Experimental Stone Tool Replication at the Early Stone Age Site of Sterkfontein, Gauteng, South Africa.

John McNabb. Department of Archaeology, University of Southampton,
Southampton United Kingdom, SO17 1BJ. E-mail - scarab@soton.ac.uk.
Telephone +44 (0)23 8059 3178. Corresponding author.

Kathy Kuman. Room 222 Origins Centre. University of Witwatersrand, 1 Jan
Smuts Avenue, Braamfontein 2000, Johannesburg, South Africa. E-mail -
kathleen.kuman@wits.ac.za. Telephone +27 (0)11 717 1000.

Abstract.

Between 1999 and 2000 a large experimental knapping programme was carried out at the early hominin site of Sterkfontein, South Africa. Its purpose was to assess aspects of the technology of lithic production found in the Oldowan and Acheulean deposits at the site. The data was used to inform technological analysis of the Sterkfontein stone tool assemblages. In the light of more recent research on raw material selection and transport at East African Oldowan sites, we report on the conclusions drawn from the analysis of the experimental cores to assess their contribution to understanding the influence of raw materials on knapping in the Oldowan and Acheulean at Sterkfontein. Hominins practised raw material selectivity and adapted their knapping strategies to fit clast shape and lithology. The experimental programme offered the opportunity to analyse some of the variables commonly involved in reconstructing lithic behaviour from artefacts and found, as with other studies reported elsewhere, that linear relationships based on one, or a few supposedly diagnostic variables do not stand up to scrutiny.

Keywords

Knapping, Stone Tools, Oldowan, Acheulean, Sterkfontein, experimental, Early Stone Age, cores

1.0. Introduction.

Sterkfontein is one of a series of sites from the Cradle of Humankind World Heritage Site in Gauteng, South Africa (Kuman, 2007). Currently it is one of the best dated Oldowan and Early Acheulean localities in South Africa (Clarke, 2006; Granger *et al.*, 2015; Herries and Shaw, 2011; Kuman and Clarke, 2000), and has the largest Oldowan assemblage yet recovered from this region (Kuman and Clarke, 2000; Kuman and Field, 2009). The Oldowan was excavated from Member 5 east breccia (Oldowan infill). The Acheulean was excavated from two locations, the Member 5 east Acheulean, overlying the Oldowan infill, and Member 5 west breccia. The Oldowan has been recently re-dated to 2.18 mya and the Acheulean is currently dated to 1.7-1.4 mya (Granger *et al.*, 2015; Kuman, 2007). Detailed stratigraphies and descriptions of the lithic assemblages are provided elsewhere (Field, 1999; Kuman, 2007; Kuman and Clarke, 2000; Kuman and Field, 2009; Kuman *et al.*, 2005; Stratford *et al.*, 2012).

2.0. The experimental knapping programme and its research aims.

Between 1999 and 2000 a large knapping programme was instigated in order to explore aspects of the relationship between the raw materials used at the site and the knapping techniques involved in producing Oldowan and Acheulean cores and flakes. These data contributed to technological analysis and description of the Sterkfontein assemblages published elsewhere (Kuman and Field, 2009; Kuman *et al.*, 2005).

More recently, the notion of the Oldowan as having been an industry that heavily exploited mostly local raw material resources has been significantly challenged by increasing evidence for the careful selection and transport of specific raw materials over considerable distances (Harmand 2008), as well as a greater selection of specific local raw materials closer to sites. These behaviours have a considerable time depth – from as early as 2.34 mya at Lokalalei, West Turkana, Kenya, and only slightly later elsewhere (Harmand, 2008; Braun 2012), well within the range of time covered by the Sterkfontein Oldowan assemblage.

The raw material used at Sterkfontein was collected locally, from the slopes of the valley in which the site is located and along the banks of the Blauubank stream. Given the perspective emerging from East Africa, the authors felt it timely to assess what contribution Sterkfontein could make to this debate and

aimed to assess what insights the experimental programme could offer in this respect.

Three experienced knappers and ten people with varying levels of experience¹ knapped 190 manuports (clasts from the river and slopes adjacent to the Sterkfontein site and labelled by us as manuports), producing 190 cores. Here we will concentrate only on the core data. The detached pieces/flake data have been reported elsewhere (Kuman and Field, 2009; Kuman *et al.*, 2005). Some manuports failed to result in a core and some produced more than one core. Following the interpretation of knapping technology at the site (Field, 1999), both freehand percussion and bipolar technique were replicated in the two main lithologies recovered from the archaeological samples, quartz and quartzite. We followed a non-targeted approach to core working. This meant that we did not knap with a given core shape in mind.

