CHAPTER 6

PREHISTORIC TOOL MICROWEAR ANALYSIS

6.1 Microwear Analysis Methodology and Procedures

Microwear analysis is regarded as a very important methodological component of this study. This is because of its previously demonstrated efficacy for helping to determine prehistoric lithic tool function with reasonable accuracy and success (e.g., Keeley and Newcomer 1977; Newcomer and Keeley 1979; Schiffer 1979; Odell and Odell-Vereecken 1980; Gendel and Pirnay 1982; Kamminga 1982; Newcomer, Grace and Unger-Hamilton 1986; Richards 1987, and many others).

A total of 35 prehistoric key-shaped formed unifaces were subjected to a detailed microwear analysis (Table 4). Using a table of random numbers, they were selected from a sub-sample of 70 items in the prehistoric study sample set that exhibited either moderate or pronounced degrees of overall microwear trace intensity (Appendix 3). Twenty (57.1%) of the 35 selected prehistoric microwear sub-sample specimens are made of chalcedony, 12 items (34.3%) are chert, and three (8.6%) are basalt. These proportions are similar to those of the 129 prehistoric study sample specimens (Appendix 3).

Each of the 35 randomly selected tools was examined under a Wild M3 stereoscopic light microscope at magnifications varying between 6.4 X and 40 X. Observed microwear traces were described qualitatively and quantitatively (Appendices 4 and 5; Tables 5, 7 and 8; Figure 8). Photographs were taken with the microscope's built-in camera and a fibre-optic light source.

The advantages and disadvantages associated with various magnification methodologies used in microwear studies have been discussed by several researchers (Keeley 1974,1981; Odell 1975,1982; Odell and Odell-Vereecken 1980; Holley and Del Bene 1981; Richards 1984,1987; Bamforth 1986b; Newcomer, Grace and Unger-Hamilton 1986). Experimental "blind tests" have also been conducted to objectively assess the accuracy of various magnification methods (see Keeley and Newcomer 1977; Newcomer and Keeley 1979; Newcomer, Grace and Unger-Hamilton 1986; Richards 1987; Shea 1987).

After considering the observations and points raised in these previous assessment studies, it was decided that a "low-power" magnification (6.4 X to 40 X) methodology was appropriate for the present study. There are several reasons why a low-power magnification analysis method was selected over high-power magnification (greater than 60 X). First, many specimens in the study sample bear intensive and extensive microwear traces that can be easily seen with the unaided eye. Therefore, it was reasoned that high-power magnification methods were not required to identify and examine the full range of microwear traces, or to determine their location, intensity, and general characteristics.

Second, low-power magnification permits large areas of a tool's surfaces to be examined, compared, and photographed within the same field of vision, whereas the high-power method permits viewing of much more restricted areas. The latter method may cause some of the more prominent microwear trace features (e.g., microflake scars or polish) to be obscured or overlooked, thus the total range of trace patterns represented may be more difficult to detect, accurately describe, and compare (see Odell 1982:19).

Third, blind tests have shown that low magnification analyses of unretouched tool edges are only slightly less accurate than high magnification methods for identifying the location of tool contact, tool movement, and relative contact material hardness (see Tringham *et al* 1974; Odell and Odell-Vereecken 1980; Odell 1982; Richards 1984). It is primarily these aspects of key-shaped formed unifaces that are of importance in this study.

Lastly, low-power magnification analysis can be undertaken rapidly and inexpensively with relatively little specialized equipment, whereas the high-power method requires access to either a specialized light microscope or scanning electron microscope (SEM). Use of a SEM requires great expenditures of time; specimen preparation involves alteration of tool surfaces which sometimes obscures certain microwear traces (see Odell 1975:230), and in some instances destruction (i.e., breaking) of specimens is required to make them fit into the scanning stage.

The location, extent, and intensity of the various microwear trace types observed in this study are described using mainly qualitative terms, as some microwear attributes are very difficult -- if not impossible -- to adequately express in any standardized quantitative manner. Location and extent were described by recording trace positions vis-a-vis ascribed parts or areas of the tool, such as the edge of the concave margin, ventral face of distal projection, ventral-lateral corners of the distal projection tip, etc. (see Chapter 2.2 and Figures 2 and 8). Definitions for each of the microwear trace types recorded in this study, and a brief discussion concerning their potential significance, are presented below.

In this study, the "edge aspect" of a margin is defined as those portions of the ventral and dorsal faces that lie about 1.5 mm back from, and along, a tool edge. The term "margin" refers to both the immediate functional edges of a tool, and their respective edge aspects (see Figure 2).

6.1.1 Polish

Polish is defined as the degree to which a use-altered edge or surface of a tool reflects light. The characteristics of various polishes are considered to vary dependently according to specific use-conditions and lithic materials being employed (see Keeley and Newcomer 1977; Keeley 1980; Moss and Newcomer 1982; Vaughan 1985).

There have been several theories advanced that attempt to explicate polish formation on edges and/or surfaces of stone tools resulting from use (Semenov 1964; Rabinowicz 1965,1968; Del Bene 1979,1980; Diamond 1979; Kamminga 1979; Anderson 1980; Meeks *et al* 1982; Unger-Hamilton 1984; Bettison 1985; Knutsson 1988). Two main types of polish formation processes have been identified and defined: (1) "additive" (also referred to as depositional or accretional); and (2) "abrasive" (also called mechanical, frictional, or attritional).

Some researchers have suggested that an additive polish results when phytoliths in plant materials and silicate components of a tool's surface are fused together in successive layers by frictional heat (Witthoft 1967; Keeley 1980; Shelley 1982), or by dissolution of the tool surface into a gel which traps plant parts on recrystallization (Anderson 1980:184; Mansur 1982). Kamminga (1979:149-151) suggests that water may be involved in the fusion process. Del Bene (1979:171, 1980) and Bettison (1983,1985) suggest that true fusion does not occur, rather, glossy layers of cohesive phytoliths adhere to a tool's surface by anchoring themselves into interstitial voids between crystals comprising the lithic material.

