REDUCTION, RECYCLING, AND RAW MATERIAL PROCUREMENT IN WESTERN ARNHEM LAND, AUSTRALIA

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ABSTRACT

Complex lithic assemblage variation in Arnhem Land, Australia, was initially explained by suggestions that multiple cultural groups had co-existed or that a single group had used different toolkits as they moved seasonally to exploit temporary resources. These models have proved untenable and differences in assemblage composition across the landscape are now explained in terms of procurement economics: as knappers rationed, recycled, and substituted artifacts in response to the varying cost of obtaining replacement stone in each location. The economics of raw material use, and its articulation with technological strategies suited to different contexts of mobility and risk, provides mechanisms that can explain the persistence of geographical differences in artifact assemblages but which can also make sense of temporal subtle changes in technological activities. Unlike earlier archaeological theories, we can now conclude that site function and identity of the local residence groups were factors of little significance in the production of assemblage differences.

Questions of why lithic assemblages display variation have been central to the explorations of Paleolithic societies on every continent. Increased understanding of lithic technology and more detailed paleoenvironmental reconstructions have, over recent decades,

led to revision of many models about the character of assemblage variability and its articulation with past physical and social environments. In the context of Australia, where Paleolithic technology and economies existed until the last few centuries, reconceptualizing prehistoric ways of life involved abandoning linear models of cultural progression and recognizing that Paleolithic economic and technological systems were elaborate and dynamically changing (Hiscock 2008). These qualities are illustrated in new models of

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technological variability and the articulation of those ancient technologies with changing resources, altered levels of foraging risk, and modified social contexts. In many Australian regions stone working technology was reorganized at times of climatic and economic shifts in response to increased foraging risks and procurement costs (e.g., Cundy 1990; Hiscock 1994b, 1996, 1999, 2002, 2006; McNiven 1994, 2000; Clarkson 2002a, 2004, 2005, 2006; Attenbrow 2003; Hiscock and Attenbrow 2005a,b; Law 2005; MacKay 2005). This proposition constitutes a powerful explanatory model that is increasingly being applied to explicate variability in Paleolithic Australia, and in this chapter such factors are explored to make sense of the lithic assemblages in western Arnhem Land.

The Alligator Rivers region of Arnhem Land has taxed the imagination of several generations of archaeologists. Fieldwork along the escarpment, and subsequently on the lowlands and wetlands to the north and west, gradually uncovered geographical differences in lithic assemblages. The perceived lithic variability was initially explained in traditional terms, involving the identity, territory, and seasonal use of territory by prehistoric foragers.

TRADITIONAL DEPICTIONS OF ASSEMBLAGE VARIATION IN ARNHEM LAND

Archeological investigations of western Arnhem Land have long recognized the existence of geographical variation in the typological composition of lithic assemblages. Initially the exploration of this phenomenon, by Schrire (e.g., White 1967a,b, 1971; White and Peterson 1969; Schrire 1972, 1982), focused on Late Pleistocene and Holocene assemblages observed at sites located in different environments along the East Alligator River corridor. These differences were expressed in terms of the position of five rock shelter deposits within the riverine corridors and their distance from the escarpment that visually dominates the landscape (see Figure 6.1). On the upper reaches of the riverine corridor Jimede I and II were overhangs located amidst the massive sandstone scarps of the dissected margins of the escarpment. Further downstream the Malangangerr shelter is a recess in a 10m high sandstone residual block near the escarpment. Even further towards the coast two sites, Nawamoy and Badi Badi, are located in small residual blocks of rock positioned

on lowland plains. These five sites display differences in the abundance of tool types and Schrire attempted to make sense of them by distinguishing what she called "plateau sites" (Jimede I and II) from "plains sites" (Malangangerr, Nawamoy and Badi Badi), and cataloguing the implement types she recognized at each.

Schrire employed a typological classification that defined a number of types found in many sites across this region (see Figure 6.2). The two dominant forms were points and scrapers. Points were flakes that had been retouched on the lateral margin(s) to produce a convergent plan shape (Figure 6.2a). They were retouched on either one or both faces, a pattern that allowed Schrire to differentiate between unifacial and bifacial points. The vast majority of points were broken and the convergence of the original margins was estimated from the shape of the remaining fragment. In Schrire's (1982) assemblages quartzite was the material from which most points were made, with chert and quartz employed to make others. Points were often shaped by invasive retouching accomplished by direct percussion. Scrapers were typically flakes which also had direct percussion retouch scars on their dorsal face but which had rounded rather than convergent plan shapes and retouched edges (Figure 6.2b). This was a morphologically varied class, and showed a different pattern of raw material usage, with most specimens being made from chert. Schrire also defined a number of types that were represented by low numbers of specimens but which she considered diagnostic of site use. Polished flakes had severe edge rounding and gloss on one or both faces (Figure 6.2c). Some specimens were retouched; others were not. Schrire also recognized what she called "bifacial ovals"; unifacially or bifacially retouched flakes with an ovate plan shape (Figure 6.2d). They often resembled points but had rounded rather than convergent forms. Another type was "fabricators," specimens that had been subjected to bipolar retouch, leaving scars which derived from opposing ends, features that Schrire referred to as "bruised ends" (Figure 6.2e). She argued that these were tools used as wedges or punches (White 1967a: 354–6; Schrire 1982: 41), although later Australian researchers concluded that such specimens were often bipolar cores (e.g., White 1968; Hiscock 1982, 1996, 2003). In addition to these flaked artifacts Schrire identified fragments of axes in many sites (Figure 6.2f). Identified by ground bevels creating the axe edge, these specimens were manufactured on igneous and metamorphic rocks by flaking and pecking prior to edge

Figure 6.1 Location of discussed sites in western Arnhem Land, showing topographic distinctions and zones of raw material procurement.

