Morphological and Reduction Continuums in Eastern Australia: Measurement and Implications at Capertee 3

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At one of the classic Australian sites we document how retouched flakes (often called ‘scrapers’) display a morphological continuum, and that this continuum is largely explained as a reflection of different levels of reduction. The measurement and interpretation of retouching patterns, and their explanation in terms of the extent of reduction, is discussed. We argue that the demonstration of continuous variation at Capertee 3 has implications for artefact analysis elsewhere in Australia. Researchers should no longer assume that a segmented model appropriately describes the fundamental pattern of morphological variation in Australian assemblages. Consequently, Australian archaeologists aiming to identify and explain the nature of artefact variation should not continue to use conventional typological classification as though this was necessarily the appropriate, or even the only, analytical practice. Instead they should be aware that a fundamental question about assemblage composition and artefact variation is whether in any particular region or assemblage morphological variation takes the form of a segmented or continuous pattern.

Introduction
One of the basic questions of Australian prehistory remains largely unaddressed: how did the prehistoric stoneworking technologies operate and what causes the variation we see in archaeological assemblages of artefacts. Although grand visions of shifts and ‘evolution’ in technology were provided by some of the founding figures of Australian archaeology (e.g. Lampert 1981; Lorblanchet and Jones 1979; Mulvaney 1969), these visions are all variants of a single image. As Hiscock and Clarkson (2000) have discussed, the presumption dominating studies of Australian stone artefacts is that implement types appear different because their makers shaped each in accordance with design rules relevant for their intended uses. Underlying that presumption is the view that implement types are morphologically distinct from one another, with not only a strong tendency to similarity of specimens within each type but also clear morphological/size discontinuities between types. These principles typify typological approaches to stone artefacts, presupposing that perceived types reveal designed tools that are morphologically distinct (see Hiscock in press; Whallon and Brown 1982). We label this viewpoint a ‘segmented’ model of implement variation, reflecting its advocacy of discontinuous implement morphology. Such a model represents one way that a technology could create archaeological implements.

An alternative structure for archaeological assemblages is a pattern of continuous rather than discontinuous morphological variation; a pattern we label the ‘continuum’ model of artefact variation. This model has occasionally been invoked for Australian artefacts, but has been more consistently emphasised by northern hemisphere researchers studying variation within assemblages of bifaces. Continuum models of this kind have often been used to argue that morphological variation primarily reflects differences in the extent to which specimens have been reduced. The linking of continuum models with explanations invoking differential degrees of reduction has now been shown to be a powerful depiction of implement variation in the Old World (e.g. Dibble 1984, 1987, 1995; Gordon 1993; Hiscock 1996; Holdaway et al. 1996; Kuhn 1992, 1995; McPherron 2000; Neeley and Barton 1994; Rolland and Dibble 1990). In Australia reduction models have been applied successfully to explain the differences between many implement types and sub-types including tulas (Cooper 1954; Hiscock 1988; Hiscock and Veth 1991), bifacial points (Hiscock 1994a), ground clyndro-conical artefacts (Cundy 1985), burinates (Hiscock 1993), ‘core tools’ (McNiven and Hiscock 1988), and retouched flakes often inappropriately labelled ‘scrapers’ (Clarkson 2002; Hiscock and Allen 2000; Hiscock and Attenbrow in press). However, despite arguments that continuum models are widely applicable in Australian assemblages their application has been extremely limited. Why?

Analyses of Australian archaeological assemblages have rarely tested whether segmented or continuum models are the best depiction of implement variation. Instead, researchers often simply employ personal or disciplinary preferences in the choice of applying one model or the other to assemblages. This is most obvious in the arid areas of Australia where it is common to see archaeologists employ a continuum model for some categories of objects (such as the view that tulas and tula slugs form a reduction continuum – see discussion in Hiscock and Veth 1991), while they apply a segmented model to the variation that is
displayed by other categories (such as the view that unifacial and bifacial points are discrete groups – see discussion in Hiscock 1994a). The application of either model typically takes place without any attempt to demonstrate its appropriateness in the context of particular assemblages, and we would encourage future studies to explicitly review the applicability of both models. As revealed in Figure 1 the contrast between the two models is dramatic, and a test of which model best fits any particular archaeological situation is in one sense simply a matter of finding ways to measure whether there are significant breaks in the morphological range visible in large assemblages.