Abrasive polish is thought to be the more common form of polish occurring on stone tools. Two separate formation model categories for abrasive polish have been proposed; abrasional, and translocative (Del Bene 1979: 172). Abrasional polish is thought to result from loss of material from the tool surface by friction (Diamond 1979:165; Kamminga 1979:151-154; Meeks *et al* 1982). Translocative polishing occurs when materials are either removed and re-attached elsewhere on the tool's working surface, and/or are deformed in their original locations (Del Bene 1979:172-174; 1980).

Due to the considerable debate and apparent uncertainty concerning the exact nature and significance of mechanical and chemical agencies responsible for polish formation, and because the two main types (i.e., additive and abrasive) can only be adequately identified with a scanning electron microscope (SEM) (see Bettison 1985; Knutsson 1988), an attempt to conclusively differentiate between the two main polish formation types was not undertaken in this study. However, the low-power magnification analysis results (Chapters 6 and 8), suggests that both abrasive and additive polish types may be represented on many of the prehistoric and experimental tools examined.

Hayden and Kamminga (1979:8) have suggested that raw material properties have a dependent relationship with the nature of polishing or smoothing incurred on tool edges or surfaces. Therefore, different materials subjected to the same use-behaviours and conditions may develop and exhibit varying types and intensities of polish or smoothing. Because the study sample contains a wide spectrum of lithic material types, accurate monitoring of variation in polish characteristics due soley to physical property differences inherent to the lithic raw materials was not considered feasible in this study.

Polish intensities were subjectively expressed in terms of relative brightness, and were recorded as being either dull, moderately bright, or bright (see Grace, Graham and Newcomer 1985). Examples of these categories are presented in Figures 21 to 38 and 54 to 65. The location and extent of polish was also recorded. It was reasoned that these polish data were suitable for: (1) helping to determine the location of tool contact; (2) providing an approximate and comparative index for the relative duration of tool use; and (3) assisting in determining the probable nature of contact material(s) when considered along with other analysis data (see Chapters 6.3, 8.4 and 9.6).

6.1.2 Rounding and Smoothing

Rounding and smoothing refer to the reduction in angularity of a tool's protruding features (e.g., flake scar ridges and functional edges). Two processes responsible for rounding and smoothing have been identified. The first, and most common, is caused by mechanical removal of small particles by attrition or abrasion during use (Brink 1978a,1978b:47; Diamond 1979; Ahler 1979:304; Keeley 1980). It is often considered to be synonymous with abrasive polish, although Ahler (1979:308) suggests that the two may be distinguished by differences in luster and texture. Abrasive agents are usually hard and angular, and can be derived directly from the contact material; from dust, sand, silt, etc. introduced incidentally from the working environment; or from particles dislodged from the contact surfaces of a tool during use (autoabrasion) (Kamminga 1979:151-154).

The second type of rounding/smoothing is additive in nature, involving accretion of silica deposits on tool surfaces derived from contact materials (particularly plants) or the tool itself. Basically, it is characterized by a build-up of an additive polish (see above) on a tool's functional edges and immediately adjacent surfaces that reduces angularity of microtopographical features.

The degree or intensity of rounding and smoothing on prominent microtopographical features and edges of tools was described as being either slight, moderate, or pronounced. Examples of various rounding and smoothing intensity categories are presented in Figures 21 to 38 and 54 to 65. Rounding/smoothing was considered to be an important microwear trace pattern because it: (1) assists in determining tool contact areas; (2) provides an estimate for the approximate relative duration of tool use; and (3) it can indicate the relative hardness of contact material(s) being worked.

6.1.3 Striations

Striations are linear scratches, grooves, furrowed depressions, sleeks, or abraded tracks which occur on tool edges or surfaces as a result of use (Semenov 1964; Brink 1978a:47-48, 1978b; Ahler 1979:314; Del Bene 1979:167-170; Fedje 1979; Hayden 1979a:192-193; Mansur 1982; Knutsson 1988: 90-101).

Two basic discrete striation categories were observed and defined in this study. They are referred to as "scratch-groove" and "sleeked". The "scratch-groove" type is characterized by linear scratches and grooves mechanically gouged into a fresh or abrasionally smoothed tool surface during use (e.g., Figures 24, 25, 27, 28 and 35). They are formed when the tool surface is in a "solid-gel" state (Mansur 1982). Most researchers agree that this striation type is produced by abrasive agents becoming incidentally introduced between a tool and its contact material (Semenov 1964:15,88; Wilmsen 1968; Sheets 1973:217; Keeley 1974:126-127; Tringham *et al* 1974; Odell 1975: 229; Brose 1975).

"Sleeked" striations appear as linear trend lines, both raised and/or furrowed, and they seem to be most commonly associated with an additive-type polish (see Figures 24 and 30). Indeed, they are typical of what Mansur (1982) has called "additive" (i.e., built-up) and "filled-in" striations most commonly formed by dissolution of silica on a tool surface when it is in a "fluid-gel" or "intermediate" state. Del Bene (1979:169) has suggested that they may also be produced by atomic adhesion and transfer of materials between the tool and its contact material.

The relative intensity of striations were described as being either slight, moderate, or pronounced. Their orientation with respect to one another was recorded as being either parallel unidirectional, parallel bidirectional, or parallel

