Functional Analysis of Flake Tools from Chiripa, Bolivia

Document 1
Taraco Archaeological Project

Matthew Sebastian Bandy
Department of Anthropology, University of California, Berkeley
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The Problem

The present paper represents an attempt to formulate a methodology for studying the uses of prehistoric flake tools in the Formative and Post-Formative periods in the Titicaca Basin. Although elaborate and standardized categories of chipped stone tools were produced in these periods, these are largely restricted to projectile points and hoes. Inspection of excavated assemblages from Chiripa, Bolivia, however, reveals unambiguously that large numbers of minimally-modified debitage pieces were employed as tools, leaving unmistakable wear traces on their utilized edges. Analysis of these implements could provide useful information on the types and patterning of activities undertaken in excavated sites. This tool industry is, however, of an expedient and informal nature, with no readily-discernable correspondence between tool form and function. Such a situation presents certain problems for the analyst interested in constructing a functional typology for flake tools. For the most part, this problem has not been addressed in the Titicaca Basin, with studies of lithic artifacts concentrating on the more elaborate projectile points and ground stone, the more informal flake tools remaining unaddressed.

It has become generally recognized that highly formal tool industries, such as those of the European Paleolithic, are exceptions rather than the rule, and that for the most part lithic industries become more expedient and less formal with the adoption of agricultural subsistence regimes (Torrence 1989). As Odell (1981: 323) notes, "In certain areas of the world where the use of stone tools has been observed and reported in the literature ... the entire concept of morphological typology appears to be either useless as a classificatory technique or functionally irrelevant." Detailed ethnoarchaeological observations (Gallagher 1977; Gould, Koster and Sontz 1971; Hayden 1977; White 1968, 1969; White and Thomas 1972) and studies of archaeological assemblages (e.g. Keeley 1980; Odell 1981; Vaughan 1985) have demonstrated that in many modern and past contexts tool production and use was conducted in an expedient manner. Analysis of these assemblages cannot rely on any straightforward correspondence between tool form and function. Accordingly, a battery of techniques has been developed over the past thirty years to allow the inference of tool function from the traces left by utilization. This paper, then, represents an attempt to employ this body of research in the analysis of the flake tool assemblage from Chiripa.

The Site

The site of Chiripa is located in the community of the same name, on the northern littoral margin of the Taraco Peninsula. Chiripa lies on the road between Taraco and Lukurmata, and is approximately equidistant from these two towns. It is about 20 km from the site of Tiwanaku. The most conspicuous architectural remnant at the site is the *monticulo,* a large mound which was originally constructed in the Formative period, and later remodeled in Tiwanaku V times. The *monticulo* was excavated by Bennett (1936) and later by Kidder (1956) and Browman, and has served as the type site for the local Formative ceramic sequence. Apart from the *monticulo,* there is no architecture visible on the surface of the site, but a dense scatter of ceramic and lithic artifacts, as well as human and animal bone, in the surrounding fields attests to the intensity of the occupation. Excavations at the site in 1992 by the Taraco Archaeological Project (TAP; Hastorf et. al. 1992) has demonstrated the presence of several terraces with evidence of habitation and mortuary use. It is probable that more architecture is present, but long-term intensive farming of the area has obscured its manifestation on the surface of the site.

In the course of the 1992 excavations, six separate trenches were opened, the majority of which were excavated until sterile soil was reached. They reveal a complex occupational history, with Formative, Tiwanaku IV and Tiwanaku V occupations evident. Apparently, there is no Pacajes or Pacajes-Inka (Albarracín-Jordan and Matthews 1990) occupation at the site.

As the analysis of ceramics from the site has not yet been completed, it is as yet impossible to assign relative chronological values to specific excavated contexts. For this reason, the present analysis will consider the flake tools from the entire site, considered as a single assemblage. Patterns of temporal variation in the assemblage will not be considered in this paper, but the functional typology elaborated here will serve as a baseline for comparing the assemblages from various periods of the site's occupation.

Use-wear Analysis

Great strides have been made in the functional analysis of stone implements since the translation of the work of Semenov in 1964 (see Vaughan 1985; Keeley 1980; Olausson 1980; Sussman 1988). A host of researchers have conducted experimental programs designed to establish correlations between specific traces on stone tools and the actions which produced those traces. This ferment has produced two broad schools of inquiry, the low and high power approaches (Olausson 1980; Keeley 1980; Vaughan 1985; Odell 1980). The high power approach, which is commonly identified with the work of Keeley, advocates the use of very high magnifications (200X or more) and concentrates on the analysis of micropolishes and striations. The low power approach, identified with Odell and his colleagues (Odell 1980, 1983; Tringham et. al. 1974), uses lower magnifications and emphasizes the examination of edge damage (i.e. microchipping and rounding).

The approach employed in this analysis will be a low power one, employing a 20X hand lens. There are a number of reasons why this alternative was selected. The first is that much of the information produced by the high power approach is of limited or no value in the analysis of wear traces on coarse-grained materials (Moss 1983; Olausson 1980; Richards 1988; Schick and Toth 1993: 176; Sussman 1988). The rather pronounced surface microtopography of these materials prevents the formation of well-developed patches of polish. In addition, the hardness of some of these materials, particularly quartz and quartzite, imparts a resistance to wear and striations. As upwards of 90% of the Chiripa flake tool assemblage is composed of local quartzites, the high magnification approach is obviously unsuitable for the present study.

Additional complicating factors for the high power approach involve the high cost in time and resources required in order to carry out an analysis. These costs usually result in a very small sample of analyzed artifacts, raising statistical difficulties. Finally, the policy of the Bolivian government regarding the export of artifactual materials made it necessary for analysis to be carried out in-country. The logistical difficulties that would have to be overcome in order to undertake a high magnification study in these conditions are obviously significant.

Furthermore, the initial confidence in the potential of high magnification studies which characterized the work of the pioneers in the field (cf. Keeley 1980) seems recently to have been tempered with a healthy skepticism (Cook and Dumont 1987; Holmes 1987; Newcomer et. al. 1987). A series of blind tests conducted by a number of researchers (Keeley 1980; Newcomer et. al. 1987; Richards 1988; Vaughan 1985) have demonstrated that the identification of tool function using the high magnification approach is ambiguous at best. This is not to suggest that high magnification studies should be abandoned, but the characteristics of wear traces as related to specific functional interpretations must be more explicitly and objectively defined (Dumont 1982; Grace 1989; Grace et. al. 1987).

For these reasons, a low magnification approach has been selected for the purposes of this study. The so-called 'low power approach' was pioneered by a group of researchers from Harvard University (Tringham et. al. 1974). Their research consisted of an extensive experimental program designed to investigate the effect of a series of use factors on the formation of edge damage (particularly microchipping) in flint tools. They concluded that patterning in edge damage in archaeological assemblages could be used to infer functional information, and that use-related damage could be distinguished from that resulting from technological or post-depositional processes.

Subsequent research (cf. Akoshima 1987; Moss 1983; Odell 1980; Odell and Odell-Vereecken 1980; Vaughan 1985) has generally supported this conclusion, although the influence of post-depositional and technological factors has come to be recognized as significant and not entirely analytically separable from use-related damage. This work has led Vaughan (1985: 12) to conclude that "The possibility that patterned edge-flaking ... on archaeological stone tools is due to non-use agencies and not necessarily to intentional retouch or utilization by humans is of significant import for any use-wear analysis which relies heavily on the attributes of edge scarring." Non-use factors, then, must be taken into account in any use-wear analysis, whether employing low- or high-power methods.

A consideration of the use-wear literature leads me to propose two general statements regarding the functional analysis of microchipping:

- 1: The current methodology of functional analysis is not sufficiently reliable to allow the establishment of a one-to-one correspondence between use factors and microchipping for individual tools. An alternate approach is to focus on the detection of gross patterns of variation to establish ranges of probable functions for classes of stone tools. These classes may be defined according to the analytical convenience of the investigator. This will be the method adopted in the present analysis.

- 2: It must be demonstrated, for any particular archaeological and depositional context, that non-use factors do not account for the assemblage-level patterning observed.

The first point is of particular significance. Practically all use-wear analysis to date has attempted to infer functions individually for specific tools. While this may be feasible in certain ideal contexts, the results of the previously-mentioned blind tests of high power microscopic analysis suggests that the margin of error is too broad for this style of analysis to be useful at present. However, the extant techniques are accurate enough to detect broad patterns of functional differentiation that may exist between different groups of tools.

This, then, will be my strategy in analyzing the Chiripa assemblage. The various use- and non-use factors relevant to microchipping will be outlined and defined, drawing on published accounts of experimental and archaeological assemblages. The classification of the Chiripa assemblage will then be presented, and gross patterning in the assemblage, so classified, will be inspected for any functional information it may contain.