The hominin knappers at Sterkfontein produced a range of flake sizes, from the archaeologists' arbitrary minimum size for a flake of 20 mm maximum length (below which it is considered a chip) up to 63 mm for quartz and 75 mm for quartzite in the Oldowan, and up to 73 mm and 92 mm respectively in the Acheulean. We replicated this range, though in the upper register, our flakes

were larger than the archaeological examples – up to 127 mm for quartz and 148 mm for quartzite.

The original aim of our experiments (in 1999/2000) was to provide flakes suitable for use as unretouched knives or as blanks for further retouching, as these were considered the goals of the Sterkfontein knappers. The experimental knappers were told to stop knapping when a platform was no longer able to produce large enough flakes for this aim (a subjective call), or could no longer sustain a run of flakes. At this point the knapper started again on another platform. In this paper we have co-opted our data to explore a new research question. As one reviewer to this paper pointed out, very appropriately, this rationale for core reduction is not necessarily the best for the research aims we set here. We acknowledge this freely. However, the Oldowan and Acheulean cores were knapped for flakes which were to be used in a variety of situations, as possibly were the edges on some of the cores. Size and suitability would have been two of the criteria uppermost in the Sterkfontein knappers' minds'. We maintain that specifics of research design notwithstanding, the experimental data is appropriate for the research question we pose. Cores were flaked primarily by alternate and parallel flaking, and episodes of single removals (McNabb, 2007) as seen in the Sterkfontein archaeological core assemblage. All cores were an accumulation of such platform flaking episodes.

In terms of the research aim stated for this paper, five research questions were asked of the experimental data for flaked pieces.

1. Are there any grounds for believing that the manuport choices made by the experimental knappers were similar to those made by the hominins at Sterkfontein?
2. What influence does raw material have on a) the basic knapping strategies applied to core reduction (i.e. bipolar vs freehand) and b) the final core forms?
3. What influence does a) manuport shape and b) technique of knapping have on final core production/form?
4. Given a non-targeted knapping strategy, what does experimental knapping tell us about core form – does it become fixed at some point in the knapping and if so, is this early or late?
5. What insights can experimental knapping provide on reduction intensity in core flaking?

3.0. Results.

3.1. Manuports.

Manuport are defined as:

“...exogenous pieces of stone raw material that show no sign of artificial chipping or use” (Potts 1988, 235)

Lithology, shape, and context, either separately or together, assist in the identification of a manuport. There are 10 certain and 3 possible manuports in the Oldowan from Sterkfontein (Kuman and Field, 2009), and 208 in the Acheulean breccia (Field, 1999). Manuports may be brought to a site for a number of reasons, raw material for knapping is only one of them. Our assumption here is that the majority, particularly the larger, were brought with the intention of being used to knap, but we acknowledge that there may have been other reasons for transporting stones to the site.

3.1.1 Manuport shape.

Following standard geological practice (Thornes, 1979), a selection of pebbles ($\max L \leq 64 \text{ mm}$, $N=8$) and cobbles ($\max L = 65\text{-}256 \text{ mm}$, $N=180$) of varying shapes and sizes were chosen for the experimental programme. Clast selection was made by experienced knappers as well as non-knappers who were told to

collect any quartz and quartzite clasts which were bigger than a tennis ball. This gave us a range of sizes as in the archaeological sample. The quartz clasts were picked up during field walking of the slopes between the Sterkfontein site and the nearby Blauubank river. The quartzites came from the river bed and its banks. They were all classified according to the shapes of manuports in the archaeological samples (Field, 1999; Kuman, 1996). These were as follows:

- blocky angular
- blocky rounded
- rounded polyhedron
- split cobble
- tabular disc
- wedge

The experimental manuports were either flaked by bipolar (direct anvil technique) or by freehand percussion, reflecting the two knapping techniques used by hominins at the site (Field 1999). The majority of the freehand experiments were carried out before the bipolar ones. The main criterion for choosing a manuport for this technique was that it could sustain a *sequence/run* of detachments. The basis of assessing whether a manuport was suitable for

this was the presence of a flat or nearly flat surface which could sustain a number of sequential blows with the hammer stone. This introduced a bias of which we were not conscious when we were knapping. It was only later when examining the data that a pattern began to emerge. For the freehand experiments, the knappers chose the larger cobbles, influenced by the need to initiate runs of flake removals. So the manuport sample for the bipolar experiments was slightly biased toward smaller cobbles before the experiments began.

Table 1 shows the relationship between manuport shape, raw material, and method of flaking in the experimental data. Clearly the blocky forms predominate, along with the wedge shape in the freehand quartzite experiments. From a knapping perspective, especially in terms of freehand percussion, the choice of blocky forms and wedges makes good sense since these shapes provide a minimum of one flat face with an angled edge from which to initiate flaking.

However blocky shapes are not necessary for the bipolar method, so why did the knappers choose them? Blocky forms occur more frequently in the modern Blauubank River gravels than any other clast shape (Kuman, 1996). Once the larger clasts had been selected for freehand knapping, the remaining sample was still dominated by blocky shapes. The low frequencies for the other

manuport shapes reflects the use of less common cobble shapes once the more frequent ones had been used up.