Figure 6.2 Illustration of the implement types recognized by Schrire in her study of assemblage variability in western Arnhem Land. (a) point, (b) scraper, (c) polished flake, (d) bifacial oval, (e) fabricator (bipolar core), and (f) axe. All specimens redrawn from Schrire (1982) and presented at the same scale.

grinding (White 1967c; Schrire 1982). Although later researchers have re-examined these types the basic divisions employed by Schrire have been maintained in many depictions of assemblage variation (e.g., Allen and Barton *nd.*; Jones and Johnson 1985; Meehan *et al.* 1985; Brockwell 1989, 1996). As a consequence many researchers have offered explanations for assemblage variation that echoed those proposed by Schrire, involving differences in the identity of resident groups and tool using activities that they undertook at each place.

Using these typological categories Schrire argued that assemblages on the plains differed from those on the plateau in the proportions of tool types (White 1967a,b, 1971; White and Peterson 1969; Schrire 1982). Sites along the escarpment contained large numbers of flakes, both unretouched and retouched; whereas on the plain her excavated sites contained few flakes. Schrire (1982: 244–5) characterized plains assemblage as having far fewer tools, proportionally fewer points and scrapers, but higher proportions of polished flakes, axes, and fabricators than in the plateau assemblages.

Initially White (1967b) hypothesized that assemblage differences were a consequence of the long-term co-existence of two cultural groups who possessed similar stone-tool traditions but emphasized different elements within them. She argued that prehistoric contrasts between plateau and plain were consistent with economic patterns observed in resident Aboriginal groups in the early decades of the twentieth century. She later rejected this hypothesis because the archaeological pattern persisted for thousands of years and was not explicable in terms of the rapidly changing structure of land ownership and identity in the period following European contact (White and Peterson 1969). Furthermore “plateau sites” were actually located in gorges on the plateau margins and were accessible by people living on the plains; hence there was no topographic barrier to help maintain long-lived cultural differences.

Schrire subsequently offered an alternative interpretation, in which the landscape was used by a single group moving seasonally (White and Peterson 1969; White 1971). Her idea was that the focus of occupation shifted from the plains during the dry season to

the plateau during the wet season, and assemblage composition in each sub-region reflected the seasonally different activities of foragers in each sub-region. Different tools were required to exploit the resources encountered in each place: on the plains foragers used bone-tipped spears and stone and shell scrapers to hunt and process fish and water-birds, while on the plateau land mammals such as kangaroos were captured and butchered using heavier stone-tipped spears and stone scrapers (Schrire 1982: 250). Knappers manufactured stone tools during their wet season occupation of the plateau, where high quality quartzite was available, and then, at the start of the dry season, they carried small numbers of stone tools onto the floodplains and emphasized organic tools such as bone points. Schrire's (1982: 251) model of seasonal mobility was therefore related to the economics of tool production. A seasonality model appeared to have the support of ethnographic information, which demonstrated that responses to seasonal inundation and variation in the abundance of plant and animal foods typically took the form of altered settlement localities and resource procurement activities (cf. White and Peterson 1969; also Spencer 1914; Thomson 1939).

Schrire's seasonality-based model has now been rejected. One reason was the discovery of further complexity in the archeological record, as new sites were reported and excavated. For example, Allen and Barton *nd.* reported a large, point-rich assemblage from Ngarradj Warde Djokkeng, a site situated at the base of a plateau near Malangangerr and the East Alligator River. Topographically Schrire considered this to be one of her "plains sites" but the assemblage was more like one of her "plateau sites," and it was considered an anomaly that signaled the inadequacy of models of seasonal transhumanence (Schrire 1982; Allen and Barton *nd.*). Further assemblage variation was identified when open sites on the South Alligator River were examined (Meehan *et al.* 1985). Studied in detail by Brockwell (1989, 1996), sites such as Kun-kundurnku, Kumunkuwi, and Kihna had few points, variable proportions of scrapers, but relatively high proportions of polished flakes and other forms of highly retouched flakes. While these assemblages resembled Schrire's "plains sites" more than her "plateau sites" they differed from both sets of assemblages. This discovery meant that a simple division of landscape and assemblages into two categories of "plain" and "plateau" was an inadequate

expression of environmental and archeological variability.

A second problem with the seasonality model was that it had limited capacity to explain chronological changes in assemblage composition, and as archeological research proceeded it became increasing clear that a number of sites displayed temporal change (see Allen 1989). It seemed likely that the seasonal contrasts had always existed throughout the Holocene, although they varied in magnitude, and several researchers were puzzled as to why implement frequencies would have altered over time if assemblage differences reflected seasonal climatic variation (e.g., Schrire 1982; Allen 1989; Allen and Barton *nd.*). Several researchers suggested that this enigma was connected to questions of environmental change.

