Quantitative exploration of size variation and the extent of reduction in Sydney Basin assemblages: A tale from the Henry Lawson Drive rockshelter

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Abstract

A study of the artefact assemblage from the Henry Lawson Drive Rockshelter, a stratified midden deposit near Sydney excavated by Peter White in 1971, reveals new information about the temporal and morphological complexities of stone working technology in eastern Australia. Not only does this site provide further evidence of the presence of backed artefacts in this region more than 5000 years ago, it also reveals abundant production of backed artefacts during the last millennium. The site contains small implements and cores that can be interpreted as being more extensively reduced than assemblages reported from other sites in the region. Quantitative examinations of size and extent of reduction reveal that artefact assemblages in eastern New South Wales display variation which has yet to be characterised or explained.

Introduction

For a brief but exciting period in Australian archaeology, artefact analysts were engaged in debates about the variability within and between implement classes using statistical investigation of quantitative data describing artefact size and shape. These debates explored fundamental issues of the discreteness of classes, the effectiveness of definitional criteria, and the causes of variation between specimens. Beginning in the later years of the 1960s, a series of papers examined morphological variation and its typological consequences (e.g. Flood 1966, 1970; Glover, I.C. 1967, 1969; White 1968, 1972; Pearce 1973, 1977; Wieneke and White 1973; Glover, E. 1974). These papers commonly followed the pioneering lead of Spaulding (1953) in employing chi-square tests, supplemented by early applications of factor analysis, to evaluate the distinctiveness of groups that had been recognised by earlier archaeologists. While these studies dealt with a range of conventionally recognised Australian implement types, including points and scrapers, the focus of quantitative analysis was firmly on two categories: backed items and what at the time were often called fabricators. Metrical examinations of both classes shared a primary concern for questions of typological uniformity or differentiation, and the implications of that variation for class function. This use of quantitative measures of artefact variation to address normative questions about implement classes reflected the theoretical imperatives of the day and is exemplified by the debates about variation in backed artefacts and bipolar cores.

Prior to the late 1960s, 'fabricators' (specimens with opposing 'battered edges') were generally thought of as punches used to produce bone or stone artefacts. The decisive paper changing this interpretation was published by Peter White (1968), who argued that most of these objects were more likely to be cores. White's argument focussed on a statistical comparison of bipolar cores he observed being reduced but not used in New Guinea with similar specimens in Australia that were classified as fabricators and interpreted as tools. Although he noted that the sizes of these bipolar objects differed between assemblages, White (1968:662) concluded that the Australian and New Guinean specimens were probably the end-result of similar processes. This conclusion has been widely accepted by archaeologists in Australia, although White's (1968:664) recognition that such an inference did not preclude individual cores also being used as tools, and that use-wear studies would be needed on each specimen to evaluate their use or non-use, has not generally been incorporated in theoretical approaches (cf. Hiscock in press a).

In the same period, studies of variation in the class of specimens we now call 'backed' artefacts also focussed on the question of pan-continental uniformity as measured by the level of similarity between assemblages in distant sites. Expressions of dimensions, and particularly length:width ratios, were employed to illustrate the strong similarities between assemblages on opposing continental margins (e.g. Glover 1967), and the capacity of quantitative methods to discriminate traditional geometric and non-geometric typological categories (Glover 1969; Pearce 1973, 1977). These analyses also revealed relationships between a number of the measured attributes, suggesting that a dedicated quantitative analysis might document substantial co-variation between features of backed artefacts. So it was that thirty years ago Wieneke and White (1973) published a small but important paper discussing backed artefact variation at a small rockshelter site in Sydney. Their study demonstrated interdependence of size and shape characteristics, suggested continuities in these characteristics across arbitrary typological sub-class boundaries, and provided an empirical platform to argue that morphological variation in backed artefacts sprang from engineering constraints rather than implying 'deliberate intention on the part of the manufacturer' (Wieneke and White 1973:37).

While these nascent metrical investigations of Australian implements acknowledged morphological variation within categories and between regions, the magnitude of intra-site morphological variation and possible explanations of that variation was little pursued at the time. Glover (1967:424) claimed that in Australia '…we have evidence that there was a degree of cultural homogeneity greater perhaps than in any other equivalent area…', and invoked common cultural tradition as the cause for minimal morphological variation in backed implements. By contrast, Wieneke and White (1973) emphasised the mechanical properties of backed specimens as an explanation for many of the similarities observable between specimens, and concluded that size and shape was probably independent of function or manufacturing technique. White (1968:662) had used the same notion in discussing metrical variation in bipolar cores between

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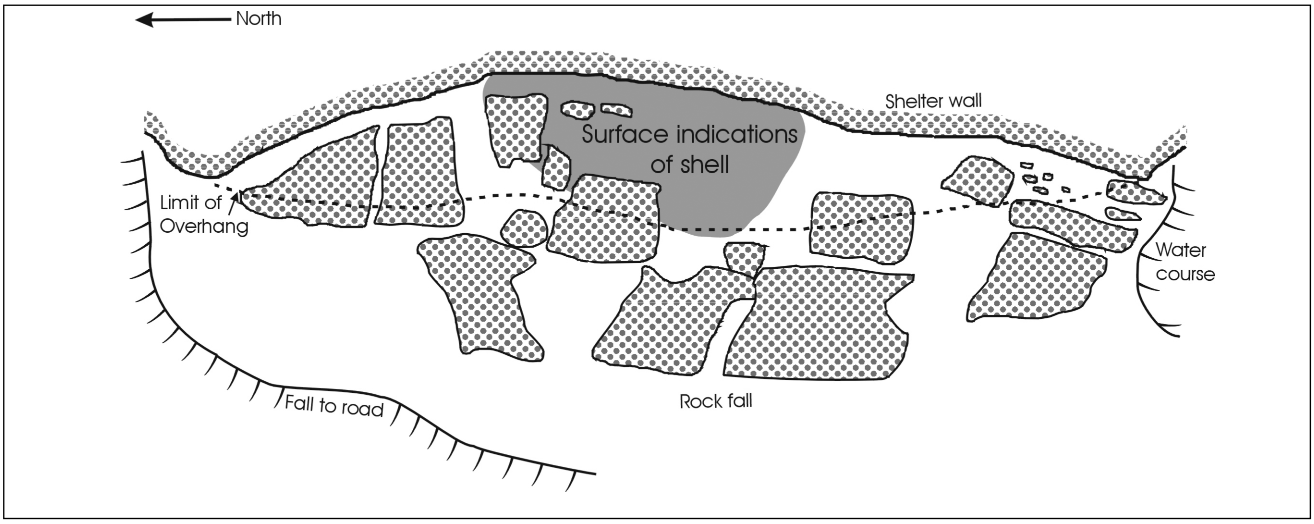

Figure 1 Plan of Henry Lawson Drive rockshelter, NSW.

assemblages, and cited raw material differences and 'local technological tradition' as likely causal factors. Broader discussions of causal factors involved in the production of implement variation were published in the 1960s (e.g. White 1967), but these factors were not examined subsequently in quantitative studies of Australian implement sizes.