As in the experimental data, the Oldowan manuports are predominantly blocky in shape, with the blocky rounded form being the most common (N=6), however frequencies are very small (tabular disc = 2; blocky angular = 3, rounded polyhedron = 1; 12 Oldowan manuports in all. The same is true for the 208 manuports in the Early Acheulean assemblage: 51% were blocky rounded, 27% were blocky angular, 9% were rounded polyhedral, and the remaining 12% were distributed across other types (Field, 1999). One difference between the larger Acheulean manuport sample and the experimental one was the much lower number of wedge shaped clasts (<3%) in the Acheulean.

3.1.2. Manuport size.

For the experimental sample, this was determined by a simple formula: volume = $(L \times W \times Th) / 10,000$. The correction factor of 10,000 was arbitrarily chosen to reduce the resulting index to an intuitively more understandable number. These data are presented in figure 1 and in the summary data in the middle section of

table 1. In retrospect we should have chosen weight as a more sensitive measure (Kimura, 1999; Kimura, 2002).

The data show three trends. Firstly, the range of quartzite manuports is on average bigger than that for quartz and this applies to the experimental data as well as the Oldowan and Acheulean data. Secondly the manuports chosen for the freehand percussion experiments were on the whole larger than those selected for the bipolar experiments.

These were the data that revealed the size bias in the freehand experiments noted above. Thirdly, and in general, the larger a manuport was, the larger its core was likely to be (figure 1 $r^2=0.5651$), though as the figure and correlation coefficient shows, there were many exceptions to this. Much of this difference is likely to be accounted for by the more brittle character of quartz which is prone to shatter.

The answer to research question 1 is as follows. From the above data it is not unreasonable to suggest that the pebbles and cobbles from the modern Blauubank river and its slopes are similar in shape and size to those used by the Sterkfontein knappers in the Early Pleistocene. They were likely collected from the same locations. It is entirely possible that the same choices were being made since they reflect the basic constraints these raw materials place on

knapping. Size wise, the same distributions in raw materials are present in the experimental manuports as in the archaeological ones. We believe the hominins at the site were carefully selecting raw material in terms of its nascent properties as they perceived them - in particular the presence of flat faces from which to initiate flaking. This type of raw material selection has been noted at other Oldowan sites as well (Blumenschine *et al.*, 2008; Braun *et al.*, 2008a; Goldman-Neuman and Hovers, 2008; Harmand, 2008). The presence of casual cores (cores with one or two flakes detached, Kuman and Field, 2009) in the Oldowan and the Acheulean assemblages have been interpreted as ‘testers’, where the suitability of a block has been assessed by a few detachments.

3.2. The influences of raw material, knapping strategies, knapping technique and manuport morphology on core production and core shape

Experimental replication studies offer a unique opportunity to observe the interplay of these variables. The following core shapes were identified in the experimental data set. They reflect the categories of core shape noted in the Oldowan and Acheulean assemblages at Sterkfontein. These have been described in detail elsewhere (Field, 1999; Kuman, 1996; Kuman and Field, 2009)

- Casual cores (≤ 2 scars)
- Chopper-cores
- Discoidal cores
- Single platform cores
- Irregular polyhedrons
- Polyhedrons
- Shattered cores
- Bipolar cores
- Irregularly fractured pieces

Strictly speaking, the inclusion of bipolar cores as a separate shape category conflates method of flaking with morphology. Core shape was not recorded for the bipolar cores; they were noted as either whole (i.e. bipolar core) or broken (shattered). The data are presented in tables 2 and 3.

The first significant point to note is that virtually all the core shapes occur in quartz and quartzite (table 2), and they reflect the full range of core shapes noted at other Oldowan and Early Acheulean sites (Isaac and Isaac, 1997; Leakey, 1971). The totals for chert and igneous lithologies are too small for comparison. As products of non-targeted flaking, our experiments fully confirm the interpretations of Nick Toth (Toth, 1985) that these particular core

shapes can arise automatically during flaking, a conclusion supported by other experimental knapping programmes (Braun *et al.*, 2008b; Braun *et al.*, 2005).

The absolute frequencies between different experimental core shapes in quartz and quartzite differ considerably (table 2), but this is not surprising since in our experiments the decision to stop flaking was taken when further runs of flakes were not possible. It is worth emphasising here that by run we mean a series of detachments from one platform, which when exhausted, is abandoned in favour of another platform which can sustain another sequence/run. Under these circumstances core shape would naturally vary from manuport to manuport. Re-run the experiments and totally different frequencies would occur, but the full range of shapes would still be created in both rock types.

These data answer our second research question - at a general level, lithology does not affect core form or the knapping strategy (bipolar vs freehand).

