7. Change and Continuity in Stone Artefact Manufacture

Chronological changes in the organisation of technology in Wardaman Country can be seen from the sequence of stone artefacts deposited at the four rockshelter sites described previously. This chapter examines changes in technological design, organisation and provisioning in relation to changes in resource structuring, abundance and heightened climatic variability during the last 15,000 years that were discussed in Chapter 3. This is achieved by documenting fluctuating discard rates, changing reduction intensity, alterations to toolkit diversity and their relationship to resource stress, subsistence risk, changing levels of mobility and changes to technological provisioning. Changing patterns of stone artefact manufacture also form the basis for an examination of continuity in the social transmission of technological practices.

To examine such changes in lithic technology, we must begin by building a regional technological database that combines artefacts from units in all four rockshelter sites and assigns each unit an age in calibrated years BP, as determined through radiocarbon dating as well as cross-dating of major assemblage changes using the technique of interdigitation (Lyman *et al*. 1998). The purpose of this approach is to enlarge the sample size for periods of low stone artefact discard and to simplify the presentation and analysis of data. The following sections then examine changes in the rate of artefact discard over time. This is followed by analysis of the intensity of core and flake reduction, retouched implement reduction and changes in raw material procurement, transport and field processing. Having documented the changing nature of stone artefact manufacture in Wardaman Country, the next section turns to examining continuity in stone working traditions over time, and pays particular attention to evidence for possible breaks in transmission, or the appearance of new reduction sequences that could signal demographic changes or the emergence of new social networks. Finally, changes in technology are considered in terms of alterations to the design and organisation of technologies that help identify the nature and timing of changes in technological provisioning, mobility and risk over the last 15,000 years.

Building a Regional Technological Database

A regional database of stone artefacts tied to calibrated ages offers the potential to describe technological changes as a single set of results, making analysis and interpretation much simpler than if multiple sites and sequences are continually compared. This is achieved through use of a technique known as interdigitation, or the ordering of assemblages using both unit frequencies and superposed positions for each site (Lyman *et al*. 1998). For the Wardaman assemblages, cross-dating of spits and squares for each rockshelter was accomplished using the following temporal markers based on dating of distinctive peaks in various cultural materials and the ordering of these in each sequence:

1. The presence of glass flakes and beads was used to assign an age of less than 200 BP (i.e. European period) for spits near the surface of sites (here ascribed a notional age of 0 BP),
2. The first appearance of bifacial points in abundance in the region at c. 3,000 Cal BP, dated by four samples from three sites which overlap at two standard deviations (Nimji: ANU-57 2,890 ± 57, Garnawala 2: Beta 66434 2,920 ± 120, Garnawala 2: Wk-9252 2,751 ± 68, and Jagoliya: ANU 11364 2,780 ± 200).
3. Dates for two distinct peaks in artefact deposition. An upper post-bifacial point peak dated to c. 1,500 Cal BP at Garnawala 2 (Wk-9248 1640 ± 90), Jagoliya (ANU-11267 1,510 ± 90) and at Nimji (GX-03 1545 ± 75), and 7,294 Cal BP (ANU-11758 6255 ± 135) for a pre-bifacial point peak in stone artefact discard at Nimji. In cases where the exact location of the upper peak was indistinct (such as when two equivalent sized peaks occur close to each other with a small trough in between) a peak in unifacial point discard which is also dated to 1,500 BP was used to assign the date.

4. Maximum ages were set according to the maximum ages for sites as extrapolated from age-depth curves in Chapter 5. These are 15,000 BP for Gordolya, 6,500 BP for Jagoliya, 13,000 BP for Garnawala 2, and 10,000 BP for Nimji.
5. Calibrated radiocarbon dates. When available, radiocarbon dates were always used in place of estimated ages in determining the age of each spit.

The age of spits for which no temporal markers exist (i.e. those in between radiocarbon dates or cross-dated spits) was determined by averaging time over the number of intervening spits. This model is appropriate given the strong linear relationship between age and depth found at all sites. The results of interdigitation are shown in Figure 7.1 for Gordolya and Jagoliya and in Figure 7.2 for Garnawala 2 and Nimji. The calibrated ages assigned to each spit are shown in the right hand column for each square. This interdigitation is used to assign ages to every artefact in the database and provides the temporal framework for the following results.

Stone Artefact Discard Rates Through Time

A necessary starting point for much of the following analysis is documenting changes in stone artefact discard through time that may be informative about occupational intensities and fluctuations in resource abundance over time.

If hunter-gatherer foraging patterns and technologies responded to fluctuations in resource abundance and structuring in the ways they are posited to do in Chapter 2, then predictions can be made about the likely effects of climate change on foragers inhabiting this region over the last 15,000 years. It was predicted in Chapter 4, for instance, that the late Pleistocene/early Holocene should have been a period of high subsistence risk for hunter-gatherers newly occupying the region, as global climates were still in a state of major fluctuation with temperatures and rainfall undergoing substantial reversals. It was argued in Chapter 4 that such a situation would be unlikely to have favoured the establishment of large hunter-gatherer populations, and technologies might be expected to reflect low population numbers and high mobility as reflected in stone artefact discard rates, the nature of raw material transport and degree of reduction.

In contrast, the early to mid-Holocene climatic optimum, dated loosely to between 5 and 8,000 years BP, should have resulted in heightened resource abundance, greater stability in rainfall and temperature, and a more homogeneous distribution of resources than had existed for at least the last 20,000 years. An increase in environmental productivity of this kind should have provided an ideal situation for hunter-gatherers occupying the region, and one that might be expected to have resulted in larger populations living more sedentary lives with fewer constraints on subsistence and technology than in previous millennia.

At around 5,000 BP, climatic variability is believed to have increased dramatically, with much greater interannual variation in rainfall and a likely increased frequency of potentially catastrophic events such as cyclones, floods and prolonged droughts. These more severe perturbations are believed to be associated with an intensification of the El Niño/Southern Oscillation system, and would likely have resulted in resource depression (particularly in comparison to the former period), increased patchiness and reduced predictability that could have elicited a change in foraging behaviour as well as introducing significantly greater levels of subsistence risk for the inhabitants of the region. A reduction in population might well be expected as well as a technological response in terms of changes to toolkit design and the organisation of technology that might register as a significant overall change in technological provisioning in the region. Interannual variability in rainfall is believed to have reached its greatest severity in northern Australia between 3,500 and 2,000 BP.

At around 1,500 BP, interannual variability is thought to have ameliorated considerably and populations might again be expected to have increased and technologies to register a shift away from more pronounced forms of risk reduction and utility increase.

Figure 7.1. Method of interdigitation for each pit and each square for Gordolya and Jagoliya.

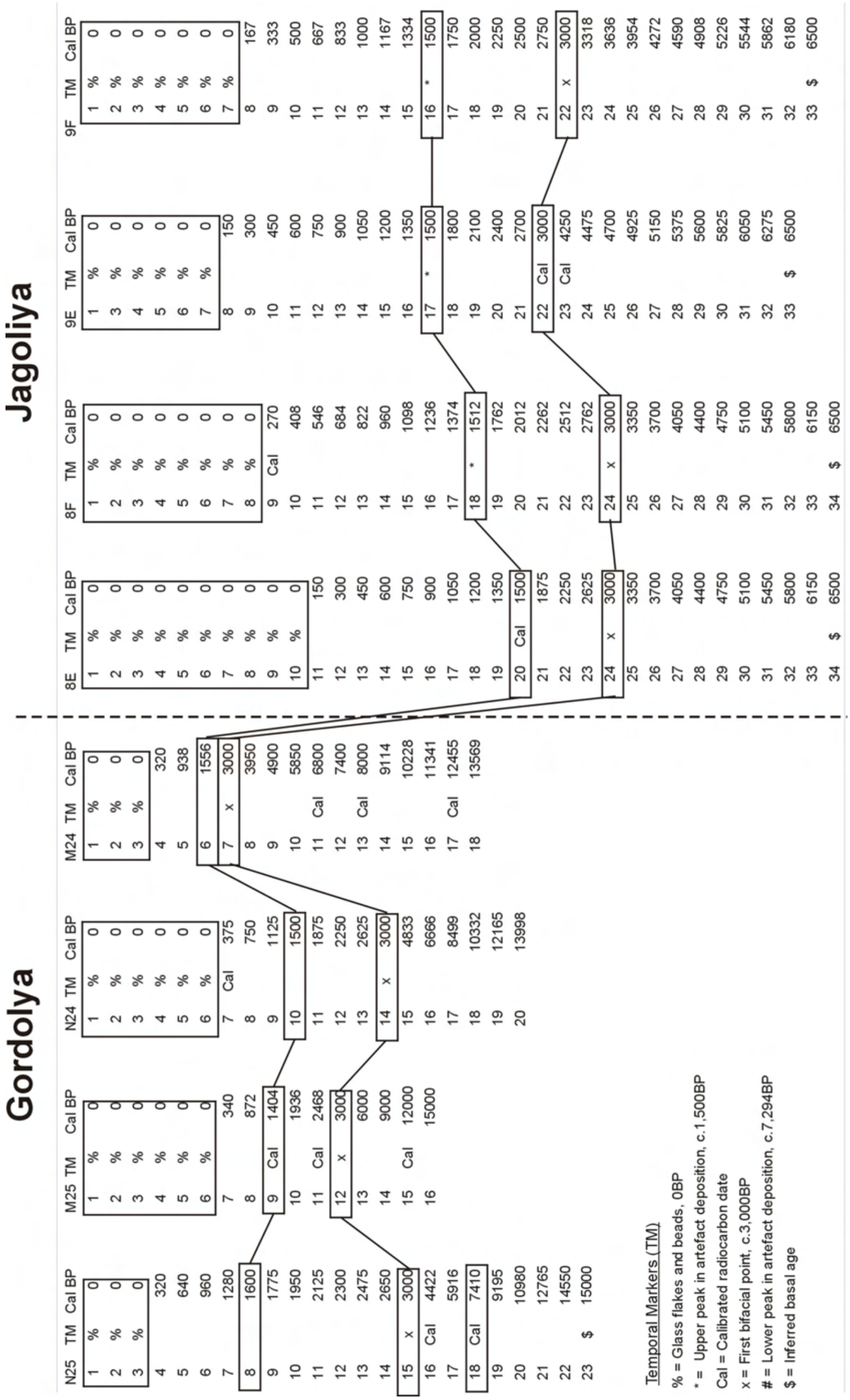


Figure 7.2. Method of interdigitation for each spit and square for Nimji and Garnawala 2.

