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Changing Perspectives in Australian Archaeology, Part IV

Quantifying Stone Raw Material Size Distributions: Investigating Cortex Proportions in Lithic Assemblages from Western New South Wales

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ABSTRACT. Recent studies using a methodology for the quantification of cortex in lithic assemblages indicate a deficit in cortical surface area in mid to late Holocene contexts in western New South Wales, Australia. This result is interpreted to reflect the extensive transport of artefacts away from their place of production, thus providing a measure of prehistoric mobility within contexts otherwise noted for technological expediency. Here we provide a further investigation of the observed pattern by testing the null hypothesis that all artefacts were discarded where produced. We calculate the size of stone cobbles required to account for the cortical surface area and volume observed archaeologically and compare these values to the distribution of cobble sizes from the raw material sources from which the assemblages were produced. Results indicate that the very large cobble sizes implied by archaeological cortex proportions are not found in a large enough frequency to reasonably represent the average cobble size chosen for reduction. We conclude that the null hypothesis, that artefacts were discarded where they were produced should be rejected in favour of the original interpretation of cortex loss indicating artefact transport.

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Archaeologists have in recent years been able to document the ways people made and maintained stone tools and how these varied with their degree of mobility and sedentism. Mobile people were often able to use distant raw material sources and carry artefacts from these places to locations where they were needed. In these situations, limitations on the quantity of raw material that might be carried often promoted an emphasis on portability, efficiency and versatility in tool design. Efforts were made to reduce waste and to decrease the likelihood of tool failure as seen by the presence of retouched flake tools, formally prepared cores, blades and bifaces. In contrast, where people were more sedentary, they were sometimes able to move larger quantities of raw material to a single location or position themselves adjacent to stone sources. In these situations an adequate supply of raw material prompted a more casual or expedient approach to technology. Non-formalized artefact morphologies were emphasized leading to the manufacture

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of unretouched flakes and informal core forms along with decreased evidence for tool maintenance via secondary edge retouch (e.g., Andrefsky, 1994a, 1994b; Gould *et al*., 1971; Kelly, 1988; Nash, 1996; Odell, 1996; Parry & Kelly, 1987; Spencer & Gillen, 1927: 25–26; Wallace & Shea, 2006; White & O'Connell, 1982: 162–163).

These relationships might be modified by differences in the relative abundance of local stone raw material. For instance, Kelly (1988: 719) states:

> …[T]he type and distribution of local raw material is the primary factor affecting the lithic technology of foragers. When raw material is abundant and of adequate sharpness there is no temporal or spatial difference in the location of raw material and the location of stone tool use; in effect, stone tools have no role to play, and we can expect groups living under such circumstances to employ an expedient flake technology…

Parry and Kelly (1987: 301–302) go so far as to suggest that where raw material was abundant, highly mobile hunter-gatherers produced stone tool assemblages similar to more sedentary populations lacking formally shaped tools. In such cases, "The effort which previously was invested in the manufacture of formal tools can be spent in some other task".

In Australia, this view is seemingly corroborated by stone artefact assemblages from the raw material rich study region of western New South Wales (NSW), where a flake and core technology (Flenniken & White, 1985) with limited retouch and the near absence of prepared core reduction dominates (Fig. 1). However, recent investigations using a large number of surface assemblages obtained by the Western New South Wales Archaeological Programme (WNSWAP) suggest that while artefact morphology might be described as technologically simple, the inferences to be drawn from this technology do not equate with simplicity in organization. Using a technique for the quantification of archaeological cortex proportions developed by Dibble *et al.* (2005), Douglass *et al.* (2008) found that cortex was conspicuously underrepresented from the NSW assemblages, a result interpreted to reflect the extensive transport of large cortical blanks away from their place of production, thus providing an indication of high levels of prehistoric mobility. In this paper we further investigate the nature of technological organization implied by the western NSW cortex studies, beginning with the null hypothesis that the assemblages do indeed represent an expedient technology as implied by their composition and artefact morphology. We assume initially that all artefacts were discarded where they were produced and calculate the size of stone cobbles required to account for the cortical surface area and volume observed in the western NSW archaeological assemblages. We report the application of geological survey techniques to measure the distribution of cobble sizes from the raw material sources from which the archaeological assemblages were produced. The difference between the estimated and actual raw material cobble size is then used to further investigate our previous conclusions regarding mobility and, therefore, the nature of technological organization in western NSW.

Cortex as a measure of mobility

Inferences about groups who move artefacts from a raw material source to their place of use as opposed to groups who rely on locally available material to manufacture their artefacts represent two conceptual extremes. Even in contexts where material abundance promoted the use of informal technologies, mobile populations still transported some artefacts as they moved about the landscape. Equally, while stone was always locally available somewhere, its use was often more widespread than at locations of raw material abundance. Thus seen from a landscape perspective, there was always a tendency for artefacts to be removed from some places for use and discard at other places. Rather than attempt to estimate mobility on the basis of the presence of certain forms of artefact, it is possible to think about mobility in relation to the availability of stone and analyse variability as the net over or under supply of the products of reduction at a series of locations. It is this that prompted the use of cortex to investigate informal lithic assemblage variability within our western NSW study region.

