6. Reduction Sequences: Artefact Form and Manufacturing Technology in Wardaman Country

Understanding stone artefact manufacture and the effects of intensity of reduction on lithic implement form and other kinds of debris are crucial steps in understanding similarity, difference and change in Australian technological traditions. As explained in Chapter 1, such an understanding should also underwrite attempts to compare industries and to determine the ways in which people organised technologies to meet their various needs. This chapter constructs reduction sequence models for a range of common stone artefact forms found in Wardaman Country, including cores, flakes (including lancets), retouched flakes (scrapers), points, burins, tulas and burrens. I will begin by exploring the effects of reduction on core and flake form, and then documenting reduction continuums and blank selection for retouched implements.

Documenting Reduction Sequences: Core Reduction

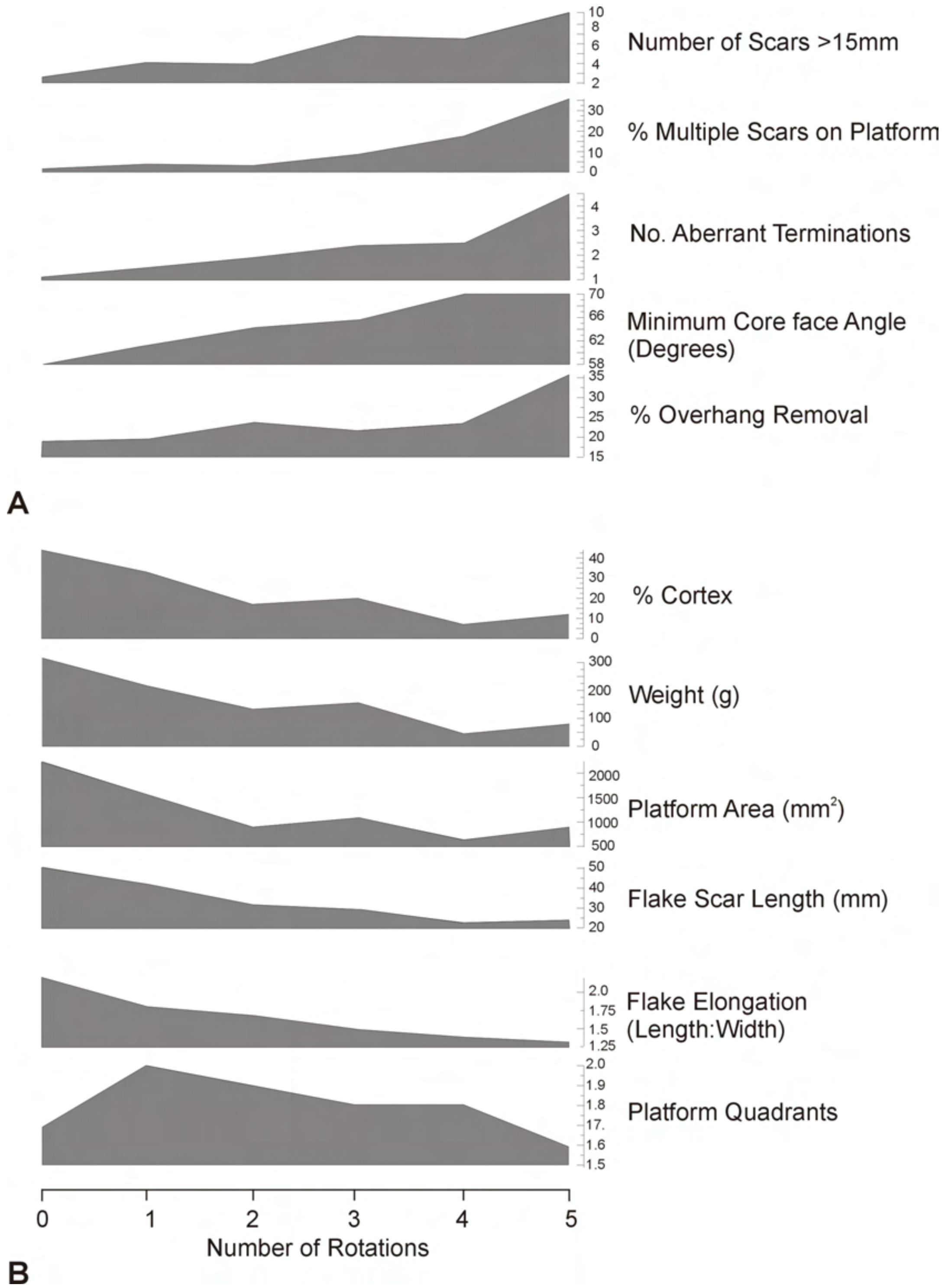
It was argued in Chapter 3 that it is possible to model core reduction by exploring changes in geometry, force variables, morphology and various measures of the quantity of flake removals. As most platforms fail to produce flakes of consistent form beyond a certain point – often determined by the build up of step or hinge terminations, increases in platform angle and reductions in platform area – one measure of overall attempts to extract the maximum number of useable flakes from a core is the number of times it has been rotated to set up new platforms. This measure is employed here as a means of ranking core reduction so that the changes in core morphology, the frequency with which particular procedures are used, and the likelihood of insurmountable problems arising throughout the reduction process can be explored.

To track changes in core form and the use of different technological strategies over the sequence of core reduction, twelve variables are plotted against increasing number of core rotations in Figure 6.1. These changes are documented from a set of 200 chert and quartzite cores spanning all available periods of occupation. This diagram shows that many of the measured core characteristics show an increase over the sequence of reduction, while others decrease.

As might be expected, the number of scars found on cores increases with each rotation, as does the percentage of platforms that have more than one conchoidal scar, resulting from the use of a previous core face as the new platform (Figure 6.1a). The percentage of scars found on the core showing step and hinge terminations also increases as core rotation proceeds, as does the minimum external angle of the last platform used on cores. The use of overhang removal also increases steadily throughout the remainder of the reduction sequence. Overhang removal was presumably used to strengthen the platform to better receive the forceful blows required to remove flakes from small cores with increasingly high angled platform edges.

In contrast to these increasing trends, cortex diminishes rapidly in the early stages of reduction, indicating that more surface material was removed prior to the first rotation than at any stage subsequent to it (Figure 6.1b). This idea is supported by the rapid reduction in the weight of cores over the first few rotations. As the weight of cores reduces with more rotations, so does the size of the platform and the length of flake scars. As length reduces, so too does the elongation of flake scars. Finally, the used portion of the platform edge first increases and then decreases as the viable platform perimeter reduces. This is no doubt largely due to irregularities left on the core face and platform by previous rotations that constrict flaking to certain areas, but may also reflect decreasing control over force variables that allow successful flake detachments.

Figure 6.1. Changes in core morphology over the reduction sequence.



It is also possible to examine variation in each of these attributes as reduction proceeds. Tables 6.1 and 6.2 provide the means, standard deviations and coefficients of variation (CV) for nine of the metrical variables shown in Figure 6.1. CV is given as well as standard deviation as the size of the mean influences standard deviation, whereas CV removes any effect the mean has on the measure of variation. The CVs for most attributes are quite high (over 50%), but most show no directional changes in variation over the sequence of reduction. The exceptions are weight, which shows a marked increase in variation as rotation continues, and length and scar elongation which both show reductions in variation over the sequence. A suggested reason for increasing variation in weight is that most cores

start large, but only some finish small, as cores can sometimes be rotated many times without reducing mass significantly. Another reason is that larger cores can be taken into later stages of reduction as their greater mass means inertia thresholds are reached later in the sequence than for smaller cores. Consequently, both large and small cores may reach late stages of reduction, creating more variation as the number of rotations increases. Reduced variation in flake elongation and length, on the other hand, probably reflects the reduced possibilities for producing long flakes later in the sequence as cores become shorter and squatter.

Table 6.1. Mean, standard deviation and coefficient of variation for four measures of core reduction, morphology and reduction technique over the sequence of core rotations.

Rotations	# Scars			% Cortex			Flake Elongation *			Flake Scar Length*		
	Mean	σ	c.v.	Mean	σ	c.v.	Mean	σ	c.v.	Mean	σ	c.v.
0	2.6	1.9	72.6	44	34.4	78.2	2.2	1.3	60.4	50.6	9.0	17.9
1	4.1	2.5	61.6	33	29.0	87.8	1.8	1.3	73.2	41.8	9.2	21.9
2	3.9	2.2	55.7	17	26.1	153.7	1.7	1.0	61.3	31.6	5.0	15.9
3	6.8	3.9	56.8	20	23.6	118.2	1.5	0.7	44.6	29.3	3.7	12.6
4	6.5	2.3	34.9	7	11.9	169.5	1.4	0.7	48.3	22.7	1.9	8.4
>/=5	9.2	6.5	71.1	12	11.2	93.5	1.3	0.8	59.5	24.0	4.1	17.2

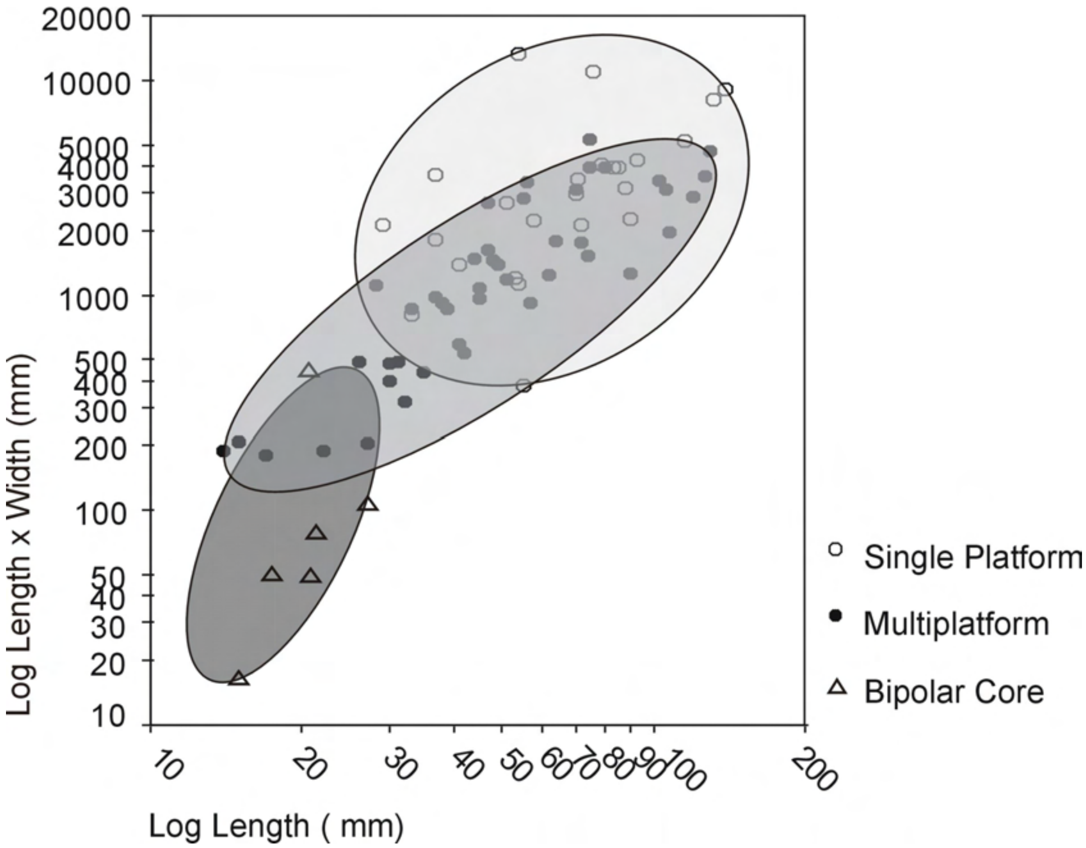
* Average taken for the last four scars struck from cores.

Table 6.2. Mean, standard deviation and coefficient of variation for a further seven measures of core reduction, morphology and reduction technique over the sequence of core rotations.

Rotations	Weight (g)			Minimum Core Face Angle			% Overhang Removal	% Multiple Platform Scars	% Aberrant Terminations
	Mean	σ	c.v.	Mean	σ	c.v.	Mean	Mean	Mean
0	316	348.5	110.3	59	13.2	22.3	19.0	1.6	1.1
1	216	271.7	125.8	62	9.2	14.9	19.6	3.9	1.5
2	133	186.6	140.3	65	11.2	17.3	25.8	3.2	1.9
3	156	246.5	158.0	66	14.4	21.8	21.7	8.7	2.4
4	45	69.9	155.3	70	9.9	14.1	23.5	17.6	2.5
>/=5	80	123.2	153.9	70	7.8	11.1	35.7	35.7	4.5

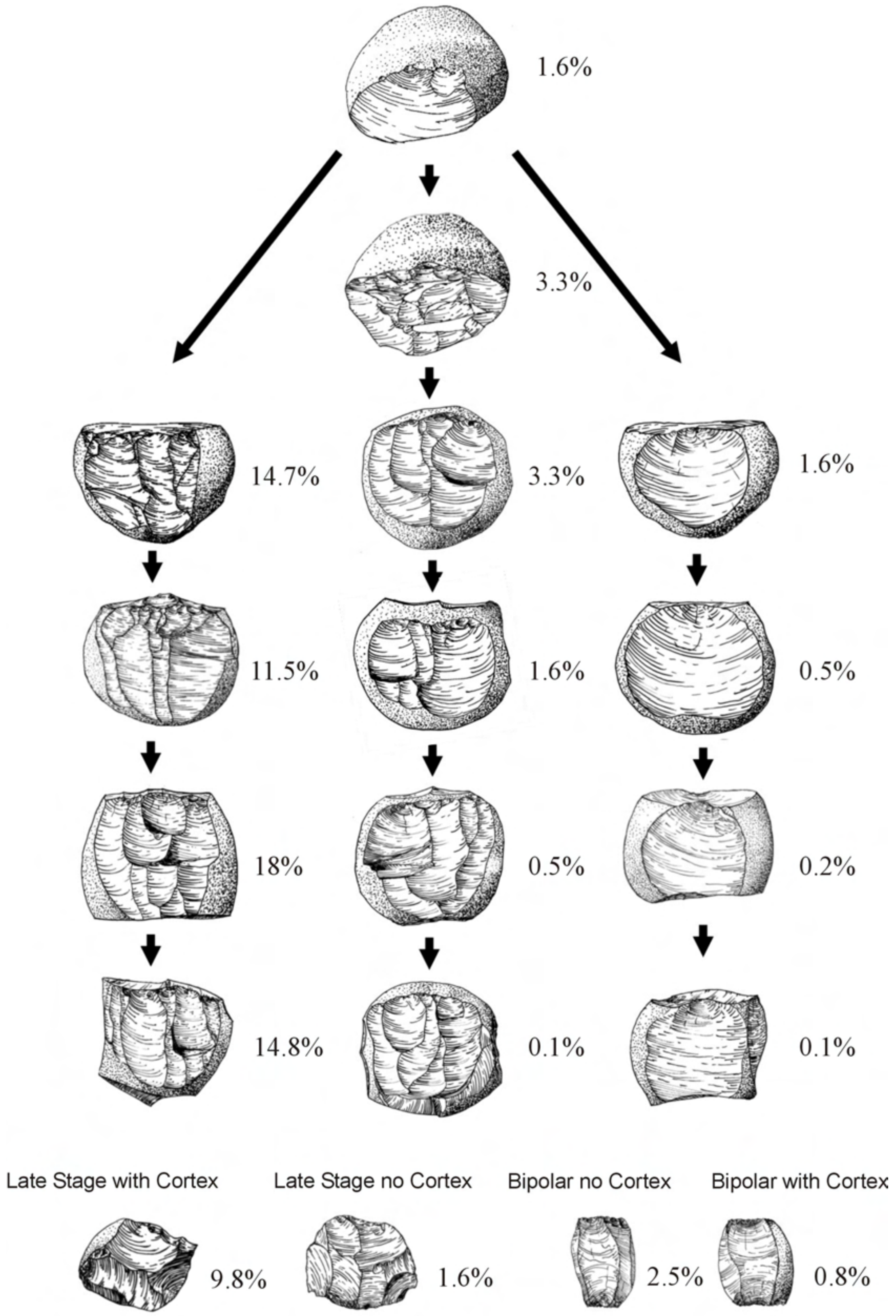
Cores are more likely to become stabilised (i.e. unresponsive to freehand percussion) as reduction proceeds, and knappers faced with this situation might opt either to discard the core, or switch to the use of a strategy that can better overcome inertia thresholds, such as the use of bipolar technique. A small number of cores in the sample were further reduced using bipolar technique. That bipolar reduction formed the end point in the continuum of core reduction is demonstrated by Figure 6.2, which shows bipolar cores as the smallest and last in a continuum of core sizes.

Figure 6.2. Changes in core size associated with changes in reduction strategy.



Changes in core morphology over the reduction sequence are illustrated as an event tree in Figure 6.3, which depicts a range of ways of flaking nodules that are commonly observed in sites in Wardaman Country. While archaeologists have sometimes used this type of chart to illustrate normative reduction sequences through which most forms are argued to pass, this chart ascribes frequencies to each stage in each sequence as determined from the assemblage itself (see also Bleed 1996). Reduction obviously begins with a single flake removed from a cortical platform. In the left-hand sequence (Sequence 1), new platforms are always created from the previous flaked surface via 90 degree core rotations. In the middle sequence (Sequence 2), new platforms are always created from cortical surfaces. In the right-hand sequence (Sequence 3), a single large scar is removed from each surface which then becomes the platform for the next removal. Also illustrated in Figure 6.3 are late stage rotated and bipolar cores, with and without cortex, which represent the very end stages of these sequences.

Figure 6.3. Event tree summarising the changes in core form that result from several modes of reduction, and their frequencies.



From the percentage frequency figures provided in this diagram, it can be seen that Sequence 1 was most commonly practised in the study region, and that Sequence 2 was also a common alternative. Sequence 3 on the other hand was rarely practiced. Mapping reduction sequences in this way allows variation as well as the central tendency to be explored, and also demonstrates that core reduction was a highly variable process, with knappers responding to the results of each successful or unsuccessful blow in a flexible fashion, in which the options for rotation, discard or strategy switching (such as to bipolar reduction) were appraised at various points along the way (cf. Young and Bonnichsen 1984).

The preceding analysis suggests that the number of rotations found on cores is likely to be a useful and reliable measure of reduction intensity in most cases. Using the number of rotations to assign each core its likely stage in the reduction process will therefore allow the intensity of core reduction to be traced over time with implications for the range of issues relating to time-budgeting, risk, mobility, and land use discussed in later chapters.

Flake Reduction

Like core reduction, it is possible to order the stage in the reduction sequence at which individual flakes are produced. Separating flakes produced by retouch and those produced by core reduction is an important first step, however, because flakes produced via different reduction processes likely possess quite different characteristics (such as platform angles, size, platform and dorsal scar morphology, initiation type etc), such that analytical combination will result in a poor description of either population. Separating flakes on the basis of different reduction processes is also desirable if the information sought about each population differs, or if the focus of investigation is upon only one of these processes (i.e. core reduction vs. retouching). The rationale for separating flakes deriving from retouch from those struck from cores is to limit detailed flake analysis to the core-struck flakes only, and in so doing, drastically reduce the size of the assemblages analyzed while also focussing on potential 'blanks' for retouching and transport rather than the by-products of resharpening and implement manufacture. Of course, retouch flakes may also have been tools, but the decision is made here to overlook this possibility in order to make the analysis more manageable.

The systematic and quantitative approach to separating core and retouch struck flakes adopted here is an attempt to avoid subjective decisions about what constitutes a retouch flake. The literature abounds with attempts to recognize such flakes (e.g. billet flakes and bifacial thinning flakes), but a simpler approach is taken here.

When the length of the longest retouch flake scar on a sample of 334 retouched implements is measured, the maximum length of retouch scars is found to be 35 mm, while 99.8% of all maximum scar lengths are less than 21 mm in length. As a second independent test, the lengths of flakes found at quarries are plotted in Figure 6.4. The mean length of core-struck flakes on quarries is 66 $\pm$ 34 mm, while flakes less than 25 mm in length are very rare. Flake length is therefore taken as a simple and reasonably effective means of separating retouch from core struck flakes. Only complete flakes larger than 20mm are therefore included in the following analyses.

Flake Morphology and Reduction Intensity

Following the changes in core form depicted in Figure 6.1 and 6.3, flakes can be roughly ordered into reduction stages according to the nature of the platform surface, and changes in flake morphology examined as the reduction process progresses. The four platform types used to order flakes are cortical platforms, representing the first stages of core reduction, platforms formed from a single conchoidal flake scar, representing early to middle stages, platforms with multiple conchoidal scarring, representing late stages of freehand percussion, and crushed bipolar platforms, representing the last stage of the reduction continuum.

Figure 6.4. Histogram of the lengths of flakes found at quarries and inferred to be 'core-struck' flakes.