Since raw material did not influence core production/core shape, did the shape of the original manuport have an effect? Table 3 clearly indicates that the four most frequently occurring manuport shapes (blocky angular, blocky rounded, tabular disc, wedge shape) could be successfully transformed into each of the major core forms, so the overall signal from these data is clear. There is no particularly strong relationship between manuport shape and core morphology at the level of *broad* controlling factors. Interesting in this respect is the

background spread of core shapes occurring as just one or two examples distributed across the remaining manuport shapes. These are important as they demonstrate the *potential to produce any core shape on just about any manuport shape* and fully supports the conclusion that there is no consistent one to one relationship between the two.

Nevertheless there are a few practical limitations to this potential. They are not evident in the quantitative data but were clear in the qualitative observations made by the experimenters during knapping.

While manuport shape does not directly control core shape following a non-targeted approach, nevertheless manuport shape can (but not necessarily always) channel the knapping along certain directions that makes some core forms *less likely* than others. This could be termed a *passive influence* on core shape. It would be very difficult (although not impossible) to end up with a discoid or a single platform core from a manuport that was a rounded polyhedron if the knapper was following a non-targeted approach. The same would apply to a discoid whose parent manuport had been a split cobble. On the other hand a chopping tool is easily made on almost any form.

Although the majority of the original clast shapes for the archaeological cores are often indeterminate, over one-third can be identified as blocky rounded and blocky angular (Field, 1999), reflecting the predominant shapes naturally present in Blauubank gravels. Table 2, which shows the range of archaeological core forms at Sterkfontein, provides support for the experimental conclusion that raw material type did not dictate core form. Although polyhedral and irregular polyhedral cores dominate, the full range of types is present in the archaeological sample, as it is in the experimental one.

So, in answer to the second part of the second research question, and the first part of the third research question, while manuport shape and rock type do not control core shape, they can impose a subtle influence rendering the occurrence of some core shapes less likely than others when a non-targeted strategy is followed.

The data for the relationship between core shape and knapping technique on experimental cores are presented in table 4.

From the table it is quite apparent that knapping technique does have a relationship with final core shape. Chopper-cores and discoids are strongly associated with alternate flaking, and single platform cores (McNabb, 2007;

McNabb, 2009) are more commonly found to have been worked by parallel flaking (although the total is small). On the other hand, polyhedrons and irregular polyhedrons were capable of being made by the application of diverse knapping techniques, and their morphologies were very often a result of the overprinting of numerous runs of flake detachments resulting from the application of different knapping techniques (personal observation JM).

Despite some small sample sizes, these results confirmed our intuitive predictions for the basic relationship between knapping technique and these core forms based on observations made at the time of knapping. The knapped edges of chopper-cores and discoids share a similar morphology, a result of alternate flaking *applied in the final phase of working*; a discoid is the extension of alternate flaking from one part of a blank (chopper-core; de la Torre and Mora 2005) to form a fixed perimeter around all or most of the core. The two polyhedral shapes can be a result of any knapping technique, or any combination of techniques. However, alternate flaking by itself is not usually predominant.

In answering the second part of research question 3 our data suggests that knapping technique does influence some final core shapes, but not others. This too can be taken to be a passive influence as opposed to a broader controlling

factor. This is because it is important to recall that the interpretable knapping sequence on a core is only that which was applied in the final stages of its working. It does not necessarily apply to the whole life history of the core. This is significant in the light of the data presented in the next section.

3.3. How quickly did the cores attain their final shape?

After every five blows (i.e. attempts at flake detachments irrespective of whether or not a flake was detached) the shape of the core was recorded. This established the possibility of tracking changes in core morphology, for each core, as knapping progressed. Table 5 provides data on how quickly in the knapping process cores achieved their final shape. There is no consistent pattern in these data. For example, the largest totals for chopping tools imply they achieved their shape within 15-20 blows, while irregular polyhedrons achieved their shape somewhat earlier, most often within 10 blows. Many variables will affect these data, with manuport size and the size of the removals being two important ones; particularly important will be the knappers decision on when to stop knapping.

In regard to core shape, the experiments made one aspect of flaking very clear. When a core did undergo a change in shape, it could radically change its

morphology within the space of just 5 removals (or less). This is why we see the drift in typological shape for some cores as shown in table 6. These data have important implications for other experimental studies. As noted earlier, Toth (Toth, 1985) asserted that final core form was a reflection of the point at which a knapper stopped flaking (for whatever reason). Braun and colleagues found this with their own replication experiments (Braun *et al.*, 2008b; Braun *et al.*, 2005; Braun *et al.*, 2006). Our data fully supports this by showing that for those cores where shape was not fixed early (i.e. in the first 5 blows), the core could drift through a series of shape variations which are the result of the knapper responding to the changing configuration of platform suitability and availability, and the relationship of these with the flaking face. In that our knapping experiments were non-targeted, these data concur with previous experimental programmes (*ibid*) in suggesting that even the most visually distinctive core shape need not imply preconceived design.