Use-related factors

Two factors related to the use of a tool are generally investigated by analysts employing the low magnification approach. These are the mode of action, that is the actual motion by which the tool was employed, and the hardness of the worked material. Low power analysts generally do not claim to be able to distinguish between damage caused by worked materials of similar hardness, such as bone and antler. Some success has, however, been achieved in the investigation of these two functional variables.

Mode of Action. A number of researchers have used the distribution of microchipping scars as an indication of the motion in which a tool was employed (Akoshima 1987; Odell 1980; Odell and Odell-Vereecken 1980; Tringham et al. 1974). Three basic modes of use have been defined by previous researchers (Tringham et al. 1974: 181). Transverse actions, such as whittling, planing and scraping, will produce microchipping that is "exclusively unifacial, or almost so" (Odell and Odell-Vereecken 1980: 99; see also Tringham et al. 1974: 188-189). In transverse motions, microchipping will occur on the surface that is opposite the material being worked. Longitudinal motions such as slicing, on the other hand, will produce bifacial microchipping. Rotative motion, such as that used in boring and drilling, will produce bifacial microchipping on an edge that is triangular in plan (Tringham et al. 1974; Yerkes 1983). Most researchers have reported results that are consistent with those presented above. However, Vaughan (1985: 19-22) observed a much greater degree of variability in his experimental assemblage. The reasons for the divergence of his results from those of previous experimental programs are not at all clear, and for the purposes of the present analysis I will take the distribution of microchipping between the two edge aspects to be a gross indicator of the mode of action.

The distribution of scars along a worked edge can also be an indication of the mode of action (Tringham et al. 1974: 188-189). Longitudinal actions will result in even, discontinuous scarring while transverse motions will produce clustered scarring on the surface opposite the contact material. Vaughan (1985: 20), however, has reported that this attribute is a very poor indicator of the mode of action, as has Akoshima (1987).

Worked material. The determination of the material worked by a tool has been a major concern of microchipping analysis (Akoshima 1987; Odell 1980; Odell-Vereecken 1980; Keeley 1980; Tringham et al. 1974; Vaughan 1985). The significance of the contact material for the formation of edge damage was first recognized by John Evans in 1872 (Tringham et. al. 1974: 183), and was also important in the work of Semenov (1964). Most analysts have established classifications of materials based on their hardness. The following list is taken from Vaughan (1985: 21). Similar lists have been compiled by other researchers (see Appendix 1)[1].

- hard: bone in any state, dry antler, dry woods, carcass;
- medium-hard: fresh and soaked almond wood, soaked antler;
- medium-soft: fresh and soaked cypress wood, reeds, barley and wild *Gramineae,*

dried beef;

- soft: meat without bones, hides, green plant stems, cattail.

The distal termination of microscars has been proposed as a potential indicator of the hardness of the material worked with a tool (Odell and Odell-Vereecken 1980; Tringham et al. 1974). Reportedly, predominantly feather terminations result from the working of soft and medium-soft materials, hinge terminations from that of medium-hard materials and step terminations from the working of hard materials. Other researchers (Akoshima 1987; Vaughan 1985) have confirmed these associations as general tendencies, but not as accurate measures of function.

Some investigators have suggested that the proximal cross-section of microscars is a better indication of worked materials than the distal termination (Hayden 1979; Lawrence 1979). Vaughan (1985: 22) encountered great variation in the expression of the proximal cross-section of microscars within classes of worked material hardness, and concluded that the attribute is of little use in the determination of tool function.

Microscar size is another attribute with potential relevance to the determination of worked material. Odell and Odell-Vereecken (1980) have suggested that the working of harder materials produces predominantly larger scars than does the working of softer materials. Other analysts (Akoshima 1987; Vaughan 1985) have confirmed this tendency through independent experimentation, although they stress, once again, that there is no one-to-one correspondence between scar size and the hardness of the worked material.

Finally, it has been proposed (Odell and Odell-Vereecken 1980; Tringham et al. 1974) that the attribute of microchipping ' edge row' , that is "small step or hinge scars within the proximal region of larger microchipping" (Vaughan 1985: 21) is produced by contact with harder materials. Vaughan (1985) has confirmed this association with the caveat that edge-row scarring is produced only infrequently, even when edges are in contact with hard materials (more than 50% of his experimental specimens used on hard and medium-hard materials displayed no edge-row formation). Akoshima (1987), however, concludes that the edge row attribute is of little analytical use.

Other use-related factors in microscar formation, such as the force exerted in using the tool, the angle at which it contacts the worked material, duration of use, edge morphology, and so on, have been less-thoroughly investigated, although some attempts have been made (Keeley 1980; Vaughan 1985; cf. Olausson 1980). Most analysts, however, simply attempt to hold these variables constant in their experiments. Their effect on actual archaeological assemblages, therefore, is extremely difficult to gauge. The best that can be done at present is simply to acknowledge that they are significant.

Non-use factors

A number of non-use factors influence the microchipping observable on archaeological chipped stone tools. The most significant of these are scarring resulting from deliberate retouch, post-depositional processes and post-excavation handling, as well as variation in the fracture properties of different raw materials.

Microchipping from deliberate retouch. Retouch of working edges in order to create a desired edge morphology also produces microchipping. This factor has been of interest to investigators since the work of Semenov (1964). It has also been discussed by Frison (1968), Tringham et al. (1974), Moss (1983), Vaughan (1985) and others (cf. Olausson 1980). In addition, edge abrasion for the purpose of platform preparation can mimic use-related microchipping (Sheets 1973). However, no criteria have been developed to distinguish use-related microscars from those produced by tool manufacture.

Post-depositional processes. A number of experiments have been devised to test the edge scarring effects of compression on buried stone tools. Tringham et al. (1974) emphasized that compression produced unpatterned microchipping, while Vaughan (1985) sees some patterned scarring evident. Patterned edge damage has also been observed to result from trampling (Flenniken and Haggerty 1979) and solifluction (Odell 1981). Vaughan (1985: 24) concludes that "microanalysts must be aware of the fact that *patterned* as well as *random* edge chipping of various sizes and types result from non-use damage mechanisms." It is apparent, however, that edge damage resulting from post-depositional processes, while it may obscure patterned damage due to use, and can even, in the case of individual artifacts, mimic use-related damage, is not, barring exceptional circumstances, patterned at the level of the assemblage.

Post-excavation damage. Vaughan (1985: 24), among others, has examined the result of rough handling of archaeological materials subsequent to excavation. While this damage, due to storage of multiple tools in individual bags, as well as to emptying large numbers of stone items onto a table simultaneously, was considerable, if the analyst is dealing with freshly-excavated materials such recent damage should be easily-distinguishable from ancient scarring.

Raw material. Most experimental studies of microscar formation have employed flint or chert tools, although a few have used basalt (Odell 1980; Richards 1988), quartz (Broadbent and Knutsson 1975; Sussman 1988) and obsidian (Schousboe 1977; Spear 1980). Odell notes that the basalt, being coarser than flint, tends to exhibit more step-terminated microscars. Early indications are that raw material has implications for microscar morphology (proximal and distal termination and size), but not for their distribution along the worked edge or between the contact and non-contact surface. This point will not be resolved, however, until more experimental programs begin to take into account differences in the fracture properties of the various raw materials which were employed by archaeological cultures.

Functional Determination of the Chiripa Assemblage

The flake tool assemblage from Chiripa consists of 280 separate pieces, bearing a total of 298 edges displaying evidence of utilization. The majority of the tools are made of quartzite, with fewer tools of metamorphic rocks, cherts, chalcedony, basalt and obsidian. All of these materials except basalt and obsidian are available locally in the form of cobbles in the alluvial terraces immediately to the south of the site. The frequencies of the various raw materials in the assemblage are shown in Classification

White (1968) and others have noted that a chipped stone artifact may display more than one utilized surface, relating to concurrent or sequential episodes of use. For this reason, the analysis presented here takes as the basic unit of analysis the individual retouched and/or utilized edge. In this I follow a number of other researchers (e.g. Barton 1988; Watson and Cole 1977; Vaughan 1985). The analysis that follows, then, is an analysis of utilized edges, and not necessarily of individual artifacts.

The classification presented here is designed to analytically highlight the functional dimension of variation in the assemblage. It is not, therefore, the only classification possible, and, in fact, is only one among infinite alternatives (see Dunnell 1971). Three dimensions of variation have been selected which are of demonstrated or potential functional significance: 1) plan of edge, 2) retouch, and 3) edge angle. Each of these dimensions, in this or any classification, has an arbitrary (i.e. analytically-defined) range of possible values ("modes"; see Dunnell 1971; Watson and Cole 1977). These modes are listed below.