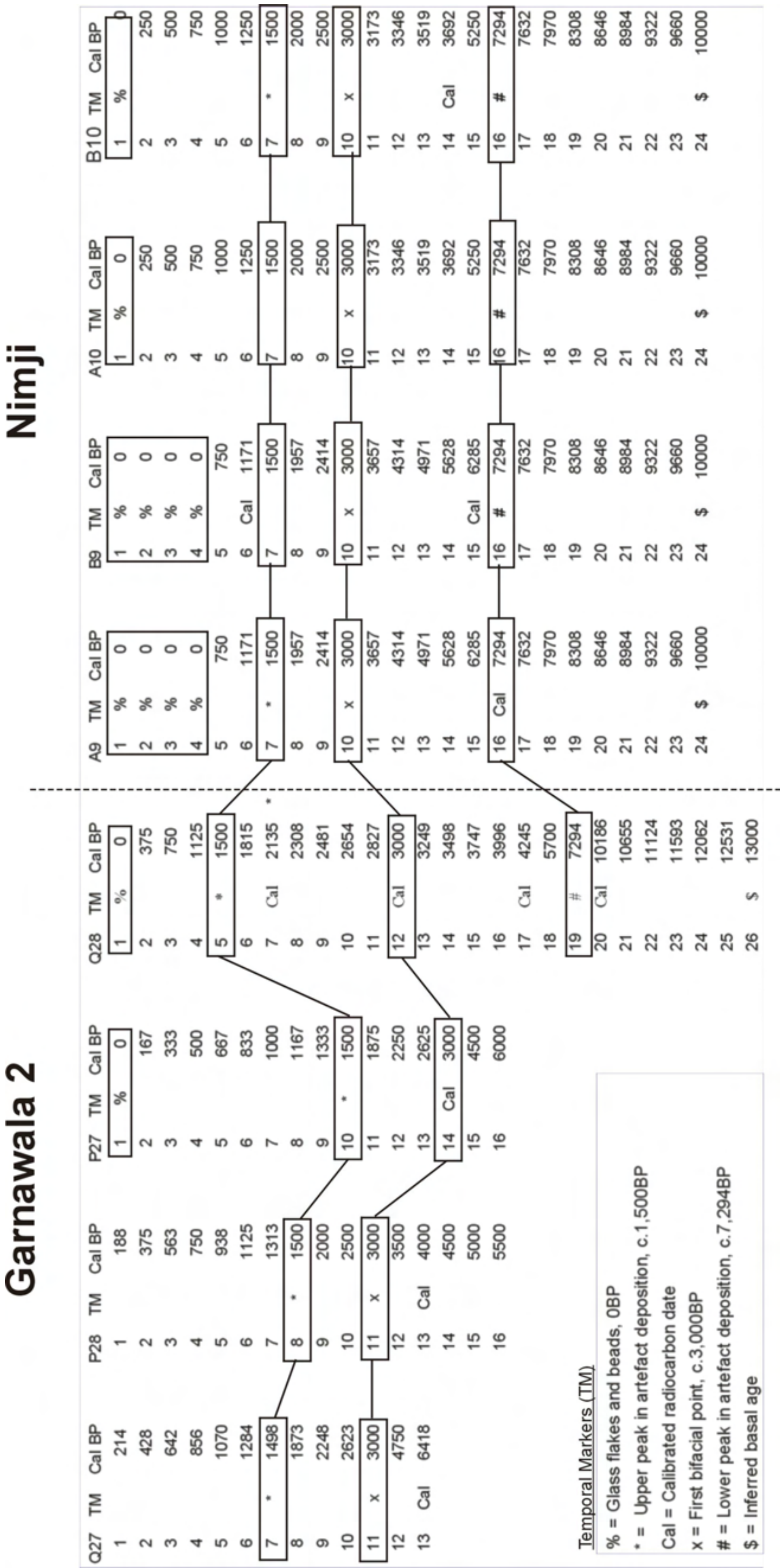
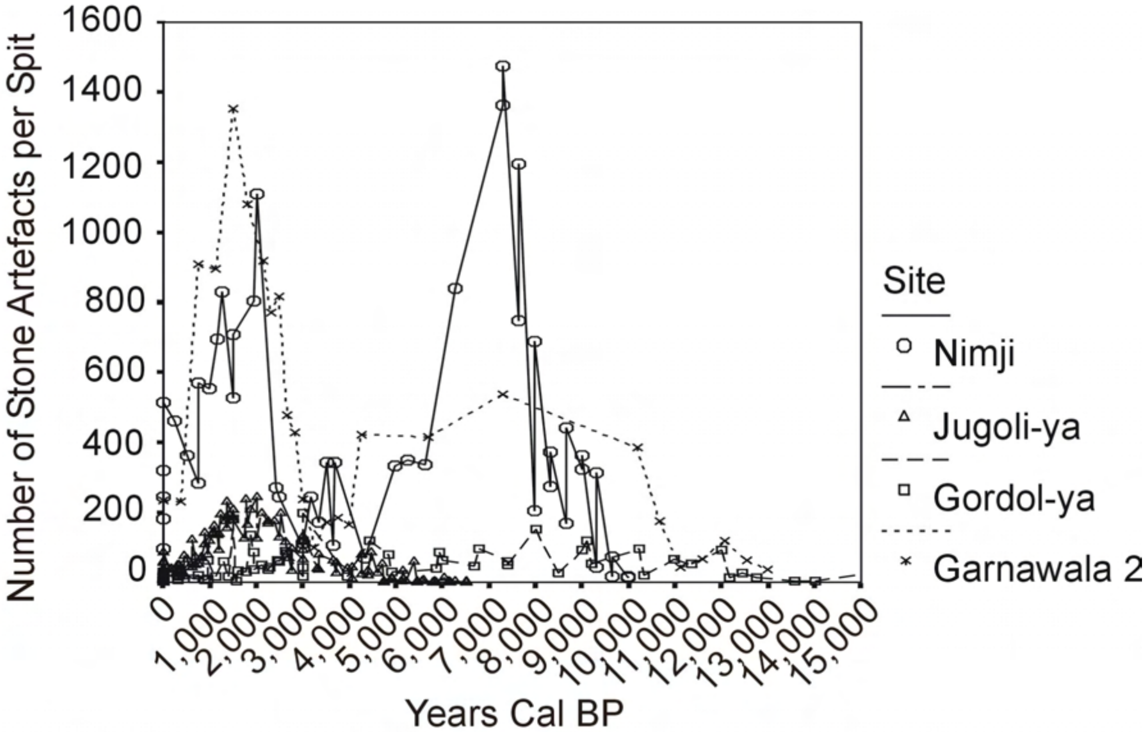
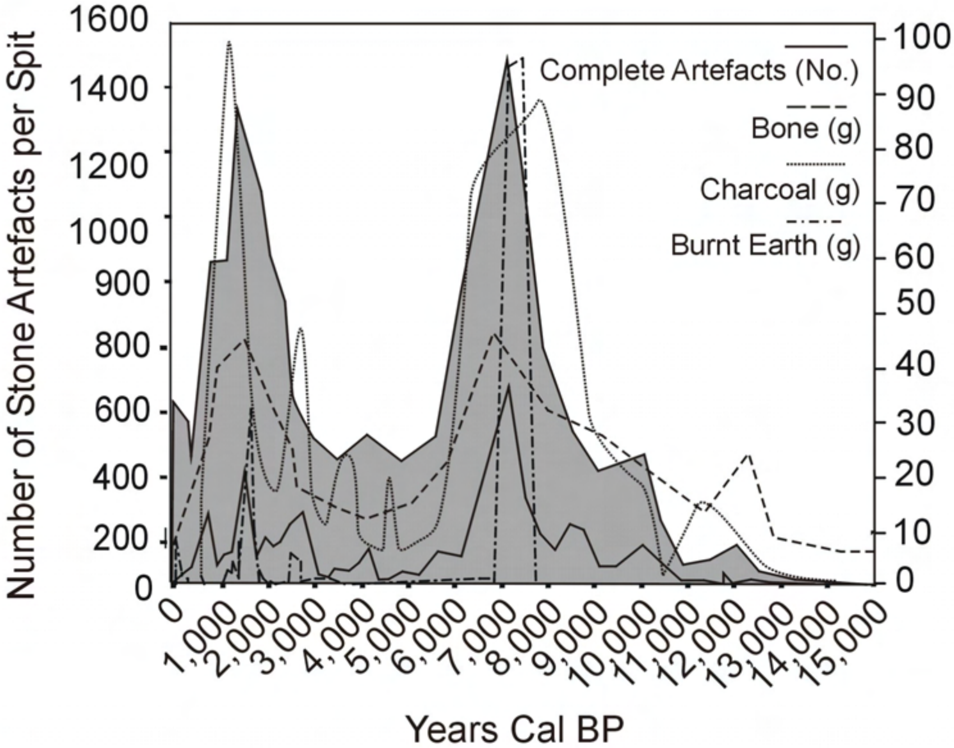


Figure 7.3. Changes in discard rates over the last 15,000 years. A: stone artefact numbers discarded per millennium for each site, and B: number of complete artefacts over 2cm in maximum dimension, bone weights (from Gordolya only), and charcoal and burnt earth weights overlayed over the average number of artefacts deposited over time for all sites.



A



B

One way to explore whether these predictions are met for the study region is to examine discard rates to ascertain any possible changes in occupational intensity that might reflect changes in frequency of visitation, the size of visiting groups, length of stay or regional population size more generally. Figure 7.3a plots the changes in pooled stone artefact discard rate for all four rockshelters over the last ~15,000 years. Two distinct peaks in stone artefact discard are evident: one between 8,000 and 5,000 years ago, and the other centred on around 1,500 BP. Both peaks are in exact agreement with the predicted times at which populations might be expected to increase as foragers enjoyed favourable conditions. Between these two peaks is a pronounced trough in artefact discard, while artefact numbers gradually trail off over the several millennia preceding the mid-to early Holocene peak in artefact discard.

Raw stone artefact numbers may not always be a very accurate measure of occupational intensity, if for example taphonomic or technological factors have inflated artefact numbers in such a way that they no longer reflect numbers of people using the site. Plotting number of complete flakes over 2 cm length, however, makes little difference to the trend, as might be expected if fragmentation were a key factor contributing to assemblage size (Figure 7.3b).

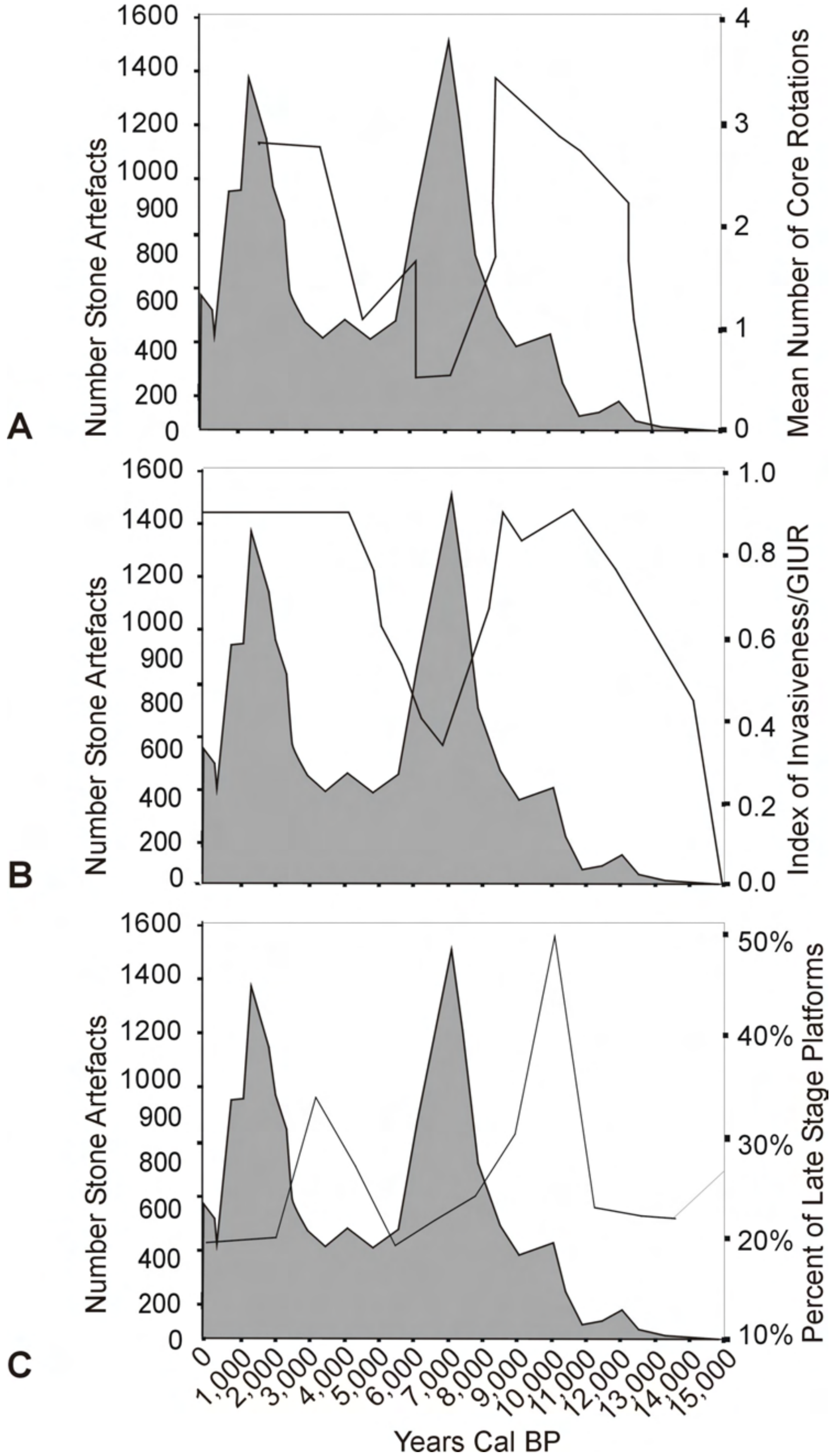
Another possible measure of occupational intensity is the size of the faunal assemblage, which could loosely reflect the number of people consuming food in the shelter. Only one intact faunal assemblage has currently been obtained in Wardaman Country, and this is from Gordolya. The quantity of bone obtained from this site over time is overlayed on top of the graphs for total number of artefacts over time in Figure 7.3b. There is clearly a close relationship between the size of the faunal assemblage and the number of artefacts being deposited at sites over time. The weight of charcoal and burnt earth might also be expected to reflect occupational intensity if fires are routinely lit when people inhabit a shelter. The quantities of these materials also correspond closely to peaks in artefact deposition (Figure 7.3b). It therefore seems reasonable to assume that peaks in the discard of all of these cultural materials at 1,500 and at 7,000 BP represents an accurate picture of heightened intensity of occupation, and perhaps population size, in Wardaman country at certain times.

Changing Reduction Intensity

It was argued in Chapter 2 that intensity of reduction is likely to be a useful indicator of a number of technological strategies. One is the degree to which the use-life of artefacts is extended to recoup costs associated with more elaborate design and manufacture of implements, a second is the need to conserve and extend the life of implements when access to replacement raw material is difficult or uncertain, a third is to shape or transform implements for use in unanticipated tasks, and a fourth is to produce fresh flakes when other sources of raw material are scarce. Determining the intensity of reduction can therefore be a useful stepping stone in inferring changes in mobility, risk and technological investment.

Changing levels of core reduction can be measured by counting the number of rotations on cores. The proportions of flake platform types are also used as a measure of stages of flake production, and either the Index of Invasiveness or the GIUR is used to measure retouch. Figure 7.4 plots changes in the intensity of core, flake and retouched flake reduction, plotted against a background of total artefact discard over time. Mean retouch results are plotted for each flake for either the Index of Invasiveness or the GIUR depending on which index gave the greatest result for that specimen. Bipolar cores and flakes, representing the most heavily reduced forms, are found only in the last 4,000 years and before 7,000 BP, and are absent between 5 and 7,000 BP. The results indicate that levels of reduction are inversely related to the number of stone artefacts discarded until 3,000 BP, when reduction intensity remains high despite another peak in stone artefact discard at 1,500 BP. This suggests that climatic changes may have shaped hunter-gatherer responses in regular and predictable ways until the last 3,000 years, when changes in the nature of technology and provisioning appear to have taken place that meant levels of reduction remained high despite improved climatic conditions and a probable increase in population and/or site useage after this time.