Toth (*ibid*) noted that in some of his experiments there was a progression through a series of logically related forms (i.e. chopping tool to discoid etc.; de la Torre and Mora 2005). While we did note this to occur, our experiments also noted that the relationships could be more fluid. For example in table 6 in the polyhedron group, one core began life as a single platform core, shifting to a chopper core, then becoming an irregular polyhedron before finally ending up as a polyhedron. Table 6 makes another very important point. For the majority

of core forms and individual cores, chains of shape variation only involved a few changes; for example of the 10 chopper cores in this aspect of the analysis, only one undergoes more than two changes of shape.

It is not possible to forge a direct link between the experimental data in tables 5 and 6, and the archaeological core forms presented in table 2. This is because no evidence of the drifting core shapes now remains for the latter. Only extensive refitting could achieve this. However, any non-targeted knapping of manuports, following freehand percussion which employs alternate, parallel and single detachment techniques, will automatically produce the core shapes noted in the experimental work.

The answer to the fourth research question is as follows. Following a non-targeted approach to core flaking, cores may achieve their final form after a few blows or after considerable working. They may undergo a series of shape changes before final shape is fixed. Those which achieve their final shape early on may reflect one knapping technique, but caution should be employed as this is not always the case.

3.4 Reduction intensity - core size, flake scar size, flake scar frequency and cortex.

The knapping programme at Sterkfontein offered the opportunity to explore aspects of lithic analysis often employed in reconstructing hominin tool behaviour from archaeological assemblages. These four variables are sometimes presented as indices of reduction intensity on cores. The smaller the core and the smaller the length of its scars, or the smaller the core and the higher its flake scar count, the more a core has been worked. The amount of cortex remaining on the core is often cited as a further measure of reduction intensity. Here we will focus on only one aspect of these debates, the relevance of these indices in relation to the size of the core as a measure of volume loss during knapping.

Core size alone would not be taken as an indicator of reduction intensity. Small cores may have started from smaller blanks, may be affected by raw material character, and even allometric considerations – small solids lose volume more quickly than larger ones. It is whether indicator proxies of core reduction can adequately explain core size that is being tested here. An advantage of experimental replication is that it allows us to calculate the quantity of volume lost during the process of knapping a core. This very precise measure of core reduction intensity is only possible in experimental situations (though extensive refitting would come a close second). This allows us to robustly test some of

the variables that are normally associated with core size and used in assessing core reduction intensity. To calculate volume loss, the volume of the core was calculated as a % of the volume of its original manuport, and this figure was then subtracted from 100 to give an index of how much of material was lost during the knapping (e.g. if manuport volume = 280.04, and core volume = 98.70, then core volume as a % of manuport volume = 35.24%, therefore volume lost = $100 - 35.24 = 64.76\%$).

Beginning with scar length, when maximum flake scar length in millimetres (on the longest scar on the core) was plotted against volume loss there was a slight negative trend to the data – see figure 2. Those cores which experienced the least volume loss had rather longer scars, and those which experienced more reduction had correspondingly shorter scars. This would conform to the expectation noted above. There was also a difference in size range when the two raw materials were compared together. However the data cloud is very dispersed (r^2 of 0.136, $N=114$) suggesting that from these data predicting reduction intensity from core size-scar length would not be particularly reliable. On a core by core basis an intensely reduced core is as likely to have a large scar as a smaller one. The frequency for bipolar cores was too low for meaningful analysis

A similar result was obtained when comparing scar frequency with volume loss. In Figure 3 the two data sets have been log transformed in order to increase the parity between the two types of data. The figure shows a general positive linear trend with increasing loss of volume accompanied by a greater frequency of flake scars, as might be anticipated. However the relationship is a very weak one (r^2 of 0.005, $N=114$) as the dispersal in the data cloud suggests. While quartz experiences more volume loss on average than quartzite, probably because of its more brittle character, freehand cores in either lithology are as liable to have a low scar count, as they are a high one. Bipolar cores were omitted as above.

The use of manuport volume loss as a measure of knapping intensity provides an insight into the conclusions drawn from the previous two figures. This is shown in figure 4, where core volume is compared with the volume loss experienced by the manuport during the knapping process. The slight negative correlation implies that smaller cores experience greater volume loss during knapping, but once more the relationship is a very weak one (r^2 of 0.221, $N=114$).

However, as the degree of dispersion of data points in the data cloud in figure 4 indicates, smaller cores are as liable to have experienced less intense reduction as they are to experience a lot of it. From a knapping perspective this reflects

our strategy of stopping when a platform could no longer sustain removals and moving on to another one rather than working the core into total exhaustion. This is the underlying explanation for the consistency of the signal in figures 2 and 3 and strongly implies that *where a strategy of flaking for sufficient flakes is being employed* (as opposed to knapping to exhaustion), flake scar size and frequency cannot always be taken as reliable indicators of knapping intensity.