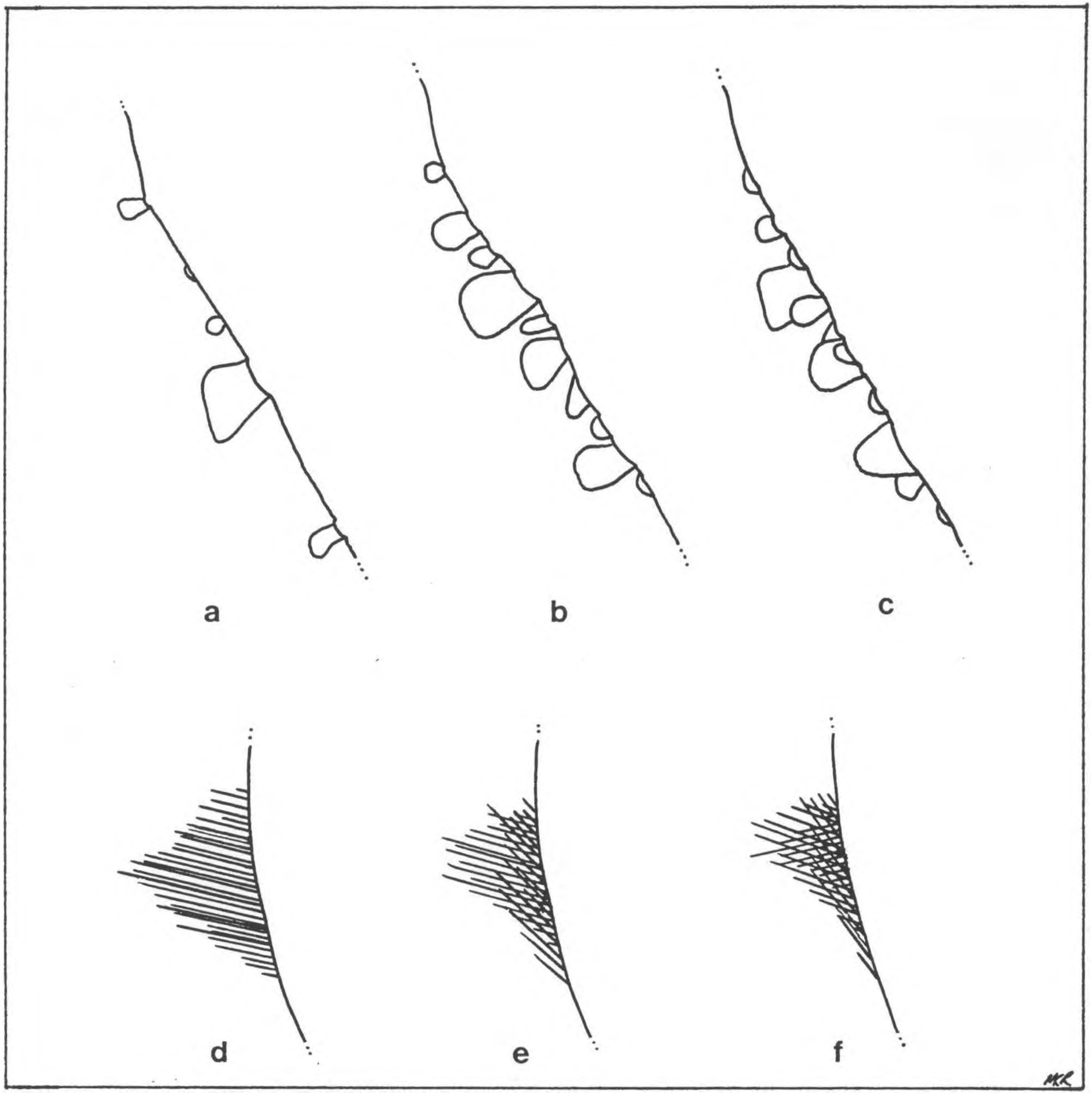

Figure 7. Typical microflake scar and striation pattern categories observed on the ventral edge aspects and ventral faces of the 35 prehistoric microwear sub-sample tools.

Edge aspect microflake scar pattern categories:

(a) random
(b) contiguous
(c) contiguous superposed

Ventral face striation pattern categories:

(d) parallel unidirectional
(e) parallel bidirectional
(f) parallel multidirectional

multidirectional (Figure 7). Certain striation attributes lend themselves to some degree of quantitative description. In this study their angular orientation vis-a-vis their respective functional edge of origin was recorded in five degree increments. "Distally" oriented striations had their "tails" pointing toward the distal end of the tool; "proximally" oriented ones had tails trending toward the butt.

Striation lengths, widths, and depths are also considered to have diagnostic value (Semenov 1964; Keeley 1980). However, an attempt to record this information was not undertaken in this study because high striation frequencies and their wide range of morphological variability would have demanded the use of high-power microscopy and enormous amounts of time to properly examine and quantify.

In this study, striations are deemed to be important data because their orientations in relation to the working edges are useful indicators of use-motion direction, and of the manner (i.e., relative working angles) that a tool was held against its contact material(s) during use. Moreover, they can also provide some information about prehistoric ambient environmental conditions in contexts where a tool was used. I have assumed that tools with a high incidence of striations were used in situations where there was an abundance of mobile abrasive agents (e.g., sand, silt, dust, grit) being introduced between the tool edges or surfaces and the material being worked. Alternately, tools with a paucity or absence of striations are regarded to have been used in contexts relatively free of abrasive materials (see Chapter 8.4).

6.1.4 Use-Fracturing

Use-fracturing refers to the manner and degree that sections of lithic materials break or shear from functional surfaces or edges of tools in direct response to applied loads of force during use. The complex laws of fracture mechanics governing use-fracturing are the same as those defined for intentional flaked tool production (Crabtree 1972:34-35; Cotterell and Kamminga 1979,1987; Lawn and Marshall 1979; Tsirk 1979; Odell 1981b).

Microflakes are commonly removed from edges of tools during use. When analogically correlated with results of experimentally generated data, their size, character, frequency, orientation, and distribution are considered to have potential diagnostic value for reconstructing motor patterns, and for helping to determine the nature of contact material(s) (Gould, Koster and Sontz 1971; Tringham *et al* 1974:188; Lawn and Marshall 1979:78; Cotterell and Kamminga 1979:110, 1987:704; Odell and Odell-Vereecken 1980:98-99; Odell 1980; Kamminga 1982).

The size, shape, and frequency of microflake scars on unretouched edge aspects of a tool can usually be easily categorized and quantified for comparative purposes (see Tringham *et al* 1974; Cotterell *et al* 1979; Hayden and Kamminga 1973; Hayden 1979a:134, 1979b; Kamminga 1982; Cotterell and Kamminga 1987; Richards 1987). In this study, only the microflake scars appearing on the ventral face edge aspects (Figure 2) of the prehistoric tool margins were examined, as it is impossible to differentiate those scars on the dorsal edge aspects that were produced by intentional retouch from ones propagated unintentionally during tool use.