The environment of western Arnhem Land underwent a series of radical changes, and the magnitude of landscape transformations represented a challenge to the seasonality model. Believing that the historical introduction of water-buffalo and pigs had degraded the riverine environments Schrire (1982) suggested that the plains had once been more productive and would have supported resident forager groups throughout the year. She concluded that there had not been a seasonal relocation of foragers between "plain" and "plateau." This proposition was adopted by Meehan *et al.* (1985) as the basis for interpreting South Alligator River sites as a closed system in which resident foragers remained annually and moved systematically between resource-rich swamp locations. Brockwell (1996: 99) hypothesized that differences between the South Alligator River assemblages reflected different site functions during the seasonal cycle of movement along the riverine plain; a seasonal model of assemblage variation and forager movement formulated at a much smaller scale than Schrire's. However even reconfigurations of seasonality models are challenged by the evidence for environmental transformations.

Landscape change in western Arnhem Land was thorough and severe, and it was not restricted to the period after European contact (see Hiscock and Kershaw 1992; Hiscock 1999, 2008). For instance, about 9000 years ago rising sea levels flooded the lower reaches of river valleys, creating mangrove fringed embayments which were then gradually filled with sediments and colonized by mangroves to form enormous swamps. By about 6000 years ago continued sedimentation had filled in the swamps to create grass covered flood plains. In parts of this new land high soil

salinity then developed, making it impossible for vegetation to exist on the plains. Eventually salt leached from the profile and grasslands were again established. During the last millennia or two fresh water lagoons were formed at a number of places on the flood plain margin, and hence today's wetlands are only the final phase in a series of environmental changes. Away from the river valleys landscape changes also occurred throughout the Holocene. Along the coast progradation formed salt-rich mud flats during the mid-Holocene, extending the shores northwards and altering shoreline characteristics (Woodroffe *et al.* 1986). On the escarpment and adjacent plateaus erosion of sediments modified the landscape, filling gorges with sediments and altering vegetation communities (e.g., Hope *et al.* 1985). The consequences of this landscape evolution were locally varied, resulting in somewhat different environmental histories in each part of the region.

Repeated alterations to the environments of western Arnhem Land meant that resources were not constant for long periods; hence forager resource use in each locality and the functions of sites cannot have been constant. If patterns of implement variation reflected the use of available resources, as implied in all versions of the seasonality model, it would be expected that there would be frequent and substantial changes through time in assemblage variation. This is not what is found! Although there are subtle changes in assemblage patterning over time many of the characteristics of assemblage difference across the region are remarkably persistent while fundamental environmental changes occurred. The long-term persistence of geographical differences in lithic toolkits in a rapidly changing landscape is the central reason that models of seasonal movement cannot explain those spatial contrasts in assemblages.

This conclusion leaves archeologists again pondering the question of how to explain lithic variation in Arnhem Land. Although the pattern of assemblage variability is complex there is a geographical coherence to the assemblage differences that were known. If seasonal movement between the escarpment and the lowlands/wetlands cannot explain observed assemblage variation, does this imply that Schrire had originally been correct in hypothesizing that the region had been occupied by different cultural groups? One response to this question is that there are other possible causes of assemblage variation that have not been adequately considered in discussions of the region.

NEW DEPICTIONS OF ASSEMBLAGE VARIATION

Alternative explanations for assemblage variation require new depictions of the variation. Traditional characterizations of assemblage difference in western Arnhem Land were presented in terms of varying proportions of several classes of implement. The implement types represented in Figure 6.2 were treated as discrete end-products designed to carry out specific functions, and the difference between assemblages was considered to reflect the functional emphasis of prehistoric inhabitants. Hence lithic assemblages were thought of as expressions of seasonal differences in the foods foragers obtained.

Over the last decade many Australian researchers, like their colleagues around the world (e.g., Geneste 1985; Neeley and Barton 1994; Dibble 1995; Shott 1995), have abandoned the twin tenets of those typological analyses. The notion that different "types" of retouched flakes were the carefully crafted, finished form of distinctly different production activities has given way to consideration of different implements as mutable objects that can be transformed from one morphology to another, and the hypothesis that variation between "types" as well as within them may represent differences in the extent to which specimens were retouched rather than differences in design (e.g., Hiscock and Veth 1991; Hiscock 1994a, 2006; Hiscock and Allen 2000; Clarkson 2002a,b, 2004, 2005, 2006; Hiscock and Attenbrow 2002, 2003, 2005a). The notion that each type was functionally distinct has also been questioned, the alternative being that tools were often flexible and multifunctional (Hiscock 2006), and it has been pointed out that if a single specimen was morphologically transformed this would have functional implications (Hiscock and Attenbrow 2005b). In combination these propositions have facilitated studies of the relationships between economic/environmental contexts and the technological responses of ancient foragers, helping to re-express assemblage differences in terms of variation in the "intensity of reduction" and to thereby identify connections between procurement economics, mobility, and technology (e.g., McNiven 1994, 2000; Hiscock 1996, 2006; Clarkson 2002a, 2006; MacKay 2005). This perspective has proved to be a powerful way of understanding the dynamics of lithic variation, and its value is revealed by reinterpretations of typological variation in terms of intensity of reduction and recycling.