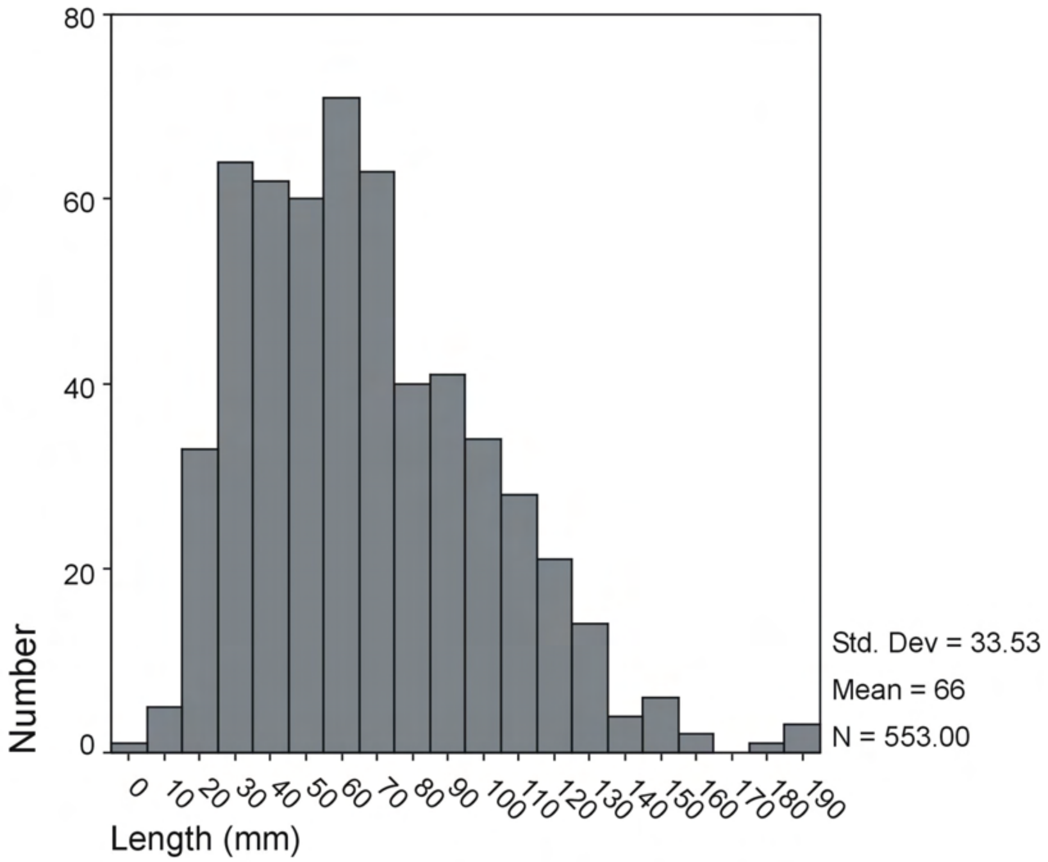


Figure 6.5 maps out the sorts of changes in flake characteristics that accompany each stage of reduction as inferred from platform surface type, including reductions in cortex, mean weight, and platform area that are consistent with the changes seen in core reduction above. Furthermore, there is evidence that knappers responded to changing force requirements by increasing the frequency of overhang removal as platform angle increased - a morphological change that is detected in core morphology as the number of rotations increases. Means and CVs are also provided in Table 6.3. No directional changes in variation are apparent from this data, and variation appears to peak in the middle-stages of reduction for most attributes. This suggests that the greatest range of flake shapes and sizes can be produced once effective platforms have been created, but before reduction proceeds too far and problems in core geometry and force input constrain the range of possible results. Interestingly, the greater number of flakes also belongs to the second and third stages when flake production was presumably under greatest control. Bipolar reduction, on the other hand, is extremely rare in Wardaman sites. No platform area is shown for bipolar flakes in Table 6.3 as bipolar reduction tends to entirely crush flake platforms.

Lancet and Leilira Flake Production

Lancets are long, elongate flakes with high length:thickness ratios, one or more dorsal ridges and parallel-sided or tapering margins, that are between 3 and 10 cm in length. We have seen from the previous analyses of core and flake reduction that elongate flakes tend to be produced early in the core reduction sequence, and hence knappers seeking these kinds of flakes would likely be most successful in the earlier stages of core reduction.

Indeed, analysis of the stages at which lancets are most commonly produced reveals a strong tendency toward early reduction stages, with most lancet flakes possessing either cortical or single conchoidal platforms, as shown in Figure 6.6. Cores found on quarries in association with lancet flakes

also typically show large amounts of cortex and either cortical or single conchoidal platforms (Figure 6.7). Many cores used for lancet production found at quarries across Wardaman Country appear to have been discarded at this early stage, with a mean weight for discarded lancet cores of 623 ± 317 g, a mean length of 110 ± 23 mm and a mean thickness of 58 ± 36 mm. These dimensions place lancet cores very early in the reduction sequence if compared to Figure 6.2.

A limited number of successful conjoins from quarries also reveals a simple process used to set up platforms for lancet production on cores that lacked a suitable cortical platform. This typically involved the removal of a large flake from one end of an angular to sub-angular nodule, followed by removal of a large cortical flake along a natural ridge-line in the nodule, creating two arises on the core face. Subsequent blows remove elongate flakes from either side of this first scar. A number of lancet flakes are produced before step and hinge terminations accumulate on the core face. For two reconstructed cores used to produce lancets and shown in Figure 6.8, recurrent step and hinge terminations were encountered after removal 13 and 14, and the cores were later discarded as a result of changes in core geometry and increased force inputs arising from the instability created by these initial aberrantly terminated flake scars. Furthermore, more than 15% of refitted lancets in these conjoin sets had broken through end shock or cone splitting, and data taken from quarries reveals that up to 60% of lancets snapped transversely or longitudinally during manufacture in some locations.

Figure 6.5. Changes in flake morphology as reduction continues. Reduction stage is measured using four platform types: cortical, single conchoidal, multiple conchoidal and bipolar. Changes in morphology include: A: % dorsal cortex, B: mean weight, C: platform area, and D: frequency of overhang removal as platform angle increases.

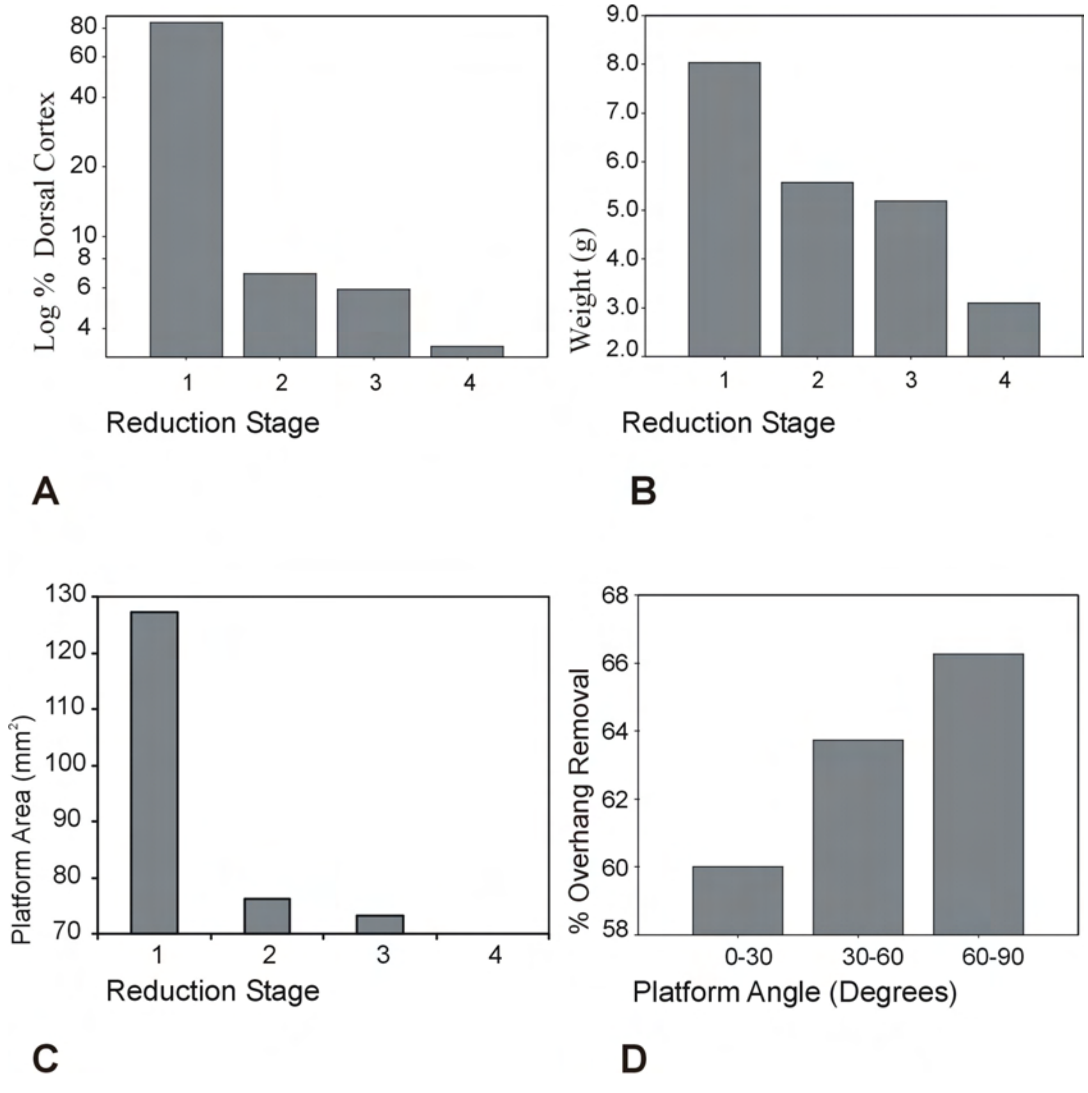


Table 6.3. Changes in flake morphology over the sequence of reduction, as inferred from platform surface type.

		Weight		Platform Angle		% Dorsal Cortex		Platform Area	
Platform Type	*Number*	*Mean*	*c.v.*	*Mean*	*c.v.*	*Mean*	*c.v.*	*Mean*	*c.v.*
Cortical	249	8.0	115.4	71.7	17.4	84.5	34.0	127.3	68.7
Single	1643	5.6	236.3	67.0	19.2	6.9	270.1	76.2	116.3
Multiple	371	5.2	121.9	67.6	20.1	5.9	298.1	73.2	109.8
Bipolar	5	3.1	89.4	--	--	3.3	173.2	0.0	0.0

Figure 6.6. A: lancet flake, and B: frequency of lancet flakes produced at each stage of reduction.

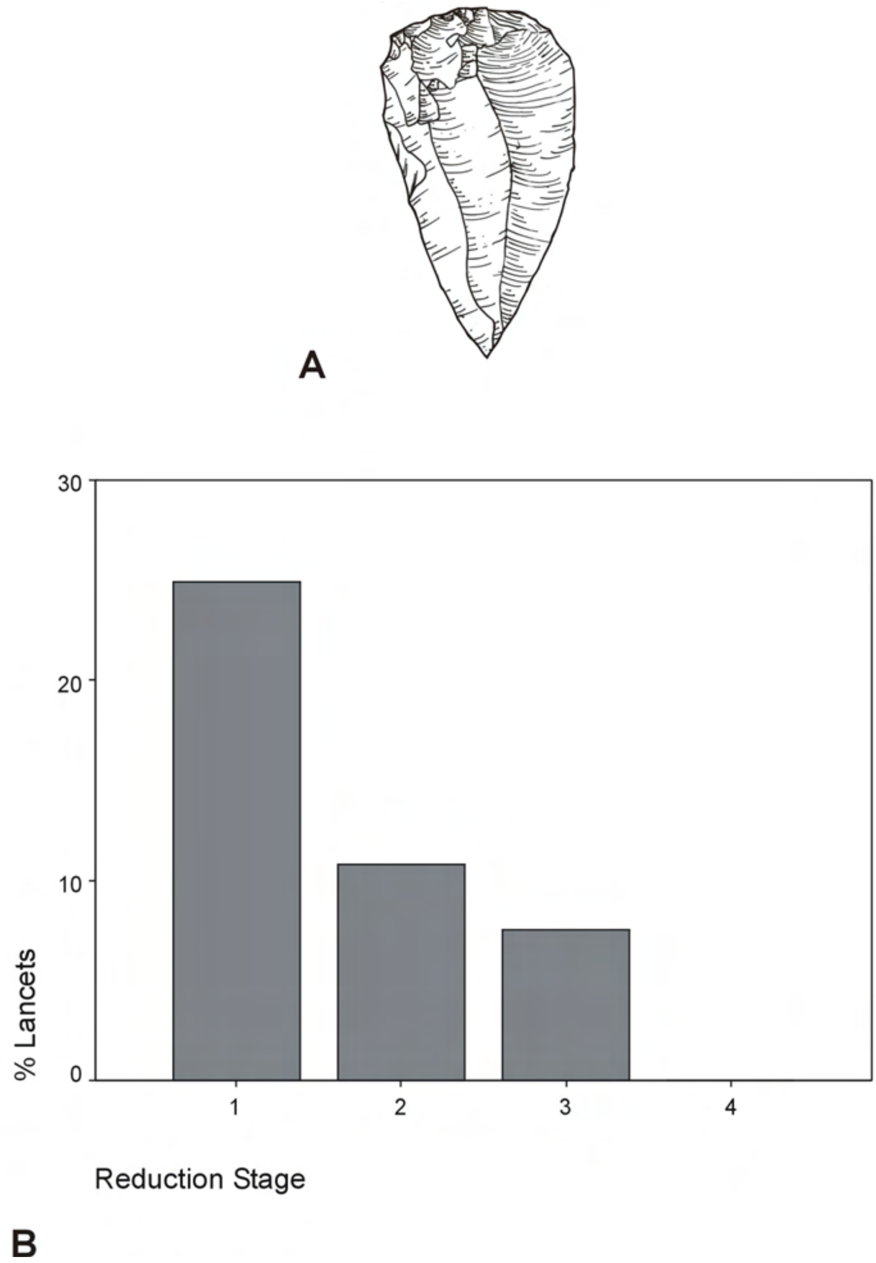


Figure 6.7. Cores found at quarries associated with lancet flakes. Note the large amounts of cortex on both cores, the cortical platform on one (A) and the single conchoidal scar on the platform of the other (B).

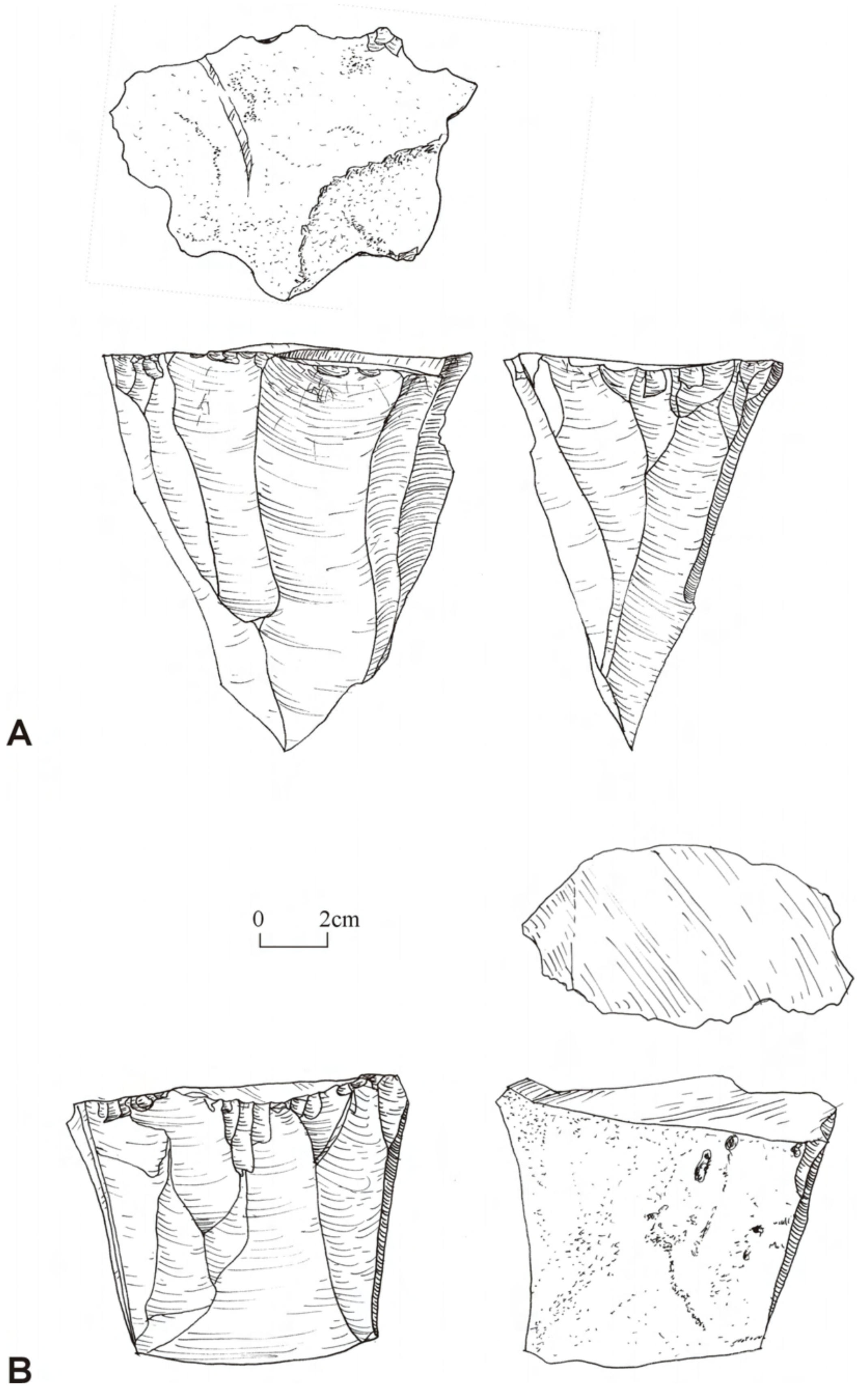
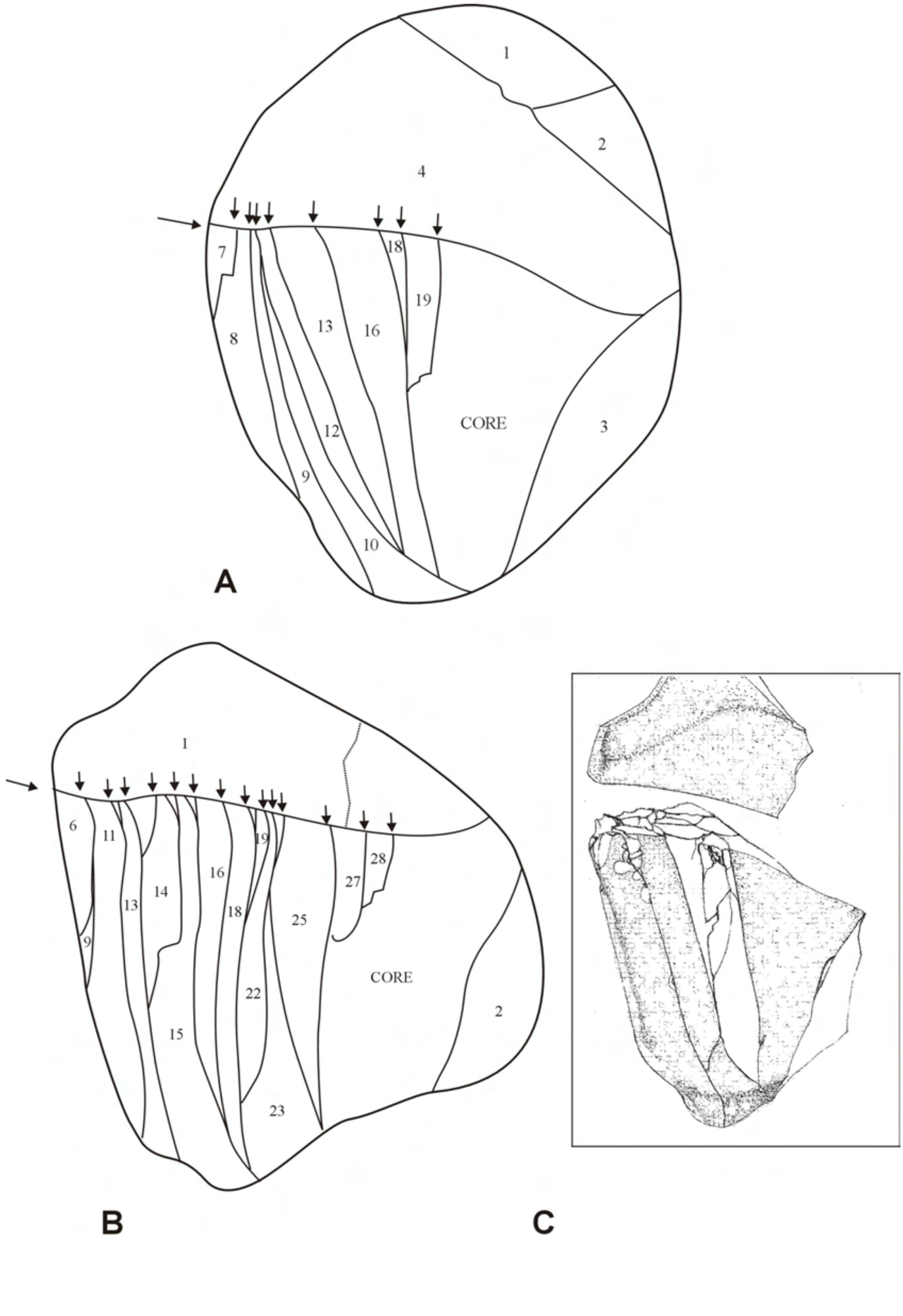


Figure 6.8. Conjoined quartzite cores and lancet flakes from A: a quarry near Wynbarr waterhole (Site 17), B and C: a quarry near Garnawala 2. Illustration C shows the actual conjoined core, while A and B show reconstructions of the original nodules and the series of flake removals taken as a slice through the centre of the platform.