Microflake scar sizes were determined by measuring their approximate diameter to the nearest .1 mm. Mean microflake scar size and range were calculated for each of the three main functional edges (i.e., the distal projection tip, concave margin, and "opposite" margin) (Table 5).

Formal attributes of microflake scars were recorded by considering their initiation types, plan outlines, and cross-section/termination types (Appendix 6; Tables 7 and 8) (see Ho Ho Classification and Nomenclature Committee Report 1979; Hayden 1979b; Tsirk 1979; Cotterell and Kamminga 1987). Use-propagated microflake initiation types were categorized as being either Hertzian (cone), or bending. Plan outlines of their scars were classified as either circular-expanding, trapezoidal-expanding, crescentic, oblique, pointed, or lamellar. Cross-section/termination types were classified as being either invasive, shallow-stepped, deep-stepped, snapped, or retroflexed (see Tables 7 to 10). Frequencies for each of these microflake scar attributes were recorded and compared with those incurred on experimental tools (see Chapter 8).

The spatial relationship, or "pattern configuration", of microflake scars with respect to each other on the main functional margins were described as being either randomly scattered, contiguous, or contiguous-superposed (Figure 7). Examples of microflake scar formal types and their configuration patterns observed on prehistoric and experimental key-shaped formed unifaces are presented in Figures 25 to 28, 31 to 34, and 54 to 65.

Microflake scars appearing on the ventral edge aspects of key-shaped formed unifaces were important for helping to determine the location and extent of use-contact. Their initiations and terminations were useful for inferring the relative hardness of contact materials being worked, and levels of force applied (Tringham *et al* 1974:188; Ho Ho Classification and Nomenclature Committee Report 1979; Lawrence 1979:118-120; Cotterell and Kamminga 1987:686,691; Richards 1987:181). Microflake scar plan outlines were helpful for reconstructing use-motions and orientation of the working edge with respect to the material(s) being worked (Tringham *et al* 188-189; Odell and Odell-Veerecken 1980:98-99; Lawrence 1979:118) (see also Chapter 8.4).

Another category of use-fracturing occurs when substantial portions or sections of a tool are broken off due to heavy force loads being applied against a hard contact material. In such instances, the intensity and direction of the applied force can usually be inferred by considering the type of fracture involved (e.g., flexure, torsion), and/or through comparison with experimental data. For this study, understanding the nature of such use-fracturing was important for helping to determine the motor patterns associated with the apparent accidental removal of portions of the distal projection tip during use (see Chapter 6.3).

6.1.5 Crushing

Crushing is characterized by intensely microfractured sections of tool edges or prominent microtopographical features, and it is usually propagated during forceful working of hard contact materials (see Ahler 1979:309). In this study, its location and extent were described using relative descriptive terms, and its intensity was recorded as being either slight, moderate, or pronounced. An example of pronounced crushing on the concave margin of a prehistoric key-shaped formed uniface is presented in Figure 34. Crushing location and intensity was considered useful for identifying sections of tool edges that had been engaged in working reasonably hard contact materials using relatively heavy force loads.

6.1.6 Prehension Wear

Prehension wear is defined as the alteration of a tool's surface resulting from extended periods of abrasive contact with the user's hands or a hafting device. It has not been traditionally regarded as a microwear trace *per se* because it is not produced by direct contact with a material being worked. Consequently, it is sometimes referred to as "non-use" wear (see Odell 1982:22). Prehension wear can provide valuable information concerning how a tool was held, used, and/or hafted (see Odell 1977,1982; Odell and Odell-Vereecken 1980), and for this reason it was deemed important to this study. I have subsumed it under the rubric of microwear simply for descriptive convenience.

Manual or "hand-held" prehension is produced by gritty fingers repeatedly rubbing a specific location on a tool's surface during use (see Odell and Odell-Vereecken 1980; Vaughan 1985:39). Hafting prehension is formed by repeated minor side-to-side mechanical abrasion of a loose hafting device against a tool's surface during use (see Odell 1977; Moss and Newcomer 1982). Both types of prehension wear are most often manifest by localized polishing, rounding and smoothing of microtopographical features, and occasionally striations. They usually appear on non-functional portions (i.e., dorsal and ventral faces) of highly curated stone tools with long use-histories. The nature and intensity of prehension wear traces on a tool depends on the physical properties of its raw material, the abrasive characteristics of the user's fingers or hafting device, and duration of tool use. Examples of prehension wear on prehistoric key-shaped formed unifaces examined during this study are presented in Figures 36 to 38.

All microwear trace types discussed above were noted in the sub-sample of 35 prehistoric key-shaped formed unifaces selected for microwear analysis. The microwear attribute data were statistically analyzed using the Michigan Interactive Data Analysis System (MIDAS) programs to generate descriptive and inferential statistical measures (Appendices 5 and 6; Tables 5, 7, 8, 12 and 13). These measures were then compared qualitatively and quantitatively with those produced for the experimental tools (Chapters 8 and 9) to permit a judgemental assessment of their similarities and differences.

6.2 Descriptive Microwear Analysis Results

Detailed descriptive data generated for microwear traces observed on the 35 prehistoric microwear sub-sample specimens are presented in Appendix 6, and Tables 5, 7 and 8. A generalized account of salient, frequently recurring, and functionally significant microwear patterns are summarized and discussed below.

6.2.1 Distal Projection Tip

Many (45.7%) of items in the prehistoric microwear sub-sample have distal projections that are considered to be "complete" (i.e., there is no evidence to suggest intentional or accidential removal). The two most common distal projection fracture types are flexure (34%) and torsion (11.4%). Two items (5.7%) had their distal tips removed by some undetermined agency, and for one specimen (2.9%) it is severely inversely retouched (Appendix 6).