POINT REDUCTION AND RECYCLING TO EXTEND USE LIFE

One of the best examples of material conservation and recycling is the production and progressive modification of stone points. Specimens classified as points have converging, often straight, retouched lateral margins, and in Arnhem Land such points share many shape similarities, being elongate and symmetrical around their long axis, as well as similarities in production, being shaped by careful direct percussion retouch (Hiscock 2006: 76). However, points in this region are also extremely variable in the amount of retouch they have received. As noted above, some were retouched on only one face (unifacial points), while others have retouch on both faces (bifacial points). Furthermore, there is variation between points in the amount of their surface covered by retouch, the invasiveness of the scars, the proportion of the perimeter that was retouched, and their dimensions. Much of this variation is now understood to be related to differences in the intensity of retouching specimens have undergone and the extent to which knappers attempted to extend the use-life of points (Hiscock 1994a, 2006: 76–8). Differences in the treatment of points at each location in the landscape were responses to variation in the suitability of blanks and the cost of replacement material. This insight explains much of the typological variation between assemblages that puzzled Schrire and others, and it also provides a framework for exploring aspects of prehistoric settlement patterns in western Arnhem Land.

Paradoxically, prolonged reduction and recycling of Australian points has only recently been widely recognized. Many earlier researchers, such as Flood (1966; 1970), Schrire (1982), Flenniken and White (1985), and Allen and Barton (nd.) treated unifacial points, bifacial points, and other implement forms such as “bifacial ovals”, as the independent and mutually exclusive end-products of different manufacturing processes. That conclusion was based on observations that each implement category contained different raw material proportions and dimensions. However Hiscock (1994a) pointed out that these patterns failed to evaluate whether each implement form was a distinct end-product or whether the classes of implement represented specimens undergoing a single manufacturing process but receiving different levels of reduction. For example, raw material differences between types of points would be created if specimens made on

some kinds of rocks (e.g., quartzite) were frequently transformed from one type to another after extended retouching while specimens made on other rocks were rarely modified. Size differences between the types would be created if small specimens were discarded after only small amounts of retouching and without being transformed whereas larger specimens were more intensively retouched and more frequently altered to such an extent they were classified as a different type. Such unequal treatment of blanks with different sizes, shapes, and materials now appears to be the best explanation of point variation.

Archeological evidence supports an interpretation in which some unretouched flakes were manufactured into unifacial points and some of those were in turn converted into bifacial points. Hiscock (1994a, 2006) has argued that in Arnhem Land and other regions of northern Australia the point reduction process generally began by retouching flakes along one lateral margin on the dorsal surface of a flake. Subsequently the second lateral margin might have been flaked in a similar fashion, and eventually one or both of these margins might have been made bifacial by the removal of flakes from the ventral surface. This sequence represents a reduction continuum from unifacial to bifacial points, as the former was gradually transformed into the latter, as shown in Figure 6.3. This sequence was not inevitable and alternatives are known, but Hiscock's (1994a) study of scar superimpositions on quartzite points from Jimede II indicates that more than nine out of ten bifacial points followed this one sequence. Studies of points in adjacent regions have also yielded evidence that unifacial and bifacial forms often represent specimens manufactured in the same way but reduced to different extents (e.g., Roddam 1997; Clarkson 2006).

Progressive reworking of some specimens proceeded even further, reducing the dimensions and shape of points, and altering some to such an extent that they no longer looked like points. For example, points were sometimes retouched until they no longer retained the pointed end and were instead oval or rectangular in shape. Schrire's “bifacial oval” is an example of an implement class that contains many highly reduced points (see Figure 6.3). Such specimens demonstrate that this process of retouching points to prolong their use-life was not focused exclusively on maintaining pointed artifacts but involved a variety of practices by which the usefulness of pieces of stone could be extended. Some of the retouching procedures may have acted as recycling, altering the form of the point to

Figure 6.3 Morphological changes associated with increasing levels of retouching. All specimens oriented with their platform at the top. (Based on specimens depicted by Schrire 1982.)

an extent that it was employed for different functions. However the naivety of imagining that points, even when they were in their initial form, were only projectile heads has been discussed elsewhere (see Hiscock 2006). When points were used as tools they were not only small and transportable but were suited to multiple uses, providing stout, sharp margins as well as a pointed shape capable of penetration (Jeske 1989: 36). Use-wear evidence confirms that points from northern Australia were used on plant material, for wood-working, as well as projectile points. Furthermore, Australian unifacial and bifacial points are small and easily transported objects capable of producing large numbers of thin, sharp flakes. This means that points as well as cores could be carried around the landscape to supply the knapper with flakes as required. Hiscock (2006: 78) concluded that points could have been used in many ways, should not be considered to be simply “spearheads”, and represent tools that were often transported, reworked, and recycled through long use-lives. The multifunctionality and capacity for extended reduction of points were properties particularly valuable in circumstances where the specimen had been carried to a locality in which replacement raw material was rare or costly, or where the access to replacement raw material was unpredictable. Extended reduction of points, signaled by morphological transformations,

such as the transition from unifacial to bifacial, is one indication that knappers prolonged their functionality in response to such contexts. The characteristics of point assemblages can therefore be used to explore geographical differences in forager economies. However there are other, even more extreme, processes for reducing artifacts in contexts of high material cost.