In summary, lancet production tends to be oriented toward early stages in the reduction process – essentially, single platform cores that have either been rotated once to create a large flat platform, or unrotated cores with cortical platforms. Most of these cores were discarded soon after lancet production began, relatively early in the reduction process and while much mass remained on cores. The large Leilira blades (defined here as lancets longer than 10 cm) found in Wardaman Country on the other hand, mostly appear to be the largest and typically earliest elongate flakes removed in the sequence. Leilira production therefore likely represents a more extreme version of lancet production in terms of being confined to even earlier stages of reduction and in making little use of the reduction potential of the core.

Retouched Flakes

One approach to exploring the continuums that underlie and connect various retouched implement forms is to develop sequence models that order individual artefacts according to the amount of retouch they have received. Most studies of reduction continuums for retouched implements have remained locked within normative typological schemes. This is best seen in the analyses of changing implement morphology that are undertaken through comparison of measures of central tendency between the type classes themselves (e.g. Dibble 1995), rather than using individual specimens removed from a typological framework.

While these type-based approaches nevertheless go some way toward demonstrating the changeability of implement forms, they are neither the most powerful nor useful means of depicting reduction continuums. This is because the type classes employed are not specifically designed to investigate reduction issues, and hence are unlikely to reveal sequential patterns to maximum effect. As Kuhn (1992) states, type classes are "created to describe formal variation as observed in the archaeological record, and not to measure the results of some specific prehistoric phenomenon or process. As such [they are] likely to embody the effects of *many* independent influences on artefact form".

An alternative approach to depicting reduction continuums in retouched flakes is adopted here which documents the series of changes to a number of important aspects of flake morphology as reduction intensity increases. This analysis is undertaken for scrapers (i.e. retouched flakes), points, tulas and burrens. This chapter therefore contributes to a small but growing body of studies that present sequence models for a variety of implement forms from different parts of the country (e.g. Clarkson 2002a, 2005; Clarkson and O'Connor 2005; Hiscock 1982b; Hiscock and Attenbrow 2003, 2005a, b; Lamb 2005, 2006).

Australian Approaches to Scraper Classification

Archaeologists have grappled with the interpretation and classification of scraper variability, or the 'amorphous' unifacially retouched flakes found in many assemblages, since archaeology began. This is best seen in Australia in the multitude of largely incompatible scraper typologies that found their most elaborate form in the period spanning the 1940s to 1970s (Clarke 2000). At this time scrapers were typically classified and named according to the location of retouch (e.g. side, end, side and end, double side and end etc), the nature of retouch (e.g. nosed, notched, denticulate), assumed function (e.g. knives, drills, piercers, adzes, choppers, planes, scrapers, spokeshaves), the curvature of the retouched portion (e.g. straight, round, convex, concave), overall shape and size (thumbnail, horsehoof, flat) and the steepness of the edge (e.g. low angled, steep edged) (Allen 1972; Bowler *et al*. 1970; Clegg 1977; Flood 1973, 1974; Jones 1971; Kenyon and Stirling 1900; McCarthy *et al*. 1946; Mitchell 1949; Mulvaney and Kamminga 1999; Sanders 1975; White 1969). Combinations of these attributes and names were also employed at various times, usually in unsystematic ways, and often ending in large and confusing taxonomies. Mirroring global trends, Australian archaeologists have tended to attribute the diversity of retouched forms to stylistic or ethnic variation (Bowdler 1981; McCarthy 1948, 1949, 1958; Mitchell 1949; Tindale 1957; White and O'Connell 1982); the functional efficiency of tool edges (usually tied to edge angle and edge shape) (Sanders 1975; White 1969), efficiency of raw material use

(Morwood and Hobbs 1995a:183), or design requirements related to hafting (Mulvaney and Joyce 1965).

The reduction sequence for north Australian scrapers is developed from observed variation in implement morphology, and by building on past observations of the interplay between various aspects of flake shape and fracture mechanics. This is achieved by observing changes in four aspects of flake morphology as retouch increases. These are edge angle, edge shape, retouch perimeter, and retouch termination type - the same four variables that are frequently used to classify scrapers into types (Clarkson 2005).

Measuring Scraper Reduction

As discussed in Chapter 3, reduction intensity is best measured on dorsally retouched flakes using Kuhn's (1990) Geometric Index of Reduction (GIUR). As the Wardaman scrapers are predominantly unifacial (82%), typically have at least one dorsal ridge (88%), and are rarely invasively retouched (mean Index of Invasiveness of 0.18), this index is highly suited to investigating scraper reduction in Wardaman Country.

The following tests employ a sample of 338 retouched flakes from the four rockshelter sites described in Chapter 5.

Edge Angle. A number of researchers (Dibble 1995; Hiscock 1982a; Morrow 1997; Wilmsen 1968) have drawn attention to the relationship that often exists between retouched edge angle and the amount of unifacial retouch a flake has received. In many cases, unifacial retouching reduces the width of a flake without reducing its thickness. This has the effect of moving the margins closer to the thickest (often central) section of the flake, causing an overall increase in the angle of the retouched edge.

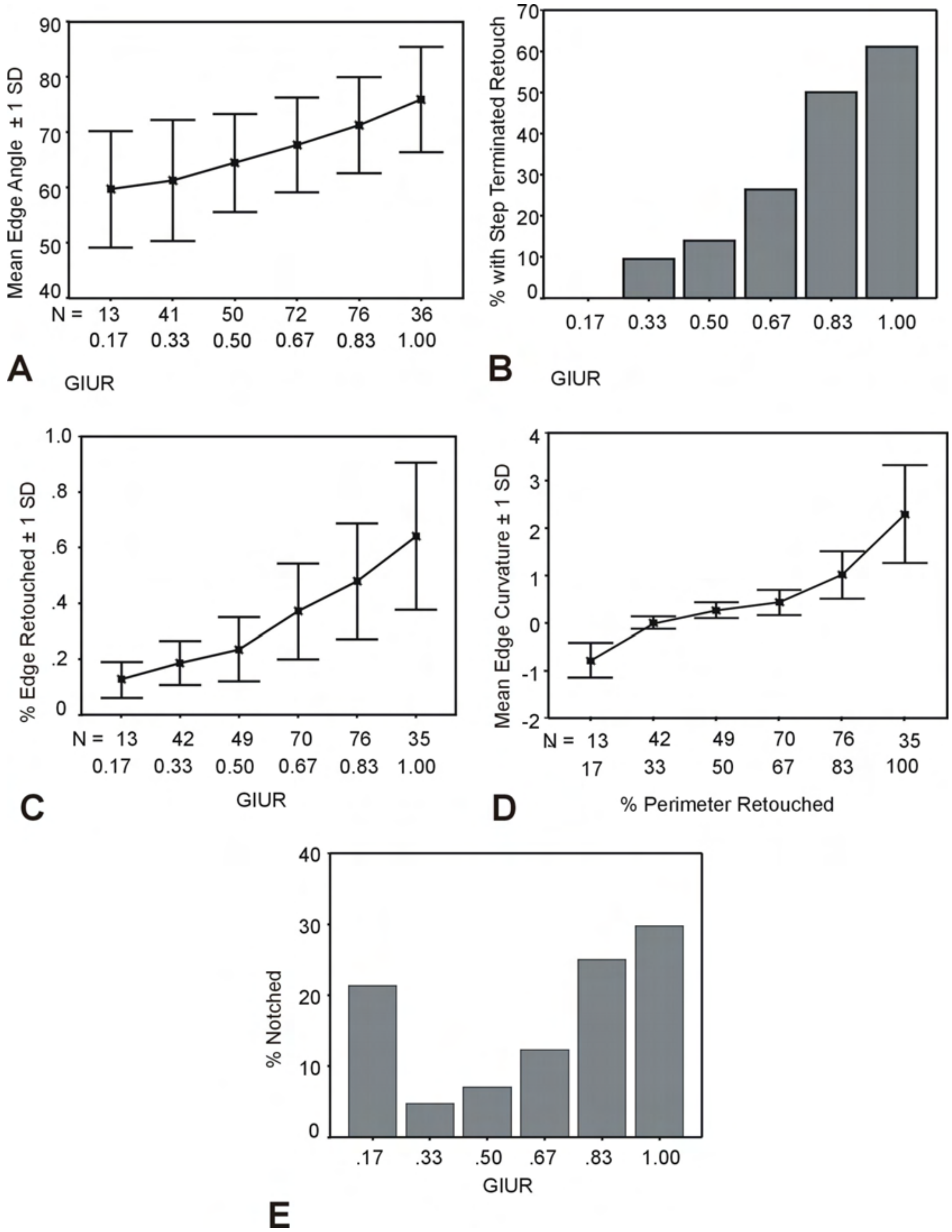
To examine whether such a relationship holds for the sample of Wardaman scrapers, edge angle was recorded at the same three locations where retouch height and flake thickness were taken for measurement of Kuhn's GIUR. Figure 6.9a plots the mean edge angle and standard deviation of scrapers for six intervals along the GIUR, and indicates that mean edge angle increases appreciably over the reduction sequence, with all means showing an increase relative to the previous GIUR interval. The standard deviations, on the other hand, overlap to some degree, indicating that a single morphological continuum underlies these sequential changes.

Step Terminated Retouch. As the angle of the retouched edge increases with retouch, it is expected that step terminations should also accrue with increasing frequency as force requirements change, flake inertia thresholds are reached, and terminations become more difficult to control (Dibble and Pelcin 1995; Pelcin 1997c, 1998). To explore this relationship, the frequency of scrapers with pronounced stepped retouching is plotted at six intervals along the GIUR in Figure 6.9b. This graph reveals a gradual increase in the frequency with which areas of step terminated retouch build up on flake edges as reduction continues.

Percentage of Perimeter Retouched. The proportion of the retouched perimeter of an artefact might also be expected to increase if new and adjacent edges are used and resharpened as existing ones are exhausted. Figure 6.9c plots this relationship and reveals a strong trend toward the use of more of the perimeter as the GIUR increases. Standard deviations also reveal the existence of continuous variation that underlies and unites the observed changes in central tendency.

Edge Curvature. As retouched perimeter is observed to increase with retouch intensity, it might also be expected that the retouched edge should become more curved as more of the perimeter is worked. Edge curvature is here calculated by dividing the depth of retouch by its diameter as outlined in Chapter 3. Using this technique, concave edges give a negative result while convex edges yield a positive one. Figure 6.9d indicates that edges start out slightly concave but become highly convex as the percentage of the perimeter retouched increases, plotted at six intervals. Perimeter of retouch is used in place of the GIUR in this test as it reveals a stronger relationship, although both reduction measures return significant results (GIUR vs. Curvature, ANOVA, $F = 18.8$, $df = 5$, $p = <.005$; % Margin Retouched vs. Curvature, ANOVA, $F = 164.1$, $df = 5$, $p = <.0005$).

Figure 6.9. Graphs showing the mean and standard deviations for changes in various aspects of scraper morphology as reduction intensity increases, as measured using Kuhn's GIUR or % perimeter retouched. A: mean retouched edge angle, B: % step terminated retouch, C: % perimeter retouched, D: curvature of the retouched edge, and E: % with notches.



Notching. Notches, or deep retouched concavities on an otherwise straight or curved margin, are found on a small number of scrapers. In her study of the function of scrapers from Ingaladdi, Sanders (1975:44) noted that notches were most often represented by a single deep retouch flake scar, with a total absence of use-wear within these edge concavities, despite noting its occurrence along portions of the adjacent margins. In these cases it seems more likely that notches represent early stage retouching rather than a functionally specific feature.

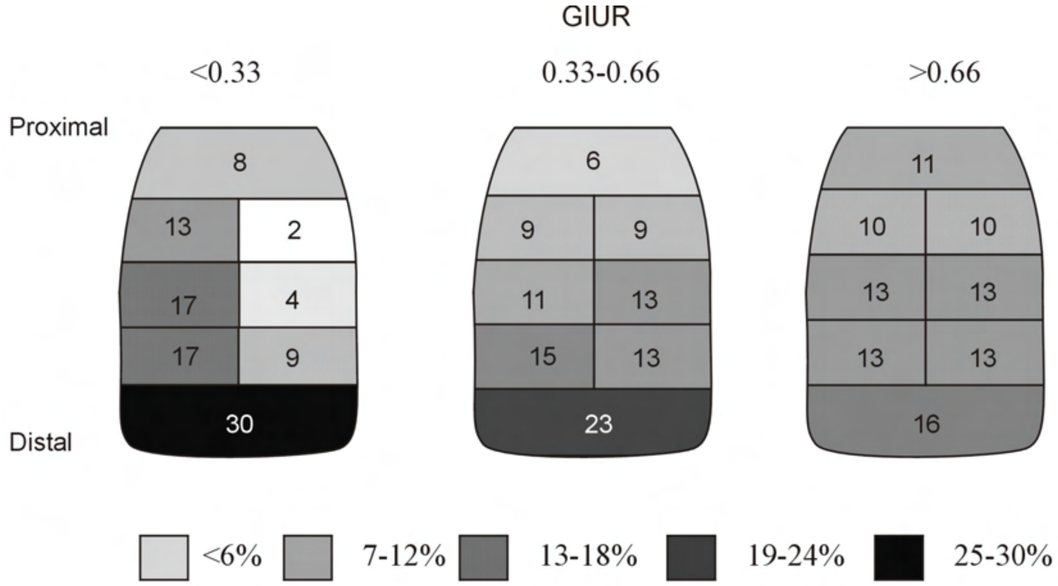
White (1969:23) and Lenoir (1986) have both noted that heavily retouched and stepped edges can at times be rejuvenated by removing deep retouch flakes from the edge. If this is the case for the Wardaman scrapers, then the incidence of deep and adjacent concavities on the margins of flakes could represent an attempt to return a heavily stepped edge to good condition. It might also be expected that deep rejuvenating blows of this kind would have a significant subsidiary effect of reducing the average edge angle as well as the number of step terminations remaining on the margin.

Examining the incidence of notching throughout the sequence of reduction reveals that edge concavities are most common in the earliest and the latest stages of reduction (Figure 6.9e). The trend apparent in Figure 6.9e confirms the operation of two separate reduction processes that may both create concavities on scraper edges: single deep flake scars added to the edge at the outset of retouching, and deep rejuvenating blows delivered to remove stepped and exhausted sections of margins from more heavily reduced scrapers.

Retouch Location. Figure 6.10 plots the changing frequency and distribution of retouch found around the perimeter of flakes as the GIUR increases. For this analysis, flakes were divided into eight segments of equal length, with the central three segments divided into 'left' and 'right' cells. The intensity of shading represents the evenness with which retouch is distributed across each of the eight segments. The number in each cell indicates the frequency (expressed as a percentage of all retouched segments) with which that segment is retouched for that interval of the GIUR.

The results show a trend from an earlier uneven distribution of retouch that is centred on the distal end and left margin, to a later and more even distribution of retouch around the entire perimeter of the flake.

Figure 6.10. Graphic depiction of changes to the frequency and evenness with which retouch is distributed across eight segments as retouch increases.



A Reduction Model for Scrapers

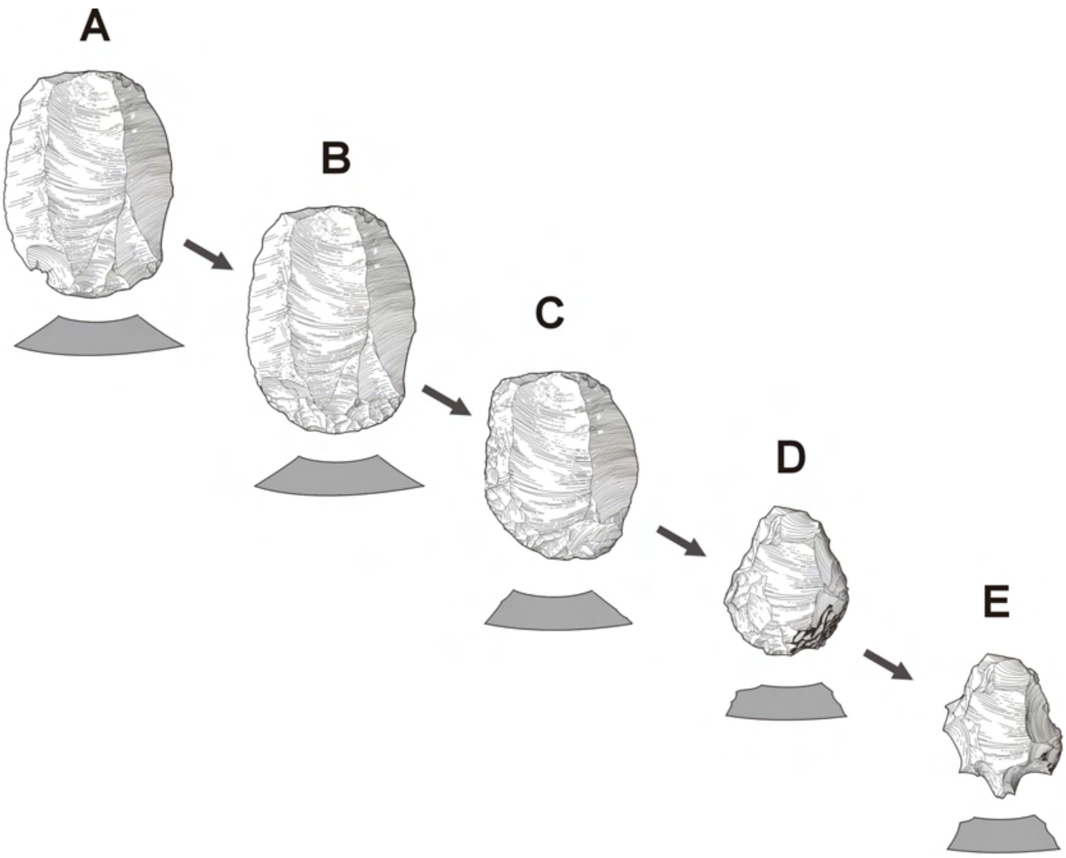
From the preceding tests it is clear that retouch intensity constitutes an important determinant of scraper morphology in the study region. To test the significance of the observed changes in implement morphology, *t*-tests were performed on adjacent GIUR categories for mean retouched edge angle, the percentage retouched perimeter and the index of edge curvature. The results are presented in Table 6.4 and indicate that almost all comparisons return significant results. The two comparisons that do not yield significant results are those between 0.17 and 0.33, and 0.33 and 0.5 on the GIUR for mean retouched edge angle. This result is quite understandable given that some flakes can be steep edged

even before retouching begins, and these will overlap to some degree with flakes at later stages of reduction. This problem disappears, however, once flakes reach values of >0.5 on the GIUR, and all comparisons return significant results thereafter.

Table 6.4. *t*-test results for changes in measures of implement morphology for adjacent GIUR intervals.

GIUR Interval	*t*	*F*	*p*
Mean Retouched Edge Angle			
0.17 - 0.33	-0.504	0.194	0.551
0.33 – 0.50	-1.527	0.657	0.13
0.50 – 0.67	-2.022	0.036	0.045
0.67 – 0.83	-2.497	0.002	0.014
0.83 – 1.00	-2.588	0.022	0.011
% Perimeter Retouched			
0.17 - 0.33	-3.228	2.087	0.003
0.33 – 0.50	-2.425	3.477	0.018
0.50 – 0.67	-5.169	10.281	<.0005
0.67 – 0.83	-3.435	2.702	0.001
0.83 – 1.00	-3.487	3.967	0.001
Index of Edge Curvature			
0.17 - 0.33	-4.269	5.977	0.007
0.33 – 0.50	-2.249	0.111	0.027
0.50 – 0.67	-4.178	7.596	<0.0005
0.67 – 0.83	-3.404	16.529	0.001
0.83 – 1.00	-2.635	8.031	0.01

Figure 6.11. A reduction model for scrapers from Wardaman Country. A-C: increasing reduction.



Chi-Square tests were also performed to measure the significance of changes in the frequency of step terminations, notches and the evenness of retouch distribution over the sequence of reduction. The results are shown in Table 6.5 and indicate that the changes over the reduction sequence are highly significant. A test of correlation between the GIUR and all measures of morphological change also returns Spearman's r and Kendell's tau results of 1, which are significant to the .01 level.

Thus, the morphological changes described above appear to take place in a consistent sequence that reflects the steady increase in reduction from relatively unworked through to relatively 'exhausted' forms. This sequence is illustrated in the reduction diagram shown in Figure 6.11, and depicts the changes to the extent, angle, shape, and location of retouch demonstrated to occur as reduction increases.

Table 6.5. Chi-Square statistics for percentages of step terminations and frequency of notching for each of the six intervals of the GIUR.