Dibble *et al.* (2005) demonstrated how the relationship between surface area and volume for geometric solids provided a means to objectively investigate variation in cortex proportions in archaeological assemblages. While the stone cobbles selected for reduction might vary, the different surface-area-to-volume ratios of separate nodules could be accurately expressed by their average size and approximate three-dimensional shapes. With this average, the total volume represented by the artefacts in an assemblage could be calculated and this used to determine the total cortical surface area that should be present within an assemblage. This value was then compared to the actual quantity measured on the artefacts themselves. The relationship between observed and expected quantities of cortical surface area was expressed as the Cortex Ratio. If all products of cobble reduction were present, the Cortex Ratio would approximate one. If products were transported to or from an assemblage, the Cortex Ratio would be either higher or lower than one accordingly.

For the NSW archaeological assemblages, the measurement of surface area for all flakes, flake fragments, and angular fragments greater than or equal to 20 mm in maximum dimension was obtained by multiplying the maximum clast dimensions of length and width. Core surface area was calculated by assuming that the core shape conformed to a scalene ellipsoid. Artefact surface area was multiplied by the proportion of cortex present on the dorsal surface (recorded in one of four ordinal measures: none, 1–50%, 51–99% and complete) to give the cortical surface area. The midpoint of each of these values (e.g., 1–50% = 0.25) was used in the estimate. The individual artefact values in an assemblage were summed to arrive at the observed cortical surface area. The procedure is summarized by the following formula:

Observed Cortical Surface Area =

$$\underbrace{\Sigma(\mathrm{M}\times\mathrm{L}\times\mathrm{W})}_{\text{for flake and flake fragments}} + \underbrace{\Sigma[(\mathrm{M})\times(4\pi[(a^pb^p+a^pc^p+b^pc^p)/3]^{1/p})]}_{\text{for cores}}$$

where M is *midpoint of core cortex proportion, L* is *length*, and W is *width*; and where p is 1.6075 and a, b, and c are the semi-axes of length, width, and thickness (Thomsen, 2004).

Calculating expected cortical surface area requires an estimate of the average nodule size used to produce an assemblage. Dibble *et al.* (2005) suggested that average nodule volume could be estimated by dividing assemblage volume by core frequency. This value was then entered into the equation for the surface area of a sphere,

$$S = 4\pi(3V/4\pi)^{2/3}$$

Figure 1. Western New South Wales lithic scatter. While retouched forms are present, they comprise less than 5% of total assemblage contents for the assemblages addressed in this study. Instead, the vast majority of the record are unretouched flakes and unprepared cores.

and multiplied by the number of nodules represented in the assemblage (i.e. number of cores)[1] to arrive at the total expected cortical surface area. Dividing the observed cortical surface area by the expected cortical surface area provided the Cortex Ratio.

Experimental testing (Dibble *et al.*, 2005; Douglass *et al.*, 2008), including the use of high precision laser scanning (Lin *et al.*, 2010) has demonstrated the utility of the cortex methodology. Results of these studies indicate that the procedures used to measure artefact cortical surface are sufficiently similar to the actual quantities observed and that estimates of average nodule size, based on the division of assemblage volume by core frequency, adequately represent cobble size variability, even with small assemblages. The repeated calculation of Cortex Ratios for complete assemblages (i.e. no artefact removal) consistently produces a value approximating one, thus demonstrating the ability of the cortex methodology to accurately measure archaeological cortex proportions.

Table 1. WNSWAP Assemblage Cortex Ratios. Assemblages from Fowlers Gap Arid Zone Research Station: Fowlers Creek (FC), Mulga Dam (MD), Nundooka (ND), Sandy Creek (SC); Paroo-Darling National Park Charlton Waterhole (CW) and Round Hill (RH); Pine Point Langwell Station Conservation One (CN1), Silcrete Quarry One (SQ 1).

assemblage	material	artefact count	estimated nodule count	estimated nodule mass (g)	assemblage mass (g)	observed cortical surface area (cm^2)	expected cortical surface area (cm^2)	ratio observed/ expected
CN1	Quartz	7270	495	182	90250	26567	40295	0.66
CW	Silcrete	5016	250	272	67971	15208	27327	0.56
FC	Quartz	4596	411	151	62119	18477	29524	0.63
MD	Quartz	2702	198	130	25675	8582	12842	0.67
ND	Quartz	2941	265	79	20949	8461	12358	0.68
ND	Silcrete	2127	87	226	19627	3105	8397	0.37
RH	Silcrete	3006	232	458	106214	18152	35894	0.51
SC	Quartz	3222	287	109	31228	11084	16560	0.67
SQ1	Silcrete	4151	97	870	84347	13124	23017	0.57