BIPOLAR REDUCTION TO GENERATE FLAKES

An entirely different mechanism that also extended the use life of stone artifacts was the conversion of specimens into bipolar cores. Bipolar knapping consists of placing a rock on an anvil and striking into it at 90°, in line with the point at which it is in contact with the anvil (Hiscock 1982). Because the specimen is immobilized by being held against the anvil, a heavy hammer can be used to apply large amounts of force and develop large compressive stresses (Cotterell and Kamminga 1987: 688–9; Andrefsky 1998: 26–8). Because bipolar techniques are uniquely suited to situations in which the worked piece has little weight, when low inertia presents a problem for continued reduction, they are often used towards the end of a reduction sequence. For this reason, in Arnhem Land,

signs of bipolar working are found only on small artifacts, and bipolar working was a technique applied to artifacts, including points, which were already highly reduced. In this sense bipolar knapping represents a later stage of reduction than that discussed above for point retouching and recycling.

The role of bipolar strategies in extending the life of already highly reduced artifacts can be illustrated by a description of bipolar reduction observed at sites

along the South Alligator River. Here a series of research projects examined scatters of artifacts at the edge of the riverine flood plain and in the woodland-covered laterite slopes that border the flood plain (e.g., Meehan *et al.* 1985; Brockwell 1989, 1996; Hiscock 1996; Hiscock *et al.* 1992). A well studied example is Kun-kundurnku 1, where several thousand artifacts eroded from a low levee bank to form a large artifact scatter (Figure 6.4). The assemblage is diverse,

Figure 6.4 Photographs of the surface artifacts visible at Kun-kundurnku 1 during the 1991–93 field seasons. (Photograph by the author.)

containing manuports, axes, anvils, grindstones, hammers, and ground haematite in addition to flaked stone artifacts. Most of the artifacts are manufactured on the locally available quartz (71%), although tuff transported from the south and high quality quartzite transported from the east are also found. Many of the flaked artifacts made from good quality materials are extensively reduced. The high level of reduction is visible in a number of ways, including the high frequency of retouch on flakes made on imported rocks, the low weight (<10g) of many of the cores and retouched flakes discarded at the site, and the abundance of cores (12% of all artifacts). Together these characteristics indicate that, as the central knapping strategy employed at Kun-kundurnku 1, bipolar knapping extended the usability of material brought to the site by employing techniques that enabled tools to be created from very small pieces of rock. In this site bipolar techniques were employed to reduce not only cores that had become too small to work with direct percussion, but also other tools which were converted into bipolar cores. An explication of this process is enlightening.

Hand-held cores, struck using direct percussion, were discarded when they were 20 to 50 g ($\bar{x} = 36.6$). Below 19 g problems of immobilizing the core made direct percussion untenable, and at about that weight knappers began to use bipolar techniques (Figure 6.5a).

All bipolar cores were lighter than 24g, with the average ($\bar{x} = 5.4$) being much less than the smallest hand-held core. This demonstrates that there was a technical threshold in the process of core reduction; substantially above 20–25 g knappers could successfully remove flakes from cores simply by striking them with a hammer, but at or below that weight knappers often switched to bipolar knapping to enable them to continue reducing the cores. Since bipolar cores were more abundant than hand-held cores it is possible that many cores brought onto the site were extensively reduced to an extent that bipolar techniques were required.

Pressure to extend the usability of lithic material at the site meant that artifacts of all kinds were intensively reduced at Kun-kundurnku 1. Consequently hand-held cores were not the only kinds of stone artifacts subjected to bipolar knapping and transformed into bipolar cores. This is known because a number of specimens were discarded immediately after knappers began to reduce them with a bipolar technique; only a portion of their surface was covered with scars deriving from the bipolar platforms, leaving relic earlier surfaces intact. For such specimens, between 22 g and 10 g, it is often possible to determine what the artifact looked like before bipolar knapping began. While some of the specimens had been hand-held cores many of them had previously been retouched or unretouched

Figure 6.5 Patterns of bipolar working in sites on the edge of the South Alligator River flood plain. (a) Comparison of weights for bipolar and non-bipolar specimens at Kun-Kundurnku 1. (b) Relationship of bipolar abundance and raw material proximity near the South Alligator River.

flakes. At Kun-kundurnku 1 it was possible to identify the previous state of some specimens, and only 20% had originally been hand-held cores. Other specimens had been non-artifactual manuports, unretouched flakes, flakes with gloss, retouched flakes that would be classified as scrapers, and bifacial points (or "bifacial ovals"). One smaller bipolar piece without preserved relic features was made on dolerite and may originally have been an axe fragment. These data indicate that most of the classes of artifact brought into the site were extensively reduced, with many becoming recycled as bipolar cores.

