius (salsify, oyster plant)
Scorzonerahis panica (black salsify)
Typha spp. (cattails)

DISCUSSION

The identification of starch grains, raphides, plant tissue, hair, and feather remains on the stone tools from Starosele provides evidence for exploitation of a wide range of resources. Some of these resources, particularly the plants and birds, are not usually included in discussions of Middle Paleolithic subsistence and economy due to poor recovery technique, previous intellectual biases, and sometimes, preservation problems. The evidence further suggests that many of the tools were hafted, a practice which is still disputed in the Middle Paleolithic.

Plants

The traditional wisdom in archeology is that plant remains only survive under unusual conditions of preservation, particularly when looking at Paleolithic sites. However, the identification of plant remains from Paleolithic contexts is becoming increasingly common as archeologists have realized that plant remains can survive and have modified their recovery techniques accordingly. At Starosele, stone tools were removed from the ground and placed into plastic bags with minimal handling and no washing, thus allowing plant fragments adhering to the tool surfaces to be observed. Microscopic analysis of sediments (e.g., Mason et al. 1994), as well as microscopic examination of artifacts for residues (e.g., Anderson 1980; Anderson-Gerfaud 1981, 1986, 1990; Fullagar and Field 1997; Hardy and Garufi 1998; Loy et al. 1992; Sobolik 1996), have helped to demonstrate that preservation of plant remains may be more common than is typically believed, at least on a microscopic level.

Although the fragmentary nature of the plant residues on tools from Starosele makes specific identification difficult, it is nonetheless possible to discuss the probable origin of these residues based on certain morphological characteristics. As mentioned earlier, starch grains are produced in various parts of plants, but are typically concentrated in starchy storage organs such as roots and tubers (Fahn 1982). The large number of starch grains present on many of the Starosele tools suggests that they may come from starchy storage organs. Were the hominids of Starosele exploiting roots and tubers? If so, was it for consumption or for some other purpose?

The starch grains and associated plant tissues are clearly patterned on many of the tools—either concentrated in one area of a tool or smeared back from one edge. They are found on both retouched and unmodified edges. This type of patterning suggests processing of starchy material either with a whittling, slicing, or scraping motion and may be due to removal of cortex or cutting of the material into smaller pieces. However, some of the patterning is also consistent with the use of a starchy substance as part of a haft. Whether these are indeed food remains or whether they are being exploited for use in hafts, the next question is, can they be identified more specifically? The identification of parenchymous tissue from roots and tubers generally requires examination with a scanning electron microscope (Hather 1992, 1994; Mason et al. 1994). Because examination of the Starosele residues was primarily limited to light microscopy, more specific identification is difficult. However, it is still possible to consider the range of starchy materials that may have been available for exploitation.

Although most of the tools in this study come from Level 3, Levels 1, 2, and 4 are also represented. Starchy residues are found on tools from all four levels. The sample thus spans a time period from approximately 80,000-40,000 BP (Marks et al. 1998) during which the climate varied. Level 4, the oldest level, appears to have been an open steppe-meadow environment, while a cold-steppe phase dominated in Level 3. Levels 2 and 1 appear to have been warmer with steppe regions, a closed canopy, and a nearby meadow zone (Chapter 11). The topographical location of Starosele, in close proximity to a canyon, may have further contributed to local environmental variability with regards to temperature and humidity. All four levels at Starosele show some amount of steppe, often with a mix of other environments. This general type of environment can contain a number of potentially edible roots or tubers from the Family Astraceae/Compositae (Mason et al. 1994), including wild parsnips, wild carrots, sugar beets, salsify, and cattails (Table 9-3). In addition to their potential use as food items, these starchy substances could have been exploited for use as a binding or mastic in hafting.

Not all of the plant tissue on the Starosele tools comes from starchy material. Some of it likely derives from wood, although diagnostic anatomical criteria is lacking. Wood was clearly being exploited in the Middle Paleolithic (Anderson-Gerfaud 1981, 1986, 1990; Beyries 1987b, 1988) and even as far back as 400,000 years ago (Thieme 1997). While it is not possible to recreate the exact uses of wood at Starosele, some tools have traces of wood from hafting.