- Dimension 1: Plan of edge.
  - Mode 1: Straight
  - Mode 2: Concave
  - Mode 3: Convex
  - Mode 4: Triangular

    - Mode 5: Irregular
    - Mode 6: Denticulate

- Dimension 2: Retouch.
    - Mode 1: Absent (unretouched)
    - Mode 2: Unifacial
    - Mode 3: Bifacial

- Dimension 3: Edge angle
    - Mode 1: 15-45 degrees
    - Mode 2: 45-75 degrees
    - Mode 3: 75-105 degrees
    - Mode 4: Highly variable

Dimension 1: Plan of edge. This attribute refers to the outline of the edge when viewed from above. Concave edges are generally thought to have been employed in a transverse manner in order to shape small, elongate pieces of wood, bone or antler such as arrow shafts, needles, awls and the like. They are conventionally referred to as shaft straighteners, spokeshaves or notches. Straight and convex edges were probably used to cut, saw, plane, whittle or scrape a variety of materials. Triangular edges were probably employed in a rotative motion (Tringham et al. 1974; Yerkes 1983) to bore or drill resistant material. Denticulate edges have been thought to have been employed in the shredding of vegetal material, and probably in other roles as well.

Dimension 2: Retouch. This dimension refers to the intentional reshaping of an edge through applied force in order to modify its morphology to a form appropriate to a specific activity or range of activities. As discussed previously, it is also significant in the analysis of microchipping, as deliberate retouch is one of the non-use factors that influences observed microscar patterning.

Dimension 3: Edge angle. This refers to the angle of the utilized and/or retouched edge (see Tringham et al. 1974: Figure 1). Of course, the angle of an edge varies a great deal. In measuring edge angle, I followed a standard procedure of recording the largest value possible on the most-utilized portion of an edge. As previously mentioned, the angle of an edge is of some significance for the formation of microchipping. Higher edge angles are more resistant to chipping than are lower ones (Olausson 1980; Vaughan 1985; contra Akoshima 1987). The dimension of edge angle has also been much-discussed as an indicator of tool function. Wilmsen (1974: 91-92) has approached edge angle from the perspective of stone fracture mechanics, and has concluded that certain ranges of edge angles are optimal for certain tasks. Specifically, he argues that edges between 35 and 45 degrees are appropriate for the cutting of soft materials and for butchering, and edges between 50 and 75 degrees for the working of hard materials; the smaller angles in this latter range would be useful for cutting these materials, and the larger ones for scraping or planing them. While Wilmsen' s work has been the subject of considerable criticism (e.g. Olausson 1980) it provides a useful baseline for analysis. Other investigators have found edge angle to be analytically useful. White (1968) found that this dimension was the single most important predictor of function in a New Guinea ethnographic assemblage, and Watson and Cole (1977: Figure 117) found a strong edge angle bimodality in New Guinea archaeological chipped stone tools. They interpreted this patterning as reflecting a functional distinction. The edges clustered at 30-40 degrees on the lower end, and at 70-80 degrees on the higher. Finally Vaughan (1985), in his study of Magdalenian ' 0' flints from the site of Cassegros, France, discovered that the angles of edges employed in transverse actions tended to be higher than ones employed in longitudinal ones. While the bimodality in his collection was weak, some blurring of patterning is to be expected, due to the uncertain nature of functional analysis.[2] The fact that a bimodal distribution was detected at all is suggestive. The predominance of particular edge angle ranges in particular classes of tools, then, can be taken as circumstantial evidence for tool function. When combined with evidence derived from microscar analysis, it can serve as an additional line of evidence to confirm or refute functional attributions of particular classes.

Some researchers have suggested that the weight of a tool is of functional significance. Rick (1980), for example, discovered a bimodal distribution of tool weight in a preceramic assemblage from highland Peru. Figure 1, however, demonstrates that the weight distribution in the Chiripa assemblage is continuous and unimodal. For this reason, weight has not been included as a classificatory dimension in the present analysis.

The intersection of these three dimensions, then, forms the ' class' . For example, class 3.1.2 refers to an edge that is convex in plan, lacks retouch and has an edge angle in the range of 45-75 degrees. The actual edges that pertain to a particular class are termed ' denotata' . Table 1 is a list of all the classes which have denotata in the Chiripa assemblage.

Microchipping in the Chiripa assemblage

Considerations of time and resources in the field required that limited information be collected pertaining to the microchipping evident on individual edges. No tabulation of scars was made, nor was any measure of scar size or morphology undertaken. The only information which was recorded was 1) the presence or absence of non-recent microchipping on each aspect of the retouched and/or utilized edge, and 2) the distribution of microscars between the two aspects. From these data, two functionally significant indices may be constructed. I have termed them the Microchipping Bifaciality Index (MBI) and the Microchipping Ubiquity Index (MUI).[3]

The Microchipping Bifaciality Index is the ratio of bifacially damaged edges in a given class to the total number of damaged edges. For the present analysis, I have defined bifacial damage as that in which no more than 70% of non-recent damage scars are concentrated on a single aspect of the edge. If b is the number of bifacially damaged edges in class, and u is the number of unifacially damaged edges, then:

MBI = b / (b + u)

MBI, then, provides a measure of the prevalence of bifacial relative to unifacial microchipping (as defined previously) within in a class. It is therefore relevant to the determination of the mode of action which was employed in the use of the tools which comprise the class.

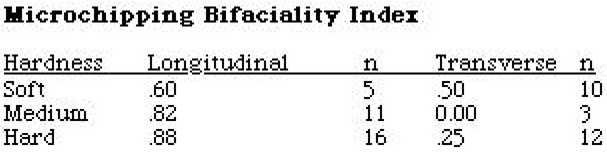
The Microchipping Ubiquity Index, on the other hand, is the ratio of damaged edges to the total number of utilized edges in a class. If a is the number of edges in a class lacking visible microchipping, then:

MUI = (b + u) / (b + u + a)

The functional significance of the MUI value is less obvious that that of the MBI. If it is remembered, however, that the edges were analyzed at 20X magnification, it becomes apparent that the index is, in essence, a combined measure of scar presence/absence and of scar size. It is the frequency, in a particular class, of edges which exhibit microchipping visible at 20X magnification. This is relevant to the determination of the hardness of the material on which the tools which comprise the class were used, as harder contact materials tend to produce both more and larger scars, and therefore higher MUI values. The higher the MUI value, therefore, the harder the contact material.

Unfortunately, most researchers who have undertaken experimental investigations of microchipping have reported their results in aggregate form rather than detailing the damage evident on individual edges. It is impossible to transform such aggregate information into MBI or MUI values. Several reports, however, have included information on damage to individual edges, and it is possible to predict from this information the expected values of both indices for a range of modes of action and contact material hardness.

Information relevant to the Microchipping Bifaciality Index was drawn from Akoshima (1987: Figure 9.4). The results are stratified according to contact material hardness, as it will be seen that this factor has significance for the expression of MBI values. The results of Akoshima' s research are presented below in highly modified form.



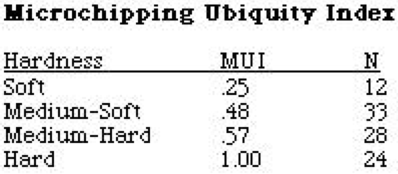
Microchipping Bifaciality Index

Hardness	Longitudinal	n	Transverse	n
Soft	.60	5	.50	10
Medium	.82	11	0.00	3
Hard	.88	16	.25	12

[4]

First of all, we may conclude from these data that MBI values are useful for separating longitudinal from transverse modes of action when harder materials are worked. The index is still useful for softer contact materials, but the modes of action are not so clearly separated. This points up one weakness of the MBI, namely that it is not as effective an indicator of mode of action for tool classes that were used on soft materials as it is for those used on medium and hard ones.

Predicted values for the Microchipping Ubiquity Index are from Richards (1988: Table 28). Transformation of the data presented by Richards into MUI values is somewhat difficult, however, as 1) he observed edge damage at a higher magnification (40X) than is the case for my observations (20X) and, 2) his measures of scar size are presented in terms of scar length, rather than presence/absence. Therefore, I have calculated MUI values from Richards'   data using only microscars longer than 2 mm in length, and ignoring shorter ones. This is roughly comparable to a presence/absence measure observed at 20X magnification (such as the one I used in the coding of the Chiripa materials) since smaller scars would not be easily visible at this lower magnification. Such an approximation is not exact, but it should provide an approximate range of MUI values for contact materials of varying hardness. These values are shown below, together with the number of tools in each group.



Microchipping Ubiquity Index

Hardness	MUI	N
Soft	.25	12
Medium-Soft	.48	33
Medium-Hard	.57	28
Hard	1.00	24

[5]

It must be remembered, however, that the experiments used above to provide comparative MBI and MUI values were conducted on tools of slate (Akoshima 1987) and vitreous basalt (Richards 1988). The values obtained, therefore, must be considered approximate and preliminary. Refinement of these figures awaits a full experimental program conducted using quartzite tools which is reported in a complete manner.

Non-Use microchipping in the Chiripa assemblage

As was previously noted, the materials were examined in the field, immediately after they were excavated. For this reason, and as the excavation was conducted carefully, using trowels and brushes, I will assume that 1) excavation-related microscarring was minimal in the assemblage[6] and 2) that I was able, in the recording the microchipping, to distinguish between ancient and recent scars. Post-excavation edge damage will therefore not be considered as a factor relevant to the microchipping observed in the assemblage.