Rounding and smoothing intensity along the distal tip margin is absent for 20.6% of the sub-sample items, slight on 32.4%, moderate on 23.5%, and

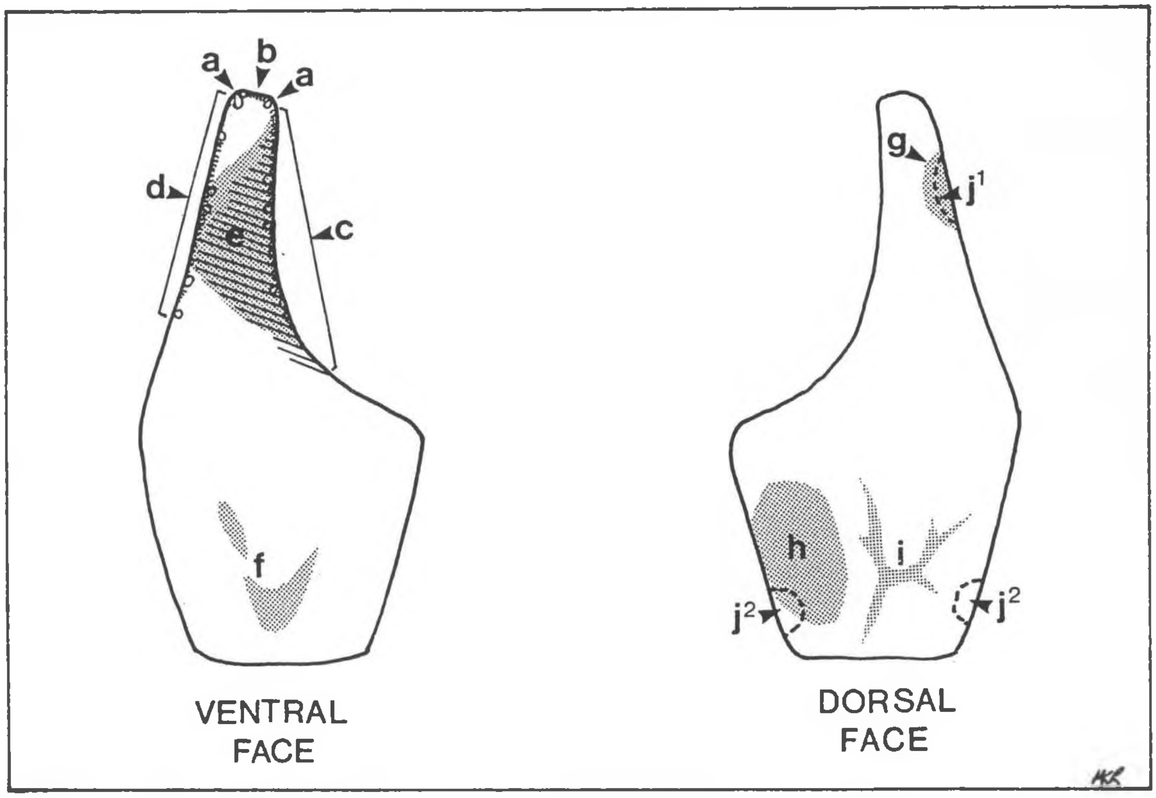

Figure 8. Typical microwear trace patterns observed on the 35 prehistoric microwear sub-sample specimens.

(a): Edge rounding and smoothing, and microflake removal on the ventral edge aspect of both ventral-lateral corners of the projection tip.

(b): Rounding and smoothing on the distal edge of the projection tip.

(c): Edge rounding and smoothing, polish, striations, and microflake removal along the ventral edge aspect of the concave margin.

(d): Edge rounding and smoothing, polish, and microflake removal along the ventral edge aspect of the "opposite" margin.

(e): Polish, striations, and smoothing on the medial or medial-distal section of the ventral face of the distal projection.

(f): Polish and smoothing on basal aspect of the ventral face caused by hafting prehension wear.

(g): Rounding, smoothing, and polish created by manual prehension resulting from the user's index finger and/or thumb rubbing on the dorsal face of the "opposite" margin.

(h): Rounding, smoothing, and polish formed by manual prehension resulting from the user's thumb rubbing on the left proximal-lateral section of the dorsal face.

(i): Polish and smoothing of ridges and microtopographical features on the proximal section of the dorsal surface caused by hafting prehension wear.

(j): Shallow indentations installed on a few specimens interpreted to have functioned as finger/thumb rests (j^1), and hafting elements (j^2).

pronounced on 23.5%. Of those exhibiting rounding/smoothing, 59.3% bear it exclusively on the ventral-lateral corners, 25.9% have it on both the distal edge and ventral-lateral corners, and only 11.1% possess it on the distal edge.

Polish intensity is dull on 17.6% of the sub-sample items, moderately bright on 55.9%, bright on 5.9%, and absent for 20.6%. Of the tools exhibiting polish, 55.6% have it on just the ventral-lateral corners, 29.6% possess it on both the distal edge and ventral-lateral corners, and 11.1% bear it on the distal edge only.

The mean number of microflake scars on the ventral edge aspect of the projection tip is 2.2, and the mean microflake scar size is 1.2 mm (Table 5). Microflakes were not observed on 48.6% of the sub-sample items. The majority (50.0%) of specimens with microflake scars have them exclusively on the ventral edge aspect of the ventral-lateral corners, 33.3% have them only along the ventral edge aspect of the distal margin, and 16.7% exhibit them on both the distal edge and ventral-lateral corners.

Crushing on the distal projection tip is absent for 64.7% of the tools in the microwear sub-sample. For items where it is present, 8.8% have slight intensity, 17.6% exhibit moderate intensity, and another 8.8% have pronounced intensity. Crushing is most common (58.3%) on the distal edge only, 25.0% of the specimens have it on just the ventral-lateral corners, and 16.7% bear them on both the distal edge and ventral-lateral corners.

Only three items in the prehistoric microwear sub-sample exhibit striations associated with the distal tip. In all cases they are parallel and unidirectional, and are oriented more or less perpendicularly in relation to the distal edge.