Cortex was recorded using the common categorical system of assigning an artefact to a percentage category (in this case 0%, 1-25%, 26-50%, 51-75%, 76-100%). Opinions vary as to the reliability of this system of recording (see Braun *et al.* 2008 and references therein). The frequencies for bipolar cores were too small to be meaningful and analysis concentrated on the free hand quartz and quartzite data.

There is an evident difference between the two raw materials present in Figure 5, so the first conclusion here is that lithology influences cortical retention as it did for volume loss, quite possibly for the same reasons. The similarity in the boxplots for the quartz data suggested that no significant difference was present between the different categories of cortex retention on the cores and the amount of volume they had lost during flaking. A Kruskal-Wallis test

supported this (Kruskall-Wallis test for independent samples, $N=57$, statistic=5.489, $df=3$, $p=0.139$).

The pattern in the quartzite data looked more promising as a reflector of reduction intensity, figure 5. As the intensity of working increases, so does the median and interquartile range for cortex loss. However, as the boxplot makes very clear there is a lot of overlap in the respective distributions, suggesting that within individual categories of cortex retention, cores are likely to have been subjected to varying levels of reduction intensity. T-tests comparing the volume loss distributions between adjacent cortex categories found no statistically significant differences between 0% and the 1-25% categories; 1-25% and 26-50%; 51%-75% and 76%-100%; there was a slight significant difference between 26%-50% and 51%-75%, but the significance was a low one (data not presented).

As with the other two predictors of reduction intensity, cortex may reflect reduction at a very general level, but when applied as a specific predictor it breaks down on a core by core basis for cores knapped following a non-targeted approach.

Our answer to research question 5 then is as follows. The Sterkfontein knapping experiments do present some interesting insights into the generalities of core reduction intensity. The reason for knapping (flake sufficiency vs flake abundance) will influence how intensely cores are reduced and therefore the viability in reduction intensity proxies. In a flake sufficiency scenario, they do not perform all that well, in the context of flaking a core to exhaustion they may perform better.

Predictors of flaking intensity should therefore be taken in context - lithology will directly affect volume loss as will allometry (small solids lose volume more quickly than larger ones). How the core is flaked, and why (sufficiency vs flake frequency) will also contribute.

4.0. Results and Discussion.

The Oldowan and Acheulean infills at Sterkfontein represent the accumulation of material that fell down avens in the limestone (Kuman and Clarke, 2000).

Hominin occupation was therefore on the land surface above the cave, effectively on its roof. This is the key difference between the East African archaeological data sets and that from Sterkfontein. In the former, experimental replication studies address issues of hominin lithic behaviour in the context of

surfaces where activity actually took place, attempting to determine not only what hominins actually did there, but what happened to those surfaces afterwards. At Sterkfontein this is not possible. Replication contributes to an understanding of site formation processes (Kuman and Field, 2009; Kuman *et al.*, 2005), as well as on the technological process of knapping employed at the site (Kuman and Field, 2009). However, these experimental data can situate Sterkfontein within the broader Oldowan discussions in East Africa.

Recent work on the East African Oldowan has moved interpretation away from the traditional scenario of intensively occupied activity surfaces on which core working occurred (Leakey, 1971; Potts, 1988), and around which raw material transport was essentially local (Harmand, 2008; Braun, 2012). There is a tendency to view the character of Oldowan occupation as a series of often repeated but more ephemeral short lived visits (de la Torre and Mora, 2005; Diez-Martin *et al.*, 2010). Additionally, the nature of the Oldowan stone tool assemblage at a number of the Olduvai Gorge localities has been reinterpreted. They are no longer being seen as a core tool and/or flake tool assemblage type. New interpretations suggest a set of lithic affordances involved in pounding and battering activities, possibly associated with processing organic materials and foodstuffs (*ibid* both). Raw material transport is also being actively reinterpreted on the basis of new work at a range of East African sites (see

Braun, 2012 for a review). Both short and long distance transport is suggested in a variety of different site contexts, as is a much higher focus on raw material selection and assessment by hominins from early Oldowan times (Isaac and Isaac, 1997; Leakey, 1971; Braun *et al.*, 2008a; Braun *et al.*, 2009; de la Torre and Mora, 2005; Diez-Martin *et al.*, 2010). At Koobi Fora it is possible that there is an increase in transport activity after the appearance of *Homo erectus* (Braun *et al.*, 2009). At Sterkfontein transport behaviours certainly change in the Acheulean breccia (Kuman and Clarke, 2000), and the Acheulean in Member 5 west is associated with *Homo ergaster* (StW80; Kuman and Clarke, 2000). Whether *Homo* is associated with the Oldowan in Member 5 east, Oldowan infill, remains unclear. The only hominin fossils from this area are currently *Paranthropus*.