Post-depositional natural and cultural factors are, however, decidedly relevant to the analysis at hand. While sub-soil turbation seems to have been minimal at the site, due to the absence of trees, burrowing rodents or solifluction, the excavation areas have been probably been continuously farmed and grazed for the past seven-hundred years. While deep-plowing has not been employed at the site, ox-drawn plows have been in use at least since the seventeenth century, hoes and digging sticks being used before the arrival of Europeans in the area. The surface of some areas has also recently been used as a source of clay for the manufacture of adobes, entailing significant churning of shallow deposits. Such activity probably also took place in prehistory. In terms of the intensity of action of post-depositional processes, then, the excavated deposits can be divided into two groups. Levels 0 (surface) and 1 (plow zone) can be expected to have been exposed to more damage by these factors than have the tools from deeper deposits. If these processes have significance for the MBI and MUI values of the assemblage, a difference should be observed between the tools from levels 0-1 and those from level 2 or deeper.

The precise manner in which these processes affect MBI and MUI must be considered before proceeding with this comparison. While processes such as trampling and plowing, as discussed previously, may produce patterned damage on individual artifacts, they do not do so on the level of the assemblage. We would not, then, expect the Microchipping Bifaciality Index to be significantly affected, since it is a measure of the relative distribution of scarring between the two aspects of an edge. Since MBI is not a presence/absence measure, a very considerable amount of post-depositional scarring must take place in order to alter the observed predominantly bifacial/predominantly unifacial ratio of a class. However, a significant amount of post-depositional scarring, unpatterned with respect to ventral or dorsal surface, would be expected to progressively obscure predominantly unifacial microchipping, thus increasing the number of apparently bifacially-scarred edges and therefore the MBI ratio, as well. The Microchipping

Ubiquity Index, on the other hand, being a presence/absence measure, would be more sensitive to these factors. Edges which previously bore no visible edge damage would be expected to incur nonuse-related scarring, thus increasing the value of the MUI ratio.

Figure 6 presents a comparison of the Microchipping Bifaciality Index values between levels 0-1 and levels 2+ for three classes of utilized and/or retouched edges. These classes were chosen for the comparison because they were the only ones with enough denotata to from each of the level groups to make meaningful comparison possible. The data show that for two of the three classes presented, MBI is actually slightly higher for the less-disturbed levels. The sole exception to this is class 3.1.2. However, the elevated MBI for 3.1.2 edges from levels 0-1 can plausibly be discounted due to the small sample size for this group (n=5). The expected pattern, then, is not evident in the MBI data. The influence of post-depositional processes on the MBI value can therefore be tentatively construed to be minimal, or at least unpatterned.

Figure 7, however, shows that for all three of the classes considered, the level 0-1 Microchipping Ubiquity Index is approximately 0.1 higher (1.1.2: 0.92 vs 0.79; 3.1.2: 0.80 vs 0.76; 3.2.2: 0.58 vs 0.46) than the MUI for levels 2+. The patterning here, then, is clear. Post-depositional processes act to heighten the MUI values of exposed edges. The degree to which these factors influence the MUI values is unclear, but seems to be relatively minor. This influence must, however, be taken into account in the interpretation of MUI ratios.

Another non-use factor which could potentially affect MBI and MUI values is intentional retouch. To investigate the influence of this factor, two classes were compared which have identical edge plan and angle ranges. The class 3.1.2 is unretouched, however, while 3.2.2 has unifacial retouch. The edges compared are from levels 2+, in order to hold constant the influence of post-depositional processes. Figure 8 indicates that the Microchipping Bifaciality Index is largely unaffected by this variable. This is to be expected, if the predominant mode of action for these classes was the same. Unifacial retouch and transverse action (indicated by the low MBI values) both produce predominantly unifacial scarring. The MBI value for the unretouched class (3.1.2), however, is 0.04 higher than that of the retouched class (3.2.2). This would seem to indicate that retouch does have a minor depressive effect on the MBI ratio. However, retouch could be a more significant factor in the MBI values in cases in which retouch and the mode of use produce different distributions of microchipping. For example, groups of unifacially retouched edges employed in longitudinal actions could exhibit low MBI values relative to groups of non-retouched edges utilized in the same fashion.

Figure 9 displays the Microchipping Ubiquity Index values for the same two classes. MUI ratios can be seen to differ significantly in the present comparison. They do so, however, in the manner opposite from the one expected. It would be expected that retouch would create visible microscarring on edges that did not have visible use-related scarring, thus elevating the MUI value for the retouched group. Figure 9, however, exhibits the opposite trend. This pattern will be seen to have functional implications. The fact that this functional differentiation was not obscured by retouch suggests that manufacturing-related microscarring is minimal in the Chiripa assemblage. Of course, the comparison of more classes would be preferable. However, the limited number of classes with large numbers of denotata, especially of denotata from levels 2+, precludes further comparisons. The conclusions drawn regarding retouch, therefore, must for the time being be considered preliminary in nature.

Edge angle is another non-use factor which can be expected to influence the MUI values of groups of edges. Since higher edge angles tend to resist scarring more than do lower ones, MUI values would be smaller for otherwise identical groups of higher-angled edges used in the same mode of action on the same contact material as compared to groups of lower-angled edges. Since edge angle is also a dimension with functional significance, however, quantification of its effects on MUI is better accomplished by experimentation than by the analysis of archaeological assemblages. Therefore, no attempt to examine edge angle as a non-use factor in microscar formation will be attempted here.

Finally, the raw material of which tools are made is of great potential significance. It has been suggested (Keeley 1980; Odell 1980; Olausson 1980; Vaughan 1985) that coarser materials are more resistant to scarring than are finer materials. Other properties of the material, such as shear strength, would also be relevant. This is a problem, as previously mentioned, because the majority of the chipped stone tools in the Chiripa assemblage are of quartzite. As previously discussed, very few experimental programs have considered microscar formation on quartzite edges. It would be interesting to compare groups of edges for the effects of raw material in the same way as was done to investigate the effects of intentional retouch. However, the extremely small number of edges on chert, obsidian or metamorphic rocks makes meaningful comparisons using the Chiripa assemblage impossible. It seems probable, however, that MUI values for groups of quartzite edges will be lower than for otherwise identical groups of edges on finer materials. As vitreous basalt is a less coarse material than quartzite, the expected MUI values taken from Richards for the various types of contact materials must be considered maximum rather than absolute values.

Use-related microchipping in the Chiripa assemblage

Since large sample sizes are necessary for MUI and MBI values to be meaningful, classes with less than ten denotata will be largely disregarded in the following discussion (see Figures 2 and 3). Future excavations at Chiripa are planned, however, and sample sizes are expected to increase. As work progresses, more detailed and secure functional determinations will be possible for the less well-represented classes. For the time being, however, reasonable inferences may only be drawn concerning the nine or so classes with large numbers of denotata, shown in Figure 2. Also, the discussion is structured so that groups of classes with common edge plans will be considered together. I have done this as a matter of expositional convenience, as some functional groups will be seen to correlate well with this dimension of variability.

Triangular edges. All classes with triangular edge plan have a Microchipping Bifaciality Index value of 1.0, indicating that all specimens have bifacial edge damage. This accords well with experimental investigations of a rotative mode of action (Tringham et al. 1974). This, combined with their edge plan (all would, in a traditional typology, be termed ' drills' or ' borers'), suggests that all edges in class 4.1.2 were used in a rotative manner to perforate materials. The MUI of .56 suggests contact with medium-hard to hard materials, such as bone, antler and wood. There is evidence for the perforation of bone at the site in the form of needles. Wood, however, was not preserved at Chiripa, so no conclusions can be drawn as to whether or not perforation of this material was taking place. No perforated antler was discovered at the site.

Concave edges. Table 1 shows that two classes, 2.2.2 and 2.2.3, account for 83% of all concave edges in the assemblage. Concave edges, therefore, tend to have edge angles over 45 degrees. This suggests a transverse mode of action, which is confirmed by the morphology of the edge (longitudinal actions would not be possible using concave, notched edges) and by the extremely low MBI values for both classes in both Tables 1 and 3.

Turning to MUI values, Table 1 yields values of .38 and .65, respectively. In Table 3, the values are .33 for 2.2.2 and .67 for 2.2.3. The close agreement between the two tables is very suggestive, especially considering the drastic differences in sample size between the two. Together with the strong correlation between higher edge angles and higher MUI values, both indicative of the working of harder materials, this suggests a functional distinction between the two classes. The class 2.2.2 seems to have been used in the working of softer materials than was 2.2.3. No non-use factors can account for this difference in MUI values between the two classes.