In this paper we provide a detailed example of the way testing can be accomplished, and argue that variation in the non-backed component of the implements from one of the classic sites of eastern Australia, Capertee 3, is best described in terms of the continuum model. We explain the measurements that provide data for that conclusion, and in the process describe some of the ways that continuous variation may be portrayed. We selected this assemblage to study the morphological variation in implements because of its formative role in the construction of culture history in southeastern Australia.

The Example of ‘Scrapers’

Our example concerns variation in that range of implement forms often called ‘scrapers’. Australian archaeologists have frequently classified marginally and dorsally retouched flakes, that were not recognised as points or backed artefacts, as one or more types of implement labelled by typologists as ‘scrapers’. Many Australian archaeologists have viewed morphological and size variation between such specimens as a reflection of different functional designs, constructing classifications of different types of implements as a way of depicting the perceived variation. The now defunct label ‘Core Tool and Scraper Tradition’ for the ‘early’ assemblages reflected that characterisation of archaeological variation (see Hiscock and Allen 2000).

Many examples illustrate this general approach. For instance, in their influential discussion of the Pleistocene assemblages of Lake Mungo, Rhys Jones and Harry Allen divided the implements into ‘steep edge scrapers’, ‘flat scrapers’, ‘multiple concave scrapers’, and ‘core tools’ (Bowler et al. 1970). Based on the shape and steepness of the retouched edges they suggested different functions for each type. Examples of similar divisions of ‘scrapers’ into types using the shape, disposition and extent of retouched edges yielded categories such as ‘side scraper’, or ‘side-side-and-end scraper’ (Lampert 1971:20), ‘round edge scrapers’, ‘flat straight scrapers’, ‘notched scrapers’, and ‘concave and nosed scrapers’ (Bowdler 1981; Jones 1977), or ‘side scrapers’, ‘double side scrapers’ and ‘concave side scrapers’ (Clegg 1977). The relative abundance of specimens assigned to each of these classes was taken to be an indication of the nature of activities carried out in a site or level. Even recent syntheses advocate the value of these kinds of categories and principles. Take for example the discussion by Mulvaney and Kamminga (1999:217-219, 227) of Pleistocene Australian implements in which categories such as ‘end scraper’, ‘straight-edged scrapers’, ‘notched scrapers’, ‘concave scrapers’, ‘nosed scrapers’, ‘Gamberian discoids’ and ‘thumbnail scrapers’ are defined. To each category they attribute a different functional design, and although they accept that notched and concave forms may be part of a continuum as resharpening proceeds, the other forms are considered typologically and functionally distinctive. All of these examples apply a similar typological approach, partly because they are all built on the classification systems developed by McCarthy et al. (1946) and Mitchell (1949:27), and used extensively, particularly by McCarthy (1948, 1949, 1958, 1963, 1964, 1967).
In the Sydney region classification of implements into one of a number of purportedly distinct types by McCarthy formed the basis of his model of the Eastern Regional Sequence. This model hypothesised a sequence with three phases which he called Capertian, Bondaian and Eloueran. This tripartite sequence was based on stratified assemblages excavated at Lapstone Creek rockshelter on the lower slopes of the Blue Mountains eastern escarpment, as well as Capertee 3, a sandstone rockshelter in the Blue Mountains west of Sydney (McCarthy 1948, 1964). Lapstone Creek, dating back 3,500 years, had Bondaian and Eloueran assemblages, whereas Capertee 3, with initial occupation estimated at around 7,000 years ago, had a Bondaian as well as an earlier Capertian assemblage. McCarthy argued that the earliest phase, the Capertian, contained ‘uniface pebble implements’, cores, ‘blocks’, and ‘dented saws’ (McCarthy 1961:98-99, 1964:238-239). He also concluded that new flaked implement types such as Bondi points, geometric microliths and ‘Elouera adze flakes’ (all now classed as backed artefacts) appeared in the Bondaian assemblages (but see Hiscock 1994b, 2001 for reasons why this is no longer accepted). McCarthy depicted the Eloueran assemblage at Lapstone Creek as being dominated by ground-edged implements, Elouera and bipolar artefacts, while Bondi points were absent. Throughout all three phases of his Eastern Regional Sequence, McCarthy identified what he called ‘a basic series of chert flake and blade implements’, predominantly specimens that he described as ‘scrappers’, together with ‘burins’, ‘knives’, ‘saws’ and bipolar artefacts then known as ‘fabricators’. It is an evaluation of the variation displayed by those thick dorsally and marginally retouched flakes that is our concern here.