One characteristic shared by many of those quantitative artefact studies in the 1960s and 1970s was the continental scale of comparisons and interpretations. Although morphological variation was examined, the data were used to test type boundaries with a presumption that same patterns would be found widely, perhaps even throughout the continent. Emerging understandings about the nature of implement types were employed in developing interpretations of culture-historical changes, while variation between contemporary assemblages in a single region were treated either as unproblematic or of minimal importance. With the progressive abandonment of continental scale stadial depictions of technology in Australia, the focus of assemblage variation has recently shifted to a regional or smaller scale (e.g. Webb 1993; Hiscock 1994a, 2002; Hiscock and Attenbrow 1998, 2002, 2003; Holdaway et al. 1998; Hiscock and Allen 2000; Doelman et al. 2001). As a result, in recent years, the interest in type boundaries and normative characterisations has gradually been supplemented by explorations of the causes of small-scale inter-assemblage variation. While factors such as raw material properties and procurement costs continue to be important in discussions of assemblage differences within any region, these mechanisms are now accompanied by considerations of others, such as the size and morphological changes wrought by different levels of reduction. This paper augments those early quantitative studies of implement and core variability in Australian assemblages by examining assemblage variability in one small area, and by exploring the possibility that differing amounts of reduction is a factor creating size differences between assemblages. The same small rockshelter site in Sydney that provided Wieneke and White (1973) with their sample of backed artefacts forms the basis for this examination of artefact variation.

Henry Lawson Drive rockshelter

Henry Lawson Drive rockshelter (HLD) is located in suburban Padstow, a short distance to the west of Botany Bay in south Sydney. At that point Little Salt Pan Creek joins the Georges River, a few kilometres upstream from where the river flows into Botany Bay. Overlooking a small, mangrove-lined tributary of Little Salt Pan Creek is a sandstone rockshelter. Facing west the shelter mouth is 16 m wide, and the overhanging rock protects a floor roughly 2 m wide (Fig. 1). Substantial rockfall from the roof shields much of the shelter floor, but near the rear wall a relatively protected section of deposit was visible, revealing marine mollusc shell fragments typical of Aboriginal middens. It was at this spot that, in the early 1970s, Peter White excavated 4 m^2 of deposit, eventually reaching bedrock (White and Wieneke n.d.). Five stratigraphic levels were distinguished in the field (Table 1). A further 0.5 m^2 of deposit was excavated outside the shelter, yielding a different stratigraphic sequence without a midden layer.

Within the shelter the midden material is concentrated in the middle part of the stratigraphic sequence, a unit designated as Level III by White and Wieneke (n.d.). The midden shells are predominantly oyster (*Saccostrea*

Stratigraphic levels	Thickness (cm)	Sediments	Cultural material
I	15	Grey sandy sediment	Twentieth century objects of plastic, glass and paper
II	26	Sandy sediment becoming darker and more charcoal-rich with depth	Grades from relatively clean sand at the top to midden at the base of the level
III	24	Brown/black charcoal-rich sandy sediments	Consolidated shell midden
IV	20	Mottled sand	Small quantities of degraded shell
V	16	Clean sand	None

Table 1 Stratigraphic descriptions for Henry Lawson Drive rockshelter (drawn from White and Wieneke n.d.)

glomerata), with small numbers of shells from other molluscs such as hairy mussel (*Trichomya hirsuta*), and Hercules Club Whelk (*Pyrazus ebeninus*). Small quantities of bone from fish and terrestrial mammals were also recovered from this midden. A charcoal sample from the base of the midden, Level III, yielded a radiocarbon age estimate of 870 ± 95 years BP (SUA-59). For the purpose of exploring the HLD artefact assemblage, this age estimate will be assumed to be an accurate indication of the antiquity of archaeological materials in Levels I-III. Since more than 90% of artefacts and 96% of implements were recovered in or above Level III, this radiocarbon date is taken to indicate that the bulk of the artefact assemblage was manufactured in the last millennium. However, since many of these stone artefacts were recovered from Level I, which contained post-contact materials, it is possible that there are site formational processes operating at this site of which we have little understanding. Until re-excavation and re-dating can clarify the situation, this uncertainty about the site's depositional history must be incorporated in inferences developed about the assemblage.

The only other radiometric date obtained from the site came from the excavation outside and below the shelter. A charcoal sample from 55 cm depth gave an estimate of 5240 ± 100 years BP (SUA-60). Since an artefact was found at the same level as this charcoal sample, the excavation may record a faint signal of mid-Holocene human use of the shelter and its surrounds. Intriguingly, the specimen associated with this dated sample is a backed artefact. Although associations of artefacts and dated samples in sandy deposits such as this are always ambiguous, making chronological interpretations suspect, there are no artefacts in the 35 cm of sediment above this level. Since there is therefore no reservoir of artefacts above the dated sample, the probability of a single specimen moving downwards to become associated with this charcoal sample might be considered small. Although a mid-Holocene age for this backed artefact is a plausible interpretation, any sceptical researcher must acknowledge the possibility of other mechanisms creating this pattern. However, this site provides a hint that the early- to mid-Holocene small-scale production of backed artefacts, unambiguously demonstrated for the area of the Sydney Basin to the north (Hiscock and Attenbrow 1998), may also have taken place in the Botany Bay catchment. Fascinating though this conclusion might be, it is the late Holocene artefact assemblage from the excavation within the shelter that is the focus of this investigation.

Characterising the artefact assemblage

Although only a small area of deposit was excavated, the density of artefacts was sufficient to yield a substantial assemblage of flaked stone, including more than 2000 flakes and 150 cores and retouched flakes. The high density of flaked stone material is consistent with other coastal rock shelters in this region (e.g. Glover 1974; Megaw 1974). The following assemblage analysis is restricted to the retouched flakes and cores in order to measure the extent of reduction that has taken place. Specimens with use damage, such as two unretouched flakes with gloss on one edge, are present in the assemblage but have not been studied since the questions posed here focus on manufacture rather than use. Table 2 summarises the cores and retouched flakes identified in the collection and included in this study.