The Microchipping Ubiquity Index value of .33 for class 2.2.2 suggests the working of medium-soft or soft materials. The only material of this hardness likely to have been worked in a transverse fashion at Chiripa is the *totora* reed. The low-angled notches (2.2.2) could have been used to fashion arrow shafts from this material. Some varieties of very soft wood could also have been worked by these tools. The higher-angled notches, however, exhibit MUI values (.67) indicative of the working of medium-hard to hard materials. Such materials could possibly include harder woods and bone. This last was fashioned into needles and awls at the site, as well as a variety of less-common ornaments. There seems, then, to be a functional distinction between the two classes which can only be explained by the functional advantage of higher edge angles in the working of harder materials. It must always be remembered, however, that this distinction is not a fine one, but indicates only general tendencies. Tools of class 2.2.3 could have occasionally been used to work softer materials, and 2.2.2 edges could at times have been employed in the shaping of bone or wood. Interpretation of the functional interpretations presented in this analysis must bear this fact in mind.

Interestingly, 72% of concave edges are located in levels 0-1. At present, I cannot account for this distribution. It may be that they are a chronological marker at the site, being more common in later periods. It is also possible that they are, in fact, produced by post-depositional processes such as plowing. This seems unlikely, since they display wear indicative of use, but at present the possibility cannot be ruled out.

Denticulate edges. Many analysts combine concave and denticulate edges in their analyses (e.g. Barton 1988; Odell 1981). In the present case, the decision was made to separate them. At Chiripa, the wear on denticulate edges was on the tips of the protrusions rather than in the concave areas between them. Wear on concave edges, by contrast, was invariably on the interior of the curve. The difference in MUI values and distribution, discussed below, would seem to confirm this functional distinction.

One class (6.2.2) contains 75% of the edges that are denticulate in form (27 of 36). Unimodal distributions such as this are suggestive of a functional unity for all of the classes of this edge plan. The very low Microchipping Ubiquity Index values for all classes of denticulate edges imply contact with soft materials, as does the lack of any denticulate edges with angles of more than 75 degrees. The low Microchipping Bifaciality Index values for this class (Table 1: .33; Table 3: .50) indicate a transverse mode of action, although the difference between the two tables on this point is puzzling. It does not meet the expectations developed for the effects of post-depositional processes. As previously mentioned, however, the MBI ratio is not highly sensitive in groups of tools which were used on soft materials. Also, the very low MUI ratios for this class (Table 1: .11; Table 3: 0.9) means that only a few of the tools displayed any scarring on their utilized edges. This means that the MBI value for the class is based on only a very few tools. This could account for the wide variation between the MBI ratios in the two tables. Finally, the fact that the other three classes of denticulate edges (6.2.1, 6.2.4, 6.3.4) all display an MBI of 0.0 on both tables would tend to support the conclusion that the mode of action for 6.2.2 was transverse.

The edge morphology of this class suggests that these edges were used for 1) scaling fish and/or 2) processing, perhaps shredding, vegetal matter. Both of these are soft materials that were likely worked in a transverse manner at Chiripa. The denticulates could also have been used for the scraping of hides. The edge morphology, however, would be highly unusual for hide scrapers. Class 6.2.2, then, can be provisionally said to have been employed in a transverse manner in the scaling of fish and/or in the processing of vegetal material. Further specification of the function of denticulate edges in the Chiripa assemblage must await a contextual analysis of denticulate tool distribution.

Irregular edges. No classes of irregular edges have more than one denotatum. No conclusion, therefore, may be drawn regarding their function.

Straight edges. Two classes of straight edges have high numbers of denotata; namely 1.1.2 (Table 1: n=27, Table 3: n=14) and 1.2.2 (Table 1: n=22, Table 3: n=14). Class 1.1.2 has MBI values indicative of a transverse mode of action (Table 1: .26, Table 3: .36) and elevated MUI values (Table 1: .85, Table 3: .79) suggesting regular use for the scraping or whittling of medium-hard to hard materials, such as bone, antler and harder woods. Class 1.2.2 seems also to have been employed in a transverse fashion (MBI: Table 1: .38, Table 3: .50), but its relatively low MUI values (Table 1: .36, Table 3: .29) suggest contact with softer material, such as fish or hides. In the case of both classes, the MUI values for the level 2+ group are somewhat lower than for the group from all levels. This can be attributed to the action of post-depositional processes. MBI, however, does not seem to have been affected in a systematic manner. Higher-angled retouched edges (1.2.3) were used in a transverse action on harder materials. In this case, retouch would have been a means to obtain these very high edge angles, useful for the working of harder materials, which occur only rarely on unmodified flakes.

Classes 1.1.2 and 1.2.3 were used on a similar range of materials in a transverse action. The probable explanation for the use of angles in the range of 45-70 degrees for the working of hard materials, when higher angles are more durable, is that the 1.1.2 tools were used for whittling of these materials, while 1.2.3 was used for scraping them. Lower edge angles are more effective in the whittling of materials, even hard materials, while higher angles are more appropriate for the scraping of medium-hard to hard contact materials. Tentatively, then, we can conclude that 1.1.2 tools were used for whittling, while 1.2.3 tools were scrapers employed on harder materials.

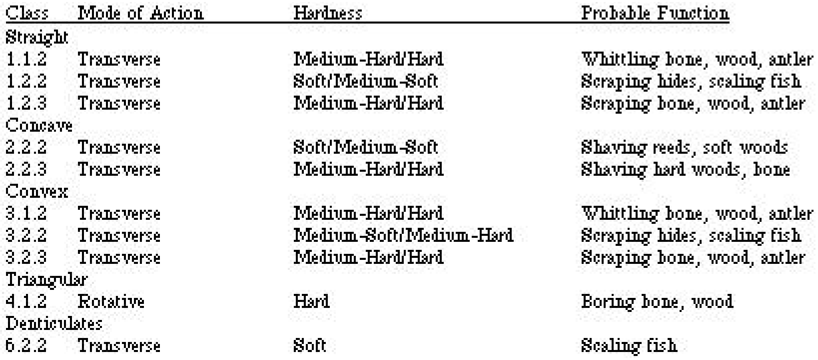
A preliminary examination of the class of straight edges with lower edge angles (1.1.1) seems to suggest a longitudinal mode of action. However, Tables 1 and 3 show that of these edges, 71% (5 of 7) are from levels 0-1, as opposed to 44% (13 of 27) of higher-angled edges (i.e. 1.1.2) from these levels. This would seem to suggest that at least some of these ' tools' could have been produced by post-depositional process, rather than by human use. The fragile nature of low-angled edges would account for the high MBI and

MUI values observed. A glance at Table 3, however, shows that there are too few denotata from these classes present in less disturbed contexts to permit any sort of functional analysis.

Convex edges. Three classes of convex edges (3.1.2, 3.2.2, 3.2.3) display sample sizes large enough to permit some conclusions to be drawn. All three display Microchipping Bifaciality Index values of .25 or less in Table 3, although MBI values in Table 1 are slightly higher. For all three classes, however, a transverse mode of action is indicated. Class 3.2.2 has the lowest MUI values of the three (Table 1: .50, Table 3: .46) suggesting a lack of contact with hard materials such as bone, dry antler or dry wood. Higher MUI values for 3.1.2 (Table 1: .77, Table 3: .76) and 3.2.3 (Table 1: .77, Table 3: 1.00), however, indicate that these classes were used in the working of these hardest materials. It was also employed in a transverse action. This pattern is identical to the one identified in the straight edge plan group, and can be interpreted in the same manner. Class 3.2.2 was probably used for scraping hides or scaling fish, 3.1.2 for whittling harder materials, and 3.2.3 for the scraping of these materials.

An examination of the lower angled convex edge classes does not reveal a pattern like that of the lower angled straight edge classes. Only 25% (3 of 12, classes 3.1.1, 3.2.1, 3.3.1) of convex edges with angles from 15-45 degrees came from levels 0-1, and there is no consistent pattern of elevated MBI and MUI values, as there was for the straight edge classes. This would seem to suggest that straight edges are more vulnerable to damage by post-depositional processes such as plowing and trampling. This is contradicts Moss (1983), who suggests that the edges most vulnerable to fortuitous damage are the most outward-projecting points of non-straight edges. The MBI values for 3.1.1 seems to suggest a longitudinal mode of action, but sample sizes are not adequate to make this determination with any confidence. Future excavations should clarify the functions of these classes.

In sum, then, eight classes have been identified as to mode of action and maximum hardness of regularly-worked material. These results are summarized below.