Typological Depictions of the Capertee 3 Assemblage
McCarthy used the large collection of implements at Capertee 3 to typify the contrast between assemblages in his early phase, the Capertian, and the subsequent Bondaian. His typological analysis of the Capertian centred on the dorsally retouched flakes he described variously as ‘scrappers’, ‘knifes’ and ‘saws’. The original typological descriptions of this assemblage involved the categorisation of different implement types on the presumption that a segmented model was an appropriate depiction of assemblage patterning.

McCarthy (1964) classified the non-backed, dorsally retouched flakes from Capertee 3 using two variables: position and number of retouched edges, and retouched edge shape. He described the number of edges containing retouch using categories such as ‘side’ or ‘end’ for those flakes with one retouched margin, ‘side and end’ or ‘double side’ for those with two retouched margins, and ‘double side and end’ or ‘semi-discoidal’ for those with three retouched margins. McCarthy simultaneously described the shape of retouched edges using labels such as ‘notched’, ‘concave’, ‘straight’, ‘convex’, ‘nosed’, ‘semi-discoidal’, and ‘disoidal’. These descriptive categories were combined in ad hoc ways rather than in an explicit and systematic framework. Consequently McCarthy (1964:246) produced labels such as ‘concave and nosed double side and end scraper’ and ‘side scraper with convex working edge’. Employing these two dimensions of implement morphology yielded a bewildering diversity of implement classes.

An Alternative Model
The question we pose here is whether McCarthy’s depiction of separate, morphologically discrete types is an accurate representation of the assemblage. The alternative hypothesis we offer is that differences between the various ‘scraper’ types that have been recognised in eastern Australia, and particularly in the Eastern Regional Sequence, are arbitrary divisions of morphological continuums and may be explained in terms of the extent of retouching each specimen has undergone (see Hiscock and Attenbrow in press). This model posits that morphological change occurs roughly proportional to the amount of retouching that has been applied to a flake, irrespective of whether that retouching was maintaining edges and/or generating flakes. Specimens that have received little retouch will have relatively straight retouched edges, with small retouch scars restricted to a short portion of the flake margin. In contrast, specimens that have been extensively retouched will have longer more curving retouched edges, with larger retouch scars spread along much of the flake margins. This reduction model can be tested by making a number of observations about each specimen.

In characterising implement variation at Capertee 3 McCarthy paid little or no attention to blank form. For this reason the differences between implement forms recognised in McCarthy’s analysis of Capertee 3 reflected only retouching, rather than technological differences in flake production, and therefore can be re-evaluated in those terms. McCarthy’s classifications act as though differences in retouch between classes were qualitative and discontinuous. Several measurements are employed below to determine whether the pattern of differences in the Capertee assemblage conforms to the segmented or continuum model.