Application to the western NSW study areas (Douglass *et al.,* 2008; Holdaway *et al.*, 2008b) showed that cortex was significantly underrepresented in all assemblages measured. Results for a sample of these assemblages using a total of over 35,000 artefacts are presented in Table 1. Because assemblages were produced from local stone, with some assemblages placed directly on high quality sources, it was inferred that the observed pattern indicates the removal of artefacts for use elsewhere. This likely reflects a preference for large and therefore overly cortical flakes, a pattern that fits with theoretical arguments about the advantages of selecting artefacts with a high edge to mass ratio for transport (Kuhn, 1994).[2]

The magnitude and spatial scale of archaeological cortex proportions provides an indication of mobility in the past. The low Cortex Ratios for the western NSW archaeological assemblages indicate that a substantial proportion of the artefacts produced at each assemblage was selected and transported beyond assemblage boundaries, meaning that prehistoric mobility within the study region was quite high. However, the validity of these results, and the operation of the cortex methodology as a whole, depends on having an accurate estimate of the average cobble size from which an assemblage was produced. Here we present an alternative means of assessing the question of underrepresented cortical surface area that does not rely on estimating average cobble size.

An alternative measure of archaeological cortex proportions

One way to examine cortex proportions without recourse to an estimate of average nodule size is by determining the size of a nodule of stone with a cortex to volume ratio in equal proportion to that measured amongst the artefacts within an archaeological assemblage. To get a reasonable measure one needs to know how big the cobbles would have to have been, on average, to produce the cortex proportions measured in an assemblage under conditions of complete technological expedience. Mathematically this may be expressed as,

$$\text{Nodule Mass} = (\text{material density} \times (36\pi(V/SA)^3))$$

where V/SA is the volume to surface area ratio and material density is 2.53 for silcrete and 2.64 for quartz (Douglass *et al.*, 2008).

Because the initial results from our previous study (Douglass *et al.*, 2008) indicated that cortex is underrepresented from all of the western NSW assemblages and, therefore, artefacts were removed, solving this equation for each assemblage results in substantially larger nodule sizes (Table 2) than our previous original cobble size estimates (Table 1). The new nodule sizes, those calculated as though no artefacts were in fact removed, range from 246 g to 636 g (mean 450 g) for quartz and from 1577 g to 4691 g (mean 3568 g) for silcrete. In the following we determine how easily cobbles approaching the indicated sizes can be obtained in each study location as a test to determine whether indeed material was left at one place or whether some material was removed as was concluded in our original study. To accomplish this requires an understanding of the natural size distribution of the cobbles that were available for artefact production in each archaeological study area.

The Wolman Pebble Count

To understand the size distribution of the cobbles from which the archaeological assemblages were produced, we utilized a sampling technique known as the Wolman method or Wolman pebble count (Wolman, 1954). The technique is used to obtain a sample of the stones (typically 100) distributed across a sampling location. The location of sampling nodes can be established by gridding with metre tapes, but typically relies on walking parallel transects. Cobble selection at each sampling interval is accomplished by reaching down and selecting the first stone touched by the forefinger while reaching over the foot (Fig. 2). In order to avoid bias in selection, the operator's eyes are averted while the finger is being placed. Cobble size is then recorded and the stone is cast aside. The simplicity and accuracy of the original method has established it as a standard in a wide array of geomorphological and biological applications (e.g., Leopold, 1970; Haslam, 1978; Carling, 1988; Flintham & Carling, 1988; Rice and Greenwood 2001; Doyle *et al.*, 2003).

Sources of knappable stone are distributed widely within western NSW (Fig. 3), with silcrete and quartz the dominant lithologies for artefact production. Silcrete occurs in outcroppings of duricrust and associated boulder mantels that form the residual capping of mesas and plateaus (Langford-Smith, 1978) and also as cobbles and gibbers that can be found along hillslopes, desert pavements and in the channel beds of the many dry creeks found throughout the region. Quartz is occasionally found in outcroppings but is most often found as cobbles and gibbers. A smooth, rounded cortex covers the exterior of both silcrete and quartz nodules (Figs 4–6).

The wide availability of raw material means that it is not possible to gain a systematic sample of the size range of cobbles for all of the stone in the vicinity of each of the western NSW archaeological assemblages. Instead, areas with the largest stone that could be obtained within a short distance (i.e. within a few kilometres) from each study area were targeted to determine whether stones with sufficient surface area and volume were present and in sufficient number to account for the cortex observed in the archaeological assemblages. While raw materials might be carried from place to place (e.g., Webb, 1993), local materials are abundant at all locations and the raw material composition of each of the assemblages resembles those that could be obtained locally (i.e. assemblages were produced from stone with the same colour range and kinds of inclusions and cortex characteristics as those found locally). Therefore the importation of indistinguishable raw material from one source to another seems unlikely.