Variable	χ^2	*df*	*p*	*Cramer's V*	*Sig.*
% Step Terminated Retouch	55.8	5	$<.0005$	.419	<0.0005
% Artefacts with Notches	428.3	5	$<.0005$	.171	0.027
Distribution of Retouch	36.6	5	$<.0005$	.328	0.039

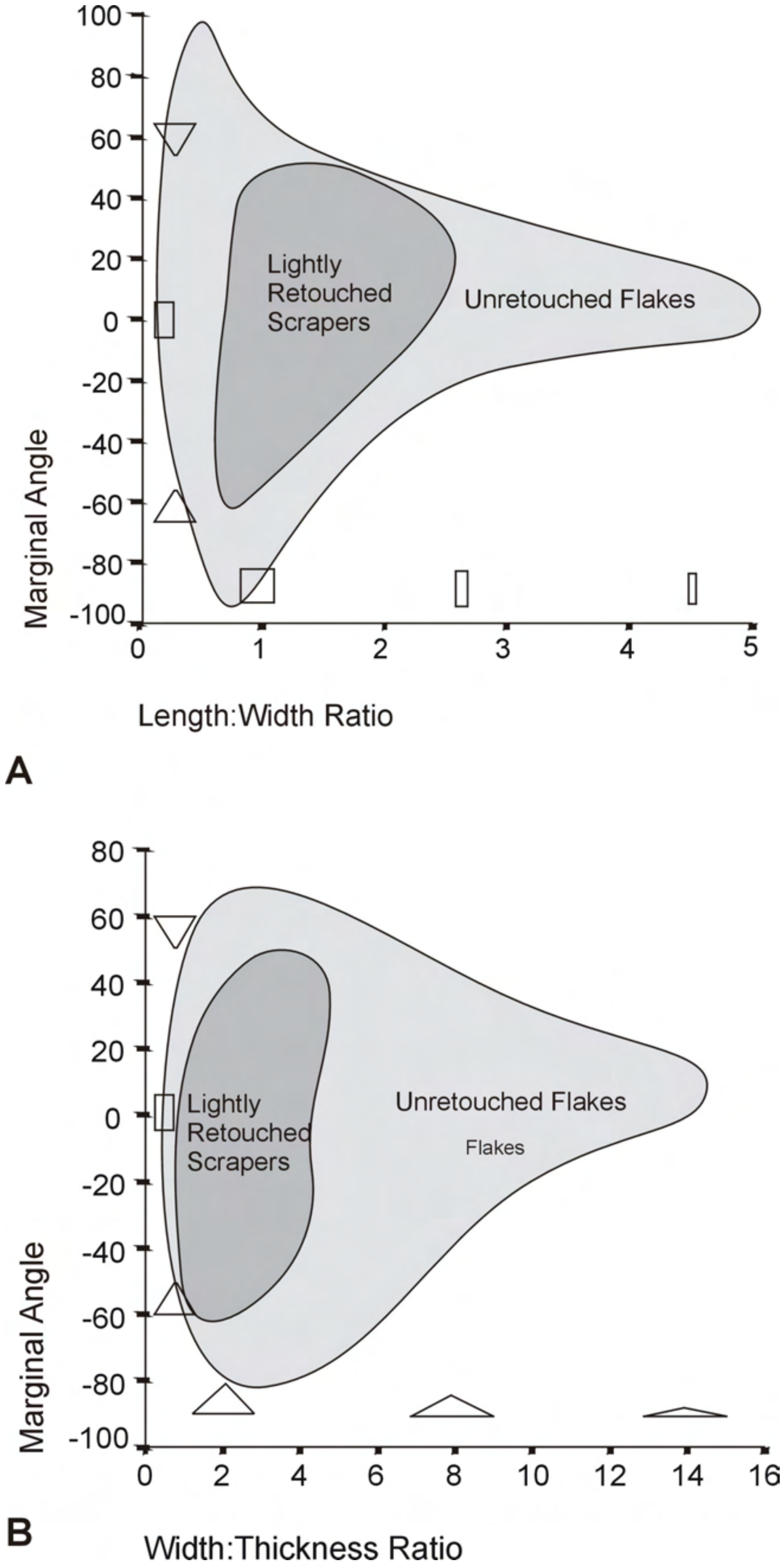
A typical sequence might therefore begin with the removal of a single deep flake scar on the left distal, or distal end of the flake, creating a small concavity or 'notch' (Figure 6.11A). This concavity is subsequently removed as retouch expands around more of the margin, creating a convex edge with a steeper edge angle (Figure 6.11B). By the time retouch spans around 50% of the perimeter, edge curvature and edge angle have both increased dramatically (Figure 6.11C). Towards the end of the sequence, retouch has increased to span the entire margin, has become very steep and exhibits areas of overlapping stepped scars in various places (Figure 6.11D). At this stage, edge rejuvenation may be attempted to remove accumulations of step terminations by delivering deep and forceful blows to the edge. This often creates a number of adjacent concavities that can give the implement a distinctive 'nosed' appearance (Figure 6.11E).

Blank Selection

It is often remarked in the Australian literature that scraper forms are highly variable in comparison to other retouched artefact forms, with little standardisation in the selection of flakes in terms of shape or size. Now that the reduction sequence for scrapers has been described in detail, it is possible to determine whether this is so for Wardaman scrapers, by examining the types of flakes commonly selected for this reduction process. This can be achieved by comparing the characteristics of scrapers that have received little overall modification, to the pool of complete unretouched flakes found in all four rockshelters in all time periods. Scrapers with little modification are here treated as those with a GIUR of less than or equal to 0.3. This cut off is implemented to ensure that flakes have begun the reduction process, and are not simply edge damaged flakes, yet are not so far advanced as to be significantly altered in size and shape by intensive retouching.

Figure 6.12 plots marginal angle against elongation (length/width) and cross-sectional shape (width/thickness) for complete unretouched flakes and lightly retouched scrapers. It is clear from this graph that flakes selected for retouch show a much reduced range to the total population of unretouched flakes, and that relatively thick, stout flakes were preferred over thin, elongate ones for scraper retouch. These flakes appear to derive predominantly from the second 'stage' of flake reduction, as 80% of lightly retouched scrapers have single conchoidal platforms.

Figure 6.12. Graphs showing the selection of a restricted range of flake shapes for scraper manufacture. A: marginal angle and elongation, and B: marginal angle and cross-section.



Variation in the size of scrapers over the reduction sequence also indicates that highly variable flakes were selected for retouching, with a mean weight of 21 ± 23 g and a coefficient of variation of 91%.

Discard Thresholds. Scrapers appear not to show any directional trend in weight loss over the sequence of reduction, with early stage scrapers (i.e. less than 0.3 GIUR) having a mean of 21 ± 18 g and late stage scrapers (i.e. GIUR of 1) a mean weight of 21 ± 26 g. This no doubt reflects the enormous variation in the size of flake blanks used. However, it also suggests that knappers were often unable to reduce scrapers down to very small sizes, probably due to the limiting variables identified above – that is, increasing edge angles and step terminations – both of which are likely to have resulted in terminating reduction prior to significant weight loss in most cases, despite the fact that most scrapers are heavily retouched (mode = 0.75).

Australian Approaches to Point Classification

Traditionally, two models of point production have proliferated in Australia, one that sees unifacial and bifacial points as unrelated and divergent forms, and another that views each type as having the potential to form stages in a continuum of reduction. Various tests and refutations of these models have been advanced over the years, although Hiscock (1994a) points out that it is the divergent model that has gained predominance in Australia. For example, differences in the types of raw material used in the manufacture of unifacial and bifacial points was cited by Schrire (1982) as evidence for divergence in point production in Arnhem Land, with unifacial points most commonly made from quartz and bifacial points from quartzite. Size differences were also advanced as evidence for the existence of a divergent model by Flood (1970) who argued that the smaller size of bifacial points at Yarrar shelter, southwest of Darwin, proved the existence of two separate types. Allen and Barton (n.d.) found the opposite pattern, with bifacial points from Ngarradj Warde Djobkeng in Kakadu tending to be larger than unifacial points, and likewise inferred from this that two discrete forms were represented. Flenniken and White (1985), on the other hand, argued on technological grounds founded in replicative experiments that true bifacial point reduction always commenced on the ventral face first, in order to move "the margins of the preform toward the middle of its mass so that flakes could be removed successfully from both faces" (Flenniken and White 1985:148). As unifacial points are typically reduced on the dorsal surface only, they reasoned that unifacial and bifacial points must be separate, as each entails a distinctive and mutually exclusive reduction sequence.

In a review of this literature, Hiscock (1994a) points to a number of flaws in the logic of arguments in favour of a divergence model. He also advances evidence from point assemblages from Kakadu and Lawn Hill in support of a sequence model. He points out that Schrire's case for a separation of point types on the basis of raw material useage is unconvincing as a number of studies have shown that both unifacial and bifacial points are made from a wide range of materials throughout Arnhem Land and Kakadu National Park (Allen and Barton n.d.; Brockwell 1989). The size differences noted by Flood also offer poor proof of the typological divergence model, and in fact, conform better to a reduction sequence model in which larger unifacial points are worked down to become smaller bifacial ones. At Ngarradj Warde Djobkeng, where unifacial points were on average smaller than bifacial points, Hiscock found the results not to be statistically significant.

Hiscock's own analysis focussed on the patterns of scar superimposition found on the ventral and dorsal surfaces of individual specimens at increasing distances to a stone source to determine the sequence of flake removals from each surface. The results showed that flaking began on the dorsal surface in the vast majority of cases for both unifacial and bifacial points, that points tended to decrease in size with distance from a stone source, and that bifacial forms became increasingly abundant in more distant assemblages. Hiscock interpreted this pattern to mean that unifacial points were often reworked into bifacial forms to extend their use-life as replacement stone became more difficult to obtain.

Roddam (1997) has also advanced evidence in support of a reduction continuum model using a sample of unifacial and bifacial points from sites across the Northern Territory. Roddam examined

changes in the morphological characteristics of unifacial and bifacial points in relation to a number of indices of reduction, including size, frequency of invasive scar removals, and the frequency with which dominant dorsal surface scar patterns shifted from an alignment parallel to the percussion axis to one that was perpendicular to it, reflecting the gradual removal of older dorsal scars that were created prior to the removal of the blank from the core. Roddam found statistically significant correlations between changes in these aspects of point morphology, including a decrease in flake weight, length and thickness from unifaces to bifaces, an increase in the frequency of invasive retouch on bifaces (with forms intermediate between marginally retouched unifaces and invasively flaked bifaces), and a shift from scars that were predominantly aligned parallel (longitudinally) to the percussion axis on unifaces to those aligned predominantly perpendicular (laterally) to this axis on bifacial points. Roddam also found that bifacial points were more likely to exhibit modification of the proximal end (or butt) into a square or rounded shape, and that platforms were often entirely retouched on bifacial points but not unifacial points. Most importantly, Roddam observed that a large overlap existed between both unifacial and bifacial points for all the attributes tested, suggesting that the two forms are merely arbitrary subdivisions of an underlying reduction continuum.

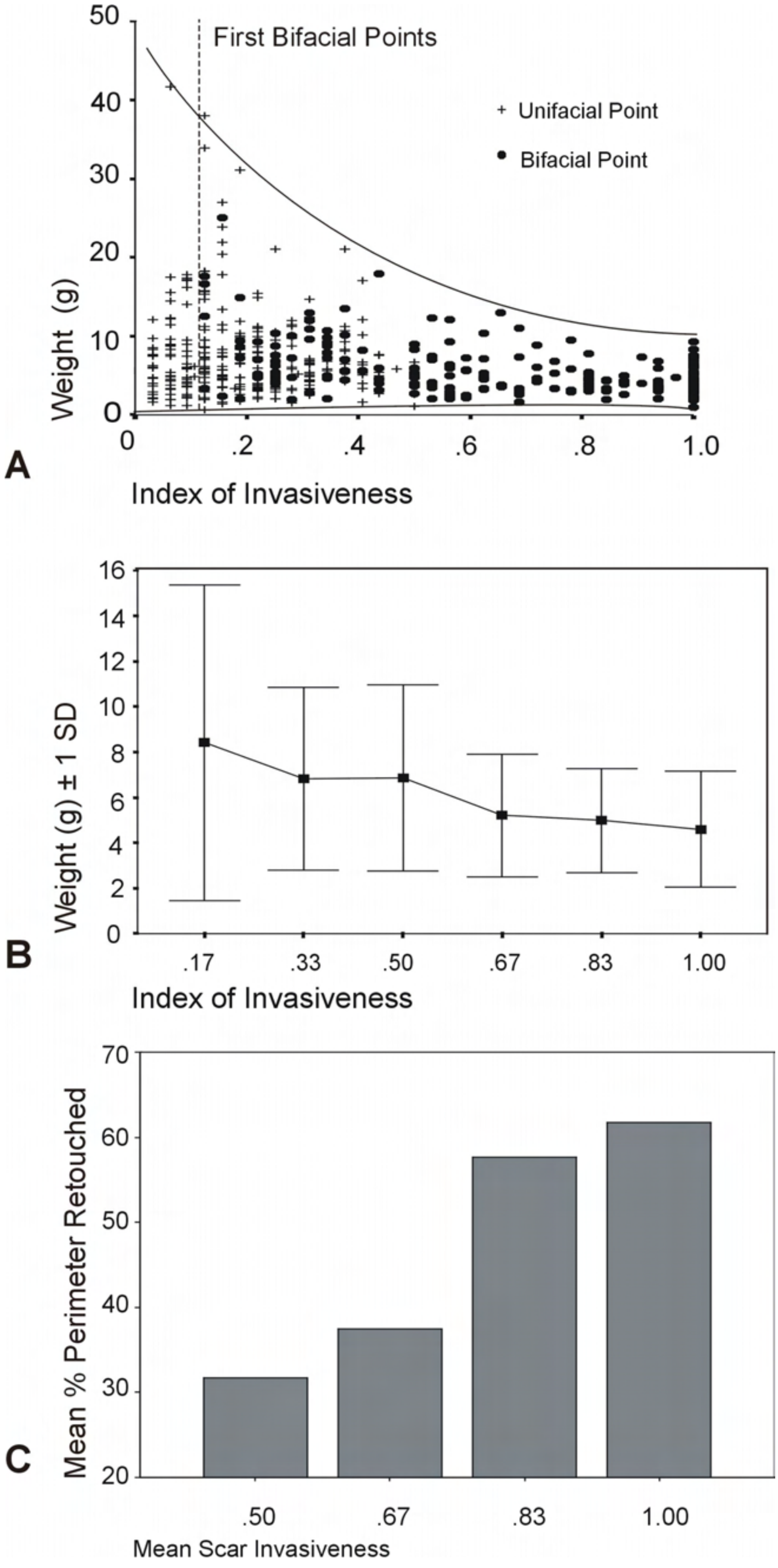
A major limitation of all of these studies is the use of a bipartite system of division that allows only two artefact classes (unifacial and bifacial points) to be examined and compared. This drastically reduces the analytical power of arguments that seek to demonstrate continuous change. In the following analysis points are subdivided into six categories according to the amount of reduction they have received. This allows the reduction process, and the continuum that underlies morphological differences, to be teased out and depicted in greater detail.

In the following sections, the reduction sequence for points is explored for the study region using a number of tests. Kuhn's index is unsuited to the measurement of invasive bifacial retouch as typically found on northern Australian points as bifacial thinning changes the relationship between retouch height and flake thickness, so that the index need not increase as a factor of retouch intensity. The Index of Invasiveness (Clarkson 2002b) is therefore employed in its place. As described in Chapter 3, this index measures the extent and coverage of retouch scars across both faces of an artefact, and expresses this as a value between 0, indicating no retouch, and a value of 1, signaling that an artefact is completely invasively retouched on both surfaces. In the following sections, changes to the size and shape of points are plotted at six intervals on the Index of Invasiveness. Unifacial points can not of course increase beyond 0.5 (i.e. one surface completely retouched), whereas bifacial points may become bifacial early in the sequence and remain so until they reach a value of 1. The sample used in the following tests consists of 495 complete points of all lithologies and from the four Wardaman rockshelters.

Morphological Changes

Size. A number of researchers have used changes in the size of points either as evidence for or against a reduction sequence model. In the following test, artefact weight is plotted against the Index of Invasiveness for unifacial and bifacial points. Figure 6.13a plots the weight of points against the Index of Invasiveness. Figure 6.13b, on the other hand, plots the mean and standard deviations for the weight of points at six intervals along the Index of Invasiveness. Both figures indicate that points become progressively lighter as retouching continues, and that more variation exists in lightly reduced points than heavily reduced ones. Differences in weight over the sequence also prove significant (Table 6.5). Figure 6.13a also indicates that points may become bifacial very early in the reduction process, suggesting that an underlying continuum unites these two forms.

Figure 6.13. Changes in the morphology of points over the reduction sequence. A and B: changes in weight, and C: changes in the % of perimeter retouched.



Percentage of Perimeter Retouched. In one sense the Index of Invasiveness already includes a measure of the perimeter of retouch, because the increasing number of segments required for the index to increase implies that retouch must be extending around more of the margin. To remove this effect, Figure 6.13c plots the changes in the percentage of the perimeter that has been retouched as the invasiveness of flake scars increases. Flake scar invasiveness calculates just the degree to which scars intrude onto the surface of an artefact by dividing the sum of all segment scores by the number of retouched segments rather than by all 16 segments. The graph shows a clear and steady increase in retouch perimeter as flake scar invasiveness increases. This relationship is also significant as shown in Table 6.6.

Table 6.6. ANOVA tests of significance for each of the attributes used to measure change in point morphology as reduction increases.

Attribute	*df*	*F*	*p*
Weight vs Index of Invasiveness	5	7.70	<0.0005
Width:Thickness vs Index of Invasiveness	5	17.35	<0.0005
Length:Thickness vs Index of Invasiveness	5	3.40	0.005
Base Curvature vs Index of Invasiveness	5	40.24	<0.0005
% Perimeter Retouched vs Scar Invasiveness	5	31.16	<0.0005

Cross-Sectional Shape. The cross-sectional shape of points has been observed to vary between different forms (Schrire 1982), principally with unifacial points tending to be thinner than bifacial points. The cross-sectional shape of points can be calculated by dividing width by thickness, for a lateral cross-section, and length by thickness for a longitudinal one. Figure 6.14a indicates that points begin as wide, thin flakes, but become narrower and thicker as reduction continues, taking on a lenticular cross-section in the later stages of bifacial reduction, before finally thinning again relative to width in the final stages. The capacity of invasive retouch to thin points is largely what allows edge angles to be maintained over the reduction sequence (with edge angles generally remaining in a narrow window of between 25 and 35 degrees). Length to thickness also reduces rapidly to begin with, but increases again in the final stages as thickness is further reduced through invasive flaking without further altering length (Figure 6.14b). ANOVA reveals both changes to be significant (Table 6.6).

Proximal Thinning and Butt Curvature. Another aspect of formal variation in points is whether the proximal end is trimmed (perhaps to better fit a haft), and the degree of curvature of the retouched base. Figure 6.15a and 6.15b indicates that the frequency with which points are thinned and shaped into a curved base at the proximal end increases significantly as retouching continues ($\chi^2 = 57.25$, df = 5, p = .005), and so too does the actual curvature of the base (Table 6.5). Lightly retouched points therefore tend to have straight and/or untrimmed butts.

Location and Distribution of Retouch. It is possible using patterns of scar location and superimposition to determine the general pattern of retouching on points, including the first surface to be retouched and the ordering of subsequent retouch on the dorsal and ventral surfaces. Shown in Figure 6.16a is a trend that confirms Hiscock's findings for points in Kakadu and Lawn Hill. Wardaman points begin in the majority of cases with retouch delivered to the dorsal face only. Then as reduction continues, the probability that retouch will be added to the ventral face increases, and this reaches its maximum likelihood by the time points have attained values of between 0.5 and 0.66 on the Index of Invasiveness.

Figure 6.14. Changes in point cross-section measured in two ways. A: lateral cross-section (width:thickness ratio), and B: longitudinal cross-section (length:thickness ratio).