Measuring Reduction at Capertee 3
We use a number of quantitative measures to evaluate the relationship of retouch characteristics and extent of reduction on the specimens that McCarthy had classified as Capertian implements. Our analysis deals with all of the specimens in the Capertian levels of the site and a sample of specimens from the Bondaian levels. Although the assemblage contains small numbers of quartz, quartzite and mudstone artefacts our analysis involves only the specimens made on ‘chert’, which is the most abundant material present. After excluding specimens that are technically cores, unretouched flakes or unmeasureable heat shattered fragments, we are left with 123 non-backed dorsally retouched flakes on which our measurements could be made. Of these 73 were unbroken. McCarthy had
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Table 1. List of the specimens employed in the analysis.

<table>
<thead>
<tr>
<th>McCarthy’s Classification</th>
<th>Complete</th>
<th>Broken</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Core</td>
<td>4</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Knife</td>
<td>4</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Saw</td>
<td>9</td>
<td>3</td>
<td>12</td>
</tr>
<tr>
<td>Scraper</td>
<td>39</td>
<td>33</td>
<td>72</td>
</tr>
<tr>
<td>Not known</td>
<td>17</td>
<td>12</td>
<td>29</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>73</strong></td>
<td><strong>50</strong></td>
<td><strong>123</strong></td>
</tr>
</tbody>
</table>

Figure 2. Illustration of a retouched flake from Capertee 3 (ESP1024, Square 9, Level G), showing the measurement of retouch intensity. The average Kuhn reduction index is calculated as \((t_3/T_3 + t_2/T_2 + t_1/T_1)/3\).

Figure 3. Illustration of a retouched flake from Capertee 3 (ESP1024, Square 9, Level G), showing the calculation of the index of retouch curvature (R3/R6).

classified these specimens into a variety of categories, including knives, cores, and scrapers, but roughly a quarter of the specimens do not retain a notation of McCarthy’s classification (see Table 1).

Dorsal retouch on these specimens is both marginal and steep. For this reason we consider that Kuhn’s (1990) index of reduction is an appropriate measure of the extent of retouching. This index takes the height of retouch scars (designated ‘\(t\)’) and divides that value by the maximum thickness of the flake transverse cross-section at the point of retouch (designated ‘\(T\)’), to express retouch height as a fraction of the possible height that could be obtained on that specimen (see Figure 2). We applied Kuhn’s measurement at three places, evenly spaced, along the longest retouched edge of each specimen (see Figure 2), and calculated the average as \((t_3/T_3 + t_2/T_2 + t_1/T_1)/3\), a value we refer to as the ‘average Kuhn reduction index’.

For the complete retouched flakes in our sample from Capertee 3 this index varied between 0.13 and 0.93 (\(\overline{\text{0}}=0.47, \text{s.d}=0.22\)). Since Kuhn’s index has the benefit of ranging between 0 and 1, it is clear that the specimens at Capertee 3 include those that had been minimally reduced as well as those that were far more highly reduced.

We take values of this index to be positively related to the intensity of retouching for reasons explored by Kuhn (1990). Furthermore, in the Capertee 3 assemblage there is a positive association between the measured index and other characteristics of retouching that could also be expected to increase as reduction proceeds. For instance, there is a strong correlation between the average Kuhn reduction index and the length of retouch on each complete specimen \((r=0.86, \text{d.f.}=69, p<0.001)\). In this regression analysis no constant is employed, thereby forcing the regression line through origin. Because the two variables being compared must both start at 0 for a flake without retouch this is the appropriate regression model. A regression with constant gives a reduced coefficient but is still significant \((p=0.002)\). This relationship holds for all dorsally retouched flakes in our sample. Hiscock and Attenbrow (in press) have established equally strong correlations between the proportion of the flake perimeter that was retouched and the average Kuhn reduction index. We suggest these relationships exist because the values of all these variables (i.e. average Kuhn reduction index, length of retouch, and proportion of flake perimeter) are higher on more heavily retouched specimens.