Animals

Animal residues are comparatively rare on the tools examined from Starosele. It is clear from the zooarcheological analysis (Chapter 1) that stone tools were being used in the processing of animals. The presence of cutmarks and percussion damage on bone is corroborated by the presence of hair on 3 tools. Hairs on STR95-10 (fig. 9-2) are trapped under the matrix adhering to the tool surface and are found on the tool edge. This location supports the interpretation that the hair is related to tool use, but does not provide sufficient information to accurately interpret the use-action of this tool. The morphology of the edge, unifacially retouched, suggests that a scraping or planing motion is more likely than a cutting motion.

The utilization of bird resources is evidenced by feather barbules on 2 tools from Starosele. Avian resources are not often included in discussions of hominid subsistence despite the fact that bird bones are often present at sites (e.g., Eastham 1989). The identification of feathers through residue analysis suggests that hominids were exploiting birds although the exact nature of that exploitation remains speculative. The presence of feathers from both predator birds and waterfowl could be due activities unrelated to hominids, but the patterning of the feathers on the tool surfaces argue that these residues are use-related.

Hafting

Evidence for hafting in the Middle Paleolithic is becoming increasingly common. Shea (1988, 1989, 1992, 1998) has suggested that evidence for hafting exists in the Levant in the form of impact fractures on pointed tools. Anderson-Gerfaud (1981, 1986, 1990) and Beyries (1987b, 1988) have both found use-wear evidence for hafting from Mousterian sites in France. Most recently, Boëda et al. (1996) have identified the remains of a mastic (bitumen) from Middle Paleolithic tools from Umm el Tlel in Syria. At Starosele, wear patterning consistent with hafting is visible on a wide variety of tool types (Chapter 8) and the starch and other plant tissues may be related to a binding or mastic, or may represent part of the haft itself. The tools with hafting evidence include scrapers, denticulates, and pointed pieces. The hafting of these tools may have been for increased leverage for plant and animal processing or it may be evidence for use of some tools as thrusting spears or projectiles. Increased leverage and ability to hunt from a distance are both potential advantages of hafting (Brace 1995). In order to understand fully the role of hafting in the subsistence and economy of the hominids of Starosele, the acquisition, manufacture, and curation of hafts must be considered.

Patterns of Tool Use

Although the sample sizes are small, certain trends in tool use are discernible. Among the broad typological categories represented, all are in some way associated with plant processing, either in the form of residues related to tool use or residues related to tool hafts. However, the results also suggest that these typological categories do not represent specialized classes of tool use. Scrapers, denticulates, and flakes all have evidence for both animal and plant processing, suggesting that many tools may have served multiple functions. Scrapers have the largest sample size of any typological category (N=20). Patterned plant residues are present on 70% of the tools, while animal residues are present on only 15%. While this may reflect a predominance of plant processing activities or be an artifact of sample size, it is also possible that animal residues are under-represented at the site due to either differential preservation or difficulty in recognition. This same pattern was also seen at the Middle Paleolithic site of La Quina, France (Hardy 1994; Hardy et al. 1997). Form and function vary. Hafting is also not limited to any one tool category, but seems rather to have been a common practice for most tool types, particularly retouched pieces. Hafting appears to have served multiple functions as well, including facilitation of increased leverage for cutting or scraping activities as well as thrusting or projectile technology. Tools appear to have been used for a variety of tasks from wood and plant processing to possible cutting of meat and bird exploitation. The broad range of tool uses seen at Starosele most likely reflects a similarly broad range of economic and subsistence resources being exploited.

Interpretations of changing patterns of tool use through time are limited since, with the exception of Level 3, sample sizes are small. Level 4, the oldest occupation, which seems to reflect a relatively short human occupation (Chapter 7), has evidence for both plant and animal processing. Level 4 also has evidence of hafting in the form of starch distribution and possible resinous mastic. If this last residue is indeed a resinous mastic, this would represent the earliest evidence to date of this kind of hafting. Level 3 has a much more complex archeological component, including a diverse lithic assemblage and a hearth (Marks and Monigal 1998), and this complexity seems to also be reflected in tool use. Scrapers, denticulates, points, and flakes all show evidence of hafting, some of which may be related to use of tools as thrusting spears or projectiles. The resources exploited with stone tools include mammals, birds, and starchy and woody plants. Several of the tools also show evidence for use on multiple materials with multiple use-actions (see Chapter 10). Levels 1 and 2 probably represent short occupations. The residue sample is small, but includes evidence for hafting, starchy plant processing and bird exploitation.

Evidence for hafting and exploitation of plants is found in all levels at Starosele. Evidence of animal processing is much less common on the lithics, although the faunal remains clearly indicate that this was a major activity at the site (Chapter 1). Despite some variation through time, the overall picture of tool use at Starosele is one of the exploitation of a wide range of resources, both plant and animal.