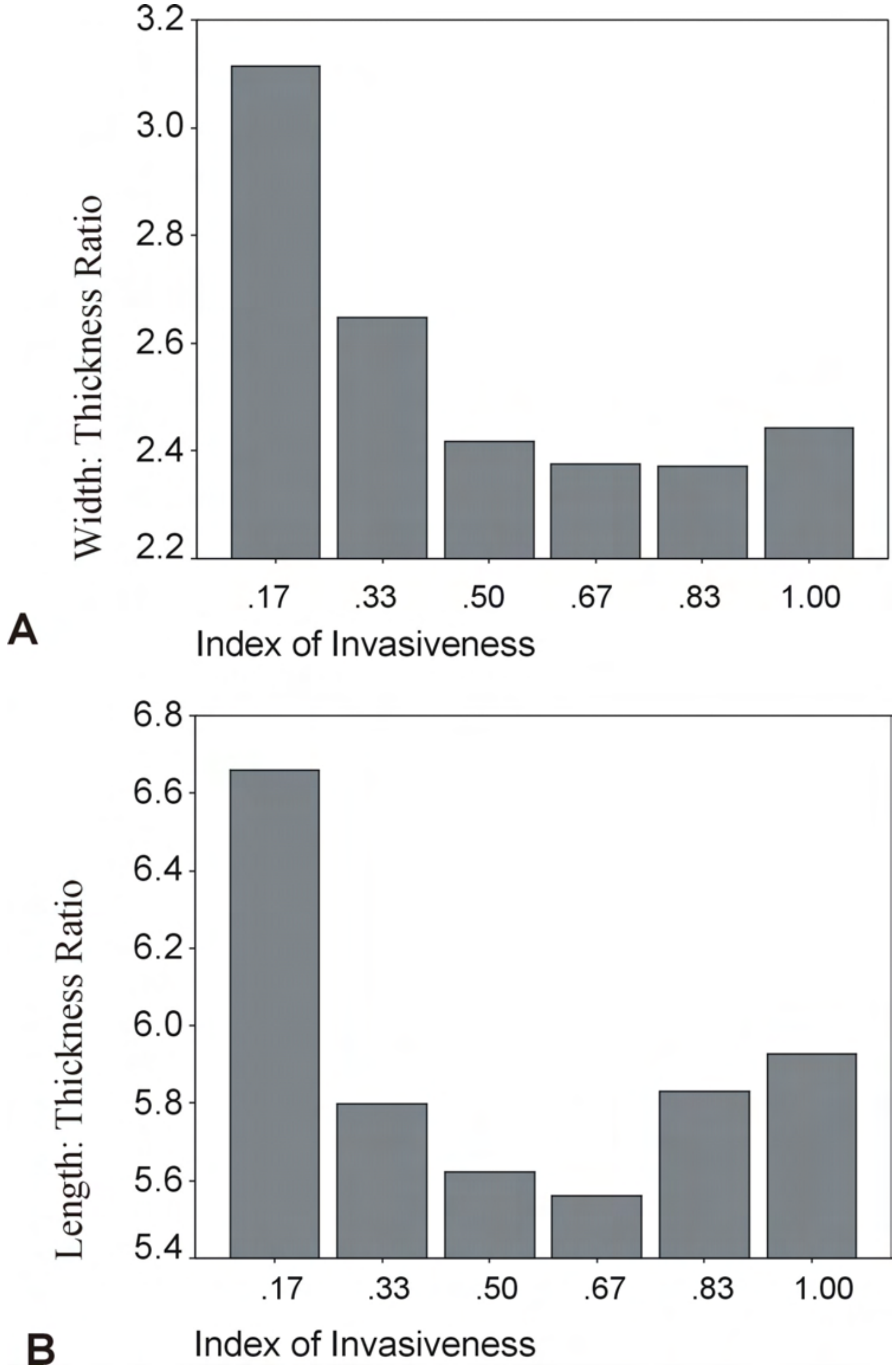


Figure 6.15. Changes in the proximal morphology of points. A: base curvature, and B: % proximal thinning.

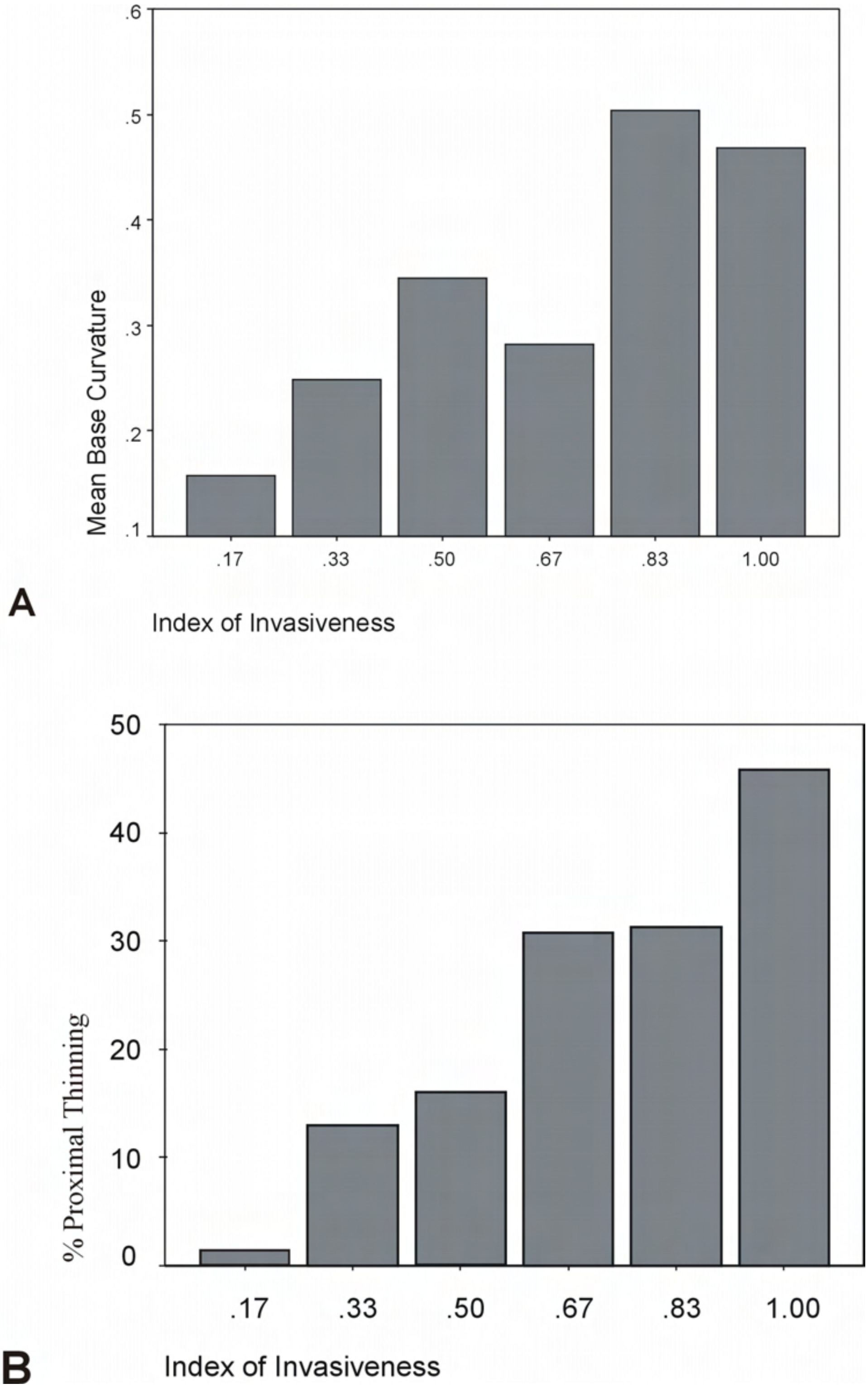


Figure 6.16. Changes to the location and ordering of retouch over the sequence of point reduction. A: order of retouch as determined from scar superimposition, and B: the evenness of retouch across 16 segments (changes in point shape and size are also represented).

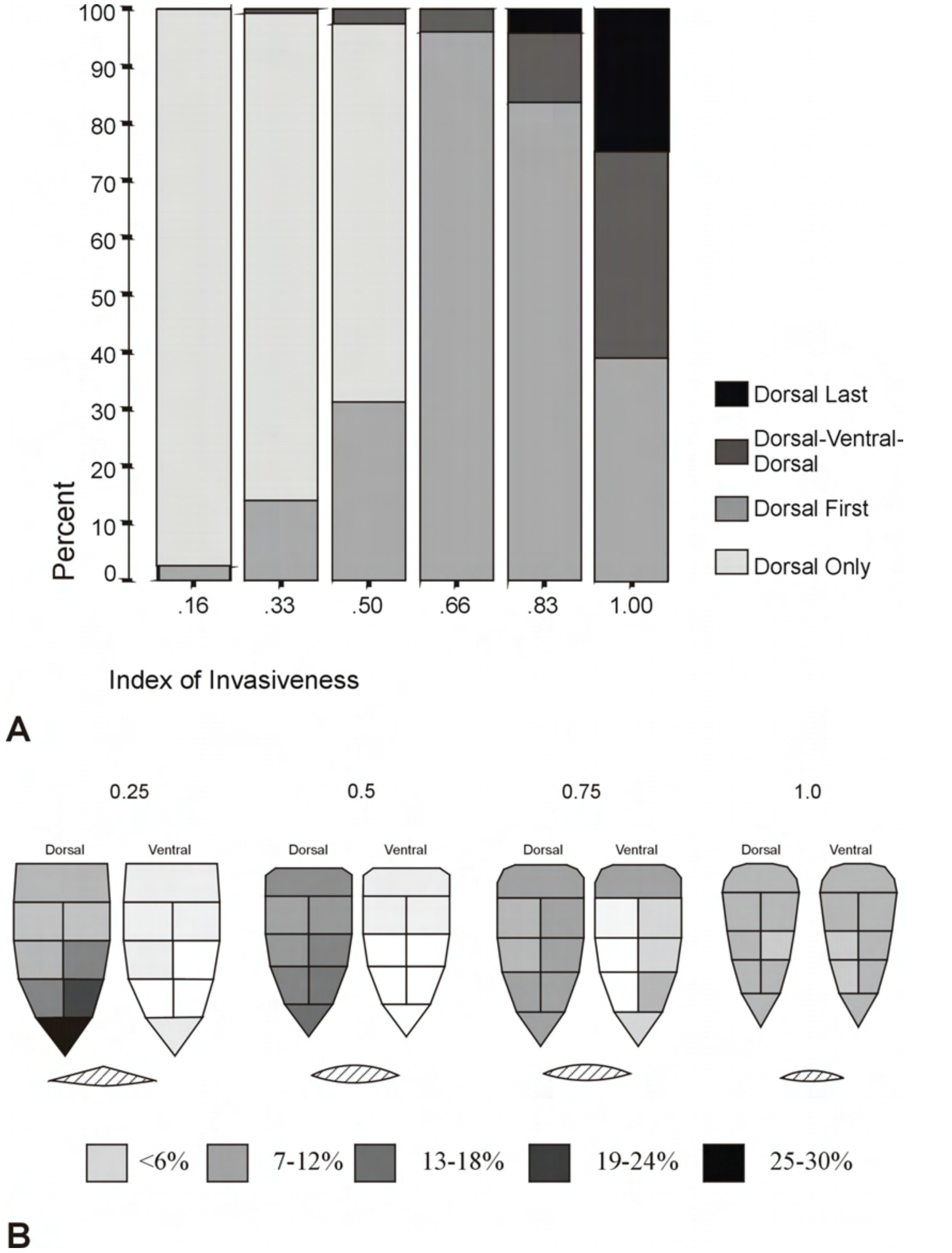
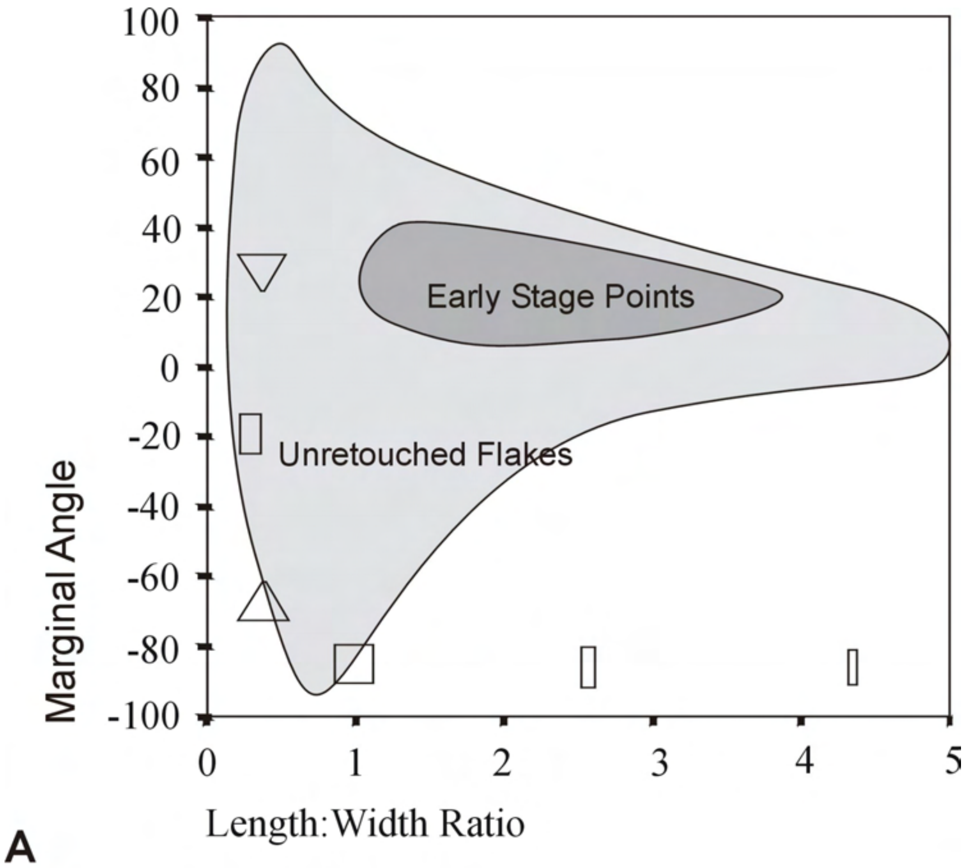
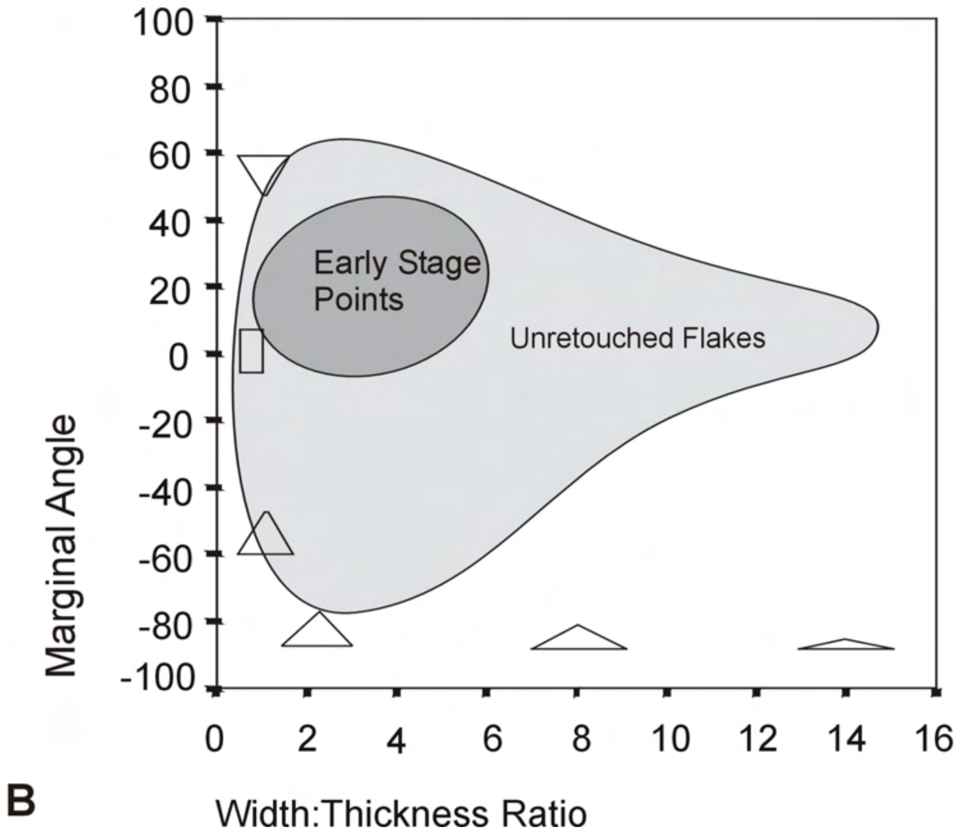


Figure 6.17. Variation in blank shape for points.





The second way of investigating changes in retouch location is to examine the evenness of retouch distribution across the 16 segments used to calculate the Index of Invasiveness. The results are shown in Figure 6.16b and show a progression from uneven retouch centred on the distal and right margin of the dorsal surface with a very low incidence of retouch on the ventral surface (mainly distal and proximal ends), steadily progressing to a very even distribution of retouch in all segments on both surfaces. Interestingly, the proximal end tends to receive more ventral retouch initially, a situation that probably reflects concern for the size and thickness of the proximal end for the purposes of hafting. Changes to the mean dimensions of points and the degree of curvature of the proximal end are also depicted in Figure 6.16b.

Blank Selection. It is possible to examine the types of flakes commonly selected for point manufacture by comparing the characteristics of lightly retouched points to the pool of complete unretouched flakes for which data exists. Points with little modification are defined as those with an Index of Invasiveness less than or equal to 0.3. This cut-off helps ensure that retouching has definitely begun but has not yet significantly altered flake form. The results are shown in Figure 6.17, and indicate that lightly retouched points represent a very narrow range of flake shapes. Examination of the attributes for this tight grouping of flakes reveals them to be predominantly lancet flakes. Lancets are elongate flakes, with low width:thickness and high length:thickness ratios and one or more arrises on the dorsal face – all of the attributes possessed by early stage points (Table 6.7).

Table 6.7. Mean attributes of lancets and lightly retouched points.

		Length : Width Ratio		Length : Thickness Ratio		Width : Thickness Ratio		Marginal Angle		No Arises	
Type	Number	Mean	c.v.	Mean	c.v.	Mean	c.v.	Mean	c.v.	Mean	c.v.
Lancet	173	2.50	23.9	7.80	32.9	3.18	27.7	22.34	21.6	1.30	83.0
Point	171	1.86	29.1	6.23	35.5	3.29	25.7	27.11	25.1	1.32	89.3

Examination of Table 6.6 reveals that all attributes except number of arrises have very low coefficients of variation, supporting the idea that points are made from a very select group of flakes best represented by lancets. However, Table 6.7 also reveals that elongation (length:width) and length:thickness ratios are lower for points than for lancets. This no doubt reflects the reduction in length that results from retouching the margins to form a strong point at the distal end. Alteration of the margins, even at this early stage of reduction means that platform attributes and weight are likely to be a better guide to similarities in the two populations than ventral measurements, as the platform is rarely altered at this early stage of reduction (see Figure 6.15b). Table 6.8 presents the results of *t*-tests on platform attributes between lancets and early stage points. None of the attributes compared show significant differences at the $p = .05$ level, and the two populations are therefore likely to be identical. It is therefore possible to conclude that points were manufactured from a narrow range of flake forms selected from a large overall pool of variation, and that selection was largely focused on the highly regular flake form represented by the lancet flake. As discussed above, lancets are best seen as flakes produced early in the process of core reduction when geometry and force variables were under the greatest control of the knapper.

Table 6.8. *t*-tests for differences in platform attributes between lancet flakes and lightly retouched points.

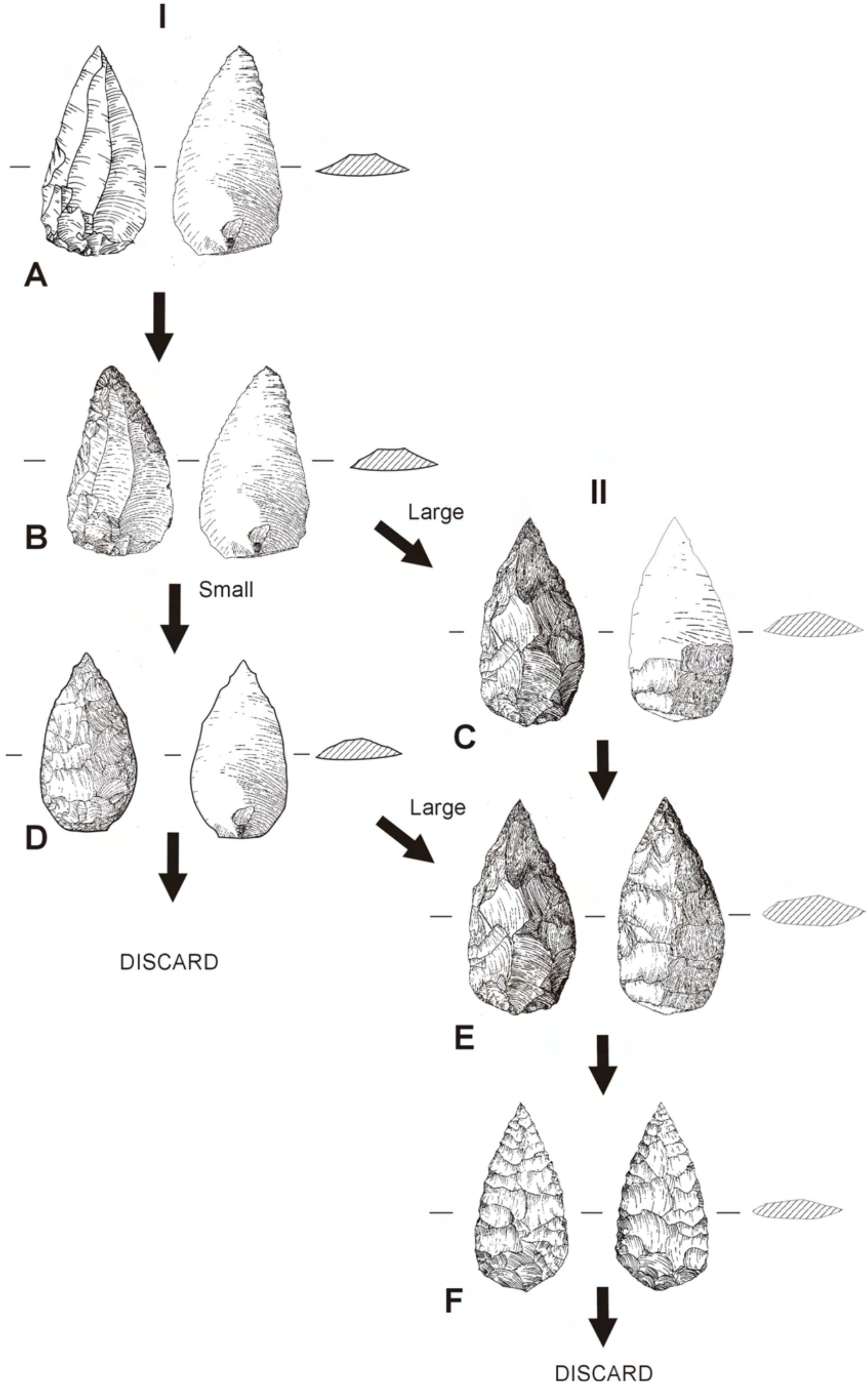
Attribute	*t*	*df*	*p*
Weight	-1.84	225.25	0.07
Proximal Width	-1.28	334.78	0.20
No. Arrises	-0.15	322.18	0.88
Platform Width	-0.93	328.17	0.35
Platform Thickness	-1.81	177.55	0.07
Platform Angle	-1.38	305.92	0.17

The size of point blanks also seems to vary, but is much more standardized than for scrapers (mean = 6.3 ± 3.9), representing around 30% less variation in blank form than for scrapers.