Extensive reduction at sites on the South Alligator River flood plain, such as Kun-kundurnku 1, has multiple causes. While the low abundance, small size, and high reduction of artifacts such as points and scrapers, typically made on good quality, non-local quartzite, chert and tuff, can be partly attributed to the distance from those stone sources it is clear that distance to replacement stone is only one factor affecting the composition of assemblages. Hiscock (1996: 153–4) observed that sites positioned on the edge of the plains had high levels of quartz core reduction, shown by high ratios of bipolar: non-bipolar cores (Figure 6.5b), whereas artifact scatters in the woodlands 5–6 km away had much lower levels of quartz core reduction. These differences are not well correlated with distance to sources of quartz alone; some flood plain edge sites had intensive core reduction even though there were nearby rock outcrops. Hiscock argued that while the cost of stone procurement was a significant factor its affect was articulated with the pattern of forager settlement, and residential mobility was the key to these assemblage differences. At some sites on the flood-plains' margins, especially those adjacent to lagoons, foragers lived for extended periods and provisioning of those sites with adequate amounts of suitable stone was potentially costly. Practices such as scavenging previously discarded artifacts and extending the life span of imported rock (even from local sources) were advantageous because they reduced the rate at which lithic material had to be carried to each site (Hiscock 1996: 152). In contrast, foragers exploiting the woodlands were more mobile; they encountered sources of stone frequently and transported it to any particular locality only at low rates, and consequently their need to conserve stone through intensive reduction was lower. This explanation of artifacts found near the South Alligator River assists in understanding the patterns of assemblage variation across the broader

region: assemblage variation was a consequence of the interaction between raw material costs, residential mobility, and forager risks.

RAW MATERIAL AVAILABILITY, FORAGER LAND-USE, AND ASSEMBLAGE REDUCTION

This conclusion indicates that a new regional synthesis of assemblage variation is possible. No doubt chronology and site use are implicated in the creation of differences in assemblage composition, but these factors fail to explain the enduring lithic variation in a context of regular environmental change. Persistence of a geographical pattern to assemblage composition can be understood as a reflection of the geological structure and history of the region. While traditional models depicted spatial differences between sites in terms of distinctions in biotic resources or topography, these did not provide a direct connection to broad-scale lithic patterns across the region. By instead thinking of this landscape in terms of the distribution of sources of rock from which people made their artifacts, it becomes possible to link environmental structure and assemblage variation.

A division of western Arnhem Land into three zones roughly describes raw material availability (Figure 6.1). The "uplands" zone contains the escarpment and nearby outliers less than 15 km from the scarp, and potential outcrops of good quality quartzite are close to sites in this area. The adjacent "outlier" zone contains small sandstone plateaus and boulders, and is 20–30 km from outcrops of quartzite in the escarpment country. "Riverine plains" are even further from quartzite outcrops found in the escarpment, but in the south the zone contains locations with outcrops of quartz and tuff. These zones are heuristic devices that simplify the geological patterns of the region, but they still offer potent descriptions of the environment. Even the low resolution description of raw material distances provided by this threefold division of the region reveals the connection of assemblage content with procurement costs.

These connections are apparent in the interrelationship of landscape position, raw material costs, and the extent of reduction that artifacts have undergone. Archeological indicators of these factors are presented in Figure 6.6, which plots information for published assemblages of adequate size (Ngarradj levels I–III,

Figure 6.6 Illustrations of the assemblage differences between environmental "zones" in western Arnhem Land. (a) Univariate distributions of assemblage characteristics for each of the three zones: raw material composition (% quartzite) and relative point abundance (points as % of implements) in linear scales, and relative abundance of bifacial points (ratio of bifacial : unifacial points) for assemblages with more than 20 specimens) and bipolar cores (number of "fabricators": number of points - exponential scale) in an exponential scale. (b) Scattergram showing the relationship of raw material composition (% quartzite) and relative point abundance (points as % of implements). (c) Scattergram showing the relationship of point bifacialness (ratio of bifacial : unifacial points) and relative abundance of bipolar cores (number of "fabricators": number of points - exponential scale). Data obtained from Allen and Barton (nd.), Jones and Johnson (1985), Schrire (1982), Meehan *et al.* (1985), and Brockwell (1996: 98) as well as personal observations.

Nauwalabila spits 2–15, Jime II level I, Malangerr level I, Anbangbang I, Nawamoy level Ia, Badi Badi all levels, Kihna, Kumunkuwi, Kun-Kundurnku). These samples date to the same 3000-year period and can be interpreted as reflecting variation with contemporary

assemblages. Aspects of the patterning are summarized as follows (see Figure 6.6a):

- Quartzite is abundant in sites near the uplands where sources are found (55–85%), is much less abundant in the outlier zone (20–45%) and rare in assemblages on

flakes. At Kun-kundurnku 1 it was possible to identify the previous state of some specimens, and only 20% had originally been hand-held cores. Other specimens had been non-artifactual manuports, unretouched flakes, flakes with gloss, retouched flakes that would be classified as scrapers, and bifacial points (or "bifacial ovals"). One smaller bipolar piece without preserved relic features was made on dolerite and may originally have been an axe fragment. These data indicate that most of the classes of artifact brought into the site were extensively reduced, with many becoming recycled as bipolar cores.