6.2.2 Concave Margin

Rounding and smoothing intensity on the concave margin edge is absent for 8.6% of the specimens in the prehistoric microwear sub-sample, slight on 48.6%, moderate on 25.7%, and pronounced on 17.1%. Of the items indicating edge rounding/smoothing, it is present along the medial-distal section of the edge on 50.0% of the tools, along just the medial section for 28.1%, and along the entire edge for 18.8%.

Polish is absent on 8.6% of the sub-sample specimens, dull on 31.4%, moderately bright on 48.6%, and bright on 11.4%. For tools bearing polish, it is located on the medial-distal portion of the concave edge for 53.1% of them, on just the medial section for 31.3%, and on the entire edge for 12.5%.

The mean number of microflake scars on the concave margin of each specimen in the prehistoric microwear sub-sample is 4.0 (s.d.= 1.1) (Table 5). The mean microflake scar size is 1.1 mm. It is important to note that ten items lack microflake scars on this margin. Of those that have them, 52.0% have them on just the medial section of the edge, 24.0% exhibit them along the entire edge, and 20.0% bear them on the medial-distal section.

The microflake scar configuration pattern is random on 61.1% of the items having more than two scars. They are contiguously patterned on 16.7% of the specimens, and contiguous-superposed on another 16.7%. The most common (33.3%) microflake scar formal type includes those with expanding plan outlines and invasive terminations (Table 7). The next most frequent type is expanding/shallow-stepped (16.2%), followed by trapezoidal-expanding/ shallow-stepped (8.1%), expanding/deep-stepped (7.1%), trapezoidal-expanding/ deep-stepped (6.1%), crescentic/shallow-stepped (5.1%), and oblique/invasive for another 5.1%.

Where possible, concave margin microflake initiation types were asssesed as being either "Hertzian" (cone) or "bending" according to criteria defined by Cotterell and Kamminga (1987:681-693). The most common (82%) initiations are the bending type, whereas the Hertzian type comprise only 18%.

Striations can be observed on the concave margin on 42.9% of the tools in the microwear sub-sample (Appendix 6). Their general characteristics are described below in the discussion of the ventral face (Chapter 6.2.5). The "heads" of the striations originate along the ventral edge aspect of this margin, and they extend onto or across the ventral face on many specimens.

Crushing on the concave margin is absent for 68.6% of the sub-sample items. Its intensity is slight on 14.3% of the specimens, moderate on 8.6%, and pronounced on another 8.6%. For those tools possessing crushing, it can be observed along the medial-distal section of the margin on 36.4% specimens, another 36.4% have it along the entire margin, 18.2% exhibit it on the medial section only, and 9.1% bear it on the distal section only.

6.2.3 "Opposite" Margin

Rounding and smoothing intensity on the "opposite" margin is slight on 41.2% of the items in the prehistoric microwear sub-sample, moderate on 32.4%, prounounced on 5.9%, and it was absent for 20.6% (Appendix 6). Of those items exhibiting rounding/smoothing, it is located on the medial-distal section of the margin for 70.4% of the tools, 14.8% have it just on the medial section, and another 14.8% possess it on the entire edge.

Polish intensity is dull on 38.21% of the specimens in the sub-sample, moderately bright on 32.4%, bright on 8.8%, and for 20.6% it is lacking. For those tools exhibiting polish on this margin, 74.1% have it on the medial-distal section, and 22.2% bear it on the medial section only.

The mean number of microflake scars appearing on the "opposite" margin for each of the items bearing them is 4.6 (s.d.= 2.8) (Table 5), indicating that they are slightly more frequent on this margin than on the concave margin. The average microflake scar size on this margin is .7 mm, indicating that they are also slightly smaller. Microflake scars are present on the medial edge sections for 43.5% of the specimens bearing them, another 43.5% have them on the medial-distal section, and 13.0% exhibit them discontinuously along the entire edge.

The most common (63.2%) microflake scar configuration pattern on the "opposite" margin is considered to be random, followed by contiguous (15.8%), and contiguous-superposed (15.8%). The most frequently represented (32.2%) microflake scar formal type on this margin has an expanding outline and invasive termination (Table 8). Coincidentally, it is also the most common type on the concave margin, and constitutes about the same proportion on both margins. Other common types include expanding/shallow-stepped (13.3%), crescentic/invasive (8.5%), and oblique/invasive (7.5%). There are also several less frequent types that are more commonly represented on this margin than on the concave margin.

Striations are present on the "opposite" margin for 14.7% of the microwear sub-sample tools. In most instances they represent the "tail" portions of striations that extend across the ventral face from the concave margin edge aspect. They are described below in the discussion for the ventral face (Chapter 6.2.5).

Crushing is considered to be absent for 73.5% of the tools, its intensity is slight on 17.6%, and moderate on 8.8% When compared to the concave margin, it is slightly less common and not as pronounced. Of the items exhibiting crushing, it is most frequently (66.7%) represented on the medial-distal section of the margin, and 33.3% have it on the entire margin.

6.2.4 Proximal Margin

Microwear traces are present on the proximal margin of only 11.4% (n=4) of the prehistoric microwear sub-sample items. For three of these specimens, the wear is characterized by very slight edge rounding, such as might be expected by intentional dulling of an edge to render it more comfortable for hand-held use. The fourth specimen exhibits pronounced edge rounding/smoothing, polish, and striations typical of "hide-scraper" microwear (Brink 1978a; Hayden 1979b) (Figure 39), indicating that it had been recycled into a tool used for this purpose.

6.2.5 Ventral Face

Polish is indicated on the ventral face of the distal projection for all items in the prehistoric microwear sub-sample. Its intensity is dull on 14.3% of the specimens, moderately bright on 51.4%, and bright on 34.3%. It is located on the medial-distal section of the distal projection for 60.0% of the specimens, and 31.4% have it on the medial section only.

Rounding and smoothing intensity on protruding microtopographical features on the distal projection's ventral face is lacking for 37.1% of the sub-sample tools, it is slight on 34.3%, moderate on 11.4%, and pronounced on 17.1%. Of those that exhibit rounding/smoothing, it is most common (50.0%) on the medial section of the distal projection, and slightly less so (36.4%) on the medial-distal section. Two specimens (5.7% of the sub-sample) exhibit slight rounding and smoothing on the medial aspect of the proximal half of the tool's ventral face which is interpreted to be related to hafting prehension wear (see below).