Figure 7.4. Three measures of artefact reduction plotted against changes in artefact discard. A: numbers of core rotations, B: mean retouch intensity for either the GIUR or the Index of Invasiveness, and C: percentage of late stage flake platforms.



Core Reduction

The changes in reduction seen in Figure 7.4 are also reflected in the morphology of cores and flakes found in these sites. Changes in core morphology are plotted in Figure 7.5 for a sample of 56 cores. The overall sample of cores is too small to allow these changes to be plotted at millennial scales, and the data is therefore grouped into blocks of two thousand years. As only bipolar cores (which do not possess many of these attributes) and a single rotated core are found in the last 2,000 years, and no intact cores are found in sites before 12,000 BP, only the period 2,000-12,000 BP is plotted in Figures 7.4 and 7.5. The absence of cores before 12,000 BP is likely just an artefact of very small sample size.

Figure 7.5 indicates that as the mean number of core rotations increases, the weight, amount of cortex, and platform area all decrease, consistent with greater mass having been removed from the parent nodule. In contrast, the number of step and hinge terminations, platform quadrants, and platform angles all increase as the number of rotations increase.

Flake Reduction

Changes in flake characteristics over the sequence are shown in Figure 7.6 for a sample of 3,373 complete and unretouched flakes larger than 2cm in length. From this figure, it can be seen that the nature of flake production appears to change markedly in the last 4,000 years, with flakes becoming more pointed, longer relative to width and thickness, and lighter overall. Non-feather terminations also reduce in frequency, and platforms show more signs of preparation. As seen in Figure 7.4c, the majority of flakes also appear to derive from earlier stages of reduction in the last 3,000 years. Cores also become rare in the last 3,000 years (Table 7.1), suggesting that flakes produced during this time were not made on-site.

Table 7.1. Break down of core types found in each site per 1000 years.

	Nimji			Garnawala 2			Gordolya	Total			
Years Cal BP	*Single Platform*	*Rotated Core*	*Bipolar Core*	*Single Platform*	*Rotated Core*	*Bipolar Core*	*Bipolar*	*Single Platform*	*Rotated*	*Bipolar*	*Total*
1,000					1			0	1	0	1
2,000						1		0	0	1	1
3,000		2						0	2	0	2
4,000		7			1		1	0	8	1	9
5,000								0	0	0	0
6,000		2		2	1			2	3	0	5
7,000		1						0	1	0	1
8,000	1	8	2					1	8	2	11
9,000	3	16						3	16	0	19
10,000	2	1			4			2	5	0	7
11,000				1				1	0	0	1
12,000								0	0	0	0
13,000								0	0	0	0
14,000								0	0	0	0
15,000								0	0	0	0
Total	6	37	2	3	7	1	1	9	44	4	57

Cores with many parallel flake scars and single or cortical platforms – in other words those identified in the previous chapter as the most likely source of lancet flakes – do not occur in the sample of cores found before 3,000 BP in rockshelters. They are however common at quarry sites, but these are likely to be younger than 3,000 BP (cf. Cundy 1990). The fact that lancet production was found to be somewhat 'wasteful' in the sense that these flakes are best produced early in the reduction sequence, have high failure rates, and cores are discarded when much of the original core mass still remains (yet also produce highly standardized flakes), might suggest high processing costs. This creates a situation where lancet production is likely to have taken place at quarries as a form of field processing, rather than transport

cores to the central place for processing. The fact that lancet production appears almost never to have been undertaken away from quarries, and that many pre-processed lancet flakes of highly regular dimensions were selected for transport away from quarries suggests that mobility constraints were very high in the last 3,000 years. This point will be revisited later.

Figure 7.5. Changes in core morphology over time.

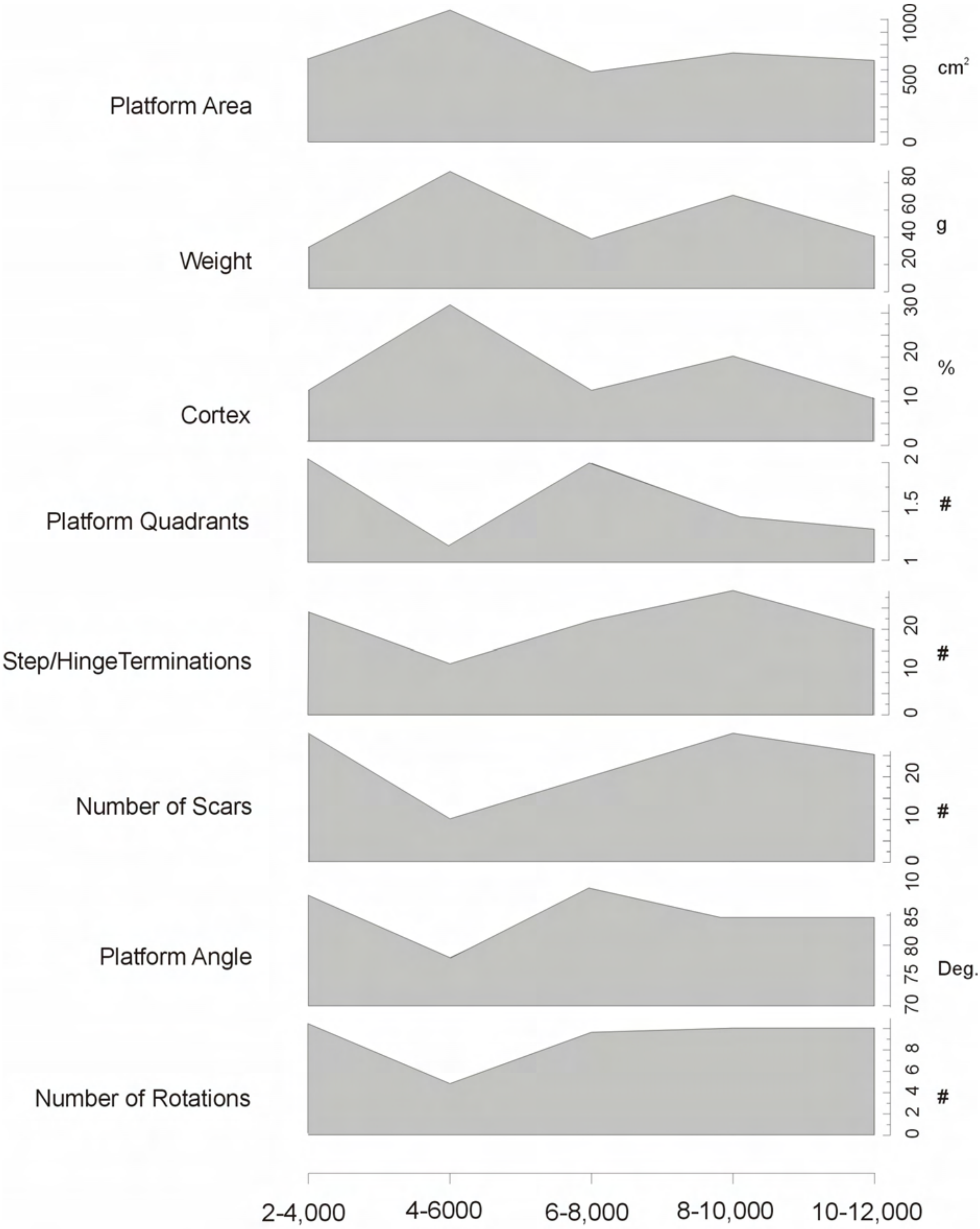
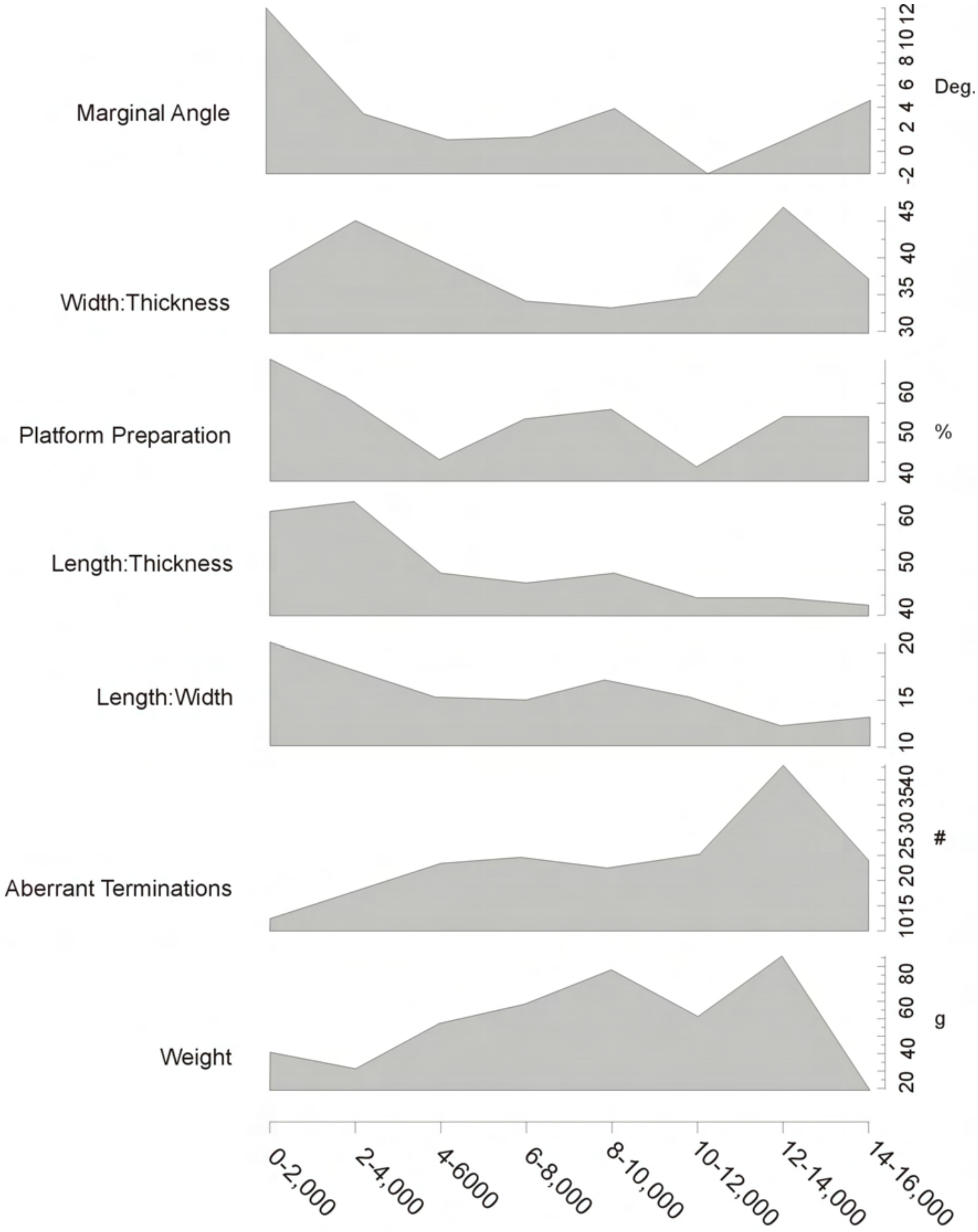


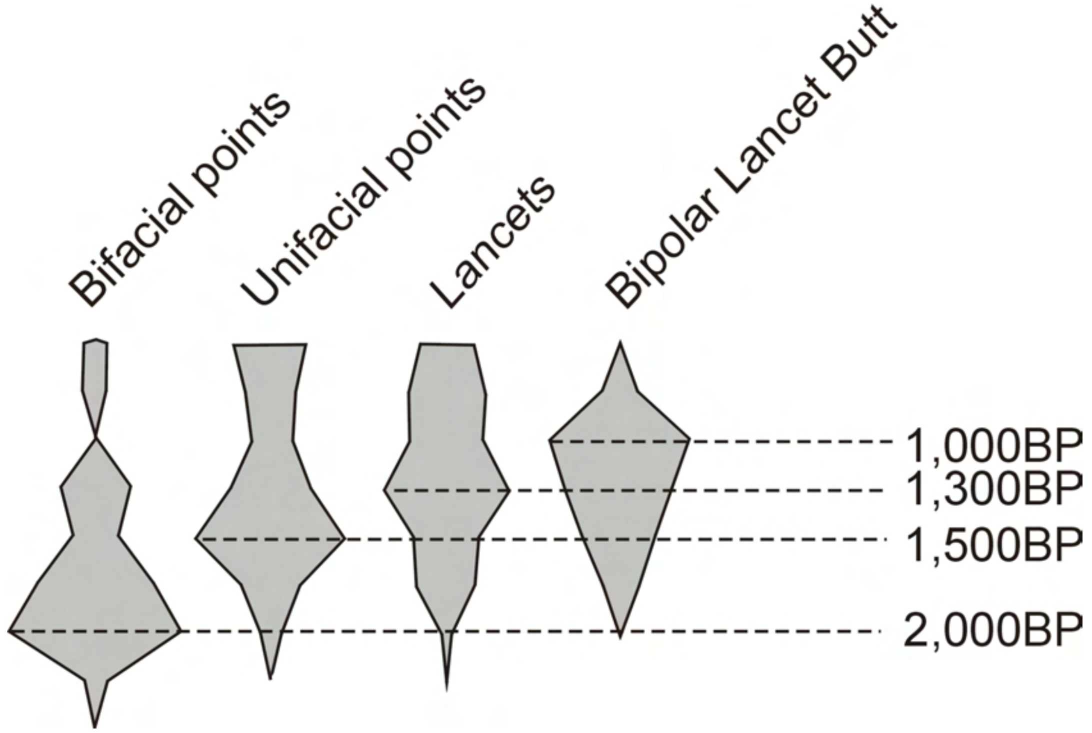
Figure 7.6. Changes in flake morphology over time.