Class	Mode of Action	Hardness	Probable Function
Straight			
1.1.2	Transverse	Medium-Hard/Hard	Whittling bone, wood, antler
1.2.2	Transverse	Soft/Medium-Soft	Scraping hides, scaling fish
1.2.3	Transverse	Medium-Hard/Hard	Scraping bone, wood, antler
Concave			
2.2.2	Transverse	Soft/Medium-Soft	Shaving reeds, soft woods
2.2.3	Transverse	Medium-Hard/Hard	Shaving hard woods, bone
Convex			
3.1.2	Transverse	Medium-Hard/Hard	Whittling bone, wood, antler
3.2.2	Transverse	Medium-Soft/Medium-Hard	Scraping hides, scaling fish
3.2.3	Transverse	Medium-Hard/Hard	Scraping bone, wood, antler
Triangular			
4.1.2	Rotative	Hard	Boring bone, wood
Denticulates			
6.2.2	Transverse	Soft	Scaling fish

The lack of evidence in the assemblage for longitudinal motions is a final fact requiring explanation. While it seems very likely that longitudinal motions were employed in the use of some stone tools (indeed, there is some direct evidence for this), such patterning would be obscured in the Chiripa assemblage for two reasons. First, such actions likely do not create visible rounding as quickly as do transverse actions, for reasons that have been discussed by Odell (1981) and Vaughan (1985). Thus, they are more difficult to distinguish from edges damaged by non-use factors, and would be largely excluded from the assemblage by the protocol employed. This is probably the cause of the very low sample sizes for all classes with edge angles between 15 and 45 degrees. Second, edges with lower angles are more vulnerable to damage by post-depositional than are edges with higher angles. Their Microchipping Bifaciality Index and Microchipping Ubiquity Index values are therefore likely to be more significantly affected. Both of these problems are expected be solved somewhat by the increased sample sizes of these classes in future seasons.

Conclusions

The present analysis has served a number of purposes. First, it has demonstrated that post-depositional processes are a significant factor microscar patterning on archaeological chipped stone tools. The affect of these processes is, at Chiripa, related to edge angle. For edge angles greater than 45 degrees, the effects of post-depositional processes seems to be regular and predictable, at least as they affect the MBI and MUI measures, but relatively minor. For smaller edge angles, however, the impact is much greater and can function to obscure use-related patterning.

More importantly, however, an analysis of the microchipping data, considered together with tool morphology and material evidence of the range of materials worked at Chiripa (in the form of finished artifacts or manufacturing debris), has permitted the identification of a number of classes of utilized and/or retouched stone tools with a specific and restricted range of functions. For the most part, the conclusions support the types of intuitive tool typologies constructed by archaeologists. For example, at Chiripa unifacially-retouched edges really do seem to be ' scrapers' . With the microchipping data, however, such an appellation is more than a simple assertion; it is a conclusion drawn from the careful consideration of direct, relevant, and, perhaps most importantly, site- and provenience-specific data.

Finally, it has been demonstrated that the MBI and MUI measures, which are easily obtained with low magnification and with a relatively minor labor investment, can reveal patterned variation in microchipping between classes of informal chipped stone tools. I have argued that this variation can, in some cases, be used to define a range of uses for individual classes of tools. The MBI and MUI indices, then, though they will never permit the identification of the history of use of individual implements, seem to be convenient and useful tools for the functional analysis of archaeological assemblages.

Appendix 1

Lists of contact material hardness employed by various researchers

Tringham et. al. 1974: 176

- soft: meat, hide, plants
- medium: wood
- hard: antler, cooked and uncooked bone

Vaughan 1985: 21

- hard: bone in any state, dry antler, dry woods, carcass;
- medium-hard: fresh and soaked almond wood, soaked antler;
- medium-soft: fresh and soaked cypress wood, reeds, barley and wild *Gramineae,* dried beef;
- soft: meat without bones, hides, green plant stems, cattail.

Richards 1988: 104

3-part scale

- soft: meat, plants
- medium: hide, wood
- hard: bone, antler

5-part scale

- soft: meat
- medium-soft: fresh hide, plants
- medium-hard: fresh wood, dry hide
- hard: dry wood, soaked antler
- very hard: unsoaked bone and antler

Grace 1989: 114

- soft: meat, plants, bark, fresh soft wood, fresh hide
- medium: other wood, fish, soaked antler, dry hide
- hard: dry antler, bone, shell

Footnotes:

[1] Rather than establish a typology of contact materials according to hardness, some researchers (Frison 1968; Lewenstein 1987; Odell 1980) have preferred to ground their analysis in the damage produced by certain tasks. For example, butchering is a single task that involves contact with materials of varying hardness (bone, hide, meat, sinew).

[2] For example, in a double-blind test of microwear analysis, Keeley and Newcomer (1977), employing basically the same techniques as Vaughan, found that they could correctly identify the mode of action in only 75% of the tools analyzed. A 25% rate of error, while still fairly low, would be sufficient to blur the patterning in an archaeological assemblage. We would do well to remember , also, that the error rate in the analysis of archaeological materials is most likely higher than for experimental collections, due to the actions of post-depositional processes.

[3] Table 1 displays the MBI and MUI values for each classes with denotata in the Chiripa chipped stone tool assemblage.

[4] Worked materials are, soft: meat, rawhide; medium: reeds, grass, hide; hard: woods, bone, antler.

[5] Worked materials are, soft: green plants, fish; medium-soft: hide; medium-hard: fresh wood; hard: bone, unsoaked antler.

[6] Artifacts were, however, sorted into plastic buckets and washed as lots. As I cannot at present control for the effect of this treatment, it will be assumed to be minimal.