Application of this method was completed at each of the study areas for which cortex ratios are reported above.

Table 2. Estimated nodule mass based on cortical surface area and volume observed in the archaeological assemblages. Assemblage abbreviations as given in Table 1.

assemblage	CN1	FC	MD	ND	SC	CW	ND	RH	SQ1
material	Q	Q	Q	Q	Q	S	S	S	S
estimated nodule mass (g)	636	616	435	246	315	1577	4464	3540	4691

Figure 2. Sample selection for the Wolman pebble count as applied in this study. Note that samples are collected with eyes averted to avoid sampling bias.

In each case, transects were walked and spacing intervals determined to collect 100 samples evenly over the area to be sampled. For particularly large areas, several samples were taken from the one location. Only cobbles of silcrete and quartz were sampled. In the event that a selected cobble was not silcrete or quartz, it was cast aside and an additional sample was taken.

The stone particle size data generated through this technique are usually presented as frequency distributions of different classes (relating to standard sieve sizes used in other sampling techniques), and are most often based on the length of a cobble's b-axis (the second longest cobble dimension). For this study the interest was not in cobble dimensions but volume as determined by dividing mass by material density. For this reason, cobble weight was used as the size measurement. To determine a minimum cobble size threshold selected in the past, we examined the lower end of nodule weights for cores showing three flake scars or fewer. The vast majority of these minimally reduced cores were greater than 30 grams. While smaller cobbles were undoubtedly used, this served as a conservative but not unreasonable approximation of the minimum sized cobble selected for reduction in the western NSW archaeological study areas.

Results

The raw cobble data obtained during application of the Wolman methodology provide a good perspective into the range of stone raw material size values that can be obtained in the vicinity of each of the sampled archaeological assemblages. These results, however, do not reflect the true proportion of cobble sizes from within each survey location (Leopold, 1970; Dunkerley, 1996). Instead, the raw data obtained with the Wolman method are biased such that larger cobbles are over-represented, an effect of larger stones creating a larger target and, therefore, having a greater probability of being selected. Thus, raw cobble data reflect the "areal proportion" of the surface of a sampling location occupied by cobbles of a given size (Leopold 1970; Green 2003: 979), and so must be transformed in order to accurately estimate the numerical frequency of cobbles of different sizes within a sampling area. Leopold (1970: 135) proposed a transformation based on weighting the size of cobbles by a "factor inversely proportionate to the square of the diameter of the b axis."

In this study only cobble weight was obtained for the cobbles in each sampling area; however, average diameter (a near equivalent to the b axis) can be easily estimated from

Figure 3. Raw material abundance within Western NSW. Cobble lined creek beds *(top)*, boulder mantled outcropping *(middle)*, and gibber pavements *(bottom)*. The abundance of stone sources and the quantities of material found within them ensured an almost limitless supply of cobbles for artefact production.

weight using linear regression since weight and dimensional volume (length × width × thickness) of stone is highly correlated (Douglass *et al.*, 2008). Average diameter is similarly correlated, but needs to be cubed in order for the relationship to be linear. The resulting regression of the cube of average diameter of a cobble shows a high correlation (r^2: 0.992; standard error: 46.05; $p < 0.001$; unstandardized coefficient 1.062). The cube root of the value predicted with this equation gives a very useful estimate with which to gauge the sampling probability of each cobble in the Wolman data.

Leopold's correction for sampling bias was calculated for individual cobbles rather than the size classes commonly used in pebble counts (Dunkerley [1996] used a similar approach). This weighting was $1/(d^2)$ where d is the average cobble diameter, meaning the resulting weighted frequency values are proportionate, but individual values are all less than one (Leopold, 1970; Dunkerley, 1996: 575). All values are multiplied by a factor to bring the weighted frequency value for the largest cobble recorded amongst all raw material surveys up to one. The recorded frequencies of all cobbles under 3500 g were thus increased upwards in inverse proportion to their sampling probability, and rounded to the nearest whole number. The result is a much-expanded data set for each sampling area that reflects the relative proportion of individual stone size frequencies, rather than exposed area.