Retouched Flake Reduction

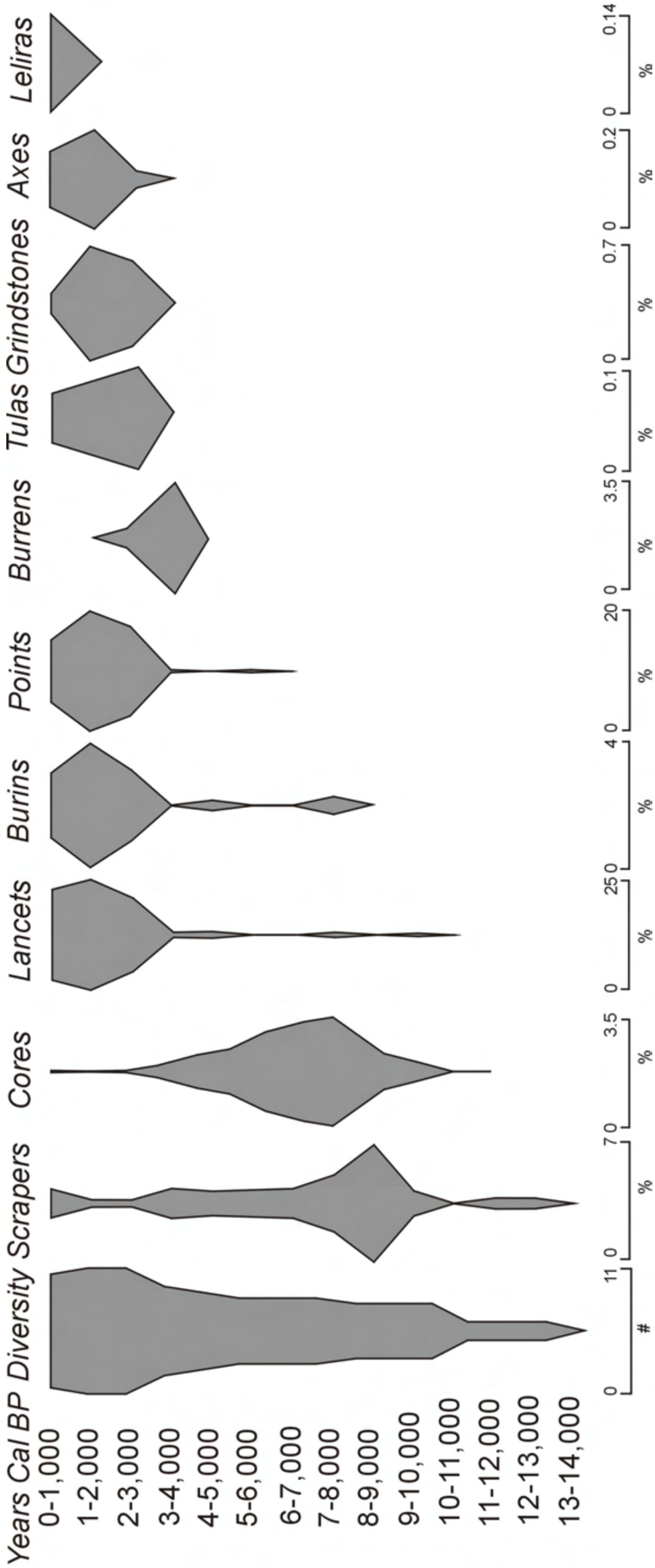
Changes in retouched flake reduction are also reflected in the frequency of implement types representative of different degrees of reduction. This can be seen in the last 3,000 years in changes in the frequency of various point forms shown in Figure 7.7. Bifacial points peak in frequency first at 2,000 BP, while unifacial points peak later at 1,500 BP. It is interesting to note that although lancets are commonly used as blanks for point manufacture, their peak comes later still. While this pattern of peak and decline may have many implications for functionality, style and transmission, it seems likely that it also represents a sliding up and down of the extendibility/reduction potential continuum through time, with an additional retouched face added to points early on that gives way gradually to the use of a single face, and then to little invasive retouch at all. As documented in Chapter 7, adding a second retouched face to points can add up to an additional 50% to reduction potential. Bifacial retouch also reaches its zenith by 2,000 BP, with bifacial points having a mean Index of Invasiveness of 0.8, which then drops back to 0.4 by 1,000 BP. Unifacial points also reach their highest mean Index of Invasiveness at 0.2 between 3,000 and 2,000 BP.

Figure 7.7. Temporal modes in the discard of various types of pointed flakes.



The review of theoretical models of tool design and technological investment presented in Chapter 2 identified higher levels of risk, greater focus on maintainability when access to replacement tools is limited, and the extension of use-life so as to recoup manufacture costs involved in producing more effective tools, as some of the likely reasons why shifts in reduction intensity like this might occur. The shift back from bifacial reduction toward less reduced (and reducible) forms is continued into later times, as unifacial points themselves wane and are replaced by a peak in unretouched lancet flake discard. As long, flat, pointed flakes, lancets are effective projectile points and require no additional retouch to serve in this role. Indeed, Davidson (1935) observed Wardaman people using unretouched lancets as spear points in the 1930s, and remarked that the use of bifacial points was unknown by this time and had clearly passed out of use since they were abundant in the eroding dripline and in lower levels of the rockshelters he visited and excavated.

Figure 7.8. Frequency of reduction sequences through time, as well as changing technological diversity for the region over time.



It therefore seems possible that the shift from predominantly bifacial to unifacial to unretouched points represents a move toward the use of a functionally equivalent form without the necessity for an extended use-life later in the sequence. The thinning of the proximal end of lancets using bipolar percussion in this late stage also suggests that this may have been an effective way of reducing basal thickness for hafting when extensive retouching of the margins and base was no longer practiced/required. In one sense then, there is good reason to believe that the progression of technologies seen in Figure 7.7 represents a series of functionally equivalent forms, where one of the design criteria – extendibility – gradually becomes obsolete over time. The significance of these changes for understanding land use and provisioning as well as for tracking heritable continuity is further discussed below.

Changes in the frequency of other heavily reduced types can also be seen, such as a peak in burrens - or heavily reduced scrapers - at around 3,657BP, just prior to the rise in frequency of points (Figure 7.8). This fits the pattern seen in reduction intensity for points, where extreme ends of the reduction spectrum peak and then slide quickly back toward less intensive reduction within 1,000 years or so of their greatest popularity. Tulas are also at their most reduced at around 3,000-2,500 BP with a mean elongation of 0.4. They then decrease in reduction intensity to a mean elongation of 0.6 by 1,500 BP. 'Slugs' too are most common between 2,500 and 2,000 BP. Burins also reach their most reduced stages after 3,000 BP. Most burins have between one and three spalls removed, but burins show a slightly greater number of spall removals between 2,000 and 3,000 BP, with cases of between 9 and 12 removals found at this time.

Also reflecting the decline in bifacial points after 2,000 years ago is the fact that 41% of spalls with old retouched margins on their dorsal ridges show unifacial invasive flaking only, whereas the 4% of spalls that preserve bifacially flaked edges are only found before 1,500 BP.

Changing Technological Diversity

Toolkit diversity was argued in Chapter 2 to provide a useful reflection of a number of features of past subsistence and technological systems. In particular, different levels of toolkit diversity were argued to be associated with limits on transportation and different kinds of mobility, and the level of task specificity and tool performance required of each technology.

Toolkit diversity cannot be measured directly, as it is impossible to differentiate 'tools' from 'non-tools' in archaeological assemblages without conducting use-wear and residue studies. However, it is possible to measure the level of diversity found in modes of implement production by counting the number of reduction sequences in existence in Wardaman Country at any one time (Table 7.2). Figure 7.8 maps the frequency of each of the major reduction sequences found in Wardaman Country over the last 15,000 years or so. The sequence of technologies is as follows. Unretouched and retouched flakes dominate assemblages when people first arrive in the region. Retouched flakes (scrapers) peak in frequency between 9,000 and 8,000 BP, and begin to decline in frequency as cores become a popular component in assemblages. Lancets and burinate retouch also appear in the early Holocene, though it is important to remember that a few lancets can be produced fortuitously from any core at early stages of reduction (e.g. Flenniken and White 1985), and their first appearance at this early time probably only reflects chance production. Burinate retouch on the other hand is a highly specific technique whose first appearance between 8,000 and 9,000 BP likely reflects a real technological change at this time.

Table 7.2. Numbers of artefacts over time grouped by reduction sequence and combined for all four rockshelters.

Years Cal BP	*Technological Diversity*	*Total Number of Artefacts*	*Scrapers (including burrens)*	*Cores*	*Lancets*	*Burins*	*Points*	*Tulas*	*Grindstone Fragments*	*Axes and Axe Flakes*	*Leilira Blades*
0-1,000	10	7604	122	3	318	28	294	3	2	13	17
1,000-2,000	11	12083	55	2	353	76	506	8	3	23	1
2,000-3,000	11	7223	29	4	218	45	312	16	4	4	
3,000-4,000	8	2249	40	9	3	1	2				
4,000-5,000	7	1451	20	15	2	4	1				
5,000-6,000	6	922	19	4	0	0					
6,000-7,000	6	1009	17	27	3	0					
7,000-8,000	6	6318	181	1	0	5					
8,000-9,000	5	977	65	33	0						
9,000-10,000	5	637	9	8	0						
10,000-11,000	5	768	0	5	1						
11,000-12,000	2	162	1								
12,000-13,000	2	169	1								
13,000-14,000	2	5									
14,000-15,000	1	45									

Points appear to have been manufactured in larger numbers in Wardaman Country after c. 3,000 BP, but make their first appearance in very low numbers at around 5,000 BP. Tulas, on the other hand, show a sudden introduction at c. 3,000 BP, but peak earlier than bifacial points at c.2,600 BP. They also decline in frequency soon after introduction, and are very rare within 1,500 years of their first appearance. Grindstones and edge ground axes both only appear in the last 3,000 years, and peak at 1,500 BP when discard rates are at their highest.

Although likely to be little more than an oversized, early-stage product of the lancet flake production system, 17 Leilira blades were found in the excavated deposits in levels inferred to be less than 1,000 years old, with only a single Leilira found before this time. This late date is in accordance with the usual occurrence of these large lancet flakes either on the surface or in the top few spits at most sites. Recent work at a rockshelter in close association with a massive quartzite quarry (Gindan) near Garnawala 2 has revealed that large numbers of Leilira blades were being produced at this quarry shortly after 330 BP (Clarkson 2001).

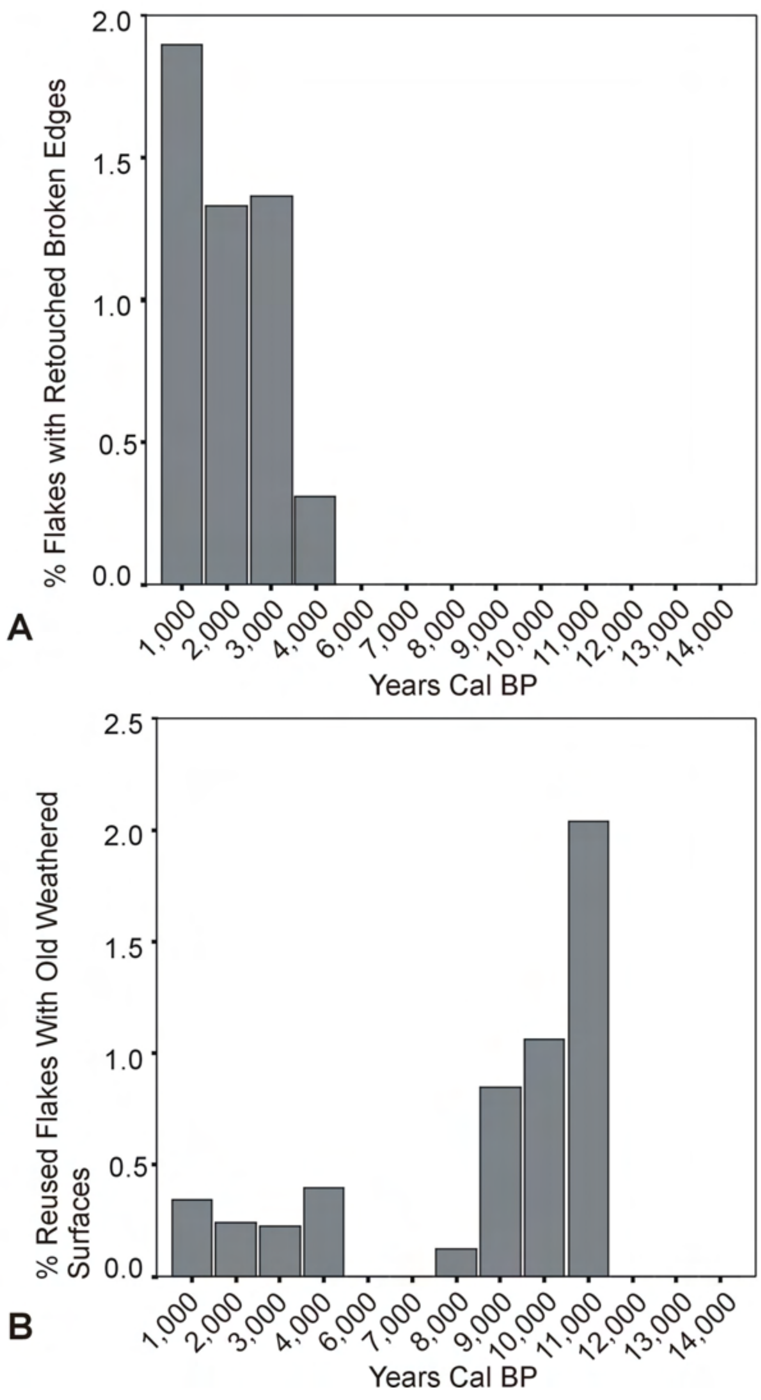
Shown at the left hand end of Figure 7.8 is a measure of changing technological diversity through time. Diversity can be seen to increase gradually between 14,000 and 4,000 years ago, increasing more dramatically after 3,000 BP, and then declining slightly in the last 1,000 years. This trend can probably be interpreted as a gradual shift from greater residential mobility (where few tools are employed) to logistical mobility through time (where many specialised tools are employed). This shift can probably be linked to increasing patchiness and a rise in mobile/clumped resources as rainfall became very variable between 3,500 and 2,000 years ago. Increasing the number of specialised tools in the toolkit would presumably have reduced time-stress and subsistence risk by increasing the chances of successful resource capture in more time-limited encounters with resources.