CONCLUSIONS

Microscopic residue analysis of artifacts from Starosele has allowed the recovery of otherwise undetectable information. The presence of starch and other plant material would not have been noticed with any other analytical technique. Furthermore, the exploitation of avian resources, as suggested by the presence of feather barbule fragments, would traditionally have been given little emphasis. The results of the residue analysis suggest the exploitation of a wide range of resources including mammals, birds, woody plants, and starchy plants (roots or tubers), among others. Furthermore, residues of starchy plant material concentrated in certain areas of some tools supports the use-wear evidence of hafting of a variety of tools at Starosele. When the results of the residue analysis are combined with those from the use-wear analysis, presented in the following chapter, an even more detailed picture of tool use at Starosele emerges.

Appendix, Chapter 9
Starosele, Summary of Residue Results (chips excluded)

Specimen	*Tool Class*	*Residues*	*Hafted*	*Use-action*	*Interpretation*
Levels 1, 2					
STR95- 1	scraper	raphides, starch grains	X	indet.	hafted, unknown use
STR95- 2	scraper	starch grains		scraping	scraping plant
STR95- 3	scraper	plant tissue, raphides, feathers		slicing	slicing plant, processing bird?
STR95- 28	scraper	plant tissue		planing	planing plant
STR95- 30	scraper	raphides, plant tissue	X	scraping	hafted, scraping plant
STR95- 31	bifacial point	raphides	X	indet.	hafted, unknown use
Level 3					
STR95- 4	core	none			unused
STR95- 5	flake	starch grains, plant tissue		whittling	whittling plant
STR95- 6	point	starch grains, raphides, feathers	X	slicing	hafted thrusting/projectile, slicing bird
STR95- 7	flake	nothing			unused
STR95- 8	scraper	nothing			unused
STR95- 9	scraper	nothing			unused
STR95- 11	scraper	plant tissue		scraping	scraping plant
STR95- 12	scraper	nothing			unused
STR95- 13	denticulate	insect, hair		indet.	unknown use
STR95- 14	scraper	plant tissue, starch grains		indet.	processing plant
STR95- 15	scraper	plant tissue, starch grains	X	planing	hafted, planing plant
STR95- 16	scraper	plant tissue	X	indet.	hafted, processing plant
STR95- 17	scraper	plant tissue		indet.	processing plant
STR95- 18	denticulate	plant, starch grains	X	indet.	hafted, denticulate edge under haft
STR95- 19	scraper	plant		indet.	processing plant
STR95- 20	denticulate	plant, starch grains		planing	planing plant
STR95- 22	scraper	nothing			unused
STR95- 23	denticulate	starch grains	X	indet.	hafted, unknown use
STR95- 24	scraper	starch grains	X	indet.	hafted, plant processing on tip
STR95- 27	scraper	plant tissue, starch grains		scraping	scraping plant
STR95- 00-2	flake	starch grains		slicing	slicing plant
STR95- 00-3	flake	hair		indet.	unknown use
STR95- 00-4	flake	plant tissue, starch grains		indet.	processing plant
STR95- 00-5	flake	starch grains	X	indet.	hafted, unknown use
STR95- 00-6	flake	starch grains		indet.	unknown use
STR95- 00-7	flake	nothing			unused
STR95- 00-8	flake	starch grains		indet.	unknown use
STR95- 00-9	flake	nothing			unused
STR95- 00-10	flake	nothing			unused
STR95- 00-11	flake	plant tissue, starch grains		whittling	whittling plant
STR95- 00-12	flake	starch grains		indet.	unknown use
STR95- 00-13	flake	nothing			unused
STR95- 00-14	flake	starch grains		indet.	unknown use
STR95- 00-15	flake	plant tissue, starch grains		slicing	slicing plant
STR95- 00-19	flake	nothing			unused
STR95- 00-21	flake	starch grains		indet.	unknown use
STR95- 00-30	flake	plant tissue		indet.	unknown use
STR95- 00-59	flake	plant tissue		indet.	unknown use
STR95- 00-66	flake	nothing			unused
Level 4					
STR95- 10	scraper	hair		indet.	processing mammals?
STR95- 21	scraper	starch grains	X	scraping	hafted, scraping plant
STR95- 25	scraper	starch grains		scraping	scraping plant
STR95- 26	point	possible mastic	X	indet.	hafted, unknown use