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Measuring core reduction using 3D flake scar density: a test case of changing core reduction at Klasies River Mouth, South Africa

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ABSTRACT

A new core reduction index is presented, calculated as the ratio of flake scar number to 3D surface area (SDI). The index is tested experimentally on five types of core (blade, discoid, Levallois, biface and multiplatform cores) and then applied to the core assemblages from five sub-stages of the Middle Stone Age at Klasies River Mouth, South Africa. Preliminary results indicate that the SDI possesses the desirable attributes of a successful reduction index and is a significant improvement on traditional proxy measures of core reduction. The results of the archaeological case study confirm previous untested observations that cores from the Howiesons Poort and MSAIII sub-stages are more heavily reduced than preceding and following stages, and that local and exotic raw materials as well as different types of cores are all more heavily reduced during these periods. The SDI fills a significant lacuna in available core reduction measures.

1. Introduction

A number of measures of retouch intensity have been developed and tested over the last two decades (Barton, 1988; Blades, 2003; Braun et al., 2010; Clarkson, 2002; Clarkson and Hiscock, 2008, 2011; Dibble, 1984, 1987, 1995; Dibble and Pelcin, 1995; Dibble and Whittaker, 1981; Eren et al., 2005; Eren and Prendergast, 2008; Eren and Sampson, 2009; Gordon, 1993; Hiscock and Clarkson, 2005, 2007, 2009; Hiscock and Veth, 1991; Holdaway et al., 1996; Kuhn, 1990; Pelcin, 1997a, 1997a, 1997b, 1997c, 1998; Shott et al., 2000), with several becoming standard measures in certain forms of lithic analysis (e.g. Kuhn, 1990; Clarkson, 2002; Dibble, 1995). Attempts to measure flake reduction through retouching have been quite successful, generating techniques capable of measuring different kinds of reduction on the lateral margins (Kuhn, 1990; Eren et al. 2005), on one or both faces (Clarkson, 2002), on the distal end (Hiscock and Veth, 1991; Blades, 2003; Morrow, 1997), and so on. More holistic measures of flake reduction from platform characteristics have also been trialled and show promise (e.g. Clarkson and Hiscock, 2011; Pelcin, 1997a,b,c; 1998; Dibble and Whittaker, 1981; Dibble and Pelcin, 1995; Dibble and Rezek, 2009; Shott et al., 2000). While no existing measure of flake reduction intensity is truly applicable to all retouched flakes in all assemblages, the field of lithic analysis is now replete with measures of retouch intensity to suit a range of different assemblage types.

Measures of core reduction, on the other hand, are largely unsystematic and have not been tested across a range of raw materials and core reduction strategies. Analysis of core reduction currently tends to employ variables such as core to flake ratios, the proportion of remaining cortex on flakes and cores, the number of flake scars present on a core, number of platforms or rotations, core size or mass, platform angles, and more, with each measure assumed to reflect the amount of mass removed and the degree of shaping or effort expended in reduction (Dibble et al., 2005; Lin et al., 2010; Marwick, 2008). While such characteristics may provide a relative measure of core reduction in some instances, and may become more powerful when used in combination, they are yet to be tested under controlled experimental conditions. Their suitability as holistic measures of core reduction is therefore uncertain and in some cases questionable. It is not difficult to imagine scenarios where such measures would be misleading. For example, such instances might include situations where:

- scar numbers increase or decrease cyclically over the sequence of reduction as large or small flake scars are added,
- where the loss of exterior cortex halts despite reduction continuing, such as the underside of a recurrent Levallois core,

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- where nodule size is highly variable or cores start and end small due to small nodule size.

In such cases, unreliable results are likely to be obtained as scar numbers may rise and fall, cortex proportion may quickly fall to zero or remain constant throughout much of the reduction sequence, and mass may show no consistent trends in relation to reduction. Thus, while a range of potentially useful measures of core reduction exist, it is uncertain to what degree they are robust and broadly applicable (see Hiscock and Tabrett, 2010).

Recent work on assessing levels of core reduction and transport at the assemblage level was undertaken by Dibble et al. (2005), and subsequently refined by Lin et al. (2010) with the use of 3D scanning, to derive an index of assemblage level core reduction. This method calculates the difference between expected quantities of cortex as determined from solid geometry, versus observed quantities of cortex measured on artefacts in an assemblage. This can then be used to determine whether cortex is under- or over-represented as may occur when products are taken away or brought to the site. This method has made important progress in assessing raw material reduction and transport, but it does not provide a means of determining how reduced any particular core in an assemblage is – a measure that is here developed for the first time.