Rates of Implement Recycling

Another characteristic of retouched implements worth examining is the rate of implement transformation and recycling through time that might give an indication of changes in technological versatility and the use of situational gear. The importance of situational gear, particularly as a form of ensuring successful resource capture when replacement tools are unavailable, was outlined in Chapter 3, and a rise in frequency of use may point to an increase in time-limited foraging, and increased constraints on the transported supply. Figures 7.9a and b show the percentages of implement recycling found in sites through time, as indicated by the retouching of broken edges, and the scavenging of flakes, as

indicated by retouch that is superimposed over older weathered surfaces. There is a clear increase in retouched implement scavenging at c. 4,000 BP and another before 8,000 BP (Figure 7.9b). No signs of the use of situational gear are found during the lower peak in artefact discard between 8,000 and 5,000 BP. This is consistent with the low intensity of flake, core and retouched flake reduction found in sites at this time, and suggests that situational gear only became important at times of greater subsistence stress associated with fluctuating climate and aridity, presumably as mobility, risk and time-limited foraging increased. The continued use of situational gear at around 1,500 BP suggests that although interannual variability may have lessened at this time, the subsistence system was still geared toward high mobility/high risk foraging.

Figure 7.9. Frequency of artefact reuse as a possible indicator of the use of situational gear. A: frequency of retouched broken edges, and B: reuse of flakes with old weathered surfaces.



Changing Stone Procurement

Changes in the nature of stone procurement can be deduced from the types of raw materials used for stone artefact manufacture and the distances over which raw materials were transported.

Raw Material Richness and Patch Use

If raw material diversity reflects patch visitation, then changes in raw material richness (i.e. raw material diversity/sample size) should give an indication of the diversity of patches and stone sources visited, and hence of overall mobility and range of foraging. As seen in Figure 7.10, raw material richness is highest during periods of lower stone artefact discard, suggesting that mobility and patch visititation was also highest at this time. The same trend is noticeable at all three sites. The range of raw materials present therefore leads to speculation that people visited a greater range of patches while travelling to and from Nimji, Garnawala 2 and Gordolya during periods of low discard, indicating a higher level of either logistical or residential mobility at those times.

Raw Materials and Transport Distance

Changing procurement patterns can be explored by examining the changing proportions of local versus exotic stone over time. The data used for these tests is drawn from Nimji and Garnawala 2, rather than the entire combined sample of rockshelters, because the location of local raw materials is relatively well known for these two sites, but is less well known for Gordolya and Jagoliya. Stone types that cannot be reliably provenanced were excluded from this analysis, and these include most varieties of chert (but all non-hydrothermal chert has an origin at least 29 km away). The results are shown in Figure 7.11 for Nimji and Garnawala 2. Following initially high proportions of exotic stone, local stone dominates the assemblage from c. 9,000 BP until around 3,600 years ago, after which time there is a dramatic drop in frequency, and local stone is replaced by a huge increase in the importation of exotic stone. This suggests that people were travelling over much greater distances in the last 3,600 years.

Raw Material Quality

It is difficult to assess raw material quality, and no quantitative measures of fracture quality, toughness or brittleness have been obtained for the region's materials, but in terms of texture, homogeneity and outcrop size, the exotic raw materials brought to Nimji and Garnawala 2 tend to be the highest quality materials found in the region (apart from local Antrim Plateau Quartzite which is also of extremely high quality). This suggests that people may have preferentially selected high quality raw materials for transport while foraging in distant patches. This does not mean that raw materials do not reflect patch useage, only that patch use and toolkit diversity might be out of phase if poorer quality materials are cleared from the toolkit whenever higher quality ones are encountered. In a manner similar to prey choice models, foragers likely procure higher quality materials whenever they are encountered, and retain, conserve and transport these in prereference to lower quality ones. If raw material procurement was embedded, then foragers must have been more mobile to have encountered these distant, higher quality raw materials so often. If procurement was organised into specialised visits to quarries, the pattern likely indicates greater investment in long-distance journeys to procure higher quality materials.

Figure 7.10. Changes in raw material richness over time superimposed over changes in pooled artefact discard for all four sites. A: Nimji, B: Garnawala 2, and C: Gordolya.

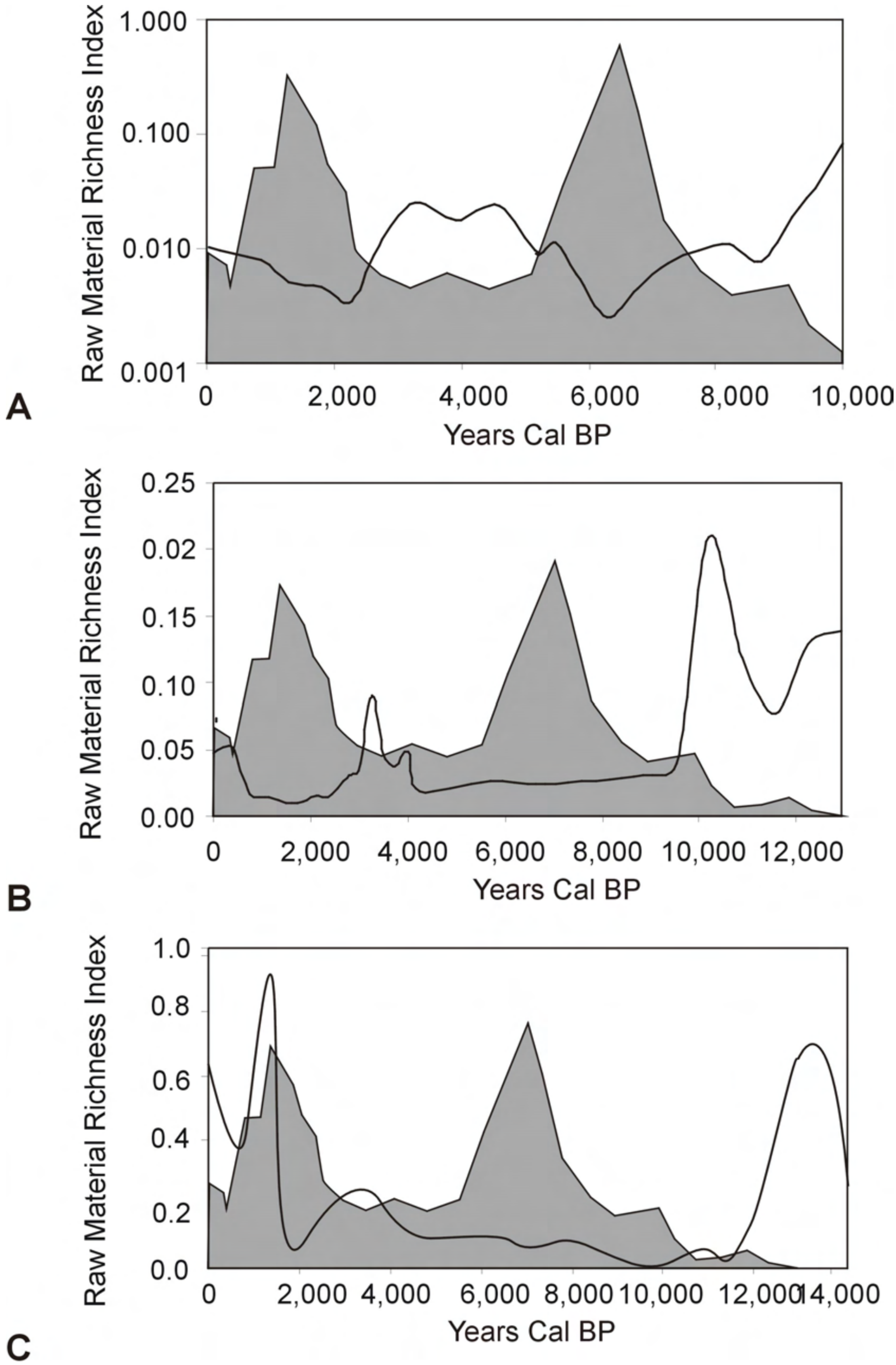


Figure 7.11. Changes in the proportions of local versus exotic raw materials. A: Nimji, and B: Garnawala 2

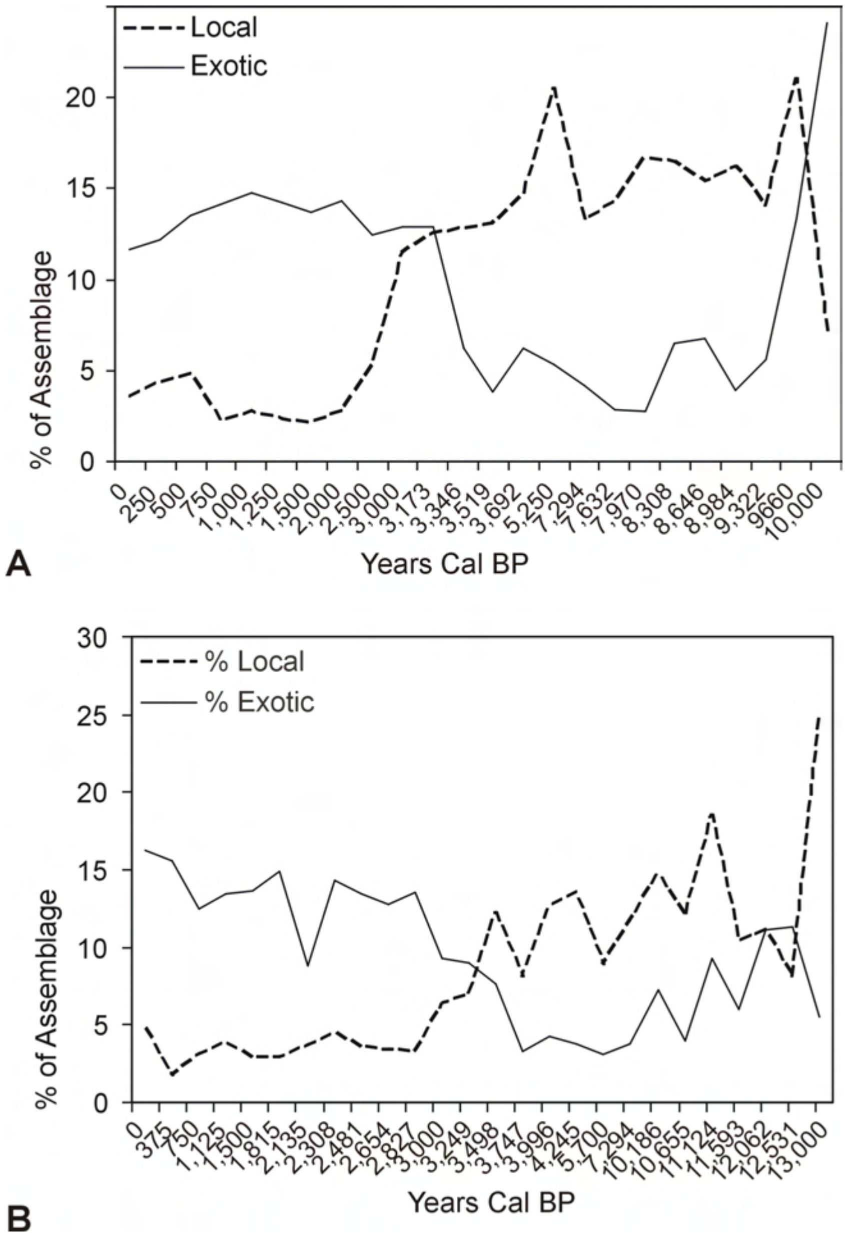
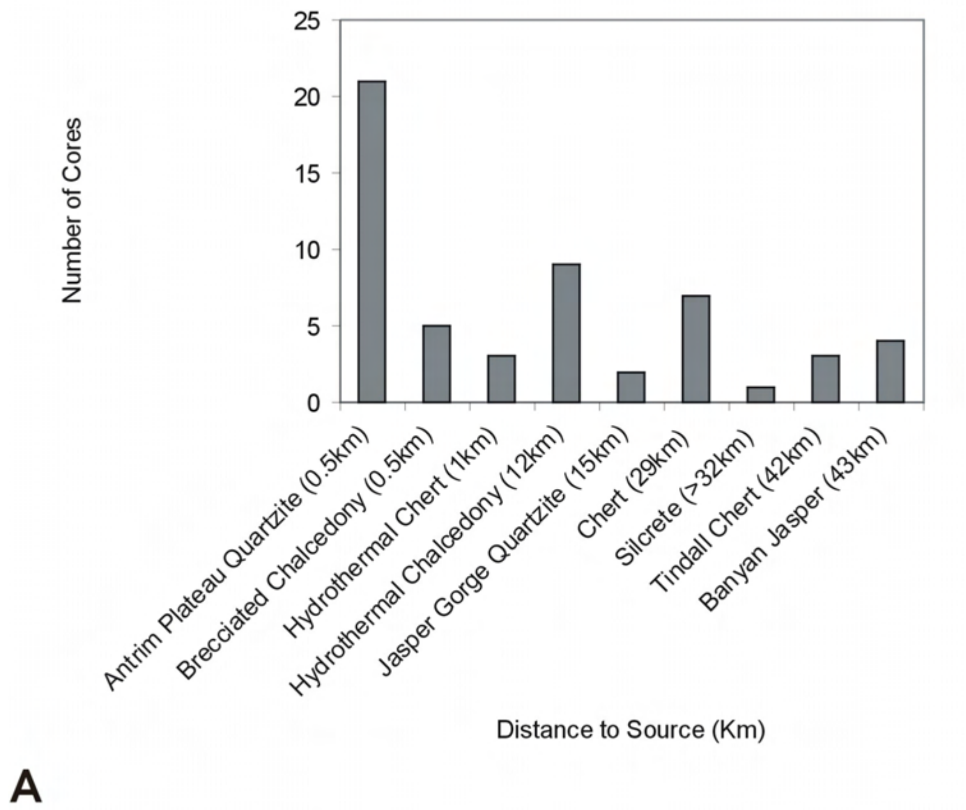