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Figures

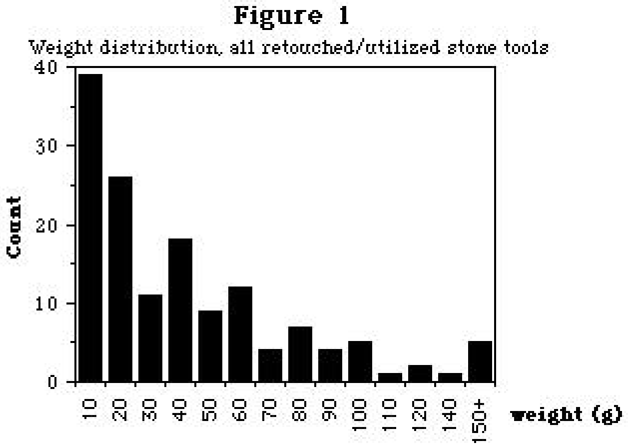

Figure 1: Weight distribution, all retouched and/or utilized flake tools

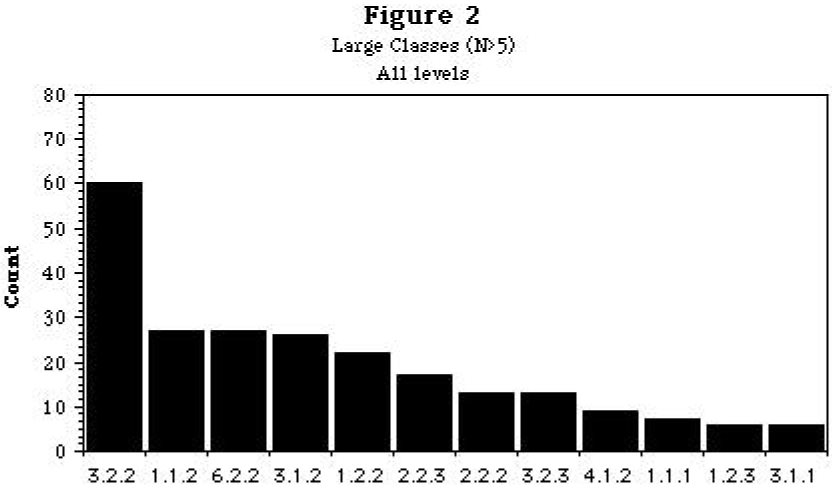

Figure 2: Count for all large classes (N>5), all levels

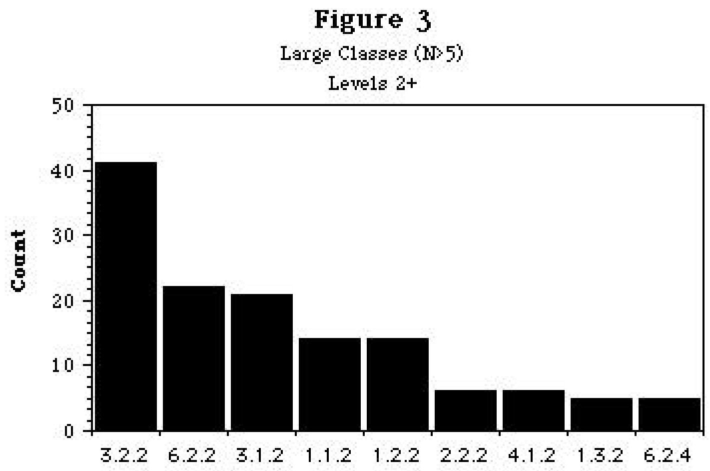

Figure 3: Count for all large classes (N>5), levels 2+

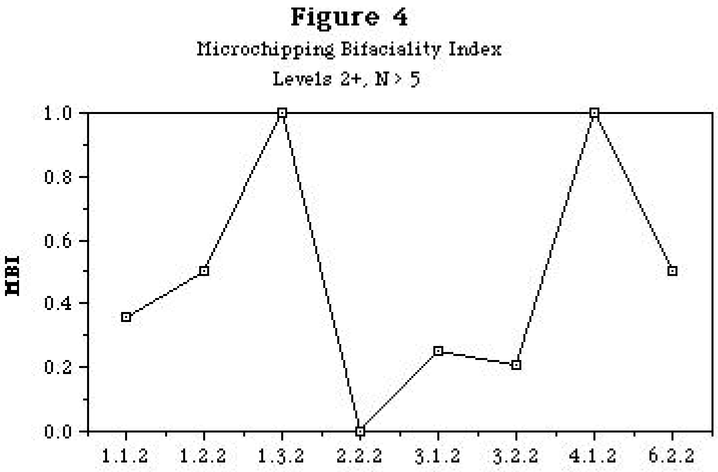

Figure 4: MBI, levels 2+, large classes

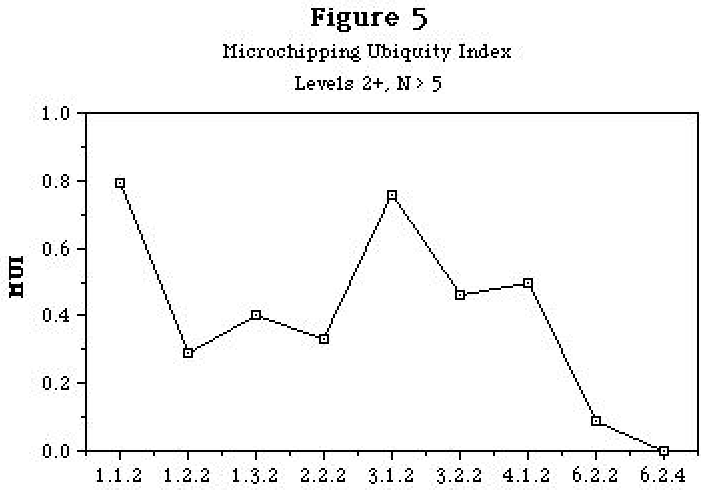

Figure 5: MUI, levels 2+, large classes

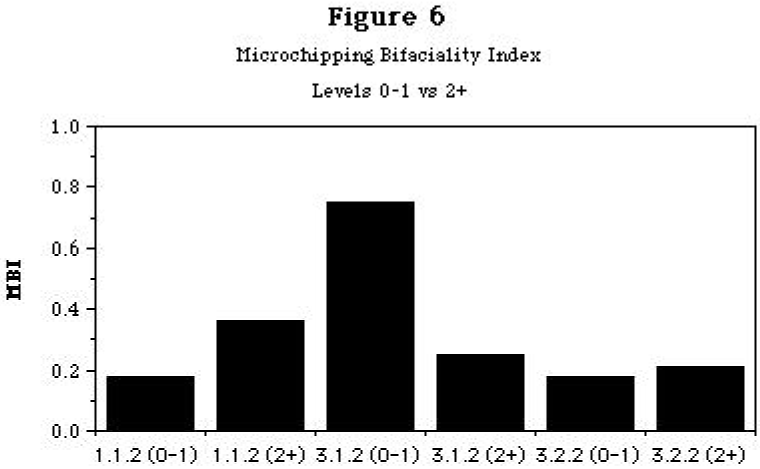

Figure 6: MBI, levels 0-1 vs. levels 2+

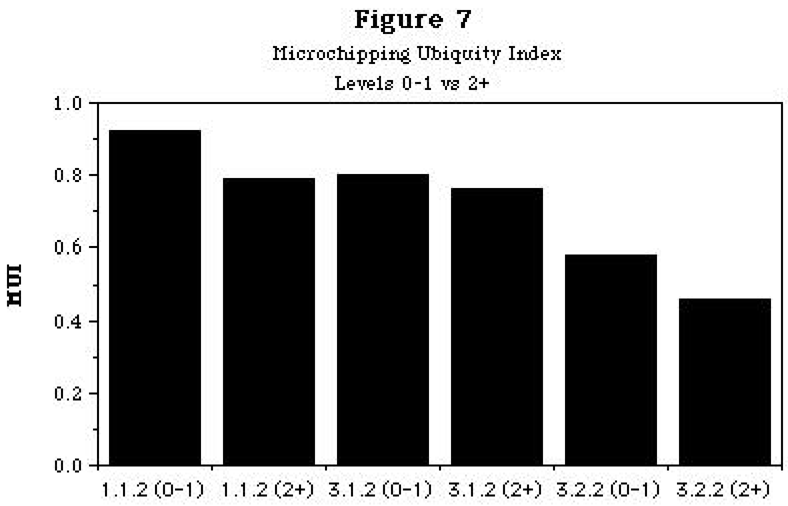

Figure 7: MUI, levels 0-1 vs. levels 2+

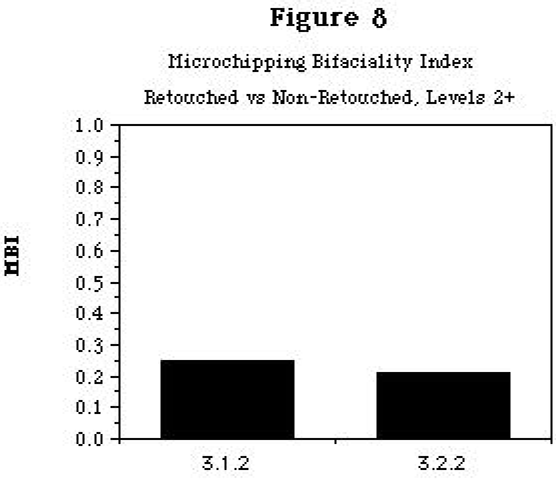

Figure 8: MBI, retouched vs. non-retouched tools, levels 2+

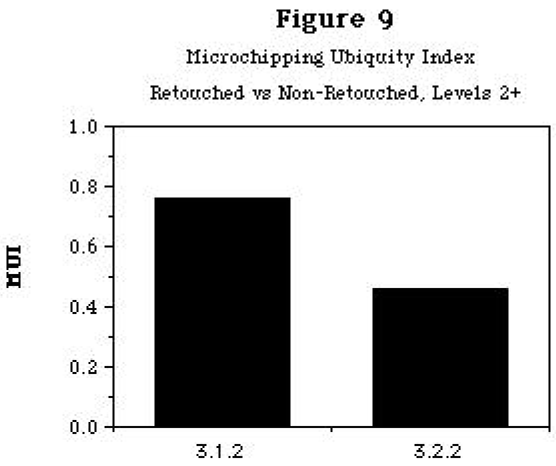

Figure 9: MUI, retouched vs. non-retouched tools, levels 2+

Tables

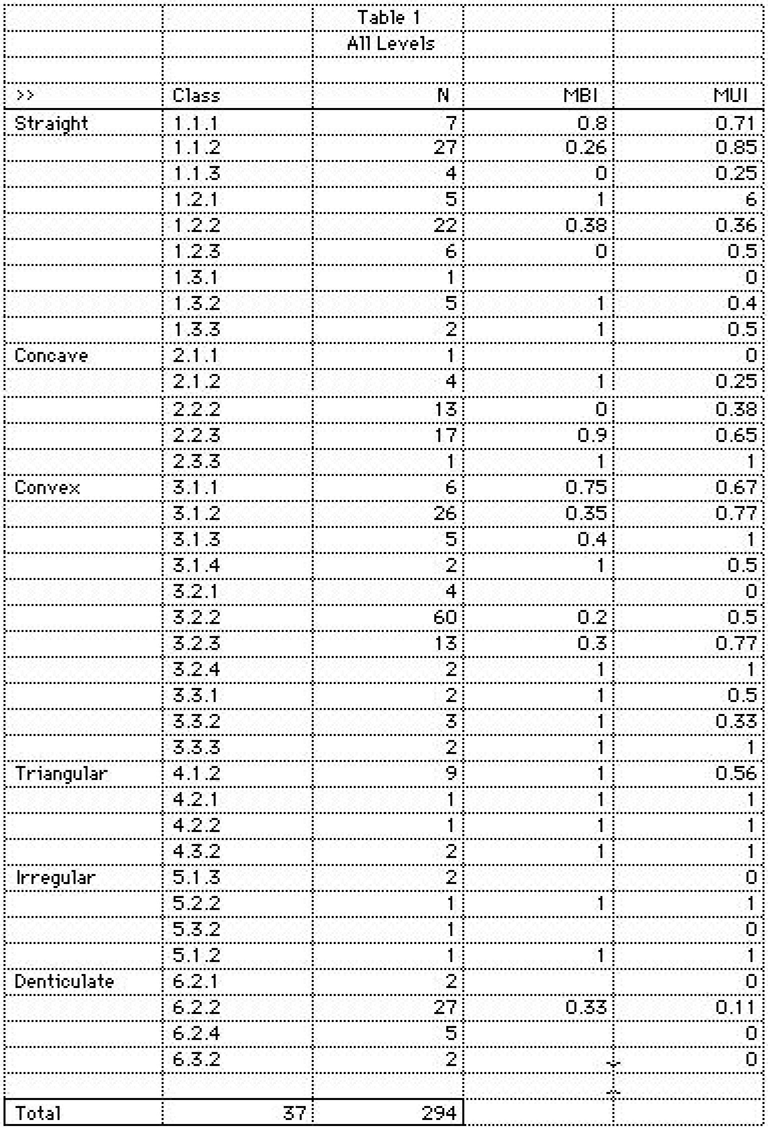

Table 1
All Levels

>>	Class	N	MBI	MUI
Straight	1.1.1	7	0.8	0.71
	1.1.2	27	0.26	0.85
	1.1.3	4	0	0.25
	1.2.1	5	1	6
	1.2.2	22	0.38	0.36
	1.2.3	6	0	0.5
	1.3.1	1		0
	1.3.2	5	1	0.4
	1.3.3	2	1	0.5
Concave	2.1.1	1		0
	2.1.2	4	1	0.25
	2.2.2	13	0	0.38
	2.2.3	17	0.9	0.65
	2.3.3	1	1	1
Convex	3.1.1	6	0.75	0.67
	3.1.2	26	0.35	0.77
	3.1.3	5	0.4	1
	3.1.4	2	1	0.5
	3.2.1	4		0
	3.2.2	60	0.2	0.5
	3.2.3	13	0.3	0.77
	3.2.4	2	1	1
	3.3.1	2	1	0.5
	3.3.2	3	1	0.33
	3.3.3	2	1	1
Triangular	4.1.2	9	1	0.56