The retouched flakes at HLD can be described as belonging to three conventional implement categories. Two stout flakes have been retouched as burins, and a larger number of flakes have marginal retouch, commonly onto the dorsal face, in configurations that allow them to be classified as 'scrapers' in the traditional typology. The most distinctive assemblage characteristic of this site is the high density of backed artefacts recovered. The present analysis recognises 34 complete and 43 broken backed artefacts. This count is less than that provided by White (Wieneke and White 1973; White and Wieneke n.d.) because of the relatively strict criteria applied in this study. Some specimens which had been labelled as backed are here diagnosed as ridge-straightening flakes, heat-shattered flakes or scrapers rather than as backed artefacts; and many specimens that were previously counted as complete are recognised as broken, often with tips missing.

A total of 45 definite cores are recorded in this study. Nearly two thirds of these are recognised as bipolar cores, while 16 are hand-held, non-bipolar cores. These numbers are also less than those recorded for this assemblage by White and Wieneke (n.d.) because of changes in classificatory conventions during the last few decades. Two classificatory rules in particular are responsible for the numbers reported here. Firstly, the focus of this analysis is on the study of core reduction, and only specimens which are technologically cores (Hiscock in press a) are included as cores in Table 2. Consequently, specimens that are technically retouched or edge-damaged flakes, which might once have been classed as 'fabricators' or 'bipolar artefacts,' are here labelled as a class of retouched flakes rather than as cores. Secondly, heat shattered fragments with negative scars that cannot be unambiguously identified as cores, as opposed to retouched flakes, are excluded from the count in Table 2 and from the subsequent analysis.

The resulting classifications provide adequate samples for a technological investigation of three categories: cores, scraper-like retouched flakes, and backed artefacts. As documented in Table 3, the raw materials on which specimens were made are broadly similar for each of these

	Backed artefacts	Scrapers	Burins	Non-bipolar cores	Bipolar cores	Total
Complete	34	18	2	16	23	93
Broken	43	22	0	-- *	6	71
Total	77	40	2	16	29	164

Table 2 Abundance of each artefact category from Henry Lawson Drive discussed in this paper. * = because of the definitional ambiguity of broken cores, no count was made of this category.

	Backed artefacts	Scrapers	Burins	Non-bipolar cores	Bipolar cores	Total
Silcrete	57	21	1	12	14	105
Chert	13	11	0	3	6	33
Volcanic	7	0	0	1	1	9
Mudstone	0	7	1	0	0	8
Quartz	0	0	0	0	6	6
Quartzite	0	1	0	0	2	3
Total	77	40	2	16	29	164

Table 3 Relationship of raw material and artefact category in the assemblage from Henry Lawson Drive.

categories, with silcrete and chert being dominant materials. The following sections provide a study of manufacturing patterns for each of these categories.

Core reduction

It has long been recognised that one of the basic choices that knappers make in reducing cores is whether they will remove flakes by placing the core on an anvil and induce high compressive stresses by applying a hammer to the core in the direction of that anvil, a procedure called bipolar knapping, or will remove flakes without this arrangement of core and anvil, a choice described as non-bipolar reduction. The uniformity in the nature of bipolar flaking in Australia and New Guinea was recognised by White (1968:662). Noting that differences in the size of discarded bipolar cores between sites required explanation, he invoked raw material and 'local technological tradition.' Elsewhere I have suggested that the key to these size variations is the extent of core reduction and the technical consequences that entail for knapping strategies (Hiscock 1982, 1996a). In particular, I have hypothesised that since stone-working can be considered as a problem of core immobilisation, the extension of reduction when cores are so small that their low inertia constitutes a mechanical problem is facilitated by switching to a bipolar procedure (Hiscock 1996a:152). This proposition is based on the recognition of bipolar techniques as uniquely suited to situations in which low inertia poses a problem for continued reduction. Consequently, bipolar knapping often appears towards the end of a reduction sequence and serves to prolong reduction, thereby extending the exploitation of cores.

This model makes sense of core dimensions at HLD. Non-bipolar cores are slightly longer and substantially wider and thicker than bipolar cores (Tables 4 and 5). Although the range of dimensions overlap between the two categories, t-tests presented in Table 6 demonstrate that the kinds of cores are statistically different in all dimensions. Non-bipolar cores at this site are typically small, but bipolar cores are smaller still. The pattern is consistent with core reduction being extended to the point where many non-bipolar cores were either converted into bipolar cores or were discarded because they could not be profitably flaked further without being converted. Moreover, bipolar cores outnumber non-bipolar ones, by a ratio of 1.4:1, suggesting that a large proportion of cores had undergone the transition to bipolar working.

The transition from non-bipolar to bipolar cores can be understood further by reference to Figure 2, a bivariate plot of length and cross-sectional area (width x thickness) for all complete cores from HLD. This diagram shows many features of a core reduction model (Hiscock 1982, 1996a). The array of data points shows bipolar cores are the smaller specimens in a continuum of core sizes, and reveals that if non-bipolar cores are not converted to bipolar ones, they are discarded before they reach threshold conditions that can be identified as a length of 16-20 mm and cross-sectional area of 150-200 mm^2. By adopting a bipolar technique, knappers were able to continue reducing some cores a considerable amount in relative terms: the smallest bipolar cores are only 10% of the cross-sectional area and 64% of the length of the smallest non-bipolar cores. In conjunction with the dispersion of data points in Figure 2, these values indicate that the main benefit gained in adopting a bipolar technique was the ability to reduce core thickness and width on low weight cores, presumably because the complications of platform angles and step terminations that impose limits on the reduction of low weight non-bipolar cores are minimal considerations when bipolar techniques are employed.

The cessation of bipolar core reduction at HLD was conditioned by a number of factors. Bipolar cores were discarded if they broke transversely; approximately 21% of

	N	Mean ± std.dev.	Minimum	Maximum
Length	16	21.9 ± 5.7	15.6	38.2
Mid-point width	16	18.7 ± 6.2	8.1	32.3
Mid-point thickness	16	14.7 ± 8.2	7.6	42.3

Table 4 Descriptive statistics (dimensions in mm) for complete non-bipolar cores from Henry Lawson Drive.

	N	Mean ± std.dev.	Minimum	Maximum
Length	23	17.5 ± 3.8	10.5	25.9
Mid-point width	23	11.3 ± 4.0	6.5	20.5
Mid-point thickness	23	4.9 ± 1.8	2.1	9.8

Table 5 Descriptive statistics (dimensions in mm) for complete bipolar cores from Henry Lawson Drive.