Striation intensity on the distal projection's ventral face is slight on 40.0% of the sub-sample items, moderate on 8.6%, pronounced on 14.3%, and for 37.1% they are absent. For tools bearing striations, they are present on the medial-distal section of the projection on 59.1% of the specimens, and 31.8% have them on the medial section only. "Scratch-groove" striations are exclusive to 63.7% of specimens exhibiting striations in the microwear sub-sample. A combination of "scratch-groove" and "sleeked" striations are evident on 22.7% items, and 13.6% have "sleeked" (see Chapter 6.3).

By far the most common striation pattern type is "parallel unidirectional", constituting 81.8% of the items possessing striations in the microwear sub-sample. This pattern is typified by minute, parallel, linear scratches or furrows on the medial-distal or medial section of the ventral face of the distal projection that originate from the concave margin edge aspect. The majority of their "tails" are oriented toward the distal projection tip at a mean angle of about 64° in relation to the concave margin (Table 5; Figure 7).

The next most frequently (13.6%) represented striation orientation pattern type is referred to as "parallel multidirectional", whose sets of tails trend in more than two directions and crosscut each other (Figure 7). The "parallel bidirectional" pattern, indicated by two separate sets of parallel crosscutting striations, constitutes only 4.5% of the tools with striations.

6.2.6 Dorsal Face

Rounding and smoothing (and sometimes polish) intensity on the dorsal surface is slight on 22.9% of the prehistoric microwear sub-sample specimens, moderate on 20.0%, and it is absent for 54.3%. Of those exhibiting rounding/smoothing (45.7% of the specimens), 37.5% have it on both the proximal half of the dorsal surface and the medial aspect of the "opposite" margin's dorsal surface; another 37.5% have it on just the proximal half of the tool's dorsal surface; 12.5% possess it on the left-proximal aspect of the tool's dorsal surface; and the remaining 12.5% exhibit it just on the dorsal surface of the "opposite" margin's medial aspect (Appendix 6). The presence of rounding and smoothing in these locations is interpeted to be wear caused by manual and hafting prehension (see below).

6.3 Summary and Discussion

The results of the descriptive microwear analysis undertaken for the 35 randomly selected key-shaped formed unifaces comprising the "prehistoric microwear sub-sample" permit several important inferences to be advanced regarding prehistoric use-behaviour associated with this tool type.

The generalized pattern of microwear traces observed on the distal projection tip (Chapter 6.2.1) indicates that the most frequently used -- and therefore most functionally important -- elements are its ventral-lateral corners. They are formed by the junctures of the concave margin, distal margin, "opposite" margin, and ventral face (Figures 2, 8a, 21 and 22). Secondary functional importance is indicated for the distal margin of the projection tip (Figures 2 and 8b). The primary motor patterns (i.e., use-motions) associated with the distal projection are a generalized burin-like gouging, prying, graving, and incising action involving both ventral-lateral corners and the distal edge (Figures 2 and 8a). Working of a relatively hard contact material is indicated by moderate to pronounced intensities of edge rounding and smoothing, polish, and crushing; and moderately high mean microflake scar frequencies and large mean microflake scar size (Table 5).

Given that the distal tip ventral-lateral corners (Figures 2 and 8a) were important functional elements of key-shaped formed unifaces, I offer that at least in some cases, flexure and torsion breaks observed on the distal ends of several items in the prehistoric microwear sub-sample (Appendix 6), (and in the larger study sample), may have been intentionally initiated during tool production and/or maintenence to create or rejuvenate acute angles on the ventral-lateral corners. This may have been executed for specimens lacking only a small portion of the original distal projection tip (e.g., Figures 12e, 13b, 13h, 14b, 14j, 15s, 16z, 16a', 18q and 20z). However, for items lacking more than 1/3 of their initial projection (e.g., Figures 11c, 11f, 11j, 11k, 13e, 15m, 16b', 16h', 18g, 18h, 19c and 19h) it seems more probable that their breaks were accidentially incurred by excessive loads of applied force during use, particularly during graving and incising activities (see Chapter 8.4; Figures 48 and 50).

The moderate to high intensity and frequency of microwear traces evident along the concave margin edge aspect and immediately adjacent ventral face (Chapter 6.2.2; Appendix 6; Tables 5 and 7; Figure 8c) clearly indicates that this margin is the most functionally important feature of key-shaped formed unifaces. The nature of these trace patterns suggests that the primary use-behaviours associated with this edge involved scraping, shaving, or planing of relatively hard cylindrical contact materials (see Chapters 5.3 and 8 for supporting data and interpretations). The high frequency (82%) of "bending"-type initiations for microflakes removed from the concave margin suggests that either wood, antler, or bone were probably being worked (Cotterell and Kamminga 1987: 690-691).

The interpretation of the microwear traces on the concave margin supports the design analysis conjecture (Chapter 3.3) that the main motor pattern associated with this edge involved placing the distal 2/3 of the ventral face of the distal projection against a cylindrical contact material with the edge facing the user's body at a slightly oblique angle such that the tip of the projection was pointing away. The tool was then drawn toward the user in repeated strokes down the length of the contact material (e.g., Figures 43 and 44).

Many specimens in the study sample testify that their concave margins were subjected to repeated resharpenings (Chapter 3.3.2; Figure 5), a maintenance practice that resulted in removal of previously incurred microwear traces along the immediate margin edge and edge aspects. This may partly explain why the mean frequency of microflake scars on the concave margin edge aspect was slightly lower than on the "opposite" margin, and why about 28% of the microwear specimens lacked microflake scars on their concave margin edge aspects altogether.