The results for each study location are provided for quartz and silcrete cobbles in Figures 7 and 8. Pebble count proportions are generally presented as "percent finer than". However, in this study the proportion of stones equal to or larger than the cobble size that would reflect surface area and volume in proportion to that observed archaeologically is required. Hence, the data are presented as "percent larger than". In Figures 7 and 8, the black vertical line indicates the mass of a cobble with the cortex area and volume required to account for the artefacts within each of the western NSW archaeological assemblages assuming no artefact removal. Table 3 gives the frequencies of cobbles equal to or larger

Table 3. Frequency of a cobble large enough to have cortex and volume in proportion to that measured amongst assemblage artefacts from the size distribution of cobbles found in the vicinity of the study area. Assemblage abbreviations as given in Table 1.

assemblage	material	frequency of large cobbles compared to total surveyed	%
CW	Silcrete	0/717	0.00
CN	Quartz	0/3902	0.00
FC	Quartz	2/1460	0.00
MD	Quartz	3/1349	0.00
ND	Silcrete	0/948	0.00
ND	Quartz	41/1339	0.03
RH	Silcrete	0/1654	0.00
SC	Quartz	139/4580	0.03
SQ1	Silcrete	0/2099	0.00

Figure 4. Silcrete cobbles collected during the application of the Wolman method in a dry creek bed. Cobbles from these contexts have a smooth, rounded cortical exterior.

than this value for each assemblage, as well as their relative percentage. These values always fall towards the high end of the natural size distribution. In fact, for silcrete there was not a single cobble recorded during the raw material surveys that was large enough to account for the cortex and volume observed amongst the artefacts in any of the archaeological assemblages.

Quartz displays a different pattern. Four of the five assemblages do have recorded cobbles equal to or larger than the size theoretically represented by the cortex and volume of the artefacts in the assemblage. This is a direct consequence of the higher Cortex Ratios of this material and therefore the lower nodule size that would have cortex and volume in proportion to that measured in each archaeological assemblage.

The proportion of quartz cobbles that fit into the required size range, however, is uniformly low, meaning that there is a low likelihood that cobbles of this size account for the bulk of the cobbles reduced to produce the archaeological assemblages. While the black vertical lines within the cobble size distributions presented in Figures 7 and 8 reflect the relative abundance of cobbles large enough to have cortex and volume in proportion to the artefacts within an assemblage, this value represents the *average* rather than the maximum cobble size required to produce each assemblage. The size of cores with only one or two flake scars, along with the size of cores that retain a sufficient percentage of their original cortical exterior to estimate the original dimensions of the unworked cobble, indicate that cobbles much smaller than this average were worked in the archaeological assemblages. To account for the cortex present in the archaeological assemblages, given the relatively small size of many of the archaeological cores, means that cobbles even larger than the average value indicated by the vertical lines in Figures 7 and 8 would sometimes have been selected for reduction. From the cobble size data obtained using the Wolman method, cobbles of such size are either exceedingly rare or absent at the locations studied. Therefore, either Aboriginal people searched out rare, very large cobbles, examples of which we could no longer locate within the vicinity the archaeological assemblages, or they used the wealth of cobbles at hand to produce flakes and then selected the largest of these (i.e. those tending to have cortex), and carried these with them when they left. Flake transport would seem to be the most parsimonious explanation given the results produced by the Wolman surveys.

As a final test, it is useful to consider the frequency of cores within each of the archaeological assemblages. The total mass of stone measured in an assemblage can be used to determine the number of cobbles reduced of a size large enough to account for the cortex area and volume required if the archaeological assemblage was manufactured and discarded at one place. This value can be compared to the actual frequency of cores found in the archaeological assemblage (Table 4). In each case, archaeological core frequencies are much higher than the theoretical number of large cobbles required for the whole assemblage (from 5.4:1 to 22:1 for silcrete, and 2.9:1 to 4.4:1 for quartz). This means that multiple cores would need to be produced for each cobble of stone that was worked at each of the archaeological

Figure 5. Quartz cobbles collected during the application of the Wolman Method. Quartz cobbles found in creek beds and in desert pavements have a smooth, rounded cortical exterior.

Figure 6. Cobbles collected during the application of the Wolman method on a boulder mantled silcrete outcropping. Silcrete cobbles obtained from outcroppings have an angular, weathered cortical exterior.