	Sample	Mean ± std.dev.	t	d.f.	p
Length	Non-bipolar (N=16) Bipolar (N= 23)	21.9 ± 5.7 17.5 ± 3.8	2.86	37	0.007
Mid-point width	Non-bipolar (N=16) Bipolar (N= 23)	18.7 ± 6.2 11.3 ± 4.0	4.53	37	<0.001
Mid-point thickness	Non-bipolar (N=16) Bipolar (N= 23)	14.7 ± 8.2 4.9 ± 1.8	5.58	37	<0.001
Mid-point cross-sectional area	Non-bipolar (N=16) Bipolar (N= 23)	297.1 ± 300.33 53.0 ± 21.9	3.91	37	<0.001

Table 6 Comparison of dimensions (mm; area = mm^2) for complete bipolar and non-bipolar cores from Henry Lawson Drive.

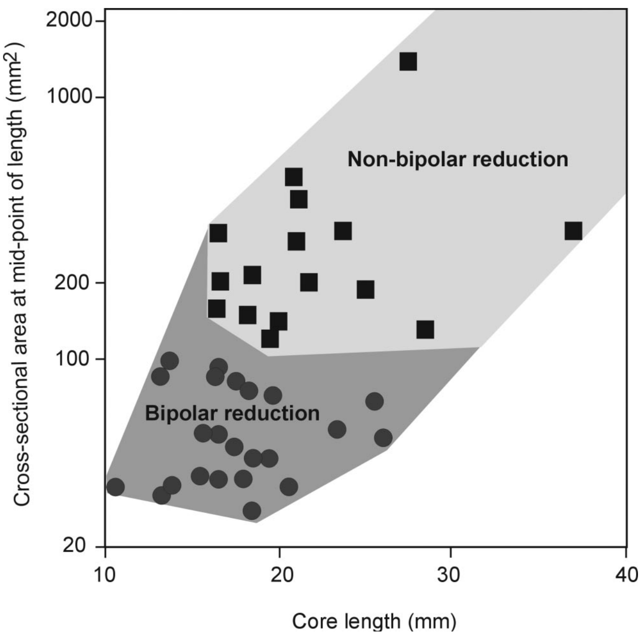

Figure 2 Bivariate plot of length and cross-sectional area (width x thickness at mid-point of length) for all complete cores from Henry Lawson Drive. Square data points represent non-bipolar cores; circular data points represent bipolar cores.

cores snapped at the mid-point of length. Cores were also discarded if they were reduced to what is likely to have been technological or mechanical limitations, in this case when length was less than 15mm and/or cross-sectional area was less than 35-40 mm^2. One explanation for this minimum length is that it represents the smallest size of a core that could be struck on an anvil while being held between thumb and finger without hurting the knapper (Dickson 1977). This hypothesis has intuitive appeal for any replicator, but does not account for either the existence of different procedures known to be used in holding bipolar cores on the anvil (White 1968; Flenniken and White 1985) or the differences in bipolar core length between assemblages.

Some bipolar cores with unsuitable shapes were abandoned before they broke or reached minimum possible sizes. This can be demonstrated by adopting the classification of bipolar core shapes advocated by Binford and Quimby (1963), which describes the platform states: point, ridge and area. No area platforms were found on the bipolar cores in HLD, but the specimens can be classified into three classes, each with a distinctive combination of the two platform states present: ridge-ridge (N=15), ridge-point (N=5), and point-point (N=3). Figure 3 plots the length against thickness of the HLD bipolar cores, and shows the range of values for each class of platform configuration. Note that specimens with a ridge-ridge configuration are frequently smaller than ones with a ridge-point configuration, and that point-point patterns are relatively large in thickness and/or length. One interpretation of these observations is that a point platform inhibited further reduction, and that bipolar cores with those platforms were more likely to be discarded at larger sizes. Consequently, bipolar cores with platforms reduced to one or more points were discarded even when they retained relatively large amounts of mass, and knappers selected specimens with ridge platforms for continued reduction. This mechanism might help to explain variations in dimensions of discarded bipolar cores, both within and between assemblages. The extent to which bipolar cores are reduced, and hence their size when discarded, may be partly conditioned by their shape and the capacity of the knapper to maintain platform and core characteristics. Hence the extent of bipolar core reduction is a reflection of a complex interaction of the techniques of reduction, the raw material properties and costs, and the knappers' maintenance of core shapes, as well as the nature of residential mobility of the groups creating assemblages (Hiscock 1996a).

Inter-assemblage variation in bipolar reduction may signal, therefore, the composite effect of a number of technological and economic properties of a stone artefact-using group. While the literature of the 1960s and 1970s observed differences between assemblages in the mean size of bipolar cores, little consideration has been given in recent decades to the causes for those differences or their space/time patterning. The HLD excavation provides an opportunity to reinitiate exploration of these issues, partly because the assemblage appears to be more extensively reduced than others reported in the region. Following from the discussion earlier in this paper there are several ways to measure the extent of bipolar reduction including the number of cores that were converted from non-bipolar to bipolar knapping, the extent of mass removed using bipolar techniques, the discard threshold for abandoning bipolar cores and the average dimensions of bipolar cores when discarded. Since most of these measures are not currently available for sites in the Sydney Basin the depiction of differential reduction will rest for the moment on average dimensions of discarded bipolar cores, a measurement which has long been presented in publications.

A comparative analysis was developed by drawing data on the mean lengths and widths for samples from a number of widely dispersed sites in eastern New South Wales: Bobadeen, Bendemeer, Currarong, Capertee 3, Chambigne, Curracurrang 1 and 2, Gymea Bay, Seelands, Sassafras, Tidbinbilla, and Wombah, as well as HLD (Glover 1974; Vanderwal 1977; McBryde 1982; supplemented by my own measurements). These data show a distinct positive

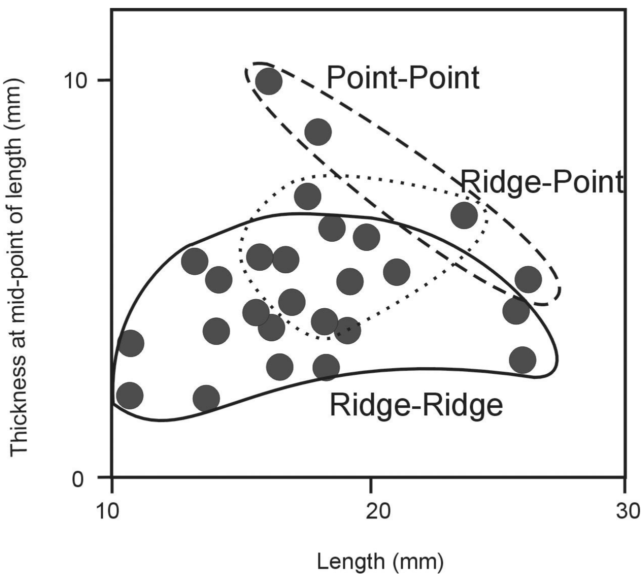

Figure 3 Bivariate plot of length and thickness of bipolar cores from Henry Lawson Drive, with ranges of platform configurations.