If this interpretation is correct, and the length of margin that was retouched increased as reduction proceeded, then at least the aspects of McCarthy’s classification that are based on the number of retouched edges are likely to vary with the intensity of reduction. We also measured the amount of retouch by recording the number of locations on which retouch occurs on the sample of complete retouched flakes. We recorded the presence or absence of retouch in eight notional sections (proximal end, distal end, and for each margin the proximal, medial, and distal thirds). Each implement could have between one and eight of these sections retouched. The number of retouched sections...
shows a strong linear relationship with the average Kuhn reduction index ($r=0.88$, d.f.$=68$, $p<0.001$), such that the extent of reduction explains more than 78% of variation in the number of retouched sections. This pattern is congruent with the hypothesis that as reduction proceeds additional sections of the flake margin are retouched. Hiscock and Attenbrow (in press) have also shown that in the Capertee assemblage the expansion of retouch around the perimeter of a flake proceeded in a regular way: often starting with blows to the distal portion of the left lateral margin and/or distal end, and spread to other sections of the flake as reduction progressed. This explains why the specimens that McCarthy described variously as side scrapers or end scrapers have low average Kuhn reduction indices.

If the proposition that increased retouching lengthens the retouched edge and involves retouching a second or third margin is correct, then it could be predicted that extended reduction may change the curvature of the retouched edge. This brings us to the second aspect of the conventional typology employed by McCarthy to describe implement variation in the Capertian: shape of retouched edges. We have developed a simple quantitative measure of retouched edge shape by a calculation ($R3/R6$) which expresses the extent of concavity or convexity of the edge in millimetres, a value labelled $R6$, relative to the distance between the ends of the retouch in millimetres, a value labelled $R3$ (Figure 3). This 'index of retouch curvature' is zero for a straight edge, negative for concave edges, and positive for convex edges. The larger the positive value the more convex is the edge. For the Capertee assemblage this index ranged from a slightly concave value of -0.11 through to highly convex value of 1.11 ($\bar{O}=0.25$, s.d.$=0.23$, $N=69$). The relationship between this index of flake shape and the extent of reduction can be evaluated through a comparison with the average Kuhn reduction index. A strong linear correlation exists between the index of retouch curvature and the average Kuhn reduction index for complete specimens ($r=0.86$, d.f.$=68$, $p<0.001$). In this analysis the extent of reduction explains more than 74% of variation in shape of the retouched edge as we have measured it. Retouch, beginning in a restricted area of one margin, typically produced a slightly concave or convex edge, but as reduction proceeded and retouching was carried out on adjacent margins of the flake the retouched edge became progressively more convex until semi-discoidal specimens retouched on three or four margins were produced. We demonstrate this in Figure 4 which plots the retouch curvature index against the number of retouched segments for each complete specimen. These measurements of the extent of retouch and the curvature of the retouched edge show a clear correlation, as calculated using Spearman's rho ($r=0.554$, $p=0.001$, $N=69$). The process of retouching at Capertee 3 is illustrated in Figure 5, which uses values predicted in the regression analyses discussed here to give an inferred interpretation of the typical morphological changes that would have taken place as reduction proceeded.

Figure 4. Scatterplot of the relationship between shape and extent of retouch, as measured by the index of retouch curvature and the number of retouched sections on each complete specimen.

Figure 5. Illustration of typical reduction continuum inferred at Capertee 3: (A) Curvature Index of 0.15 and Reduction Index of 0.38, (B) Curvature Index of 0.27 and Reduction Index of 0.65, (C) Curvature Index of 0.38 and Reduction Index of 0.74, and (D) Curvature Index of 0.57 and Reduction Index of 0.92.
We therefore conclude that variation in the location of retouch and the shape of retouched edges is largely explicable in terms of the extent of reduction. Since shape and extent of retouch is the basis McCarthy used in classifying implements into different types this inference reveals that the difference between many of the McCarthian types merely reflects different levels of reduction.