Figure 7.12. Changes in the size and abundance of cores transported over varying distances to Nimji. A: number of cores, and B: mean weight of cores.



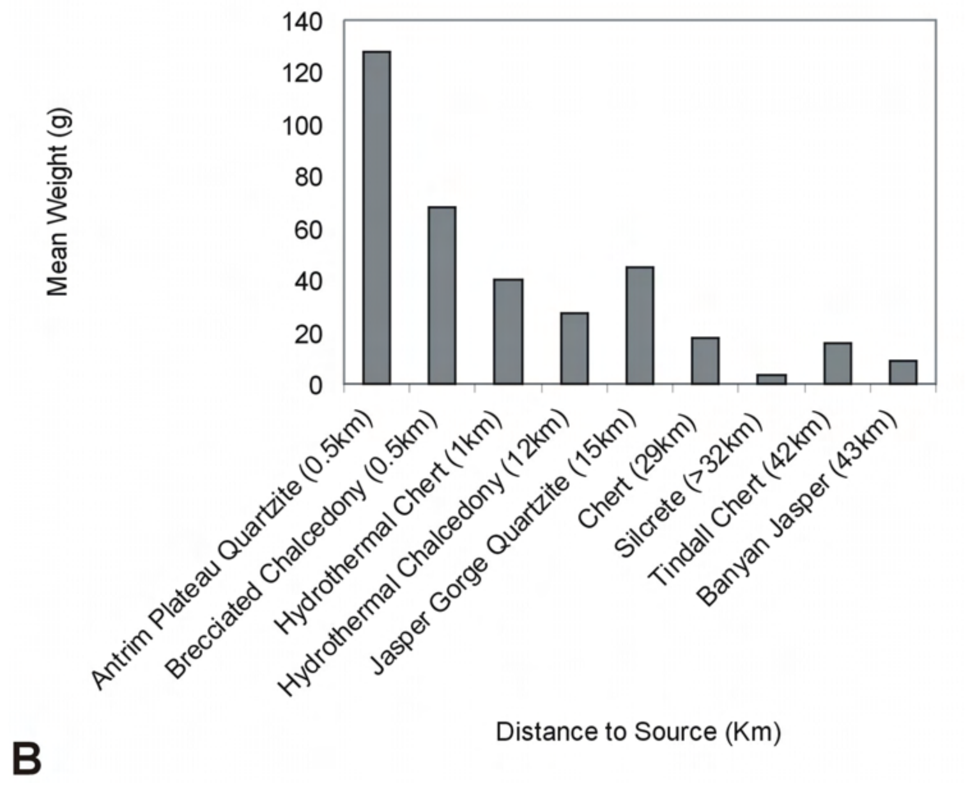
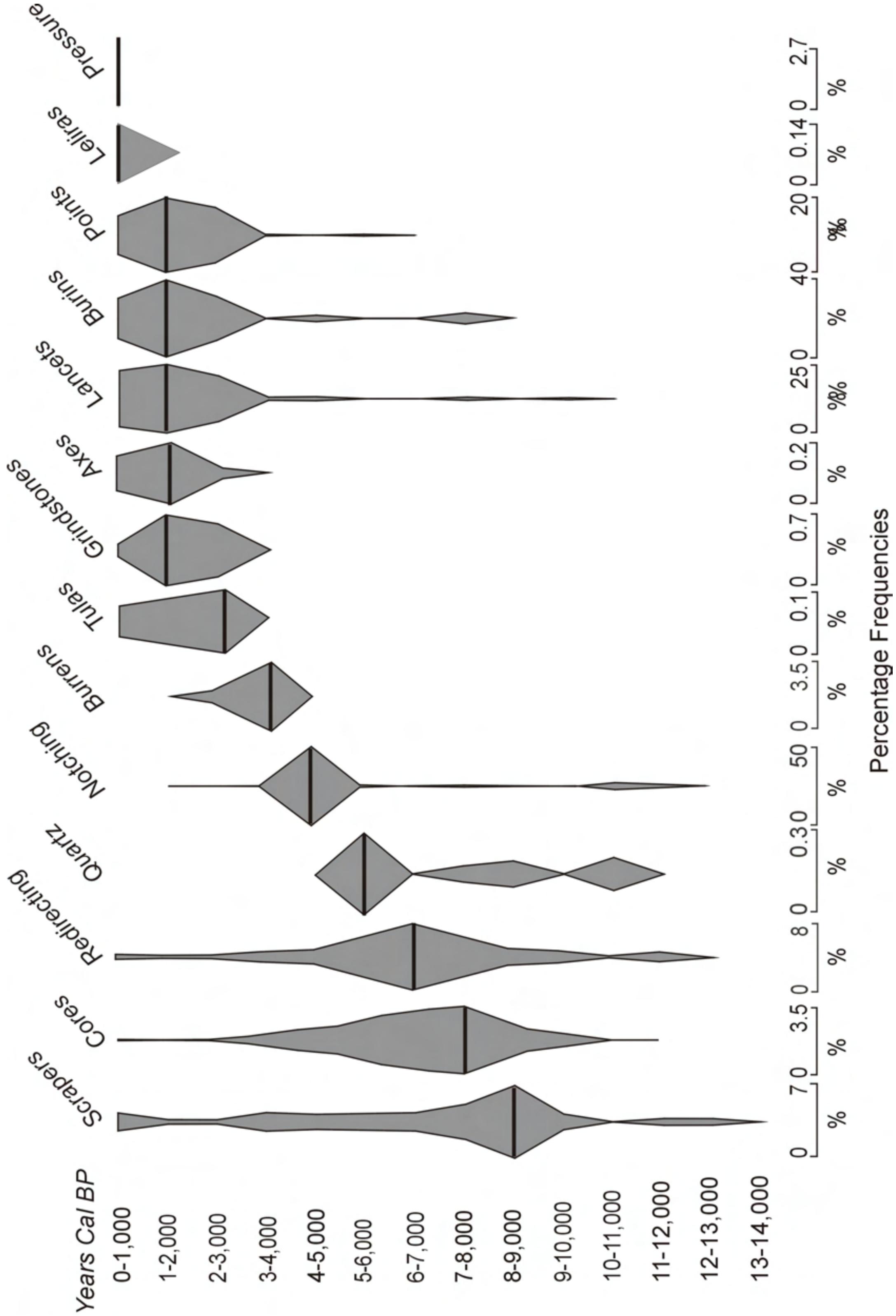


Figure 7.13. Evidence of continuity in stone artefact manufacturing technologies over the last 14,000 years.



Field Processing and Distance Decay

It was argued in Chapter 2 that the transport of materials to a central place may be optimized through pre-processing of materials at the source to reduce transport costs, and that this might be detected archaeologically by certain distance-decay relationships in raw material size and weight. Essentially, the field processing model predicts that the further cores are to be transported to the place of reduction, the more superfluous mass should be removed from them before transport to increase utility:weight ratios. Figure 7.12 plots the mean weight and number of cores brought to Nimji from sources at differing distances to the shelter. Only data from Nimji is used here as Nimji has the largest sample of cores. The results show a strong distance decay relationship in the weight of transported cores (Figure 7.12b), but a weaker relationship for the number of transported cores (Figure 7.12a). The weaker relationship between distance and core numbers can be understood in relation to the argument made previously about preferential retention and transport of higher quality raw materials. Chalcedony, chert and jasper are all extremely high quality materials and cores made from these materials are proportionally more abundant than would be expected for a simple distance decay curve. The weight of cores transported, however, is strongly patterned by distance and hence likely reflects decisions about how much mass to remove from cores before tranport as well as how long they have been in the use/transport system.

Continuity in Stone Artefact Manufacture

So far this monograph has examined patterning in the manufacture, transport, and discard of stone as an indicator of the constraints and opportunities placed on foraging by local and long-term ecological variables. Another important issue centres on whether there is evidence for continuity in the transmission of cultural information over time, or in this case, in the ways of manufacturing stone artefacts to meet various needs. By examining the frequency distributions of major stone artefact manufacturing techniques and other more minor techniques (such as notching, serrated pressure retouch), as well as the use of distinctive raw materials over time, it is possible to determine whether overlap exists in manufacturing traditions that might point to continuous transmission of manufacturing practices over time. If overlap does not exist in the technological traditions found in the region, and major discontinuities in manufacturing traditions are evident, then there may be grounds on which to argue for breaks in transmission – perhaps as a result of demographic change (such as migration and population replacement), or overwhelming cultural replacement. It has been routine in archaeology since the 1930s to test for continuity in social transmission by searching for lenticular frequency distributions over time in cultural phenomena (i.e. battleship curves), and the theoretical basis for this approach has recently been reasserted by evolutionary archaeologists (Bentley and Shennan 2003; Neiman 1995 and many others)

Figure 7.13 displays the frequency of manufacturing techniques, sequences and distinctive raw materials found in the Wardaman sites over the last 14,000 years. There is clearly a great deal of overlap in the occurrence of these technological features through time, and all display unimodal, lenticular distributions. The apparent overlap in time between technologies suggests that there is no major break in cultural transmission in this region, despite waxing and waning in the frequency with which each component is represented through time. Of course, changes in the frequency of reduction sequences may track a combination of different traits (i.e. both functional and stylistic), and it is difficult to extend the same interpretive argument that might follow from seeing such a pattern in, say, decorative pottery motifs, to retouched implement forms. However, as the rise in frequency in many retouched implement forms at 3,000 BP takes place without a major break in the manner of retouched implement production (i.e. scraper reduction sequences after 3,000 BP appear to be identical to those before 3,000 BP), and since the changes in core and flake form and abundance can be seen as alterations to rates of core transport and reduction, technological changes appear to have taken place within a framework of continuous transmission and without any evidence of a dramatic break from what came before.

Standardization in Production Systems

To explore whether the observed changes in technology are also accompanied by changing levels of variation in the production process, changes in central tendency and variation are plotted for key indicators of retouched implement shape, size and retouch type over time in Figures 7.14 to 7.16. These traits are selected as they were hypothesized in Chapter 2 to be features that might be modified as elements of designs that seek to increase utility, and might therefore be expected to be heavily modified in certain contexts. Shape, for instance, was reasoned to strongly dictate the functional efficiency of a tool and its suitability for hafting, size to affect portability and hafting, and retouch type to effect extendibility and artefact use-life.

Shape. Figure 7.14 plots central tendency and variation for marginal angle, length:width, width:thickness and length:thickness. Only the last 10,000 years are plotted as sample size becomes too small before this time (n = 8). It is clear from these graphs that the distinctive upward trend in mean values in the last 3,000 years is accompanied by a marked decrease in variation, as indicated by the standard error of the mean. Furthermore, central tendency tends to move up and down in a pattern that is suggestive of stochastic variation prior to 3,000 BP, but holds a steadier trajectory after this time. These combined features of mode shift, variation reduction and random versus directional mode shift point to strong pressures to standardize aspects of lithic production and tool design.

Size. Variation and central tendency for the size of implements can also be examined by plotting the mean and standard error for a number of implement dimensions. Figure 7.15 plots changes in the mean and standard error for proximal width, thickness, distal width and weight. These graphs reveal an overall decline in both central tendency and variation over the sequence. Like those for shape, these graphs also show greater fluctuation in mean values prior to the last 3,000 years, with more steady and directional changes thereafter.