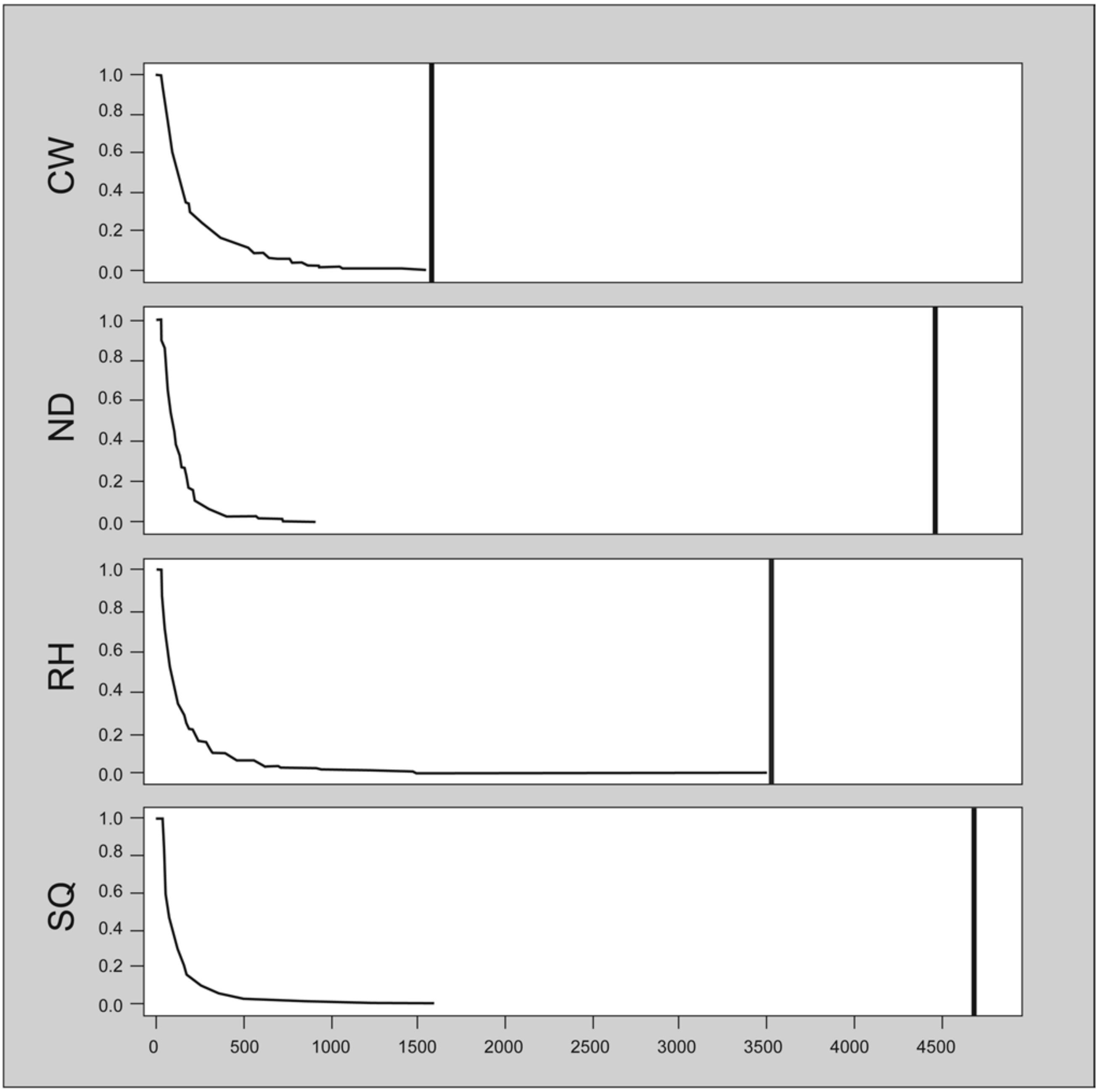

Figure 7. Cumulative silcrete cobble percent larger than frequency distributions. y axis = percent larger than; x axis = nodule mass(g). Black lines indicate size of required nodule size (i.e. cortex and volume in proportion to assemblage measures).

assemblages studied to account for the archaeological assemblage cortex surface area and artefact volume.

To determine if indeed multiple cores were being worked from a single cobble, a Minimum Analytical Nodule Analysis (MANA, Larson & Finley, 2004) was undertaken with the cores sampled from each study location. All cores from each archaeological assemblage (or, in the case of spatially extensive assemblages, within each sampling unit), were compared. Following Larson and Finley (2004), determinations were made on the basis of colour, texture, inclusions and, when present, exterior cortex.

The considerable colour variation that exists in silcrete made this process relatively simple. Quartz dominated assemblages proved more of a challenge because of greater uniformity in quartz colour. However, slight variations made it possible to distinguish between different cobbles on the basis of colour and texture in most cases. Additional determinations for cores that possessed similar colours (particularly quartz) were made based on the texture and nature of inclusions, cortex colour and lustre, and finally position of residual cortex (i.e. only surfaces free of residual cortex have the potential to conjoin). Results indicate that while there were a few occurrences of multiple cores per nodule (Fig. 9), the small number of cases where this was demonstrated suggests that cores within the western NSW assemblages follow the one-core-per-nodule pattern in the majority of cases. This result provides further support for the observation that the limited quantities of cortex in NSW assemblages are not the result of rare large cobble reduction.