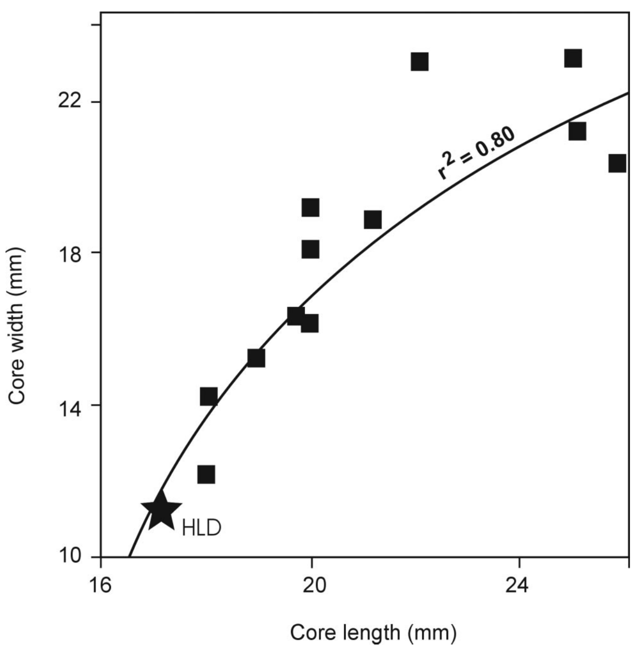

Figure 4 Bivariate plot of mean length and width dimensions of bipolar cores in eastern NSW (data from McBryde 1982; Vanderwal 1977; Glover 1974; and data presented here). Solid line is the best non-linear regression for these data.

relationship (Fig. 4). A linear regression on these data gives a strong coefficient ($r^2 = 0.65$), but the pattern of data points is visibly curved and the non-linear regression line displayed in Figure 4 has a coefficient of determination of $r^2 = 0.80$, indicating a strong relationship between intra-site differences in both mean length and width of bipolar cores. This curvilinear relationship is described by a line of best fit given by the equation $y^2 = 761.8 + 188933/x^2$, where y is core width and x is core length. This diagram can be broadly interpreted as displaying more extensively reduced assemblages on the lower left and less reduced ones on the upper right. Note that the HLD values are on the extreme left, with the smallest mean length and width values. This pattern is consistent with bipolar reduction at HLD being extended to a greater degree than at other previously reported sites in eastern New South Wales. The inference of relatively high levels of core reduction at HLD is intriguing because of the similar image that can be obtained from other categories of artefacts.

Scrapers

The 40 non-backed retouched flakes, broadly classifiable as 'scrapers', have been analysed using a number of the methods exploited by Clarkson (2002a) and Hiscock and Attenbrow (2002, 2003, in press). Twenty-two of these specimens were broken, and the majority of fragments (86%) were either distal or proximal portions of flakes. Table 7 gives t-test comparisons of the means of a number of key variables on broken and complete flakes and shows that complete flakes are not statistically distinguishable from incomplete ones. The one possible exception, which is percussion length, probably reflects the fragmentation process, since the high proportion of transverse breakage would explain shorter length on the proximal and distal pieces compared to complete specimens. The similarity of broken and unbroken specimens reveals that complete specimens can be used as a representative sample in characterising the size and extent of reduction of scraper-like retouched flakes.

Descriptive statistics for scraper-like retouched flake dimensions and reduction indices are presented in Table 8. The patterns that emerge from mean values are indicative of typically very small specimens, barely 2 cm by 1.5 cm in plan dimensions, with medium to high edge angles produced by steep non-invasive retouch. These characteristics, particularly the small size, may reflect small blank size and/or the extent of retouching. A number of reduction indices suggests that the amount of reduction on specimens is often medium to high. For instance, on complete specimens the Average Kuhn reduction index has a mean value of more than 0.7, and an average of one third of the flake margin and more than four out of eight segments of the flake margin were retouched. The difficult question is what level of reduction do these values imply? Without experimental calibration of the kind being developed by Hiscock and Clarkson (in press), the interpretation of such indices must be based on local assemblage comparisons.

Comparative statistics for dimensions and the extent of reduction of scraper-like retouched flakes in the Sydney Basin are very limited and the only available values come from the recent analyses of Capertee 3 by Hiscock and Attenbrow (2002, 2003). By comparison with the Capertee scrapers, specimens at HLD are small. Both length and width of specimens in this class have mean values about half those at Capertee (Table 9). Student t-tests reveal that these assemblages are significantly different and these differences are unlikely to have arisen through chance. Additionally, the significantly higher mean value of the Kuhn reduction index at HLD is one indication that the small size of specimens may have resulted, at least in part, from more extended reduction than at Capertee 3. While further examinations of the effects of blank form on such size differences should be sought, the data presented here are consistent with these size differences between assemblages being at least partly a result of different levels of retouching to flakes.

Backed artefacts

Wieneke and White (1973) argued that many of the variables commonly measured on Australian backed

	N	Mean ± std.dev.	Minimum	Maximum	Median
Length	18	20.2 ± 8.4	10.0	45.7	20.0
Width	18	15.4 ± 6.2	6.1	30.4	13.7
Thickness	18	4.9 ± 2.3	1.6	10,7	4.3
Elongation (L/W)	18	1.36 ± 0.34	0.89	2.00	1.2
Average edge angle	17	68 ± 8	53	85	70
Invasiveness Index	18	0.16 ± 0.07	0.06	0.34	0.15
Retouch curvature index	17	0.42 ± 0.64	-0.13	2.23	0.20
% of margin retouched	17	38 ± 15	18	68	30
No. of retouched segments	18	4.3 ± 1.37	2	8	4
Average Kuhn Index	15	0.72 ± 0.18	0.43	0.98	0.68