This paper presents a new measure of core reduction that is suited to the estimation of the mass lost from any core through freehand percussion. The technique employs the ratio of the number of flake scars on a core to its surface area as the measure of reduction. The index employs the relative increase in the density and coverage of flake scars as core surface area decreases as the measure of size reduction. A similar index has previously been proposed as a measure of biface reduction (Shipton, 2011, 2013). Here it is extended to all cores, it is measured more accurately, and its efficacy is experimentally tested. This index is hereafter referred to as the *Scar Density Index*, or SDI. It is anticipated that as core mass and surface area decrease, the ratio of flake scars will increase.

To test the accuracy and versatility of the SDI as a measure of the proportion of core mass lost, an experiment was performed in which whole stone nodules were reduced using five different core reduction strategies. The SDI was calculated at various points in the reduction sequence until each core was exhausted. The index was then compared to the proportion of mass lost from each core to determine how much variation in core mass could be explained using the index. The general approach to experimentation and testing followed that of Clarkson (2002), Clarkson and Hiscock (2011), and Hiscock and Clarkson (2005) whereby index increase was tracked against reduction in mass from the original piece. The performance of the index as a measure of proportion of mass lost was compared to the performance of several conventional measures of core reduction for the same population of experimental cores. These include proportion of cortex remaining, number of scars present, core mass, and the proportion of scars with non-feather terminations (Clarkson and O'Connor, 2006).

Size-adjusting core surface area by volume also generates a second index that is a useful means of assessing core shape that is essentially a measure of compactness. This index is employed to test the sensitivity of the SDI to changes in core shape as each core is reduced.

Three-dimensional analysis of lithics is becoming increasingly popular as archaeologists seek to capture the complexity of stone artefact morphology as well as create virtual archives (Braun et al., 2010; Bretzke and Conard, 2012; Grosman et al., 2008; Lin et al., 2010). This movement takes advantage of the low cost, high performance and portability of commercial desktop scanners now available to researchers.

2. Materials and methods

2.1. The reduction experiment

Twenty-five whole stone cortical nodules of different starting shapes were knapped by the author to the point of exhaustion using five different reduction methods (i.e. five cores for each technique). Exhaustion was defined as the inability to remove flakes longer than 2 cm after ten flake detachments. The reduction sequence usually ended when cores became too small to yield flakes of this size, or step terminations prevented further successful flake removals. This equated to an average final core mass of 13 ± 6 g, or $4.2 \pm 3\%$ of original nodule mass. Nodules varied greatly in initial mass, ranging from a minimum of 161 g to a maximum 5023 g, with a mean mass of 1008 ± 961 g. There was no deliberate selection of nodule shapes or sizes for each reduction sequence. All cores were knapped with an 8oz copper bopper. A copper bopper was employed as it is durable and easy to use and the copper head is of intermediate hardness between a soft hammer (e.g. antler) and a hard hammer (e.g. quartzite).

The core reduction strategies employed in the experiment include blade, Levallois, discoidal, multiplatform and biface reduction. Several raw materials were used in the experiment to determine whether grain size and toughness significantly affected the results. The raw materials used were flint, obsidian and quartzite. The method followed for each reduction sequence were as follows:

Blade – A single platform was made at one end of the core, either through removal of a large flake or by faceting, and elongate flakes were struck either around the entire perimeter of the platform, or from one portion of the circumference. Cresting was rarely used to initiate blade removals, but ridge straightening was occasionally employed during the reduction sequence. Occasionally a platform was created on the opposite end to the main platform from which to strike one or two flakes back up the core face to straighten ridges or remove step terminations.

Levallois – Levallois reductions followed a pattern of centripetal flaking of the upper core face with alternate flaking of the lower surface to create lateral and distal convexities on the upper core face (Boëda, 1995). Once convexities were present, a strong, faceted platform was prepared at one end of the core and a flake running more than 60% the length of the core was struck from this platform from the upper surface. The lateral and distal convexities were then re-prepared, a new platform created, and another large flake struck from the upper surface. Cores were typically scanned after each successful Levallois removal.

Discoidal – For discoidal cores, an upper and lower surface was created and continuously flaked via alternating centripetal removals from each surface, creating a peaked conical surface on each hemisphere. Platforms were not faceted and detached flakes often had dihedral or trihedral platforms.

Multiplatform – Cores were constantly rotated after a few flake removals taking advantage of any available area of high potential mass with an appropriate flat striking platform and platform angle less than 90°. Cores at first resembled jagged, angular pieces, but later become increasingly spherical as fewer platforms yielded viable flakes and step terminations accumulated on many surfaces. Final core forms often resembled 'polyhedrons'.

Biface – Cores were flaked on two faces to create a thin, oval or tear-drop shaped biface by alternating the removal of invasive flakes from each surface. Platforms were sometimes faceted or ground and many characteristic thinning and bending flakes were produced over the sequence of reduction.

Cores were weighed and scanned after each $25 \pm 12\%$ of mass was removed. Nodules were scanned with a NextEngine^{tm} HD