Discard Thresholds. Not all points continue on into bifacial stages, and many very small, heavily worked unifacial points are found (down to 0.6 g). It also seems that only heavier (i.e. larger) points are taken into later stages of reduction, presumably because bigger artefacts possess greater reduction potential – and some support for this notion is found in Figure 6.13a, where the minimum weight of points at discard increases over the sequence of reduction from a minimum discard weight of around 0.6 g at an index of 0.1 to a minimum weight of 2.1 g at an index of 1.0. The success of invasive bifacial knapping in maximizing the reduction potential of artefacts is seen however in the mean loss of 60% of the original weight of points over the reduction sequence. This is therefore a vastly more successful approach to extending the reduction of flakes than is marginal, unifacial scraper reduction. Adding a bifacial stage to point reduction also leads to noticeable improvement in the degree to which points can be reduced. The mode weight of dorsal only unifacial points with an index of 0.5 is 5 g (equal to a 20% reduction of original mean weight), whereas the mode weight of fully invasive bifacial points is only 3 g. Adding this last stage in the reduction process therefore adds further maintenance and resharpening time amounting to the equivalent of an additional 32% of the original mean weight of points.

The Reduction Sequence Model for Points. It is now possible to summarise the reduction sequence for points found in Wardaman Country. This sequence is illustrated in Figure 6.18. Point blanks were selected from a highly standardised pool of lancet flakes, with high length:width, high length:thickness and high width:thickness ratios, all properties that were sought after for point manufacture (Figure 6.18a). Retouching of the point blank began on the distal and right margin of the dorsal surface of the lancet flake (Figure 6.18b). Some ventral retouch was added early in the sequence if points were destined for bifacial stages, whereas unifacial points continued to be retouched around the perimeter until the entire dorsal surface was entirely invasively flaked (Figure 6.18d). Generally, it seems that only larger points were selected for bifacial working, whereas smaller flakes were more likely to remain unifacial. Flakes entering truly bifacial stages still tended to be worked more heavily on the dorsal surface than the ventral, with ventral retouch mainly concentrated on shaping and/or thinning the proximal end (Figure 6.18c). Truly bifacial points began to take on quite thick cross-sections due to reductions in width and length (Figure 6.18e). Only late in the reduction sequence did bifacial points receive substantial thinning on both faces, with length:thickness ratios climbing again (Figure 6.18f). As the sequence continued, points were more likely to receive thinning and shaping of the proximal end, resulting in a bifacially trimmed base with a pronounced curve (Figure 6.18e and f).

Figure 6.18. Reduction model for points, showing the flexibility in the system to either take points into a bifacial stage if large enough, or continue with unifacial reduction (generally if small).

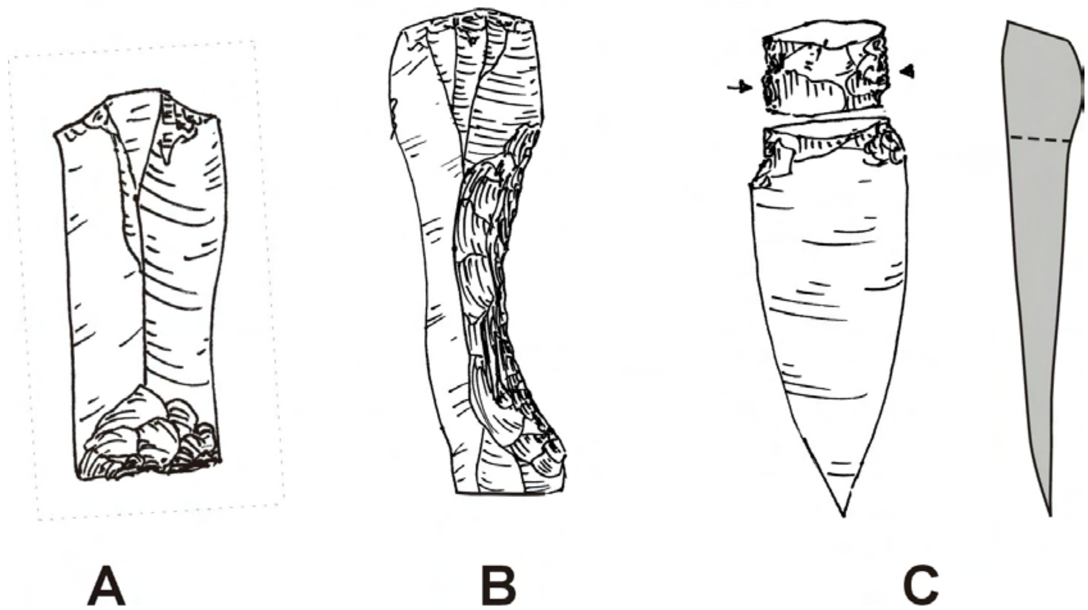


This reduction model allows us to talk of a first and a second sequence. The first sequence is purely unifacial, while the second diverges at various points into sequence II bifacial point manufacture. No cases have yet been identified in Wardaman Country of the manufacture of bifacial points from blocks of stone rather than flakes (as seen for instance in the Camooweal district of north Queensland [Moore 2003]). There is some evidence for the existence of a potential third sequence involving alternative bifacial reduction from the very earliest stages, although this strategy is very rare (only 8.3% of early stage points, as opposed to 80% that show initial retouch on the dorsal only). Chapter 7 explores alterations in the frequency with which sequences I and II were used through time.

Non-Point Lancet and Leilira Reduction

While lancets appear to have commonly been used in point production, these regular flakes were often retouched into other forms as well. For instance, a large number of lancet and Leilira blades were retouched on the distal end to form a steep edge (Figure 6.19a). Some of these show signs of having snapped transversely prior to retouching the broken distal end. Leilira blades in particular also often possess steep, convex retouching along the lateral margins. Additionally, lancet flakes sometimes had their proximal ends smashed off using bipolar percussion directed onto opposed lateral margins. Cundy (1990) called the bipolar butts that are produced by this process 'bipolar cores', and while this is technically correct, it is likely that this common procedure was performed to thin the proximal end by removing the thick bulb of percussion, rather than to produce bipolar flakes *per se*.

Figure 6.19. Examples of non-point retouch on leiliras and lancets.

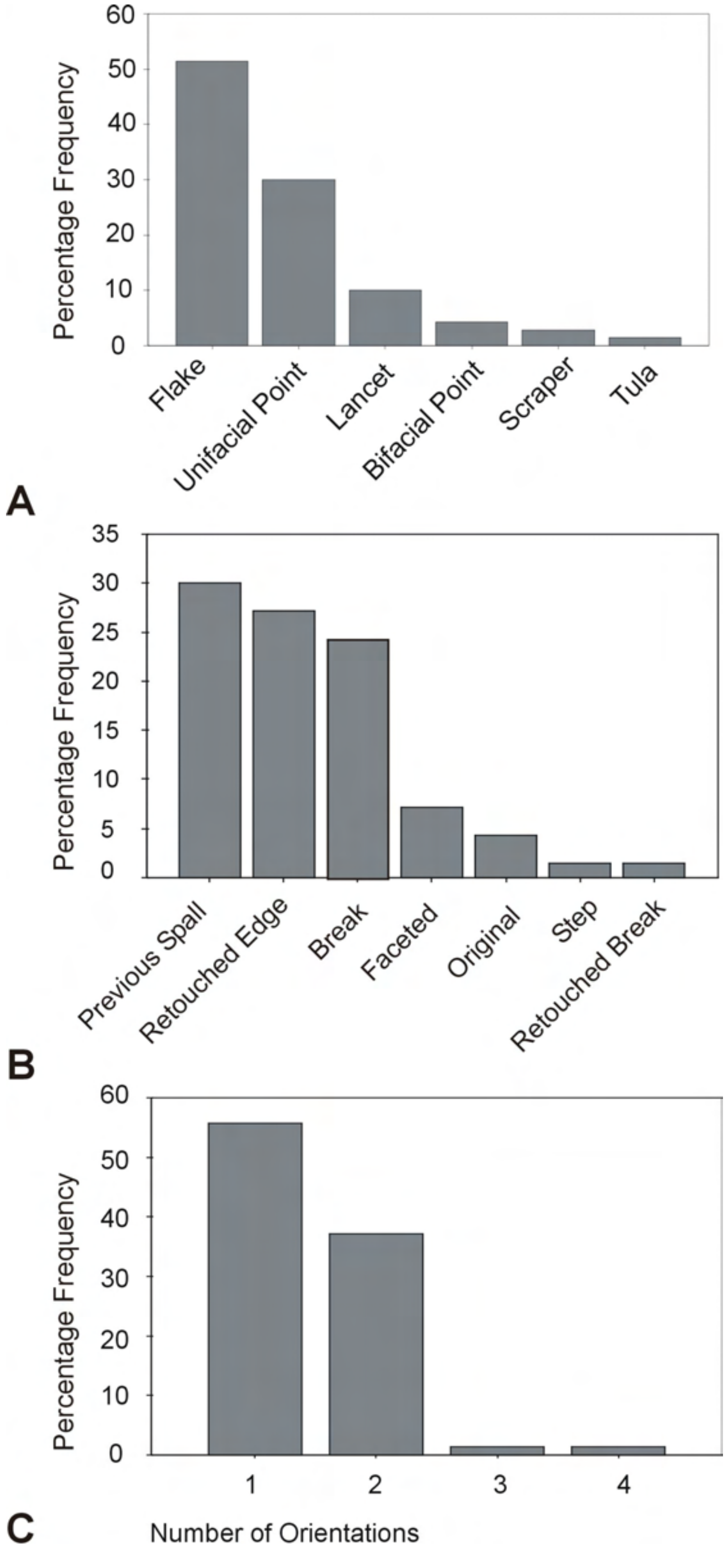


Burinate Reduction and Australian Classification

A distinctive characteristic of the Wardaman assemblages is the high prevalence of burinate retouch - or retouch that has removed one or more of the lateral margins of a flake by directing blows along the margins rather than away from them. Burins are known throughout much of Australia (Cundy 1977; Dortch 1977; Hiscock 1988, 1993a; McCarthy 1948; McCarthy 1964), but are generally poorly reported and their technological relationship to other classes of artefacts is not well understood (but see Hiscock [1993a] for a detailed reduction model for the Hunter Valley). The reduction process for burins is modelled here using a sample of 162 burins and spalls.

Blank Type Burinate retouch appears to have been delivered to a wide variety of flake forms, as shown in Figure 6.20a. Among these, flakes are most common, followed by unifacial points, then lancet flakes, then bifacial points, then scrapers and finally a single example of burinate retouch was found on a tula.

Figure 6.20. The nature of burinate reduction. A: frequency of burinate retouch on different artefact classes, B: frequency of different initiation surfaces, and C: the frequency of rotation.



Burinate Initiation. An important step in understanding the nature of burinate reduction is to examine the point of initiation for burin spalls. The frequency with which spalls are initiated from different types of surfaces is shown in Figure 6.20b. Burin blows are most commonly initiated from the scars left by previous spalls with a different orientation (i.e. usually at less than 90 degrees to the second series). This means that spalls were often struck from burins in more than one direction, and that the scars left by the first series of detachments were often used as a platform for the next series. This use

of previous burin spall scars to initiate reduction along a second margin often creates characteristic dihedral burins, particularly when both are initiated at the distal end (as is 75% of all burinate retouch). Despite the frequency of multiple burin platforms on flakes, single-platform spalling is most common in the sample of burins from rockshelters (Figure 6.20c).

The second most common initiation surface is retouched edges – essentially just sections of usually steep retouch close to the junction of two margins. A third common platform type for burinate retouch is a transverse break. Platforms are also often created by faceting a section of the end of one margin to form a flat surface suitable for use as a platform for striking blows along the adjacent margin. Original surfaces and step terminations are the next most common platform surfaces, while transverse breaks that have been retouched to provide a platform better suited to burination are the least common. Clearly, this set of platform surfaces suggests that burination was a common way of reusing flakes once they had broken, or of transforming plain and retouched edges for some specific purpose. This may have been to create a robust scraping implement, to make long thin spalls for a specific purpose, or simply to create fresh flakes with sharp edges when little other raw material was available.

Number of Spalls. Turning to the spalls themselves, Figure 6.21a indicates that the number of spalls struck from burins is strongly related to the number of initiation points (or orientations). As the number of spalls increases, the platform angle left after the last scar also gradually increases (Figure 6.21b), mirroring the changes in platform angle seen in core reduction described above. The frequency of step and hinge terminations also increases as the number of spalls increases (χ^2 = 4.18, df = 1, p <.0005, V = 0.273), presumably as a result of increasing platform angle and excessive force requirements.

Spall Length. Burinate production tends to produce extremely elongate flakes (mean = 5.6, s.d. = 2.8, maximum = 16, N = 65) up to 50 mm long (mean = 26 mm, s.d. = 8), sometimes with a characteristic twist in the ventral face along the percussion axis. As burinate reduction continues, as measured by the number of spalls removed from burins, the length of burin spall scars decreases markedly as shown in Figure 6.22. ANOVA returns a significant result for changes in length as reduction continues (Table 6.9).

The Reduction Sequence for Burins. The analysis of the nature of burinate reduction as well as changes in the morphology of burins and the resulting spalls, allows a simple reduction model to be built for burins, as shown in Figure 6.23. Burin reduction appears to be principally focused on otherwise unretouched flakes, but unifacial points, lancets and other implement classes have all had burin spalls removed to varying degrees. The vast majority of spalls are oriented from the distal end, and initial spalls are struck either from retouched edges, breaks, plain or faceted margins. As the number of spalls struck from the burin increases, the chance of ending reduction from a specific platform also increases as platform angle and the frequency of step and hinge terminations increase. Knappers often responded by starting burinate flake production again on a new platform, most commonly the flat surfaces left by previous spall removals, sometimes creating classic dihedral burins on the distal margins of lancets (Figure 6.23a), points and other flakes. Rotation of flaking around the margin continued in some cases until up to 12 spalls have been removed from all four margins (Figure 6.23b).

Table 6.9. ANOVA tests for significant changes in burin morphology as reduction continues.

Attribute	*df*	*F*	*p*
No. Platforms vs No. Scars	3	34.03	<0.0005
Last Platform Angle vs No. Scars	3	4.55	0.06
Burin Length vs No. Scars	3	3.7	0.015

Figure 6.21. Changes in burin morphology as the number of platforms and scars increases. A: number of orientations, B: changes in mean platform angle, and C: changes in the frequency of step and hinge terminations.

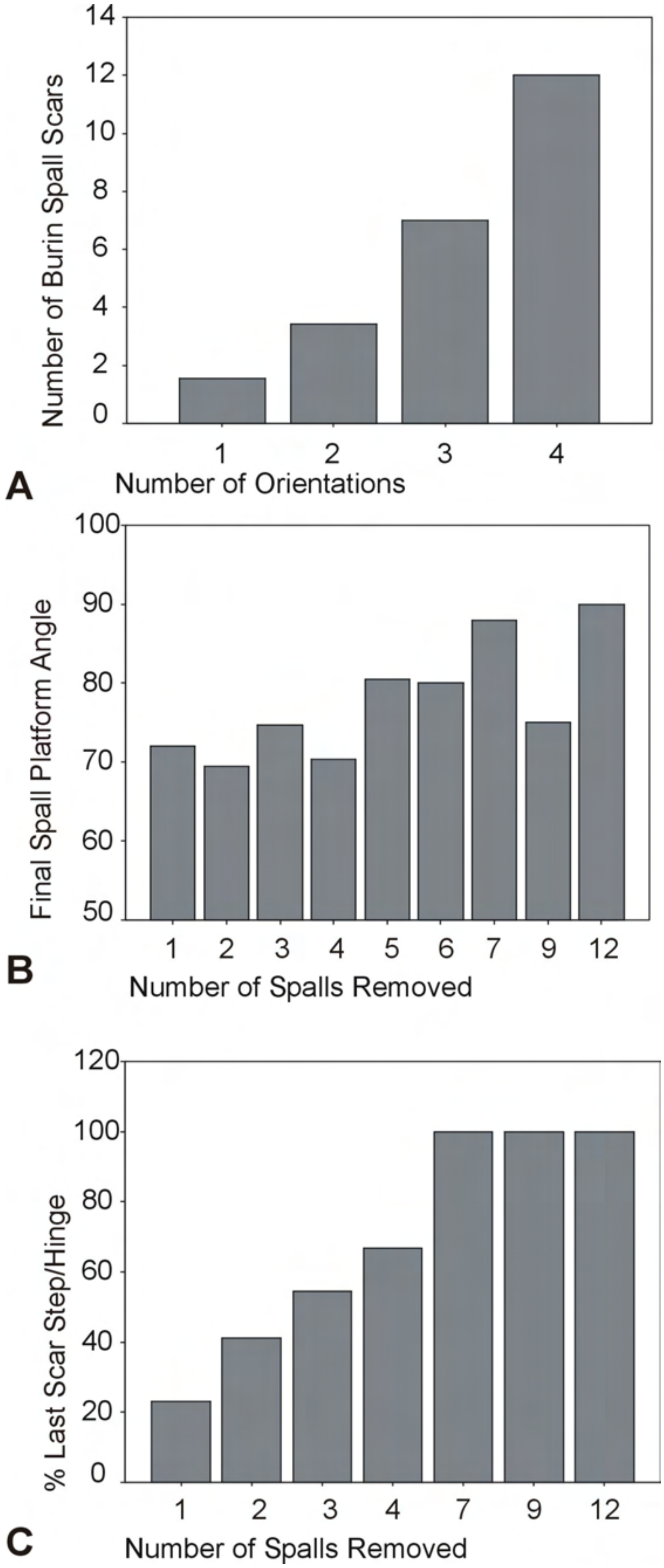
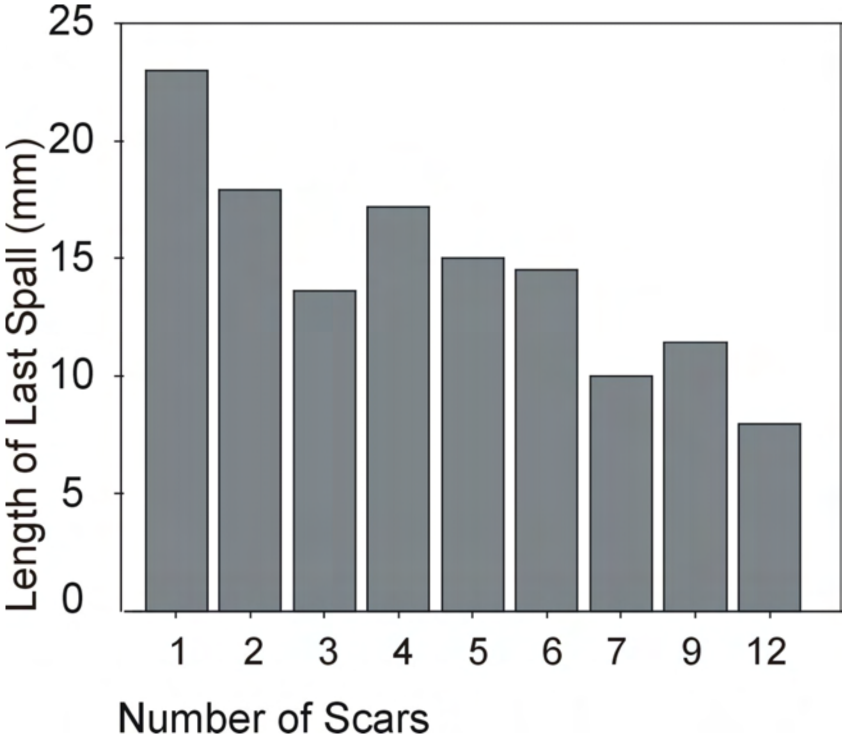


Figure 6.22. Changes to the length of burin scars as reduction continues.