Extensive reduction at sites on the South Alligator River flood plain, such as Kun-kundurnku 1, has multiple causes. While the low abundance, small size, and high reduction of artifacts such as points and scrapers, typically made on good quality, non-local quartzite, chert and tuff, can be partly attributed to the distance from those stone sources it is clear that distance to replacement stone is only one factor affecting the composition of assemblages. Hiscock (1996: 153–4) observed that sites positioned on the edge of the plains had high levels of quartz core reduction, shown by high ratios of bipolar: non-bipolar cores (Figure 6.5b), whereas artifact scatters in the woodlands 5–6 km away had much lower levels of quartz core reduction. These differences are not well correlated with distance to sources of quartz alone; some flood plain edge sites had intensive core reduction even though there were nearby rock outcrops. Hiscock argued that while the cost of stone procurement was a significant factor its affect was articulated with the pattern of forager settlement, and residential mobility was the key to these assemblage differences. At some sites on the flood-plains' margins, especially those adjacent to lagoons, foragers lived for extended periods and provisioning of those sites with adequate amounts of suitable stone was potentially costly. Practices such as scavenging previously discarded artifacts and extending the life span of imported rock (even from local sources) were advantageous because they reduced the rate at which lithic material had to be carried to each site (Hiscock 1996: 152). In contrast, foragers exploiting the woodlands were more mobile; they encountered sources of stone frequently and transported it to any particular locality only at low rates, and consequently their need to conserve stone through intensive reduction was lower. This explanation of artifacts found near the South Alligator River assists in understanding the patterns of assemblage variation across the broader

region: assemblage variation was a consequence of the interaction between raw material costs, residential mobility, and forager risks.

RAW MATERIAL AVAILABILITY, FORAGER LAND-USE, AND ASSEMBLAGE REDUCTION

This conclusion indicates that a new regional synthesis of assemblage variation is possible. No doubt chronology and site use are implicated in the creation of differences in assemblage composition, but these factors fail to explain the enduring lithic variation in a context of regular environmental change. Persistence of a geographical pattern to assemblage composition can be understood as a reflection of the geological structure and history of the region. While traditional models depicted spatial differences between sites in terms of distinctions in biotic resources or topography, these did not provide a direct connection to broad-scale lithic patterns across the region. By instead thinking of this landscape in terms of the distribution of sources of rock from which people made their artifacts, it becomes possible to link environmental structure and assemblage variation.

A division of western Arnhem Land into three zones roughly describes raw material availability (Figure 6.1). The "uplands" zone contains the escarpment and nearby outliers less than 15 km from the scarp, and potential outcrops of good quality quartzite are close to sites in this area. The adjacent "outlier" zone contains small sandstone plateaus and boulders, and is 20–30 km from outcrops of quartzite in the escarpment country. "Riverine plains" are even further from quartzite outcrops found in the escarpment, but in the south the zone contains locations with outcrops of quartz and tuff. These zones are heuristic devices that simplify the geological patterns of the region, but they still offer potent descriptions of the environment. Even the low resolution description of raw material distances provided by this threefold division of the region reveals the connection of assemblage content with procurement costs.

These connections are apparent in the interrelationship of landscape position, raw material costs, and the extent of reduction that artifacts have undergone. Archeological indicators of these factors are presented in Figure 6.6, which plots information for published assemblages of adequate size (Ngarradj levels I–III,

Figure 6.6 Illustrations of the assemblage differences between environmental "zones" in western Arnhem Land. (a) Univariate distributions of assemblage characteristics for each of the three zones: raw material composition (% quartzite) and relative point abundance (points as % of implements) in linear scales, and relative abundance of bifacial points (ratio of bifacial : unifacial points for assemblages with more than 20 specimens) and bipolar cores (number of "fabricators": number of points - exponential scale) in an exponential scale. (b) Scattergram showing the relationship of raw material composition (% quartzite) and relative point abundance (points as % of implements). (c) Scattergram showing the relationship of point bifacialness (ratio of bifacial : unifacial points) and relative abundance of bipolar cores (number of "fabricators": number of points - exponential scale). Data obtained from Allen and Barton (nd.), Jones and Johnson (1985), Schrire (1982), Meehan *et al.* (1985), and Brockwell (1996: 98) as well as personal observations.

Nauwalabila spits 2–15, Jime II level I, Malangangerr level I, Anbangbang I, Nawamoy level Ia, Badi Badi all levels, Kihna, Kumunku, Kun-Kundurnku). These samples date to the same 3000-year period and can be interpreted as reflecting variation with contemporary

assemblages. Aspects of the patterning are summarized as follows (see Figure 6.6a):

- Quartzite is abundant in sites near the uplands where sources are found (55–85%), is much less abundant in the outlier zone (20–45%) and rare in assemblages on

the riverine plains (10–30%). This reflects both the decreased number of quartzite artifacts transported further than 30–40 km from the escarpment as well as the greater number of alternative material sources supplying stone to sites on the riverine plains.

- Points decline in absolute and relative abundance (as a proportion of the assemblage) from uplands to plains. In the uplands they are often the most common implement type, whereas at sites on the riverine plains less than a tenth of the implements were classified as points. There is a significant correlation between the abundance of quartzite and points in each assemblage (Figure 6.6b), a pattern that partly reflects the production of many points on quartzite but also reflects the altered levels of reduction that occurred with increased distance from the escarpment.

- One measure of reduction intensity presented in Figure 6.6 is the amount of retouching on points. Using the ratio of bifacial : unifacial points as an indication of the frequency of more reduced (bifacial) specimens it is clear that the points in the outlier zone tend to be more intensively retouched than in the uplands, and those found on plains sites are very intensively reduced. Heavy retouching in the outlier and riverine plains zones would have reduced many specimens to states in which they were no longer classified as points, contributing to low point abundance away from the uplands.