At Sterkfontein the lithologies of the manuports allow for sourcing the raw materials. Igneous rocks, quartz and the cherts can all be found on the slopes adjacent to the site, and there is no reason to believe this was not the case in antiquity. However the quartzite is exclusively found in the river bed and along its immediate banks. The higher frequencies of the better quality quartzites, and casual cores/test pieces suggest hominins at Sterkfontein were assessing and selecting particular lithologies and probably individual clasts for transport to the site. This has been noted at Kanjera and Olduvai (Braun *et al.*, 2009; de la

Torre and Mora, 2005). Additionally, our experimental knappers' approach to manuport selection and flaking was a straightforward pragmatic one determined by the physical requirements of mechanical percussion. We believe those same choice were made by the Oldowan and Acheulean knappers at Sterkfontein.

Our approach to the experimental knapping was a non-targeted one mapping onto previous replication studies (Braun *et al.*, 2008b; Toth, 1985) which suggested that final core morphology reflects the process of reduction and not cultural choices. The new work on Oldowan activities at the East African sites is suggesting less emphasis on form and typology, and more on the production of serviceable edges with tools effectively representing a support for different edge types. These accompany a greater emphasis on percussion processing activities.

For flaked pieces/cores, our experiments have shown that lithology and clast shape do not condition knapping choices, although in some cases they may limit the choices available. Similar conclusions have been drawn from knapping programme at the East African sites also.

Detached pieces have formed a major element in reconstructing lithic transport behaviours (Braun *et al.*, 2005; Kimura, 2002; Kimura, 2006), but experimental studies have shown that manuports/core size affects flake type and flake frequency (Braun *et al.*, 2008b). From the core perspective, our experiments have supported an initial influence on core size by manuport size, but our data warns against simple one to one relationships between reduction intensity and variables such as scar counts or cortex quantity analysed in isolation. Such conclusions have also been emphasised in East African experimental programmes (*ibid*).

Although site formation processes and site context differ between Sterkfontein and the East African Early Pleistocene sites, the knapping programme from Sterkfontein shows that the technological strategies, and decision making that underpins much of the core working in these two distinct regions are similar. However, grafted on to this basic parity are local and regional differences (primarily lithological and raw material context driven) which give each location a discreet signature in lithic behaviour.

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Footnote.

One of the reviewers for this paper expressed concern that the introduction of inexperienced knappers created significant bias within the results. This point is well taken. However we do not believe this has affected our results. Of the 190

cores knapped in the experiments only 20 (10.95%) were knapped by inexperienced knappers. There were eight of these. Four of them were archaeology Ph.D students or archaeology lecturers all of whom were familiar with the aims of the knapping project, conchoidal fracture, and with some of the decision making processes involved in knapping. At least two of them had 'had a go' at knapping before, but did not consider themselves proficient and were given the same level of basic introduction in flaking and platform choice (c. 30 minutes of basic instruction) as the other two archaeologists who had not knapped. In all, these four experimenters made 10 cores. The remaining four experimenters were not archaeologists and did not have any experience. They too were given a basic 30 minute introduction in how to flake, platform choice etc. They made 10 cores in total. Each of the experienced knappers had been knapping for more than 3 years, two of them considerably more than this, and two of them had been replicating Sterkfontein cores during this time.

It is not an unfair assumption that hominins varied in their knapping skills and experience levels. Some would be better than others and some would have been doing it longer than others. Our rationale for introducing the inexperienced knappers was to try and replicate an end result that reflected a range of abilities, thus making the experimental results more realistic.

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Experimental manuport shape	Knapping method and raw material			
	Bipolar		Freehand	
	Raw material		Raw material	
	Quartzite	Quartz	Quartzite	Quartz
Blocky angular	10	10	19	7
Blocky rounded	15	17	21	37
Rounded polyhedron		3	1	2
Split cobble	1			6
Tabular disc	6		4	7
Wedge shape	2	1	16	4
Not recorded			1	
Mean experimental manuport volume (x2 freehand quartzite manuports not measured)	64.29 (N=34; SD=32.42)	40.01 (N=31; SD=36.62)	98.42 (N=60; SD=65.71)	51.25 (N=63; SD=41.15)
Mean maximum length of manuports	Quartzite		Quartz	
	Oldowan			
	Acheulean			
Experimental				
	97 mm (N=8; SD=10)		74mm (N=3; SD=11)	
	85 mm (N=160; SD=27)		81 mm (N=17; SD=13)	
	124 mm (N=94; SD=29)		95 mm (N=94; SD=27)	

Table 1. Experimental and archaeological data. Upper section of table presents frequency of occurrence for each experimental manuport shape in quartz and quartzite, knapped by both freehand and bipolar methods of flaking. Middle section of table gives summary statistics for manuport size as measured by volume ($L \times W \times Th / 10,000$). Lower section of table is a size comparison between experimental and archaeological data. Size given in length in millimetres as only the length data was available for archaeological samples.