Discussion and conclusion

The extreme rarity of stone cobbles large enough to have cortex and volume in proportion to that observed in the study assemblages suggests that the observed pattern of underrepresented cortex found for all of the study assemblages could not have resulted from an error in the estimate of Average Nodule Size. Cobbles that would

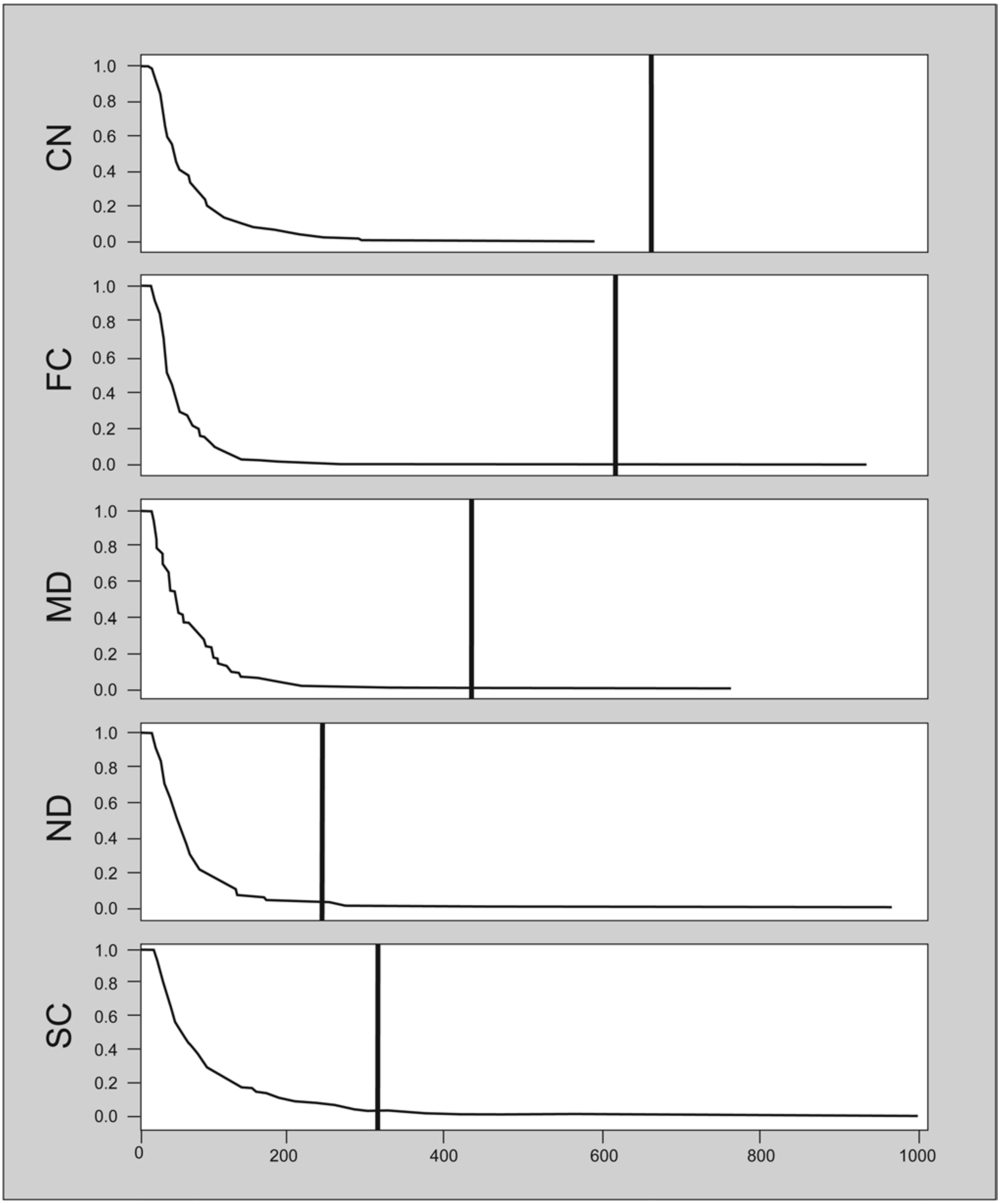

Figure 8. Cumulative quartz cobble percent larger than frequency distributions. y axis = percent larger than; x axis = nodule mass(g). Black lines indicate size of required nodule size (i.e. cortex and volume in proportion to assemblage measures).

create cortex proportions as measured in the western NSW archaeological assemblages, without artefact removal, are not found in a large enough frequency to reasonably represent the average cobble size chosen for reduction. This observation is further bolstered by the fact that MANA supports the initial assumption of one-core-per-nodule in the majority of cases. Therefore the production of multiple cores per nodule that would be necessary if very large cobbles were being reduced is not supported. The limitations imposed by the raw material record act as an independent variable with which to investigate inferences about Aboriginal technological organization. Results show that the archaeological measurement of cortex does provide a measure from which valid inferences about prehistoric mobility may be drawn and, based on this, inferences about how Aboriginal populations organized the use of their lithic technologies.