Tulas and Australian Classification Systems

Tulas are predominantly distally retouched flakes with a pronounced bulb of percussion where dorsal retouch has removed all excess ventral area, leaving only the bulb intact. Ethnographically they are known as specialized tools for adzing hard woods. Alongside points, tulas are perhaps the best recognized retouched implement form in Australia, and their reduction sequence has been well documented by early commentators such as Horne and Aiston (1924), and later by Cooper (1954), McCarthy *et al*. (1946), Tindale (1965) and Gould (1980), though not all Australian archaeologists have accurately identified these artefacts in archaeological contexts (see Hiscock and Veth 1991). Cooper (1954:92) summarized Horne and Aiston's earlier comments on the nature of tula reduction as follows: "Horne and Aiston (1924) remark that during the process of shaping a boomerang the native tradesman trims the Tula from time to time as its edge becomes blunted, by means of a hammerstone, until it is discarded and a fresh implement inserted in the gum. In consequence of continued use and the resultant symmetrical re-sharpening of the working edge to compensate for it, the Tula is gradually but evenly diminished in size and shape in the direction of its base… until it finally attains that state of diminution where it is no longer practical to embed it firmly in the gum or continue its employment economically."

Cooper's, and Horne and Aiston's, comments provide insight into some of the likely changes in morphology that should accompany continued reduction of tulas. They suggest that tulas are predominantly retouched in a succession of flake removals across the distal end, retaining the symmetry of the artefact, and ending when the flake is so shortened that it can no longer be reliably hafted. Hiscock and Veth's (1991) reanalysis of the tulas from Puntutjarpa found this progression in distal retouch to be readily identifiable on archaeological specimens, and were able to separate tulas and their heavily reduced slug forms from other retouched flakes on the basis of length:width ratios and the location of retouch. The sequence of changes to tula morphology is explored in this section using a number of measures of reduction, but primarily elongation (following Hiscock and Veth (1991)), for a sample of 66 tulas.

Size. If the reduction sequence outlined by Cooper and Hiscock and Veth holds for the Wardaman tulas, then changes in reduction intensity as measured by elongation should be accompanied by reductions in length, as length should show greater reductions than width. This turns out to be the

case for the Wardaman tulas as shown in Figure 6.24a, with a significant decrease in the length of tulas occurring as elongation decreases (ANOVA, $F = 23.3$, $df = 5$, $p < .0005$).

Figure 6.23. A reduction model for burins. Two common sequences are illustrated. A: the sequence leading to dihedral burins, and B: a sequence of rotations leading to multiple orientations and the removal of substantial numbers of spalls.

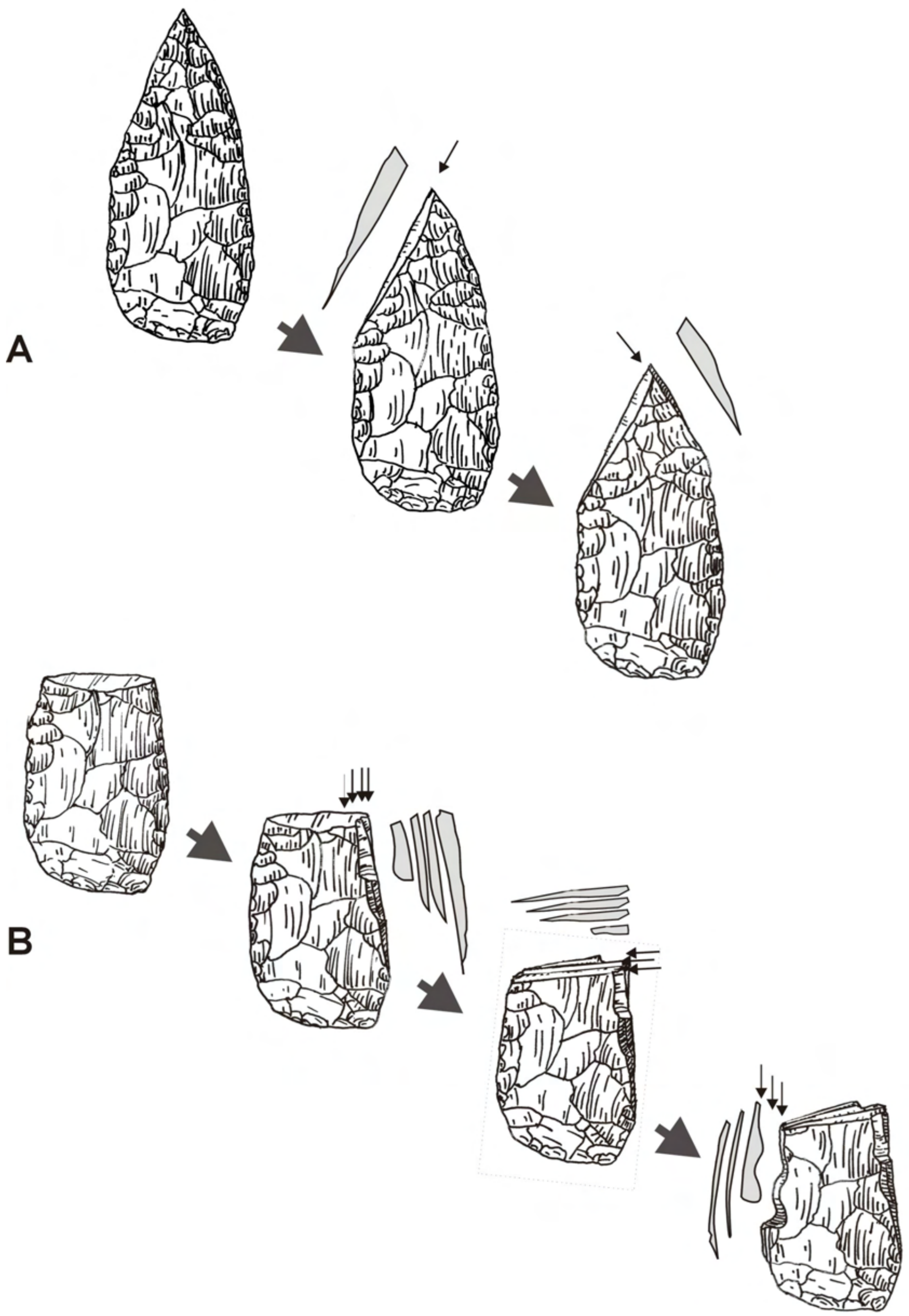
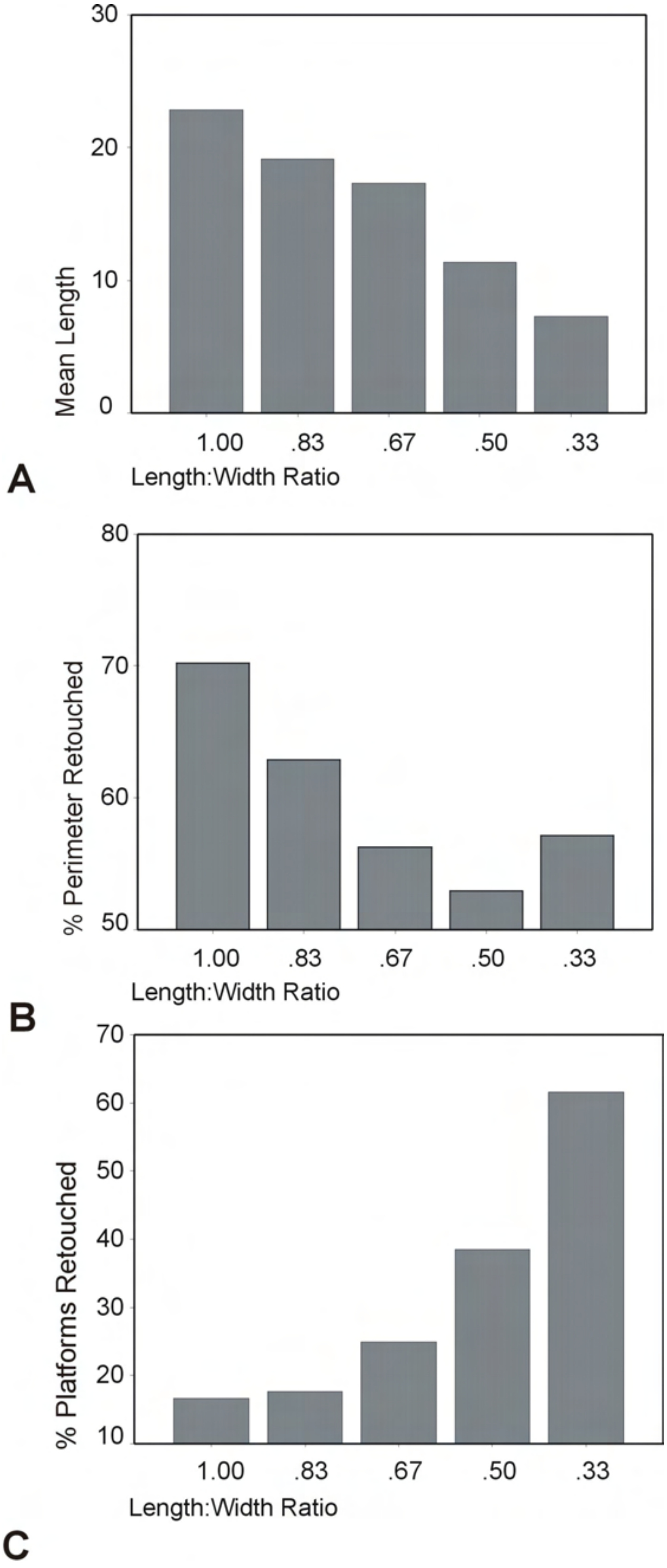


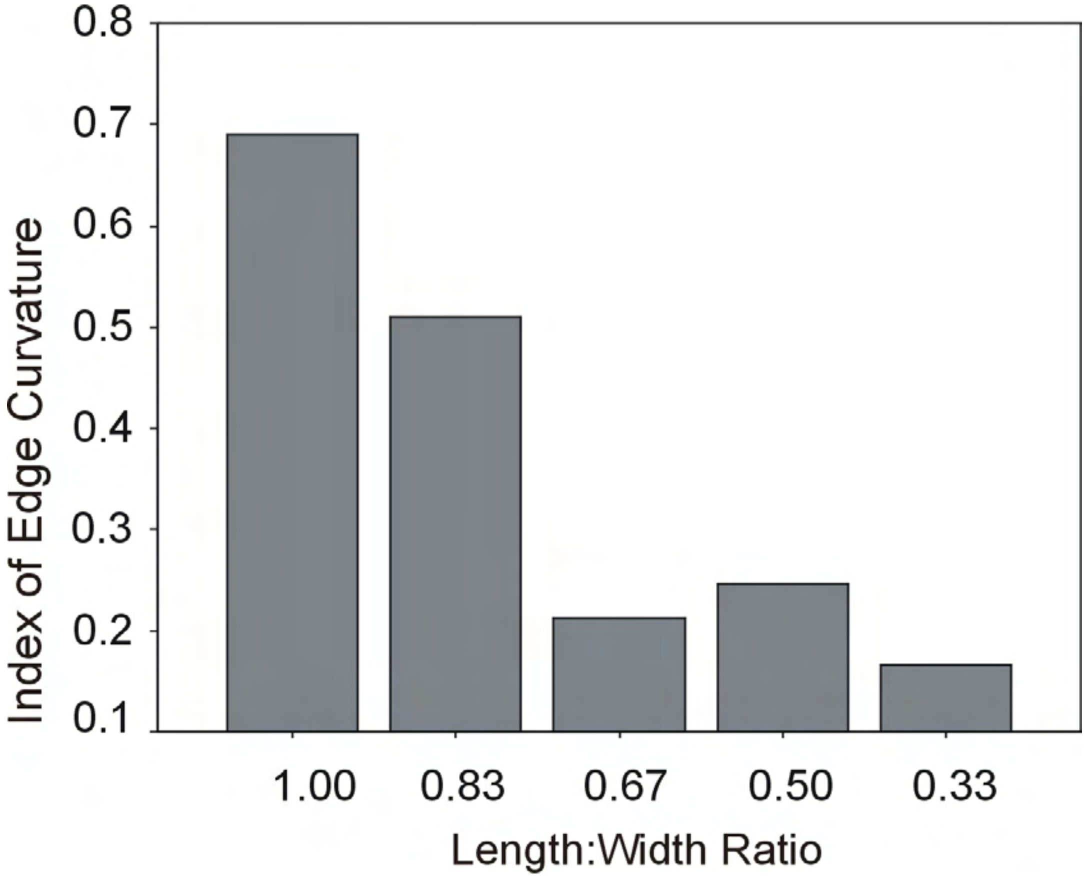
Figure 6.24. Changes in the morphology of tulas over the sequence of reduction. A: reduction in mean length, B: reductions in the % perimeter of retouch, and C: % platforms retouched.



Percentage of Perimeter Retouched. According to ethnographic accounts of tula manufacture, an important first step is the removal of excess ventral area so that only the convex bulb of percussion is left intact. Tulas are then steadily dorsally trimmed from the distal end back toward the proximal end as use and resharpening continues. The result is a gradual loss of perimeter as reduction continues, but also a relative increase in the proportion of the unretouched edge as represented by the platform. This pattern should be represented by a decrease in the perimeter of retouch as reduction continues. This is exactly what is found for tulas, as shown in Figure 6.24b. However, in the final stage of reduction, perimeter of retouch increases again. This likely represents the reduction of the platform in the final stages of reduction. Turning the tula 180 degrees in the haft and retouching the old platform edge as the new working edge was observed ethnographically, and some tula slugs show signs of working on both proximal and distal ends. Figure 6.24c confirms that as tulas enter late stages of reduction, platforms are retouched with increasing frequency.

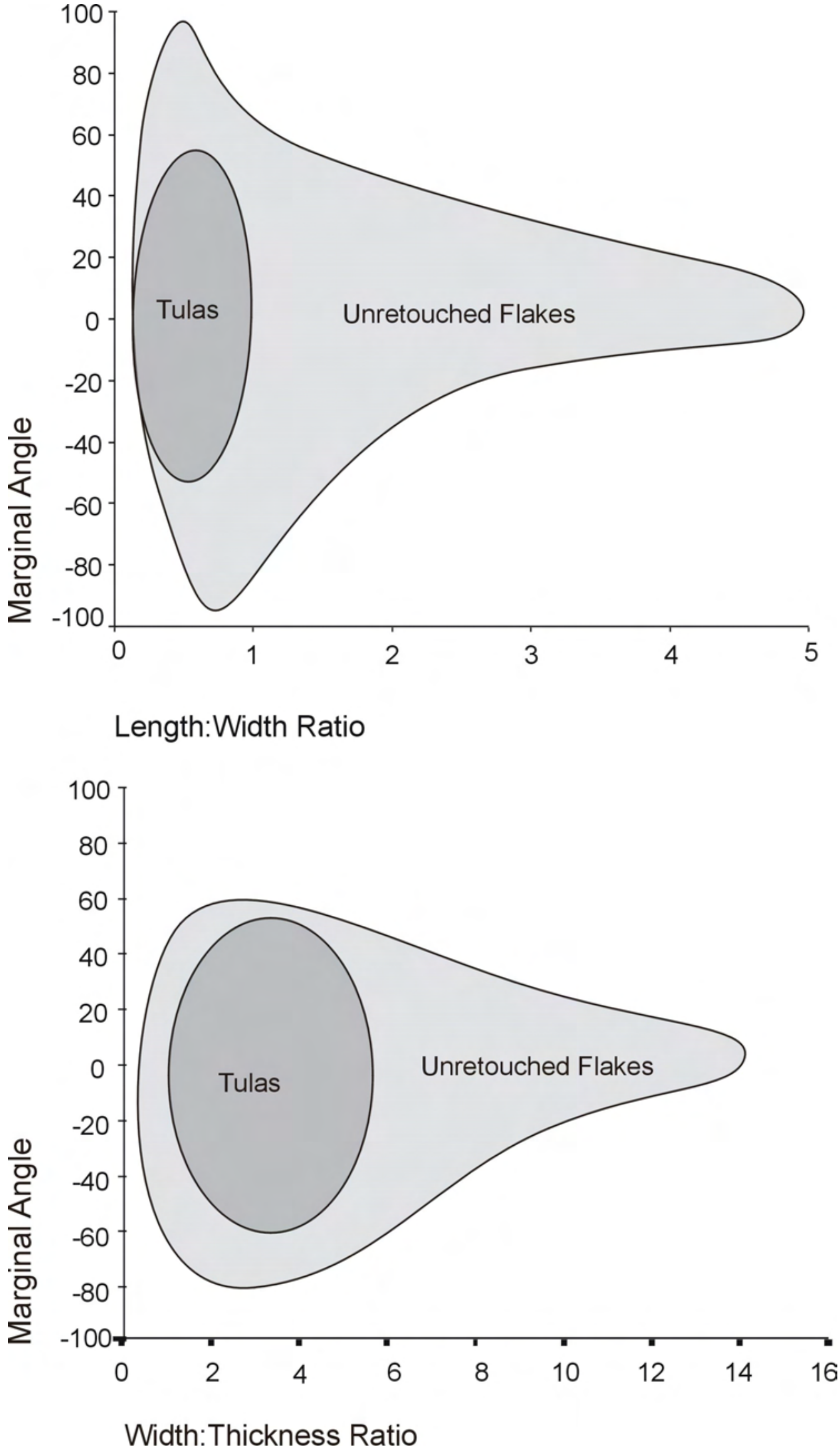
Edge Curvature. Cooper's description also suggests that sustained reduction of the distal end should result in decreases in the curvature of the edge. This is because the edge should be at its most curved once trimming of the bulbar area has finished, resulting in a wide arc of retouch around the bulb. As retouch continues, the edge straightens out and may finally become concave. This progression of changes in edge curvature is shown in Figure 6.25, and is measured using the same index as that used to describe scraper morphology. An ANOVA test also reveals the change to be significant ($F = 4.39$, $p = .005$).

Figure 6.25. Changes in edge curvature for tulas as reduction continues, measured using flake elongation (length:width ratio).



Blank Selection. Unfortunately there are next to no lightly retouched tulas in the sequence and so the dimensions of fully retouched tulas must be plotted instead, as shown in Figure 6.26. Perhaps not surprisingly given extensive reduction, tulas cluster together very tightly in terms of elongation, but vary extensively in cross-section and marginal angle.

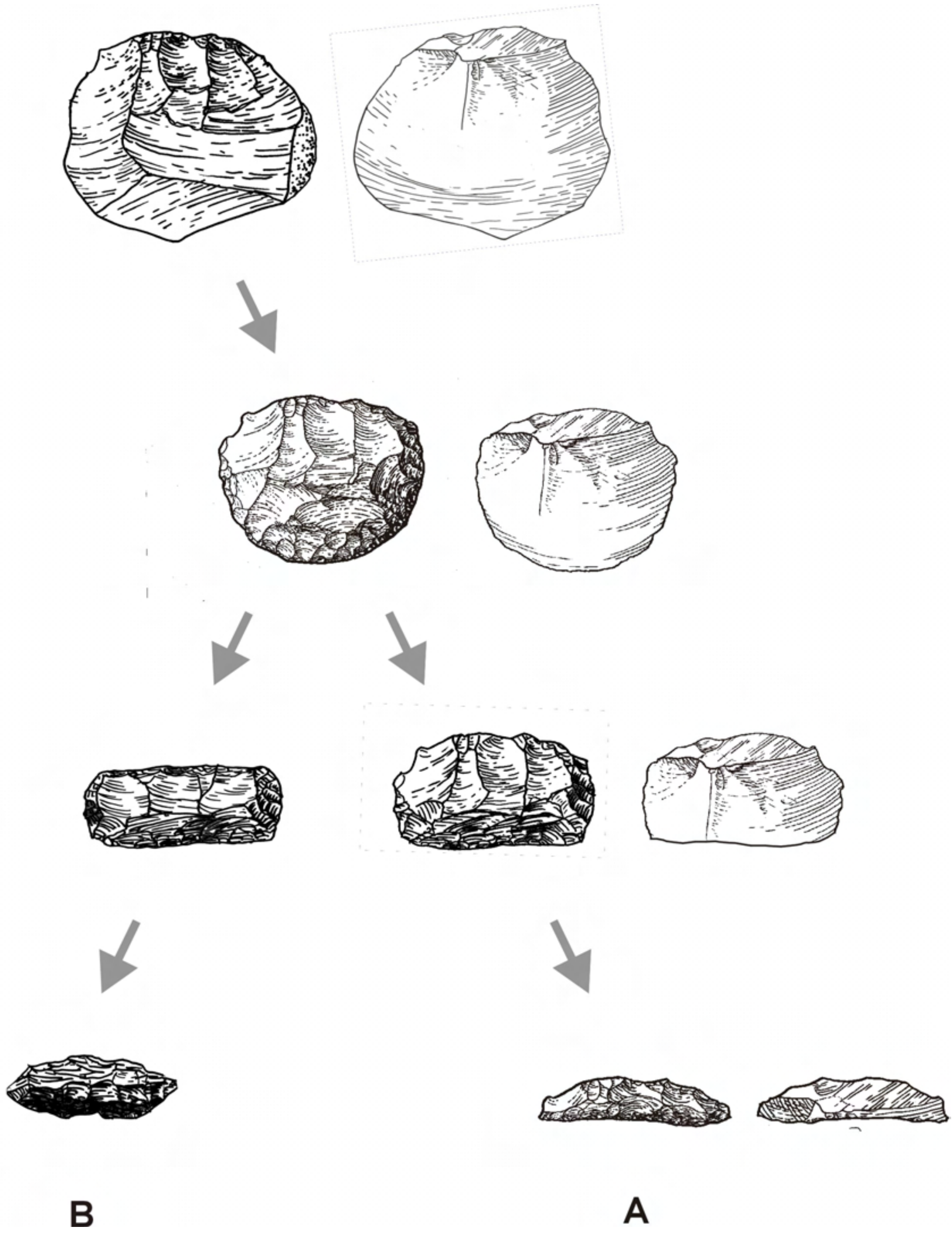
Figure 6.26. Variation in tula shape in comparison with unretouched flakes.