- Another measure of reduction intensity is provided by the frequency of bipolar cores, or “fabricators,” an extremely reduced form. The ratio of “fabricators” : points in Figure 6.6 is an expression of bipolar abundance. High frequencies of bipolar cores were found on the riverine plains, not only because points were rare but also because many implements including points had been converted into bipolar cores. Both the bifacialness of points and the frequency of bipolar cores show the same pattern of stone reduction: outlier and riverine plains sites have more intensively reduced artifacts than sites in the uplands (Figure 6.6c).

These differences in assemblage composition across the landscape are explicable in terms of procurement economics: they emerged as knappers rationed, recycled, and substituted artifacts in response to the varying cost of obtaining replacement stone in each location. The processes involved may have been very simple. For instance, when knappers were far from replacement stone they changed their methods of manufacture and use to increase the return they obtained from material they already possessed, thereby reducing the cost and inconvenience of obtaining replacements. In western

Arnhem Land changed practices in response to material cost often took the form of extending the use-life of tools made on flakes by maintaining their edges through additional retouching. An example of this process is the re-working of points. Another strategy by which use-life was extended was to recycle objects, converting them from one usable form into another. An example of recycling was the reduction of exhausted stone tools as cores, to produce small flakes with usable edges, thereby transforming retouched flakes and other objects into bipolar cores. These two mechanisms, point retouching and bipolar recycling, are provided as illustrations of the kinds of changes to tool making and maintaining behaviors that are observable across Arnhem Land, but other ways of responding to high costs of replacement lithic material, such as employing locally available organic tools rather than costly, non-local stone ones, are also likely.

Technological behaviors sensitive to the economic contexts of artifact manufacture probably explain much of the geographical variation in assemblages, and their persistence over time. However, lithic variation in the region was not fixed; there were temporal changes in the extent of implement reduction. This is expected because the costs of material replacement are not merely a product of distance to stone sources; they are additionally a consequence of the settlement systems that were employed by ancient foragers. Two aspects of settlement have been widely discussed in the Australian context. The first is the level of sedentism of foragers, which has implications for the rates at which particular sites must be supplied with replacement stone. Mobile foragers employing a “provisioning of individuals” strategy (Kuhn 1995) would be advantaged by a portable toolkit that could be used for an extended period, thereby reducing rescheduling costs of frequent tool replacements (Hiscock 2006). The long-lived point reduction sequence employed in Arnhem Land is typical of extendable tools suited to those situations. Relatively sedentary foragers, such as the Late Holocene dwellers on the South Alligator River wetlands, may also have been under stress to extend tool usefulness as a cost reduction measure. A second feature of settlement affecting the extent of tool reduction was the level of foraging risk: the probability and cost of a failure to procure resources in a timely and cost-efficient manner (Bamforth and Bleed 1997). Maintaining a continuously functioning toolkit, including extending the use-life of tools, is a technological strategy that can provide benefits in situations

with heightened risks (Hiscock 2006). In combination changes in mobility and foraging risk might be reflected in toolkit composition and extent of reduction.

These considerations provide an explanation for the chronological changes apparent in Arnhem Land assemblages. The onset of stronger El Niño conditions 3000–4000 years ago, created drier and more variable conditions that increased foraging risk and was probably associated with high levels of mobility. In response to these conditions there was intensive point production and intensive tool reduction creating bifacial forms which were more common in that period (Hiscock 2002, 2006). Point abundance and bifacialness declined during the Late Holocene, as levels of tool reduction diminished in line with lessened levels of mobility and risk. This parallels trends observed by Clarkson (2006: 104) in the region to the south, and he also concluded that the period of intensive implement reduction was a technological response in which foragers dealt with conditions of higher risk through extending the use-life of their tools. During the same period there were also alterations in forager mobility. In the Late Holocene riverine plains underwent a number of environmental transformations, culminating in the development of scattered wetlands and lagoons which provided reliable and abundant resources, and altered the economic context from one driven by foraging risk to one dominated by concerns for provisioning costs. The consequence was a shift from highly residually mobile foraging strategies emphasizing point reduction as a solution to material costs, to relatively sedentary strategies emphasizing extended bipolar reduction of stone as a cost reduction measure. In a landscape where foragers constantly employed greater or lesser levels of reduction to balance tool using needs with provisioning costs, the temporal changes between mobile and more sedentary settlement patterns, and heightened and reduced foraging risk, was significant in creating chronological variations in persistent geographical patterns of lithic variation.

This model of lithic variability, focusing on the economics of raw material use and its articulation with technological strategies suited to different contexts of mobility and risk, provides mechanisms that can explain the persistence of geographical differences in artifact assemblages but which can also make sense of temporal subtle changes in technological activities. The complex lithic variation visible in Arnhem Land arose from the operation of multiple factors. However, unlike earlier archeological theories, we can now conclude

that site function and identity of the local residence groups were factors of little significance in the production of assemblage differences. Instead, assemblage variation is largely a consequence of the interaction between raw material costs, residential mobility, and forager risks. That conclusion provides a basis with which to examine the changing adaptive strategies employed by prehistoric foragers living in northern Australia.

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