Table 8 Descriptive statistics

	Sample	Mean ± std.dev.	t	d.f.	p
Length	Complete (N=18) Broken (N= 21)	20.2 ± 8.4 15.7 ± 5.7	2.01	37	0.051
Width	Complete (N=18) Broken (N= 19)	15.4 ± 6.2 13.8 ± 7.0	0.73	35	0.468
Thickness	Complete (N=18) Broken (N= 22)	4.9 ± 2.3 5.3 ± 2.7	-0.52	38	0.607
Elongation (L/W)	Complete (N=18) Broken (N= 19)	1.36 ± 0.34 1.19 ± 0.40	1.42	35	0.164
Average edge angle	Complete (N=17) Broken (N= 22)	68 ± 8 71 ± 9	-1.36	36	0.183
Retouch curvature index	Complete (N=17) Broken (N= 22)	0.42 ± 0.64 0.21 ± 0.17	1.49	37	0.144
Average Kuhn Index	Complete (N=15) Broken (N= 17)	0.72 ± 0.18 0.64 ± 0.19	1.15	30	0.278

Table 7 Comparison of dimensions (mm) for complete and broken scrapers from Henry Lawson Drive.

	Sample	Mean ± std.dev.	t	d.f.	p
Length	HLD (N=18) Capertee 3 (N= 54)	20.2 ± 8.4 37.0 ± 13.8	6.16	70	<0.005
Width	HLD (N=18) Capertee 3 (N= 54)	15.4 ± 6.2 37.9 ± 14.7	9.08	70	<0.005
Average Kuhn Index	HLD (N=15) Capertee 3 (N= 69)	0.72 ± 0.18 0.47 ± 0.22	4.90	82	<0.005
% of margin retouched	HLD (N=17) Capertee 3 (N= 48)	38 ± 15 27 ± 16	2.56	65	<0.01

Table 9 Comparison of dimensions (mm) for complete scrapers from Henry Lawson Drive and Capertee 3 (data from Hiscock and Attenbrow 2002, 2003)

	Length	Width	Thickness	Thickness of backing	Length of backing	Elongation	Kuhn index	Thickness index	% Margin retouched
Length	1.000	**0.503**	0.333	0.058	**0.390**	**0.364**	-0.210	-0.086	**-0.411**
Width		1.000	**0.401**	0.183	**0.767**	**-0.600**	-0.073	**-0.491**	0.037
Thickness			1.000	**0.770**	**0.373**	-0.089	0.215	**0.559**	0.017
Thickness of backing				1.000	0.331	-0.086	**0.768**	**0.551**	0.383
Length of backing					1.000	**-0.420**	0.221	-.263	**0.478**
Elongation						1.000	-0.053	**0.500**	**-0.337**
Kuhn index							1.000	0.272	**0.646**
Thickness index								1.000	0.038
% margin retouched									1.000

Table 10 Correlation coefficients for characteristics of complete backed artefacts at Henry Lawson Drive (coefficients significant at p=0.05 designated by bold typeface)

artefacts were mechanically related to each other. Their statistical analysis of the HLD specimens was geared to identify covariation between variables, and they argued that size and shape were associated. This was an important conclusion because at the time archaeologists were tempted to treat individual variables as typologically diagnostic, especially in using elongation to differentiate sub-groups of backed artefacts broadly corresponding to asymmetrical and symmetrical forms (Glover 1967; Pearce 1977).

Table 10 presents an analysis of linear correlations between variables on the complete backed artefacts from HLD, using the sampling and identification procedures described earlier. This analysis confirms many of the interpretations Wieneke and White (1973) derived from their study. For instance, using chi-square tests they found significant non-random associations between length and maximum width, thickness and maximum width, and length and elongation (Wieneke and White 1973:36). These same variables are significantly correlated in the regression analysis presented here. However, other variable pairings show different patterns. Whereas Wieneke and White (1973:36) found length and thickness associated, this relationship is not visible in the new analysis (Table 10). In view of these differences, a reconsideration of interpretations of backed artefact dimensions is worthwhile.

Wieneke and White (1973) explained the statistical relationships between variables in terms of engineering/mechanical constraints. The viability of this interpretation has been demonstrated by many experimental investigations into fracture mechanics during the last three decades (e.g. Pelcin 1977a, 1997b; Dibble and Whittaker 1981). While such constraints undoubtedly exist, the size and shape regularities in backed artefacts could be produced in a number of ways, such as through the production of flakes of particular dimensions or by the retouching of the flake blank. The issue explored by Wieneke and White (1973) and other pioneering researchers into the variability of Australian artefacts was the nature of different processes that might have generated regularities and variety in assemblages of backed artefacts. This issue is still far from resolved, and the HLD collection of backed artefacts prompts a radical suggestion: that the extent of reduction is a powerful force in creating size and shape patterns amongst backed artefacts.

The distinctive feature of these backed artefacts from HLD is their small size. Descriptive statistics for complete specimens are given in Table 11. Almost every specimen is less than 20 mm in chord length and 15 mm in maximum width, with mean plan dimensions being approximately 14 mm by 8 mm. There are no statistical differences between the specimens made from the dissimilar raw materials (t=1.45, d.f.=26, p=0.16 for a comparison of chord length on silcrete and chert; t=-0.917, d.f.=26, p=0.37 for silcrete and volcanic). The backed artefacts from HLD were regularly worked until they were small, irrespective of the raw materials that were employed. Furthermore, these patterns are not biased by excluding broken specimens, which have similar dimensions with the exception of length which is shorter in fragments simply because they have been broken transversely (Table 12).

If the small size of backed artefacts at HLD is explicable in terms of extensive reduction, a number of expectations should be met. Variation in the extent of reduction between individual specimens might be reflected in size and shape differences. Evidence for this proposition is available in Table 10, which documents a significant positive relationship between the Kuhn index of reduction and the percentage of specimen margin retouched. This pattern can be interpreted as revealing that some specimens were more intensively retouched than others, with less retouched specimens having retouch limited to a fraction of the margin and a relatively low Kuhn value, while intensively retouched specimens have retouch on a large portion of the margin and a high Kuhn value. As retouching extended around the backed artefact this reduced chord length, yielding the

	Mean ± std.dev.	Minimum	Maximum
Length	14.2 ± 3.3	9.5	21.2
Width	7.8 ± 2.2	4.7	14.3
Thickness	3.5 ± 1.0	1.7	5.9
Elongation (L/W)	1.9 ± 0.6	1.2	3.3
% of margin retouched	93 ± 14	46	100

Table 11 Descriptive statistics (dimensions in mm) for complete backed artefacts from Henry Lawson Drive (N = 34)