	4.2.1	1	1	1
	4.2.2	1	1	1
	4.3.2	2	1	1
Irregular	5.1.3	2		0
	5.2.2	1	1	1
	5.3.2	1		0
	5.1.2	1	1	1
Denticulate	6.2.1	2		0
	6.2.2	27	0.33	0.11
	6.2.4	5		0
	6.3.2	2		0
Total	37	294		

Table 1: All classes, all levels: N, MBI, MUI

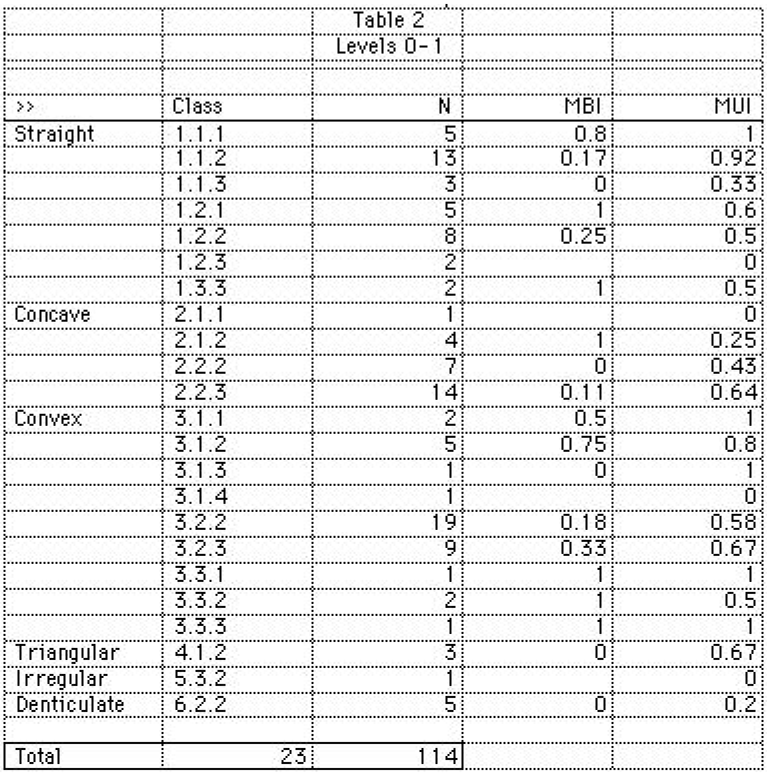

Table 2
Levels 0-1

>>	Class	N	MBI	MUI
Straight	1.1.1	5	0.8	1
	1.1.2	13	0.17	0.92
	1.1.3	3	0	0.33
	1.2.1	5	1	0.6
	1.2.2	8	0.25	0.5
	1.2.3	2		0
	1.3.3	2	1	0.5
Concave	2.1.1	1		0
	2.1.2	4	1	0.25
	2.2.2	7	0	0.43
	2.2.3	14	0.11	0.64
Convex	3.1.1	2	0.5	1
	3.1.2	5	0.75	0.8
	3.1.3	1	0	1
	3.1.4	1		0
	3.2.2	19	0.18	0.58
	3.2.3	9	0.33	0.67
	3.3.1	1	1	1
	3.3.2	2	1	0.5
	3.3.3	1	1	1
Triangular	4.1.2	3	0	0.67
Irregular	5.3.2	1		0
Denticulate	6.2.2	5	0	0.2
Total	23	114		

Table 2: All Classes, levels 0-1: N, MBI, MUI

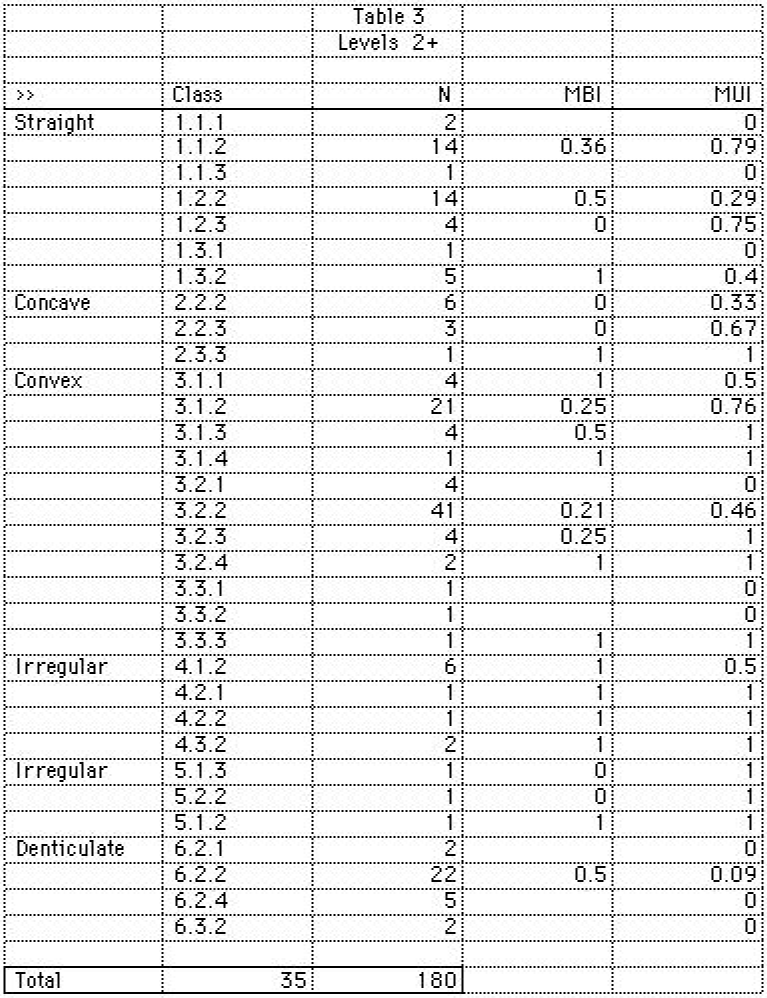

		Table 3		
		Levels 2+		
>>	Class	N	MBI	MUI
Straight	1.1.1	2		0
	1.1.2	14	0.36	0.79
	1.1.3	1		0
	1.2.2	14	0.5	0.29
	1.2.3	4	0	0.75
	1.3.1	1		0
	1.3.2	5	1	0.4
Concave	2.2.2	6	0	0.33
	2.2.3	3	0	0.67
	2.3.3	1	1	1
Convex	3.1.1	4	1	0.5
	3.1.2	21	0.25	0.76
	3.1.3	4	0.5	1
	3.1.4	1	1	1
	3.2.1	4		0
	3.2.2	41	0.21	0.46
	3.2.3	4	0.25	1
	3.2.4	2	1	1
	3.3.1	1		0
	3.3.2	1		0
	3.3.3	1	1	1
Irregular	4.1.2	6	1	0.5
	4.2.1	1	1	1
	4.2.2	1	1	1
	4.3.2	2	1	1
Irregular	5.1.3	1	0	1
	5.2.2	1	0	1
	5.1.2	1	1	1
Denticulate	6.2.1	2		0
	6.2.2	22	0.5	0.09
	6.2.4	5		0
	6.3.2	2		0
Total	35	180		

Table 3: All classes, levels 2+: N, MBI, MUI