Retouch Type. Changes in central tendency and variation in retouch type can be assessed by use of the scar invasiveness index which examines the invasiveness of retouch scars when the effects of perimeter of retouch are removed from the equation. This index measures the tendency for retouch scars to run across the face of the artefacts toward the mid-line. Figure 7.16a plots mean and standard error for scar invasiveness over the occupational sequence. There is a marked trend toward increasing invasiveness through time, and a reduction in variation toward the end of the sequence. Another measure of change in retouch technology is the frequency of bifacial retouching. Bifacial retouching was argued in Chapter 2 to provide a solution to the problem of accruing step terminations on the margins of flakes that inhibit reduction and shorten the use-life of tools. Figure 7.16b plots the central tendency as well as standard error for the number of bifacially retouched segments found on retouched flakes out of a total of 16 possible segments. Not only does the mean number of bifacially retouched segments increase over time, but variation also reduces in the last 3,000 years. While these trends do of course reflect the manufacture of bifacial points in large numbers after 3,000 BP, many other retouched implements also possess bifacial retouch, and it is therefore not the case that points alone drive changes in retouch type. Indeed, bifacial flaking appears with increasing frequency from a very early date, and therefore is not only associated with points.

The results presented here suggest a trend toward reduced variation through time, which is what would be expected if the tendency were to standardize technologies and design features in periods of increased risk and resource depression. What does not appear to be in evidence, at least in terms of the attributes examined here, is an increase in variation immediately preceding the appearance of new implement types around 5,000 years ago of the kind Fitzhugh (2001) argues should occur as innovation increases in relation to heightened risk. This suggests either that periods of technological innovation were perhaps too rapid to be detectable in archaeological assemblages, or that that they did not take place in this case. Another possibility is that innovation is best represented by the sudden increase in implement diversity at 3,000 BP. These arguments are further discussed in the final chapter.

Figure 7.14. Changes in mean and standard error for four measures of retouched implement shape.

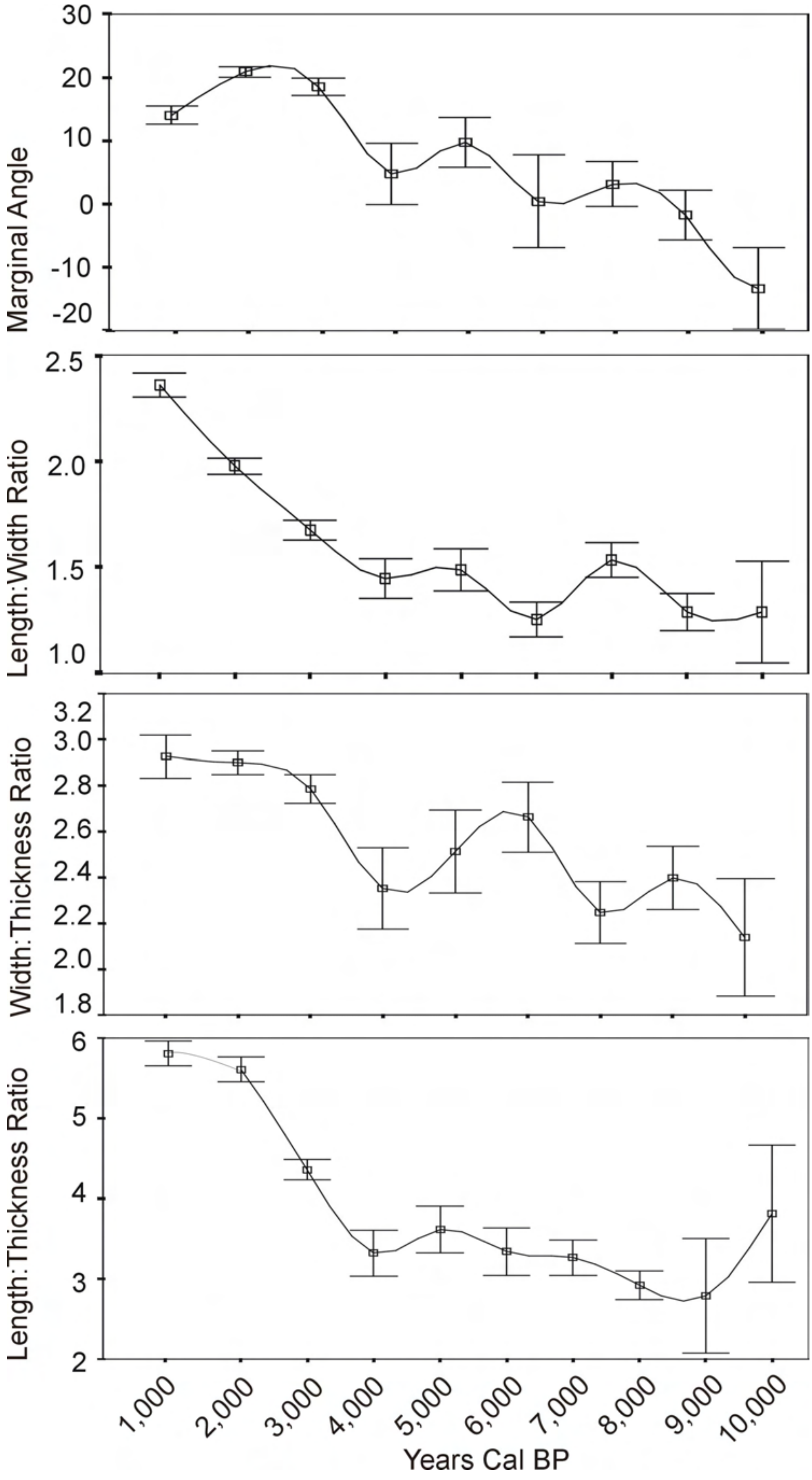


Figure 7.15. Changes in mean and standard error for several measures of retouched implement size.

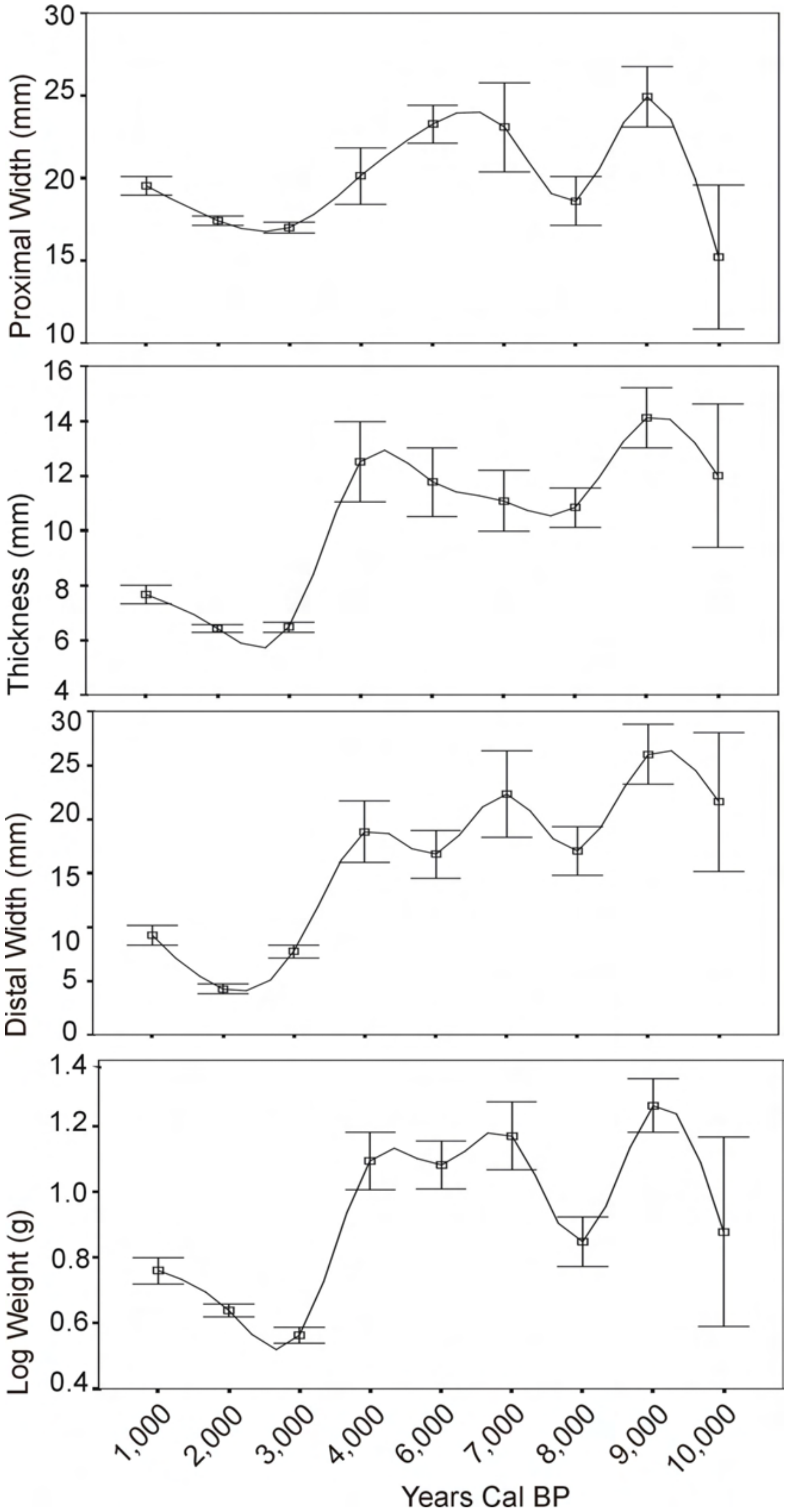
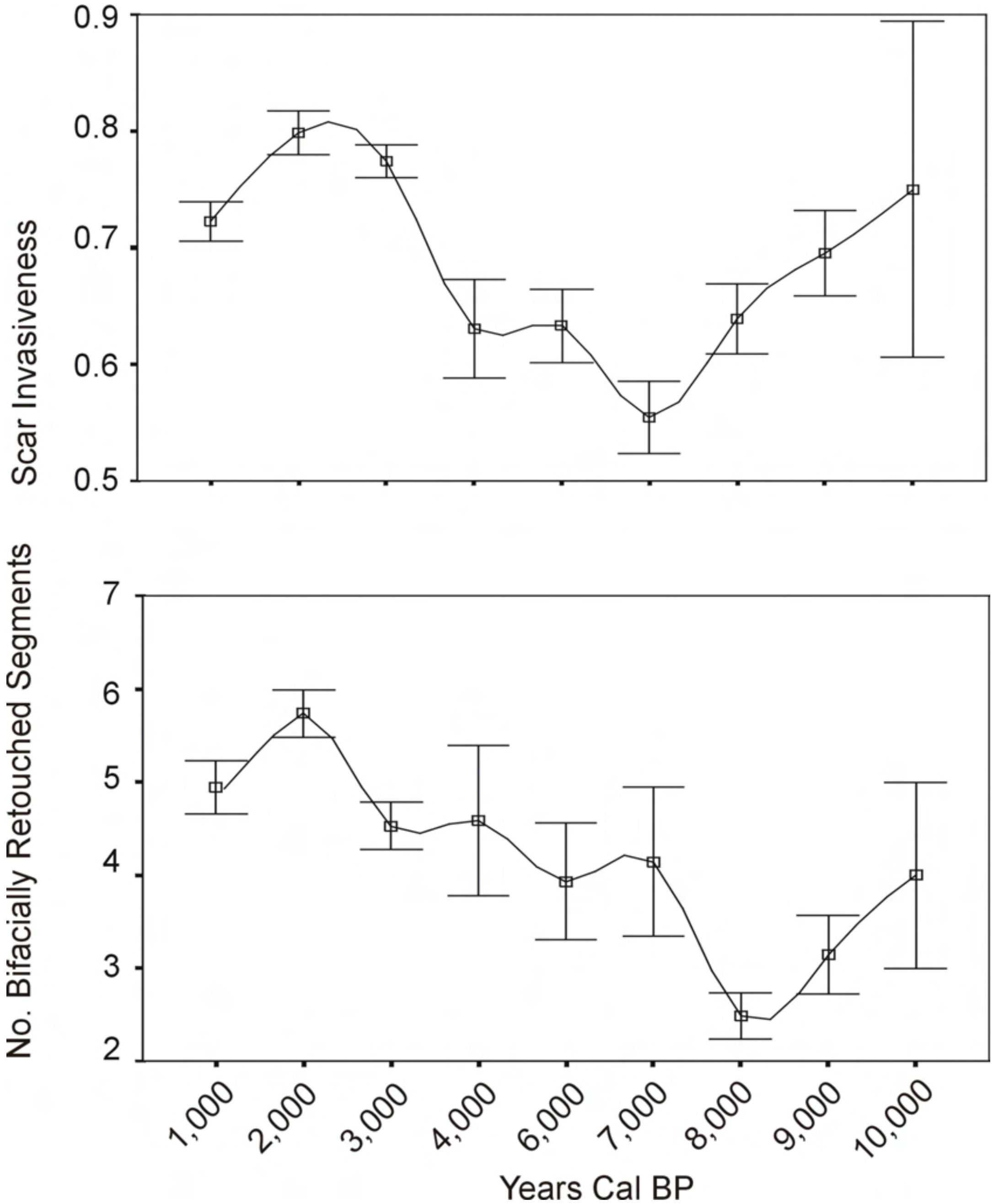


Figure 7.16. Changes in mean and standard error for two measures of flake retouching. A: the Index of Invasiveness, and B: the number of bifacially retouched segments.