	Sample	Mean ± std.dev.	Minimum	Maximum	t	d.f.	p
Length	Complete (N=34)	14.2 ± 3.3	9.5	21.2	2.12	74	0.038
	Broken (N= 42)	12.3 ± 4.6	5.5	20.8			
Width	Complete (N=34)	7.8 ± 2.2	4.7	14.3	0.52	74	0.608
	Broken (N= 42)	7.5 ± 2.0	4.6	12.9			
Thickness	Complete (N=34)	3.5 ± 1.0	1.7	5.9	1.07	75	0.290
	Broken (N= 43)	3.2 ± 1.0	1.5	6.0			

Table 12 Comparison of dimensions (mm) for complete and broken backed artefacts from Henry Lawson Drive

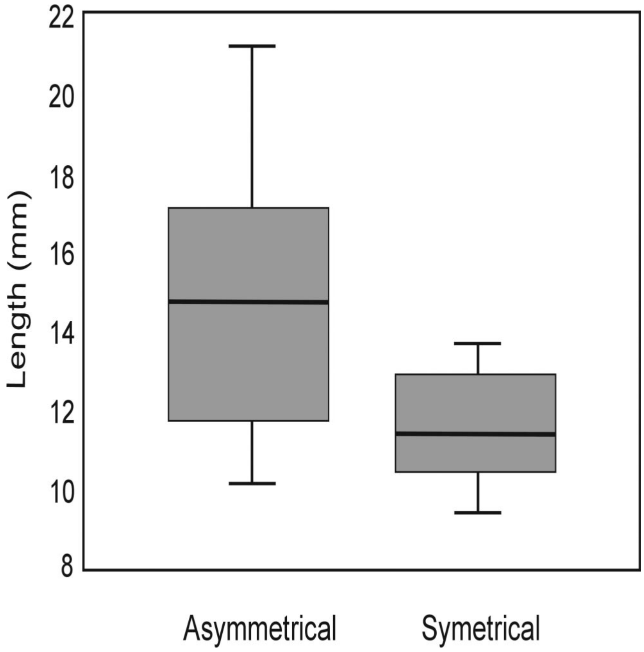

Figure 5 Box plot of lengths for symmetrical and asymmetrical backed artefacts at Henry Lawson Drive.

statistically significant inverse correlation between percentage of margin retouched and chord length. These patterns indicate that differential reduction might partly explain the variation in chord length amongst backed artefacts from HLD. It is hypothesised that at HLD backed artefact length was progressively reduced as retouching proceeded, with little modification of width beyond a minimum value, leading to smaller elongation values on more reduced specimens. Such a pattern would create the inverse relationship between percentage of margin retouched and elongation observed in the assemblage (Table 10). This may reflect mechanical constraints in the following sense. The width of these specimens is small relative to flake thickness, with a width:thickness ratio averaging 2.3:1 but being as low at 1:1. It was probably difficult to decrease width further on flakes of this thickness without incurring high rates of transverse snapping. However, even when width reached these critical values the length of a backed artefact could still be reduced by retouching. A sequence of dimension change on these backed specimens is therefore hypothesised: 1) initial shaping reduced width to a standard or minimum level, perhaps a mechanical threshold, and 2) further reduction was concentrated on distal and proximal ends, thereby decreasing length but not width, consequently reducing elongation. Consideration of why such a pattern of reduction would have been applied to backed artefacts is beyond the scope, and word limit, of this paper and will be pursued on another occasion.

While this model deserves and will no doubt prompt further testing, two implications will be examined here. If correct, the suggestion that elongation changes with the extent of reduction implies that more extensively retouched specimens might be more symmetrical. The HLD site can shed light on this prediction because 28 (82%) of the 34 complete backed specimens are noticeably asymmetrical, while the other six are symmetrical. The hypothesis that symmetrical specimens are shorter because they are more reduced is congruent with the data presented in Figure 5.

		N	Mean	df	t	p
Length	Asymmetric	28	14.8 ± 3.3	32	2.244	0.032
	Symmetric	6	11.7 ± 1.6			
Width	Asymmetric	28	7.9 ± 2.4	32	0.650	0.520
	Symmetric	6	7.2 ± 0.6			
Thickness	Asymmetric	28	3.4 ± 1.1	32	-0.398	0.693
	Symmetric	6	3.6 ± 0.8			
% margin retouched	Asymmetric	28	92 ± 15	27	-2.964	0.006
	Symmetric	6	100 ± 0			

Table 13 T-tests on the difference between symmetrical and asymmetrical specimens backed artefacts at Henry Lawson Drive (% of margin retouched calculated for unequal variance).

The Independent Samples' t-tests indicate that width and thickness are not significantly different between the two symmetry categories, while differences in mean chord length between the two categories are statistically significant (Table 13). This pattern is consistent with both forms having been made from similar blanks, with some specimens retouched on proximal and distal ends more extensively than others and in the process becoming less elongate and more symmetrical. Note that this inference is not meant to apply beyond, or even to, the entire Sydney Basin; it is simply an inference of the retouching patterns at HLD.

If backed artefacts were reworked to create shorter specimens, it would follow that average length might indicate the extent of reduction. This measure reveals that in the context of the Sydney Basin the dimensions of HLD backed artefacts are atypical. Mean chord length of backed artefacts at HLD (14.2 ± 3.3) is distinctly smaller than means of backed artefact length from Curracurrang 1 (21.4 ± 6.1), Capertee 3 (24.9 ± 6.2), Bondi Beach (26.1 ± 5.0), and Kurnell (25.9 ± 5.2). Statistical comparison of values from those assemblages and HLD using t-tests demonstrate significant differences ($p<0.005$) in all cases. If chord length is a measurement of the extent of reduction, HLD has an assemblage of backed artefacts that was more heavily retouched than those at other sites.

Conclusion

Peter White's excavations at HLD more than thirty years ago produced an assemblage that continues to offer potent insights into the nature of Australian assemblage variation. Quantitative reanalysis of this assemblage has yielded a distinctive image of a site at which the stone artefacts were reduced to a greater extent than was common at other sites in eastern New South Wales. Cores were worked extensively, with many being reduced using a bipolar technique until they were extremely small, and scrapers were also retouched to a degree not observed in many local sites. Even backed artefacts can be depicted as being smaller than, and more reduced than, specimens at many other sites in the local region. In this way all three components of the HLD assemblage display size and morphological features that are consistent with them having been extensively reduced.