Discard Thresholds. Although no early stage tulas have been recovered at sites, mid-stage tulas weigh in at around 6 ± 4.2 g, and end up weighing around 3.8 ± 1.8 g. This represents nearly a 50% drop in weight just between middle and late stages, and suggests that tulas might be capable of sustaining use/maintenance adding up to around 80% of original weight lost. This is a very long use-life, especially for such a small artefact. The smallest 'slug' discarded weighed 1.5 g with an elongation of 0.2.

The Reduction Model for Tulas. The changes to size, shape and edge morphology documented here helps build a reduction sequence model for tulas like those for burins, points and scrapers above. Tulas begin as flakes with a pronounced bulb of percussion, and are first trimmed along the distal margin to leave only the bulb of percussion.

Figure 6.27. A reduction sequence for tulas. The A sequence represents continued reduction of the distal end. The B sequence results from turning the tula around and flaking the platform.



As retouch is added to tulas, length is reduced rather than width, the curvature of the distal margin straightens out and the unretouched platform represents an increasing proportion of the overall edge (Figure 6.27a). As tulas near the end of the sequence, they are sometimes flipped over and the platform is retouched to form a new edge, thereby maximizing the reduction potential of the implement (Figure 6.27b). This process takes place with increasing frequency as reduction continues. Finally, tulas are discarded once they have reached the point at which they can no longer be hafted. This usually takes place once tulas have been reduced to around 4 mm in length reaching a minimum weight of 1.2 g and an elongation of 0.2. Tulas have very much taken on their 'slug' form by this stage.

Burrens and Australian Classification

Burrens are essentially invasively retouched scrapers with retouch located on both lateral margins. Simultaneous reduction of both margins tends to result in an elongate slug-form. Burrens are perhaps the least well documented retouched artefact form discussed here, despite their frequent mention in the older Australian archaeological literature (Johnson 1979; Lampert 1971; McCarthy 1967; McCarthy *et al*. 1946). McCarthy argued that the burren was likely to be a functional equivalent of the tula, though with the haft set at 90 degrees to the lateral margins rather than parallel to it. Mulvaney (1969:82-83) also adopted the use of the term 'burren adze'. An adzing function for these implements seems unlikely, however, at least in the same manner as the tula, since most burrens lack the pronounced bulb of percussion that enables tulas to function as efficient adzing tools when encased in large amounts of resin. Others have tended to group burrens with other scrapers as a form of stylized scraper (Sanders 1975). While plausible, functional speculations of this kind are unhelpful in understanding the reduction process, and are not considered further here.

It is possible to test whether burrens stand out in any way from scrapers by examining their place within the continuum of retouch morphologies used for scrapers earlier in this chapter. This data is presented for 14 burrens and 341 scrapers in Figure 6.28. Burrens clearly sit neatly within the range for scrapers in terms of their edge curvature, perimeter of retouch, edge angle and invasiveness of retouch in relation to the GIUR. When the range of flake shapes associated with burrens and scrapers is examined, however, as in Figure 6.29, burrens do stand out as a sub-group of particularly parallel-sided implements with a narrow range of cross-sections in comparison to scrapers. The separation of burrens and scrapers is therefore likely to be an arbitrary one based on the straightness of the lateral margins, but no other aspect of formal variation. It therefore seems that burrens should not be considered a distinctive class in Wardaman Country, but rather one of a number of morphologies that could be teased out from the broader group of scrapers. In all other respects, burrens appear to fit neatly within the overall scraper reduction sequence.

Blank Selection and Flake Implement Standardisation

As the final piece of analysis for this chapter, the variation in shape for each group of retouched artefacts is overlayed in Figure 6.30. From these graphs, the degree of standardisation in implement form can be gauged. It is clear for instance that some forms are highly standardized, while others are extremely variable. Points and tulas, for instance, show highly restricted variation in shape, whereas scrapers and burins are highly variable. It can be inferred from these diagrams that much stronger selection criteria applied to the manufacture of points and tulas than to other classes (assuming that burrens are but an arbitrary sub-set of scrapers as argued above). This point will have significance in the discussion of temporal trends and provisioning discussed later.

Figure 6.28. Relationship between burrens and scrapers. A: % perimeter retouched, B: edge curvature (against perimeter of retouch), C: edge angle, and D: Index of Invasiveness.

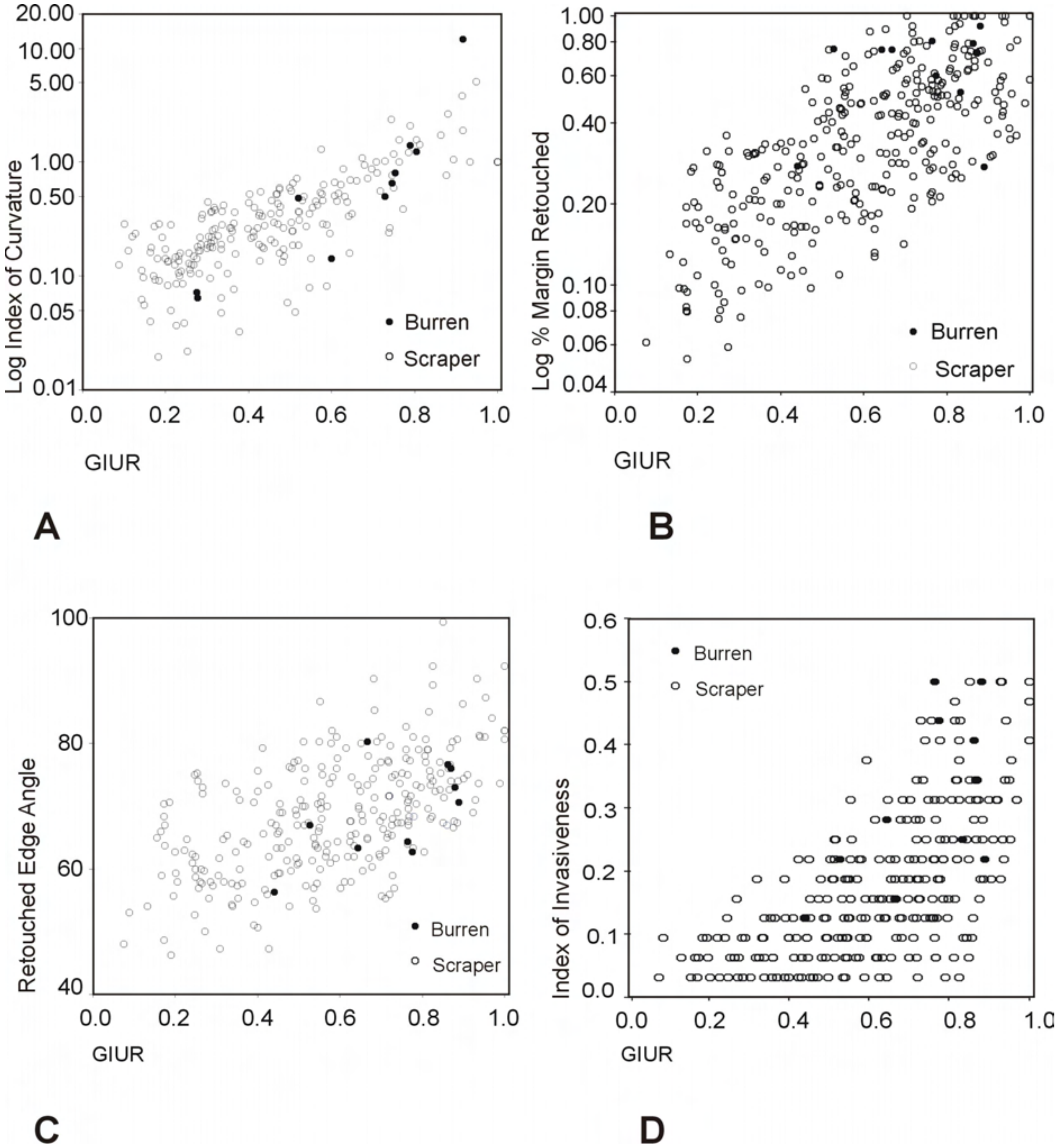


Figure 6.29. Variation in flake shape for burrens.

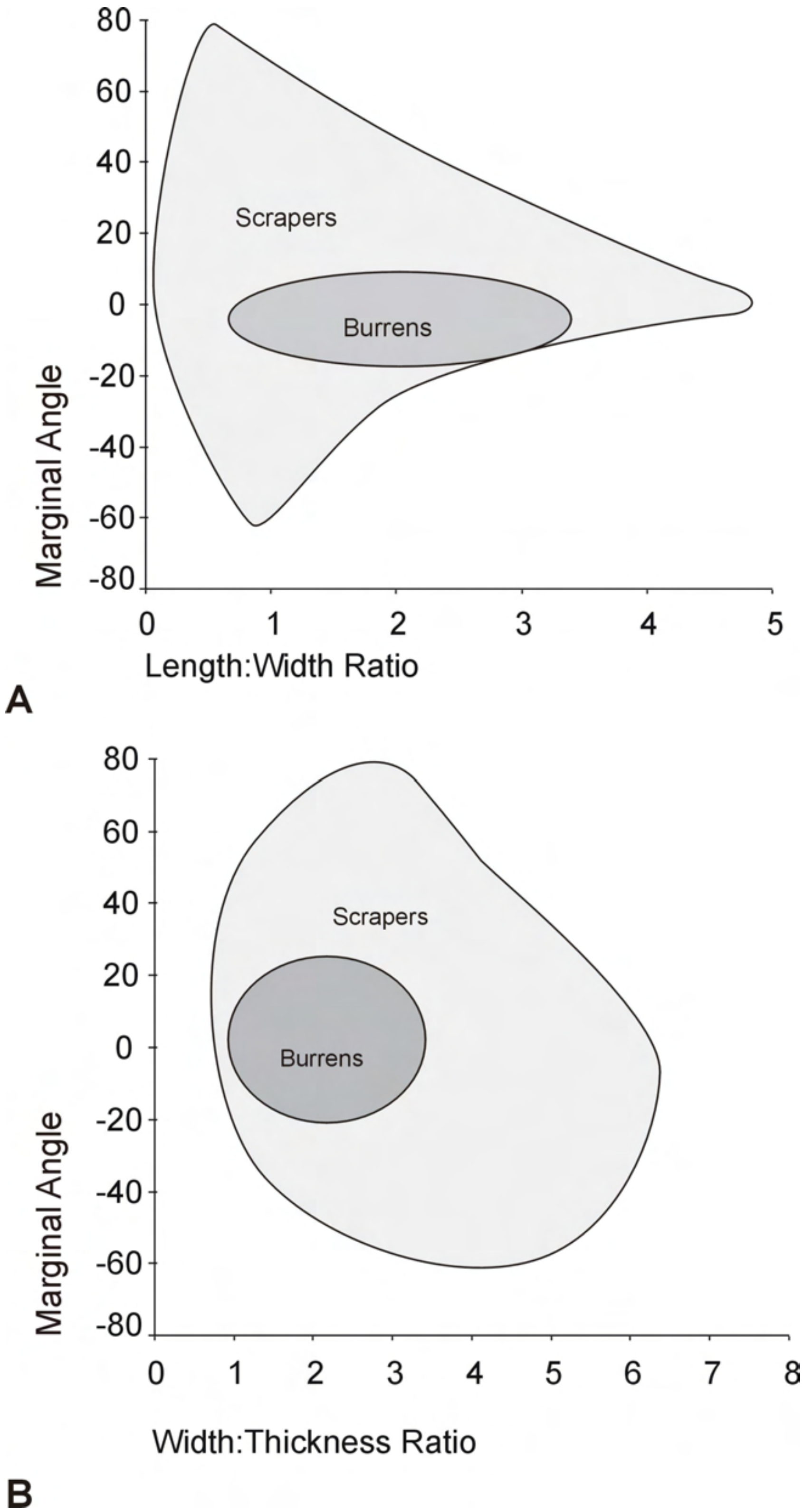
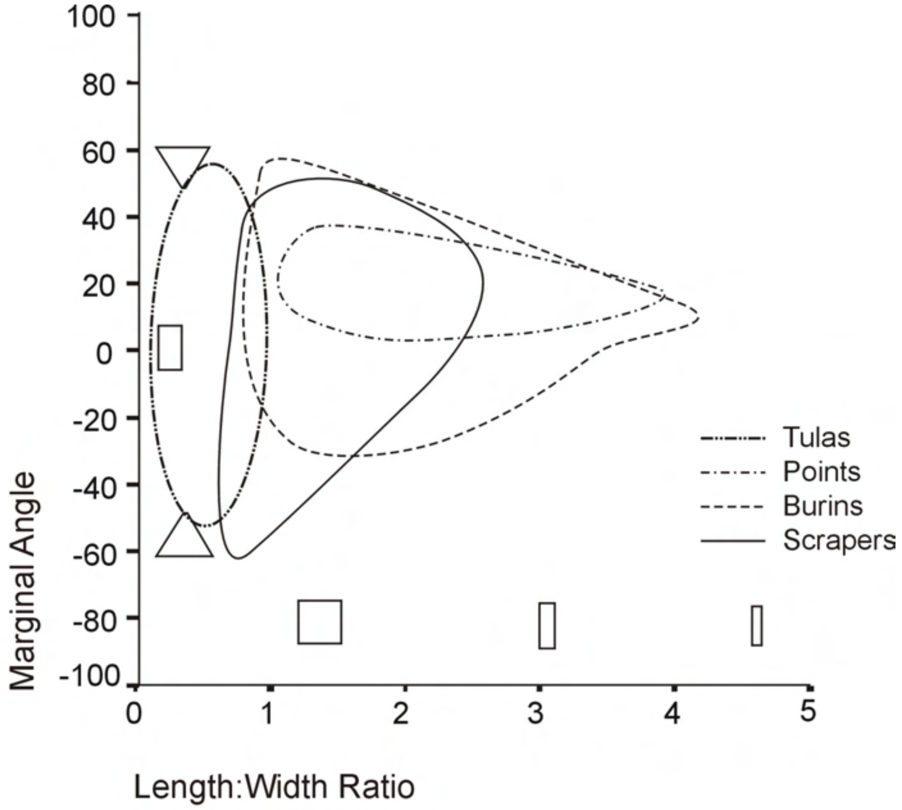
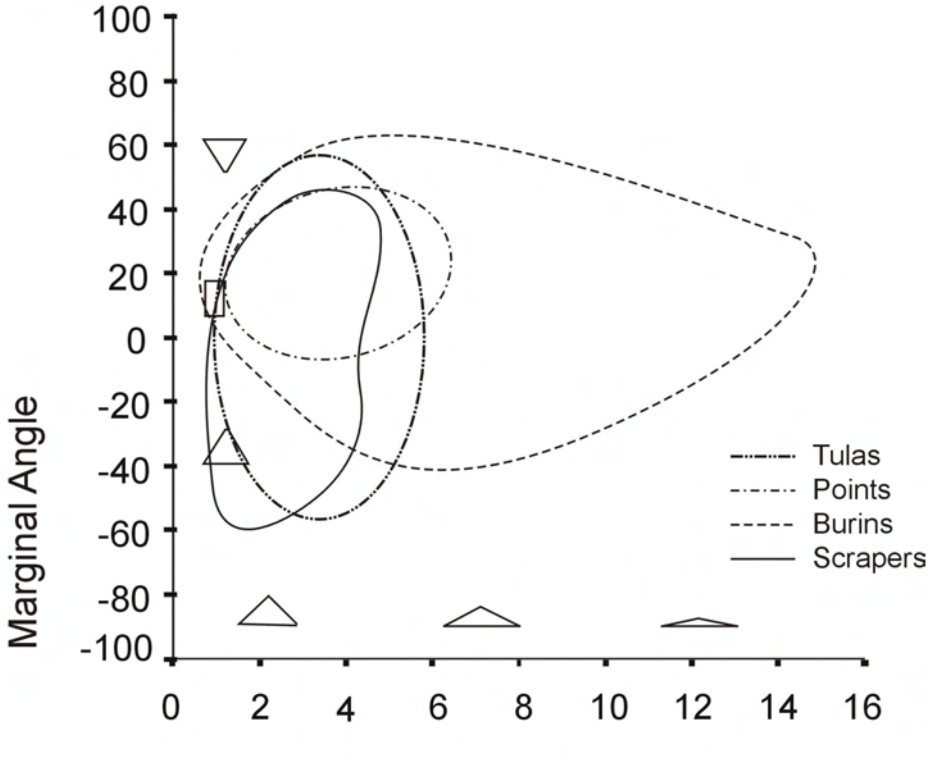


Figure 6.30. Overlay of the variation in retouched implement shapes by class. A: marginal angle plotted against elongation, and B: marginal angle plotted against longitudinal cross-section.





Reduction Sequences and Tool Design

Besides understanding the ways in which implements were manufactured and the reduction continuums that underlie variation in certain morphologies, reduction sequence models also allow us to speculate about the various advantages offered by certain tool designs in terms of standardisation, maintainability and reduction potential. It is clear from the descriptions of each mode of implement manufacture that certain trade-offs in design, investment and utility are at play. Firstly, implements such as lancet flakes are costly to produce in terms of the amount of core reduction potential foregone to make lancet flakes, which entails high breakage rates and early discard of the core. Because cores used to make lancets are often under-utilised in terms of their mass, they are also costly to transport since much unused weight must be transported along with the core to produce only a few unbroken lancets. These disadvantages are obviously traded against the highly standardized flakes that are produced through this manufacturing strategy.

Another set of trade-offs can be identified for scrapers. Scrapers are selected from a highly variable pool of blank sizes and shapes, and generally both begin large and end large (in terms of the reduction sequence). Furthermore, the exclusive use of unifacial reduction on irregular flake blanks means that there is great potential for the build up of step terminations and intractable edge angles to cause early termination of the reduction process in terms of the amount of weight left in the implement. Compared to points, which routinely result in the loss of more than 50% of original blank weight over the reduction sequence, scrapers are wasteful and unconducive to extended use-maintenance schedules. However, scrapers are obviously tools with minimum startup costs since little effort is expended in standardising blanks or shaping implements in particular ways, and it is therefore no surprise that scrapers are discarded early with regard to loss of original mass.

Points appear to represent the opposite extreme to scrapers. Points are regularly made from lancet flakes that are more difficult to produce, but provide the level of standardisation that might be required of a technology that was probably designed to perform in a relatively specialised role with high effectiveness (i.e. as projectile tips, although the possibilities do not end there). Maintainability is clearly also a focus of point design since invasive reduction of the sort employed in point reduction is capable of extending the use-life of the implement by a substantial degree, by maintaining platform angles and keeping step terminations to a minimum through opposed marginal thinning. The reduced variation in the size and shape of points that results from invasive flaking and the use of a standard blank form also likely enhanced the reliability of the technology by allowing modular replacement of the tip with another tip of similar size and shape, rather than make the entire tool again from scratch.

Tulas also appear to operate within a narrow morphological spectrum, but it is likely that most selection criteria were focused on the nature of the bulb of percussion. The tula shows the longest reduction sequence of any retouched implement documented here, with perhaps as much as 80% of original weight lost through maintenance and rejuvenation. The lengthy amount of time spent resharpening and resetting tulas into their hafting gum has been documented ethnographically (Gould 1980; Hayden 1979), and is consistent with the long reduction sequence documented for the Wardaman tulas.

Thus both tulas and points have remarkably long use-lives and appear to represent functionally effective tools designed for maximum performance in semi-specialised tasks (i.e. as spear points and hardwood working tools?). Their increased performance also likely comes at the expense of greater startup costs – making standardized blanks, constant resharpening, and the lengthy manufacture of hafting devices. Unfortunately, little is known about the methods of manufacture or selection of tula blanks, but the regularity of bulbar proportions and fine attention to bulbar trimming suggests there were initial start up costs to implementing this technology as well (not least of which is the manufacture of the haft). We should therefore expect both forms to have developed in response to strong pressures to increase the use-life and effectiveness of tools at the cost of greater manufacture and repair times, perhaps in response to increased mobility, risk and uncertainty. The issue of the origins, technological context and persistence of these implements will be dealt with in the next chapter.

Conclusion

Reduction sequences provide a means of tracking morphological transformation, and of reducing typological variability into a number of more meaningful units that are constructed via reference to the temporal process of reduction that unites various common forms. Knowledge of the number and nature of sequences allows us to identify the differential distribution of various stages of reduction, examine assemblage diversity in more meaningful terms than a simple tally of different forms, and to explore issues of reduction potential and provisioning through time. The reduction sequences constructed in this chapter therefore form the basis of the following analysis that examines temporal variation in stone artefact manufacture, transport and discard as a reflection of mobility, landuse and provisioning.