**Evaluating the Continuum Model at Capertee 3**

Showing that variation in non-backed implement morphology is a consequence of reduction implies that a single specimen might change its shape during retouching in such a way that a typologist would classify it as one type early in its reduction history but as a second or even third type later in its reduction history. If a collection of specimens were progressively transformed from one typological category into another it is predicted that we would often observe a series of intermediates. In that way the reduction of specimens could produce an unbroken range of morphological variation, creating an assemblage pattern that would conform to the ‘continuum’ model as we have defined it.

Continuous variation can be demonstrated by univariate analyses. For example, in Figure 6 histograms show the continuous distribution of observed values for both the average Kuhn reduction index, and the index of retouch curvature. These distributions are flat or unimodal and reveal no basis for imagining breaks in the morphological range that would signify discrete groupings.

The continuous nature of these observations can also be observed in bivariate plots. For example the relationship between the index of retouch curvature and the average Kuhn reduction index is shown in Figure 7. The image reveals a continuous distribution of data points, with any minor gaps explicable simply in terms of low numbers of observations. The absence of identifiable clusters and the continuous array of data points are evidence that, contrary to traditional conclusions about Capertee 3, the assemblage is not composed of a number of discrete types. Instead we have shown that the non-backed retouched flakes form a continuous morphological series created by different degrees of working between different specimens.

**Conclusion**

We have shown that at Capertee 3 non-backed retouched flakes form a morphological continuum that reflects variations in the amount of reduction between specimens. This is not an observation that the typological system previously employed had been capable of making, because typological practice is built on the presumption that artefactual variation will inevitably display a segmented pattern. The demonstration that the Capertee 3 assemblage displays continuous variation has implications for artefact analysis at this site and elsewhere in Australia. Analyses of assemblages can no longer assume that a segmented model appropriately describes the fundamental pattern of morphological variation. Researchers aiming to identify and explain the nature of artefact variation should not continue to use conventional typological classification as though this was necessarily the appropriate, or even the only, analytical practice.

Australian archaeologists concerned with lithic variability should be aware that a fundamental question about assemblage composition and artefact variation is whether in any particular region or assemblage morphological variation takes the form of a segmented, continuum, or even composite model. The results presented here for Capertee 3 reveal the falseness of justifying typological practice by claims that the types measure patterns in the archaeological assemblage. At Capertee 3 we have demonstrated that McCarthy’s typological divisions were in fact arbitrary divisions in continuous reduction-related morphological variation. The application
Figure 7. Scatterplot of the relationship between a measure of reduction intensity (the average Kuhn reduction index) and a measure of retouch curvature. Solid data points are complete specimens; unfilled circles are broken specimens. The shaded area envelopes the morphological space defined by complete specimens.

of a standard typological classification to any assemblage cannot establish the location or absence of breaks within a morphological range, because by definition such classificatory practice imposes standard boundaries between classes which may or may not reflect the patterning present in any assemblage. Standard typologies are therefore incapable of measuring the presence or absence of morphological breaks in many assemblages, even though that is the very purpose for typological analyses.

It is for this reason that archaeologists such as Dunnell (1986) have advocated a study of variation rather than modalities in artefact assemblages, what is called a population-oriented analysis. Such a population-oriented approach to measuring morphological variation avoids the presumptions inherent in archaeological typologies by providing a means of studying the magnitude and direction of difference between specimens without making presumptions about the discreteness of the classes, their design characteristics or their functional roles. For that reason a population-oriented analysis of attributes allows the analyst to determine whether segmentary or continuum models describe the pattern in any given assemblage. Such an approach is the basis for the analysis we have presented here and we recommend it to other researchers concerned with the exploration of variation within and between archaeological assemblages.

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