The fact that cortex is so underrepresented in assemblages that show limited retouch and tool formalization reflects the organization of technology to deal with the unique

Table 4. Comparison between the frequency of cobbles that should be represented in an assemblage if it is assumed that assemblages had no artefact transport to the number of cores measured in the assemblage (excluding flake and bipolar cores). The ratio of cores to the implied number of nodules is presented in the column "Core to Nodule Ratio." Assemblage abbreviations as given in Table 1.

assemblage	material	theoretical nodule mass	theoretical nodule frequency	archaeological core frequency	core to nodule ratio
CN1	Quartz	636	142	495	3.5
CW	Silcrete	1577	43	250	6.3
FC	Quartz	617	101	435	4.4
MD	Quartz	435	59	199	3.4
ND	Quartz	246	85	266	3.1
ND	Silcrete	4464	4	88	22
RH	Silcrete	3540	30	232	7.7
SC	Quartz	315	99	288	2.9
SQ1	Silcrete	4691	18	97	5.4

circumstances faced by populations living within the arid environment of western NSW. While stone is abundant in this environment and this abundance helps to account for a lack of formal artefact types, the time and place of artefact usage was not uniform across the landscape (Holdaway *et al.*, 2008a). People likely had to move out far and wide in search of patchy resources and thus they took artefacts with them. Stopping to make tools as the need arose when resources were encountered may have been too costly. However, raw material abundance allowed artefacts to be replaced frequently, and therefore the need to maintain transported forms through extensive retouch, or to place extra consideration into the design of specific forms through prepared cores technologies, did not eventuate. Instead, a strategy of rapid production and selection at areas of raw material abundance was used. Selected forms were then carried across the wider landscape in a form that afforded a high quantity of available cutting edge for a given weight. The fact that cortex remains underrepresented within all of the assemblages we have studied indicates that this pattern of artefact transport was part of a general strategy of equipping mobile populations, a conclusion that fits well with ethnographic observations of high mobility (e.g., Gould, 1991).

Contrary to the impression of apparent technological simplicity indicated by considerations of artefact form, particularly the relative dearth of formal tool types, studies of cortex demonstrate considerable complexity in the organization of Aboriginal lithic technology, a conclusion also reached in our previous study (Douglass *et al.*, 2008). Stone abundance may have removed the need for larger numbers of formal tools, a reliance on extended artefact maintenance and the presence of complex core forms but the absence of these measures should not be used to diagnose a simple technological system. As the western NSW case shows, organizational complexity may coexist

Figure 9. Example of multiple cores per nodule. Of the few cases where Minimum Analytical Nodule Analysis resulted in the identification of more than one core being created from a single cobble, the majority related to the splitting of a core due to a flaw in the original cobble and the two separate cores were found in close proximity to one another. Examination of these cases indicated that flakes were seldom knapped on the surface created from the split, thus suggesting that the core was discarded soon after fracture had occurred.

with technological simplicity.

As discussed previously (Shiner *et al*., 2007), the results of this study and of our original cortex work (Douglass *et al*., 2008) also illustrate the danger of seeking a single variable to explain stone artefact assemblage variability. Raw material form and location is certainly significant for understanding stone artefact variability but only as a variable to be interpreted along with others rather than an explanation on its own. It is not sufficient for instance to simply illustrate changes in artefact form with increasing distance from source if the goal is to understand the nature of technological organization. The same is true of the presence of formal tools, the process of tool edge rejuvenation and the morphology of cores. All are potentially important variables but none on their own can be used to fully describe how technology was organized to aid resource exploitation across space. The danger is that in elevating any one of these variables to the status of explanation, other aspects of assemblage variability are ignored. In the case of our western NSW assemblages, it is only by analysing all assemblage components that the missing component, the large flakes that tend to be cortical, can be identified. Ironically it is this missing component that has the most to say about the technological organization used by people in the past.

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Endnotes

[1] Flake and bipolar cores were excluded from core counts when estimating the number of nodules represented in an assemblages. Flake cores were themselves produced from the nodular cores that are of interest to this study. Bipolar cores tend to be made with small nodules and produce only a few flakes. Their inclusion in core counts would thus deflate estimates of average nodule size used in the calculation of the Cortex Ratio.

[2] The observation that a deficit in cortical surface area likely reflects a preference for larger flakes relates to the association between cortex proportion and core reduction intensity. Overly cortical forms tend to be produced early in cobble reduction. Because average flake size tends to decrease as reduction proceeds, early stage and therefore overly cortical flakes tend to be *relatively* large. Because the cortex methodology measures cortical surface area to volume, it is the selection of not only large and therefore on average overly cortical flakes, but also thin flakes that most affects the Cortex Ratio. While other forms may have a higher edge to mass ratio, large thin flakes provide a balance between portability and functionality as they possess a high quantity of cutting edge in a light weight package that is easily grasped and affords increased leverage (Kuhn, 1996; Morrow, 1996; Prasciunas, 2007).