The intensity of microwear traces exhibited on the "opposite" margin indicates that it was used less frequently than the concave margin, and it also displays much greater morphological and technological variability (Chapter 6.2.3; Appendix 6; Tables 5 and 8). For these reasons I have inferred that it had less functional importance than the concave margin. This is supported by the observation that clear evidence for resharpening of this margin is rarely indicated for specimens in the prehistoric study sample. Direct evidence for resharpening is considered to include: sharply differential microwear intensities (notably rounding, smoothing, and polishing) appearing discontinuously along functional edges and/or their edge aspects; functional edge margins that are markedly indented relative to adjacent non-functional margins; and functional edges that have fairly regular (i.e., consistent or non-sinuous) outlines.

The primary reconstructed motor pattern associated with the "opposite" margin is a generalized shaving/scraping/planing action similar to that described above for the concave margin. However, for this margin, the tool would have been pushed away from the user along the length of the contact material in a "flicking" or "whittling" action (e.g., Figures 45 and 47). Working of a relatively hard contact material is also indicated by the nature and intensity of microwear trace patterns.

The microwear trace patterns appearing on the ventral face of the distal projection on the majority of the prehistoric microwear sub-sample tools (Chapter 6.2.4; Figure 8e) indicate that the distal 2/3 of the projection's ventral face was often incidentally engaged with the contact material during use of the concave margin. The character and orientation of striations, and the location and intensity of polish both reinforce the conclusion that the concave margin was the primary functional edge of prehistoric key-shaped formed unifaces.

Most striations appearing on the ventral face are classified as the "scratch-groove" type (e.g., Figures 24, 25, 27 and 35). They are linear trough-like features with "U"- or "V"-shaped cross-sections that have been gouged directly into the surface of the tool by abrasive particles (e.g., silt, sand, dust, grit) introduced between the ventral face of the tool and the contact material while the tool surface was in the "solid-gel" state (Mansur 1982) (see Chapter 6.1.3). Autoabrasion is not suspected to have been a significant contributor to striation development on most tools, as very little or no material loss is indicated along concave or "opposite" margin edges.

"Sleeked" striations occur less commonly, and appear as flowing and undulating trend lines (Figures 24 and 30). It is probable that "sleeked" striations were initially the "scratch-groove" type incurred during the early stages of a tool's use-history. During subsequent use they became mechanically smoothed, rounded, and polished while silica on the tool surfaces was in the "liquid-gel" or "intermediate" state (Mansur 1982).

Because the most common striation pattern type is classed as "parallel unidirectional", and most striations are the "scratch-groove" type displaying consistent formal regularity for their entire lengths, I conclude that the contact material being worked must have had high abrasive particle "holding" or "fixing" properties. This refers to the ability of a contact material to stabilize (i.e, trap) and maintain abrasive particles in direct contact with a tool during use (see Lawn and Marshall 1979:79-81).

Knutsson (1988:92) indicates that the high holding/fixing properties of wood, which can easily stabilize abrasive particles within and between its fibres, results in production of continuous and morphologically regular striations. In contrast, antler and bone do not readily trap abrasive grains because of their greater hardness and density. Consequently, particles are transfixed only momentarily or roll around freely, producing striations that are more likely to be morphologically irregular and discontinuous. Following these criteria, striations observed on almost all the prehistoric microwear sub-sample specimens were likely produced by contact materials with holding/fixing properties more similar to wood than those characteristic of antler and bone.

Polishes on the ventral face suggest that the most common type can be provisionally classified as "abrasive", although the "additive" type may be represented on some specimens. In general, abrasive polish was inferred when the tool surface had a worn-down appearance in relation to adjacent unaltered surfaces and microtopographical features; additive polish was provisionally identified when it appeared to be built-up. Given the mechanical and chemical processes contributing to the formation of these two main polish categories are controversial and still not completely understood, and their differentiation requires electron microscopy (see Bettison 1985; Knutsson 1988), an attempt to identify and quantify them was not undertaken in the present study. Regardless, it is clear that the contact material most commonly worked by prehistoric key-shaped formed unifaces produced predominantly moderately bright to bright intensity polishes, such as that produced by working plant parts or antler (see Chapter 8).

It is evident that the proximal margin had absolutely no functional importance with respect to the primary use-behaviour of key-shaped formed unifaces. This is indicated by the very low incidence and slight intensity of observed microwear traces; its high degree of morphological and technological variability; and since many tools appear to have been hafted, it would have been unavailable for use. Nevertheless, broken or exhausted tools were occasionally recycled into "endscrapers" by modifying and using this edge (Figures 5 and 39).

For many specimens (46%) in the microwear sub-sample, discrete areas of rounding and smoothing (and occasionally associated slight polish) on the dorsal tool surface are interpreted to be prehension wear caused by the user's hands and/or a hafting device rubbing in these locations (see Chapters 6.1.6, 6.2.6 and 8.4). Wear appearing on the left-lateral aspect of the proximal half of the dorsal surface is attributed to the user's thumb having rubbed in this location for extended periods of time while the tool was being used hand-held (Figures 8h and 36). Abrasive wear appearing on prominent features over the medial section of the tool's dorsal face (and occasionally on the ventral face) was likely caused by side-to-side movement within a loose haft (Figures 8i and 8f). Wear appearing on the medial aspect of the "opposite" margin's dorsal surface is likely the result of the user's thumb or forefinger rubbing this location for tools used either hand-held or hafted (see Figures 8g, 37, 38, 43, 44, 46 and 48).

"Atypical", random, or low frequency microwear trace pattern types (e.g., unusually large microflake scars, extensive and intensive edge crushing, multidirectional striation configuration patterns) observed on some of the specimens in the prehistoric microwear sub-sample (Appendix 6; Tables 5, 7 and 8) may be attributable to either: (1) incidental forceful contact with hard objects while being curated in prehistoric times; (2) improvisational execution of unanticipated or infrequently recurring situational tasks; (3) post-depositional trampling; and/or (4) accidental damage incurred during contemporary artifact transport, storage, and analysis.

The general microwear patterns observed on the 35 microwear sub-sample specimens described in this chapter serve as a comparative basis for attempting to infer the primary function of prehistoric key-shaped formed unifaces through a judgemental "best-fit" comparison with microwear traces observed on the ten experimental tools used in this study (Chapters 7 and 8).