Technological Change, Toolkit Design and Provisioning

The analyses presented in this chapter have revealed major changes in technology that likely correspond to a complete shift in the way technologies were organised, toolkits were designed and raw materials were provisioned over the last 15,000 years. These changes will be interpreted in broader socio-economic terms in the next chapter, however, it is useful to conclude this analysis by briefly summarizing temporal changes into a coherent model of changing subsistence, mobility and land use and to review how closely the results match the predictions made in Chapter 3 about the effects of climate change on demography, subsistence and technology.

15,000 to 8,000 BP

The first signs of human occupation of the region appear at around 15,000 BP with very small numbers of stone artefacts and a wide range of raw materials. Flakes and retouched flakes are the only technological categories found at this time, but this is almost certainly a factor of low sample size. By 12,000 BP, numbers of stone artefacts had more than doubled, small heavily rotated cores were becoming a significant feature of assemblages, and reduction intensity was on the increase. By 10,000 years ago, stone artefact numbers were still increasing and reduction intensity had reached very high levels. Raw material richness remained high, and scavenged and recycled artefacts were in common use. By 8,000 years ago, retouched flakes (scrapers) have reached their peak, retouch intensity is very high, and new forms of artefact transformation appear with the first signs of burinate retouch at this time.

The progression of technological changes over this initial period of occupation from 15,000 to 8,000 BP seems to indicate increasing concern for the extension of artefact use-life, with cores, flakes and retouched implements all taken to later stages of reduction. Raw material richness, as a proxy measure of patch visitation, and the frequency of exotic raw materials, as a measure of foraging range, both indicate high mobility and long-range foraging over this period. Technological diversity, however, remains quite low at this time, suggesting that few if any specialised implements were being manufactured or transported. The signature for this early period therefore appears to be one of mostly individual provisioning, but with both small cores and retouched flakes forming a strong component of the transported toolkit. The transport of cores would have increased technological flexibility by allowing fresh flakes to be created from cores on demand. Transporting a supply of raw materials would also have lessened the need to extend the use-life of retouched implements beyond a certain point, and the exclusive use of relatively short use-life implements at this time (i.e. scrapers) is understandable as a low-investment/low-use-life strategy aimed at maximising toolkit flexibility at the expense of toolkit diversity and efficiency. This combination of design features as well as indications of high-frequency, relatively long-range mobility is what would be expected of a highly residentially mobile system of land use, where resources tend to be stable and evenly spaced rather than mobile and clumped.

8,000 to 5,000 BP

An apparent major reversal in trends takes place between 8,000 and 5,000 BP. This coincides with a major peak in stone artefact deposition which is argued to reflect an increase in occupational intensity. Reduction intensity decreases in cores, flakes and retouched flakes at this time, as does the proportion of exotic raw materials and raw material richness. The proportion of larger, more lightly reduced cores in the assemblage also increases, and the proportions of retouched flakes declines. The combination of factors points to reduced range and frequency of mobility, an increase in stockpiling of sites with raw materials from local sources as well as a reduced range of distant sources, and a discontinuation of artefact scavenging and recycling. The signature is clearly one of place provisioning – a strategy that is most suited to more regular movements within the landscape where the types and frequency of subsistence opportunities can be predicted. In the context of greater predictability of use and lower residential mobility, the peak in occupational intensity also suggests an increase in people visiting the shelters, more frequent visitation, longer visitations, or an overall increase in population density such that all forms of site use are intensified. Climatic data for this period indicate a time of increased rainfall and reduced interannual variability. Phytolith analyses undertaken using sediments from these sites also point to a wet phase at this time (Clarkson and Bowdery 2005; Clarkson and Wallis 2003). These are exactly the sorts of conditions under which we should expect population growth to take place and technological strategies to emerge that take advantage of higher resource abundance and more predictable availability of food and raw materials.

5,000 to 1,500 BP

After 5,000 BP there is a change in technology back toward the higher levels of reduction that existed in the initial period of occupation. However, the nature of technological strategies employed after

5,000 BP appears to differ from those employed earlier on. Standardised retouched implements begin to make their appearance from 5,000 BP, including unifacial points and late reduction stage scrapers (identified as burrens), and raw material richness and the proportion of high quality exotic stone increases once again. Cores too begin to drop out of the record and the size of artefacts begins to decrease markedly.

The rate of change intensified at 3,000 BP, including a marked increase in technological diversity, with up to five new reduction sequences appearing in the region, and a rapid increase in the recycling of artefacts. Reduction intensity and the extension of reduction potential also peaks between 2,000 and 3,000 BP, with the most reduced stages of many retouched implement forms (i.e. bifacial points, tulas and burins) and the end points in core reduction (i.e. bipolar cores) peaking at this time, and then declining soon after. Edge ground axes, arguably the most extendable and most costly implements to produce, also make their first appearance at this time. The rise in diversity represents a far greater investment in technology in terms of time and labour that can only have been recouped through the extension of artefact use-lives. The greater attention to design and standardisation of form at this time was no doubt targeted at increasing the efficiency of tools in performing particular tasks and may also have aided in reducing the risk of subsistence failure by increasing capture rates for mobile prey (as in the case of points), reducing handling times (as in grindstones and tulas), while also building in an element of flexibility through the transformation and recycling of tool-bits to guard against potential technological shortfall (in the case of burination and the reworking of broken artefacts).

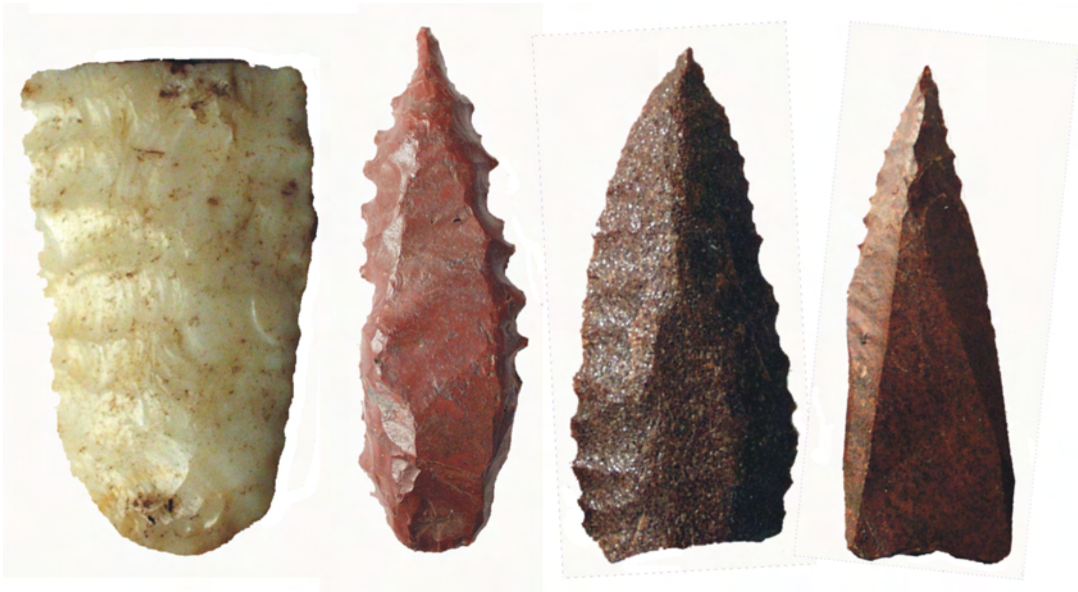
Hafting was almost certainly a key element in technological change after 5,000 BP, as seen in the diminution of implement forms, and an increased concern for standardising the proximal dimensions of flakes. Standardisation and the use of invasive retouching and bifacial reduction over this period also likely improved the maintainability of tools, by allowing the use of interchangeable forms within costly, pre-designed hafts, and by ensuring that problems in implement geometry (such as steep edge angles and the accumulation of step and hinge terminations) could be overcome through careful invasive flaking across the surfaces of implements.

The nature of technological change over the period from 5,000 to 1,500 BP can be characterised as a shift from place provisioning toward an extreme form of individual provisioning, where very little besides small, standardised, and highly retouched implements were transported. Rates of diverse patch visitation were high, as was the long distance import of raw materials, implying mobility had greatly increased over this period. The increase in toolkit diversity, on the other hand, points to higher logistical rather than the earlier residential mobility. This implies that resources may have become more mobile/clumped after 5,000 BP, and that longer, dedicated foraging trips under increased time-limited circumstances were required after this time. The rise in risk reduction strategies after 5,000 BP, such as increased maintainability of toolkits, use of higher quality raw materials and increased diversity and increased effectiveness of tools points to a period of increased subsistence risk at this time. Climatic data indicate that interannual variability peaked between 3,500 to 2,000 BP. The change in technology toward pronounced individual provisioning points to the use of mechanisms that evolved to cope with decreased certainty over access to resources like food, water and stone, and increased logistical mobility to reconcile the differences between the location of people and fluctuating resources. Interestingly, Fitzhugh (2001) predicts that foragers facing less than minimum subsistence returns are more likely to focus efforts on improving technologies that enhance capture rate of larger, high-ranked prey, but as these are driven to decline, the focus should shift to hardier, and more reproductively stable r-selected species. The appearance of points after 5,000 BP, and around the time of intensified climatic variation, may represent an instance in which foragers attempted first to improve success rates in hunting larger, higher ranked game such as macropods, but were also led to improve handling times for more reliable, lower ranking resources like seeds (as represented by a later rise in the frequency of grindstones) once high ranked game became depleted.

Other forms of risk reduction are also hinted at. The origins of the new standardised retouched implement forms that appear around 5,000 years ago and which appear widely distributed across large parts of northern and central Australia has always been a source of speculation about inter-regional

contacts. Since it is unlikely that these technologies were independently invented many times in various regions of northern Australia, it seems highly likely that the appearance of these new forms in Wardaman Country is a measure of social transmission between this and neighbouring regions that already possessed these technologies, such as Arnhem Land to the northeast where points appear to have been in use since before 6,000 years ago[1] (Hiscock 1993b; Jones and Johnson 1985; Kamminga and Allen 1973), and central Australia to the south where tulas seem to have their origins around 5,000 BP (Gould 1967; Law 2005). It is intriguing to consider why these new technologies might have begun appearing in Wardaman Country after this time, and why they did not appear in abundance until 2,000 to 3,000 years later. One possibility is that people inhabiting this region began to experience greater subsistence risk after 5,000 BP with the onset of ENSO-driven variability, and began to establish forms of social storage through risk reduction reciprocity with neighbouring groups. Such social networks brought the inhabitants of Wardaman Country into contact with new technologies that were successful in reducing risk. Their gradual appearance in Wardaman Country after 5,000 BP might therefore represent a gradual trickle of information across kinship and linguistic boundaries after this time. The fact that much of the rock art of Wardaman Country also bears close ties to the rock art of more northern regions (Attenbrow *et al*. 1995; Clarkson and David 1995; David *et al*. 1990; David *et al*. 1994) suggests that social ties to neighbouring regions, possibly begun as early as 5,000 BP, resulted in the transmission of a great deal of cultural information between regions over long periods.

Figure 7.17. Examples of pressure flaked points from Nimji dating to the last 1,000 years.



1,500 to 0 BP

The final phase of technological change takes place after 1,500 BP at which point a second peak in stone artefact discard occurred. This last period also witnessed a decline in reduction intensity as seen in the frequencies of highly reduced implement forms. Raw material richness and the proportion of exotic materials decreased, and therefore so presumably did the level of logistical mobility. The fact that most technologies persisted throughout this last period, however, suggests that changes back toward a system of lower mobility and increased abundance and predictability of resource availability after this time were likely to be minor in comparison with the complete system change that took place between 5 and 8,000 BP. This is understandable given that interannual variation in rainfall continued to the present day, and that despite a reduction in overall amplitude, oscillations are still capable of producing regular floods and droughts. Subsistence risk therefore likely remained high right up until

[1] Hiscock (1994b, 1996, 1999) argues that points arose earlier in Arnhem Land than in other regions because the sub-coastal plain was undergoing extremely rapid changes in salinity, hydrology and vegetation that were related to sea level rise. He argues that these changes created increased subsistence risks for hunter-gatherers occupying this region. These changes likely pre-date the onset of ENSO and may have given rise to an earlier emergence of new technologies there than in nearby regions.

the arrival of Europeans, and many of the technological and social strategies set in place after 5,000 BP for coping with risk, unpredictable resource abundance and increased mobility appear to have continued to some degree until historical times.

New technologies and implement forms, such as large Leilira blades and serrated pressure retouching, also appear in the last 1,000 years (Figure 7.17). Leilira blades are ethnographically known to have been traded over large areas (Allen 1997) and are dated in Wardaman Country to the last 330 years. The appearance of serrated pressure retouch in the last 1,000 years may also indicate inter-regional contacts with the Kimberley region at this time, as this technique is common (although in undated contexts) in that region but appears always to have been rare in Wardaman Country. Kimberley points are also a well-documented exchange item, traded over many hundreds of kilometres in the recent past. The emergence of both of these new systems of manufacture and exchange may signify ongoing, albeit altered, social networks for the purpose of (among other things) social storage and ensuring access to resources in bad times.

Conclusion

It is clear that major changes in stone artefact production and design took place over the last 15,000 years in Wardaman Country. The results point to major alterations in provisioning and land use that are probably closely tied to changing resource abundance, stability and structure over time. In the final chapter these observations will be drawn together to offer new insights into Wardaman Prehistory and socio-demographic changes in northern Australia more generally.