This depiction of the assemblage is yet another example of the powerful effect that extent of reduction has on artefact variation. Outside Australia, this perspective has explicated variation in each of the classes of artefact described here: scrapers (e.g. Dibble 1984, 1987; Gordon 1993; Hiscock 1996b), bipolar cores (e.g. Jeske 1992), and small backed artefacts (e.g. Neeley and Barton 1994). Within Australia, reduction has also been shown to be a fundamental factor creating variation within and between assemblages of points (Hiscock 1994b), cores (Hiscock 1996a), scrapers (Clarkson 2002b; Hiscock and Attenbrow 2002, 2003) and other implement forms (Cundy 1985). The HLD assemblage provides another instance of reduction-induced variation in artefact size and shape. Additionally the inferred transformation of hand-held cores into bipolar cores illustrates the way in which conventional types and categories may merely represent different portions of morphological continuums created by differential reduction of specimens in an assemblage (Clarkson 2002b; Hiscock and Attenbrow 2002). This principle is contrary to more traditional approaches that have treated many such categories as end products, and reveals the potential folly of presuming that there is a distinct reduction strategy leading to each category of core that analysts have arbitrarily defined in an assemblage. Replicative experiments which also presume categories to be independently derived end products are no test of either the non-arbitrariness of core categories or their position as end products, and the recognition of reduction related sequential changes in core and implement morphology are more readily explored through quantitative studies capable of measuring reduction and of expressing the variation in artefact form.

What is unique about this analysis of HLD artefacts is the demonstration of reduction-induced morphological changes for three different and independent categories within a single assemblage: scrapers, backed artefacts, and cores. Each of the groupings display the same pattern, the extensive reduction of many specimens compared to assemblages from other sites reported in the vicinity. The similar levels of reduction intensity may suggest a general economic/energetic factor being played out in stone-working activities at HLD. High costs of raw material replacement and/or comparatively sedentary residential systems at this locality would be obvious mechanisms capable of causing high levels of reduction. But identification of the factors that encouraged extended reduction at this site will require similar analyses of other sites in the Sydney Basin to yield an understanding of the economic context in which this level of reduction was beneficial. The consistency of this pattern of intensive reduction at HLD is noteworthy and demands further examination.

Assemblage differences highlighted in this paper are specific instances of a recent trend towards the recognition of diversity in Australian archaeological assemblages (Hiscock 1994a, 2002; McNiven 1994, 2000; Gorecki et al. 1997; Hiscock and Attenbrow 1998, 2002, 2003; Hiscock and Allen 2000). Early explorations of the Australian record concentrated on the search for similarity in chronological and spatial trends in assemblage composition, imposing structure on the observed collections through the construction of geographically broad and integrating frameworks of stadial change. These frameworks typically implied that the direction and timing of assemblage change would be very similar, if not identical, for sites in the same region, perhaps even across the continent. In the case of the continental stage labelled the ‘Small Tool Tradition,’ those assumptions created an image of chronological uniformity, rather than reflecting the diversity of evidence (Hiscock and Attenbrow 1998), and emerging explanations of technological activities as cultural responses suggest that a continent-wide uniformity should not be expected (Hiscock in press b). Those normative depictions of assemblages as uniformly and regularly patterned are increasingly being revealed as both inaccurate and simplistic. At one scale, the re-evaluation of notions of spatial and temporal uniformity has been expressed in the rejection of pan-continental models in favour of regional configurations of technology and implement variation (e.g. Hiscock 1994a). At a finer scale, the evidence does not invariably support regional or even local uniformity in the trajectory or timing of assemblage changes. It is this fine-grained variability that most potently challenges normative models of internally regular and coherent regional change in technology.

What this paper reveals is the existence of assemblage variation operating over small distances within the Sydney Basin. The HLD rockshelter is distinguished from other sites not only by the extensive reduction of all artefact categories, but also by the relative abundance of backed artefacts. If the existing radiometric estimates are correct, almost all of this assemblage dates to the last millennium, and the numerically dominant implement category is the backed artefact. One way to measure the dominance of backed artefacts in the HLD assemblage is to calculate a backed artefact: bipolar core ratio, which yields a value of 2.7:1. Such a ratio is inconsistent with the conventional depiction of the archaeological sequence along this coastal portion of New South Wales, where the last millennium is said to be a period in which backed artefacts were abandoned and bipolar core reduction became the dominant theme of knapping technology (e.g. Attenbrow 2002:122, 156-57; Flood 1995:224). The silcrete and backed artefact dominated Henry Lawson Drive assemblage is also unlike assemblages that have been used to typify the coastal sandstone country in the Sydney Basin (see literature summary in Attenbrow 2002:120-21, 156-57). These anomalies reveal that the artefact assemblages and technological changes in the Sydney Basin may not be adequately characterised by the normative stadial model known as the Eastern Regional Sequence. Small-scale quantitative inter-site variation in artefact size and reduction presumably reflects local differences in economy, technology and landscape use. These differences have not often been revealed in qualitative typological depictions of the regional industrial sequence. In light of this realisation, archaeologists should not continue to presume regional or even local uniformity in technological activities and technological trends within the Sydney Basin. Only coherent investigations into the diversity of technological variation will lead to a greater understanding of changing foraging and industrial organisation. It is both ironic and fitting that this agenda arises from a study of the Henry Lawson Drive rockshelter, the site at which Wieneke and White (1973) explored quantitative assemblage variation in an earlier phase of Australian archaeology.

Acknowledgments

The bibliography of this paper begins and ends with two of my favourite people. I thank Val Attenbrow for her comments on drafts of this paper, and especially for her perceptive suggestion of the symbolic and substantive opportunities offered by the Henry Lawson Drive assemblage. Of course acknowledgement is also due to the excavator of Henry Lawson Drive, Peter White. Although he taught at a different university in a different city, Peter was a key influence on my archaeological thinking as an undergraduate. Peter introduced me to the critically important concept of site formation, encouraged my interests in ancient technology and as editor of *Archaeology and Physical Anthropology in Oceania* published my first tentative work. His approach to both stone artefacts and Australian prehistory was deeply influential during my formative years as an archaeologist and I, like my discipline, owe him gratitude for the enthusiasm, encouragement and honesty that has marked his teaching and research career. Thanks Peter!

The Henry Lawson Drive collection is housed at the Australian Museum in Sydney, and I thank the Trustees of the Australian Museum for access to the material. I acknowledge the assistance of Susan Whitby in organising access to the collection, and an unnamed referee for comments on the paper.

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CHARLES GATES

Routledge
2003
ISBN 0415018951
RRP £60.00
(hardcover)