Knapping method	Shape	Quartzite	Quartz	Chert	Igneous	Total
Bipolar	Shatter	9	16			25
	Bipolar core	25 (0,1)	15 (3,6)			40 (3,7)
Freehand	Casual core	1 (0,19)	0 (2,12)			1 (2,31)
	Chopper core	14 (3,24)	9 (1,6)	(0,1)	(0,1)	23 (4,32)
	Discoid	4 (0,10)	9 (1,0)			13 (1,10)
	Single platform core	4 (1,10)	4 (1,6)	(0,2)		8 (2,18)
	Polyhedron	3 (0,42)	15 (6,14)	(0,1)	(0,1)	18 (6,58)
	Irregular polyhedron	32 (3,64)	20 (3,33)		(0,2)	52 (6,99)
	Shatter/core fragments	3 (1,0)	6 (3,0)	(1,0)		9 (5,0)
	Irregularly fractured cobble/chunks	1 (11,0)	0 (120,0)			1 (131,0)
	Indeterminate	0 (0,1)	0 (0,1)		(0,2)	0 (0,3)

Table 2. Experimental and archaeological data. Upper numeral in each cell represents the frequency of different core shapes occurring in the experimental data set. Archaeological frequencies for the same cores shapes at Sterkfontein are given below in parentheses in the following order, Oldowan (first) and Acheulean (second). Data for the Oldowan are taken from Kuman and Field (2009), and for the Early Acheulean from Field (1999; N.B. in Field, 1999 the

term edge core was used for what is now more commonly known as single platform core).

Core shape	Manuport shape						
	Blocky angular	Blocky rounded	Rounded polyhedron	Split cobble	Tabular disc	Wedge shape	Not recorded
Casual core						1	
Chopper core	4	8	2	1	2	6	
Discoid	2	8			2	1	
Single platform	1	5			1	1	
Polyhedron	2	9	1	2	1	3	
Irregular polyhedron	16	22		2	4	7	1
Shatter	9	18	2	2	1	2	
Bipolar core	12	20	1		5	2	
Irregularly fractured cobble					1		

Table 3. Experimental data. Frequency of core shapes in relation to the shapes of their original manuports.

Core type	Different knapping patterns and combinations of flaking patterns					
	Alternate flaking	Alternate flaking with parallel flaking	Alternate flaking with parallel and/or single removals	Parallel flaking and/or single removals	Parallel removals	Single or multiple episodes of single removals
Casual core						1
Chopper core	16	3	4			
Discoid	10	2	1			
Single platform	1	1			4	1
Polyhedron	4	4	4	2	3	
Irregular polyhedron	9	9	16	9	4	1

Table 4. Relationship between knapping technique and core shape for freehand cores from experimental data. Data for quartz and quartzite combined. Totals reflect only those cores for which these data could be recorded. Casual means only one or two removals present – test piece. Alternate flaking represents the turning of the core and the use of the proximal end of one or more flake scars just created, as platforms for the detachment of more flakes. Parallel flaking refers to the detachment of flakes from one or more contiguous platforms. The axes of percussion for the adjacent flake scars must be parallel to each other. Single removals, or multiple episodes of unrelated single detachments on a core, are recognised when they occur either off cortical/natural platforms, or from the lateral or distal margins of flake scars - this is in order to prevent them being confused with flake scars from alternate flaking (McNabb 2007, McNabb 2009)

Core shape	Number of cores that achieved their final shape within 5 blows.	Number of cores that achieved their final shape within 10 blows.	Number of cores that achieved their final shape within 15 blows.	Number of cores that achieved their final shape within 20 blows.	Number of cores that achieved their final shape after more than 20 blows.
Chopper core (N=22)	1	4	10	6	1
Discoid (N=13)	2	1	1	2	7
Single platform (N=7)		3	1	3	
Polyhedron (N=18)		2	4	5	7
Irregular polyhedron (N=52)	4	18	12	14	6

Table 5. Summary experimental data showing at what point in the knapping process individual cores (as judged every five blows) achieved their final shapes. Data for freehand quartz and quartzite cores only; totals reflect only those cores where these criteria could be successfully recorded.

Final core shape	Patterns of shape variability through which cores passed prior to achieving final shape	Frequency with which pattern was seen (i.e. total of cores)
Chopper core	SP to IRP to CH	1
	SP to CH	7
	IRP to CH	2
Discoid	CH to DI	5
	DI to IRP to DI	1
	IRP to DI	1
	CH to SP to DI	1
	SP to CH to DI	1
Single Platform Core	IRP to CHUNK to SP	1
Polyhedron	SP to POLY	1
	IRP to POLY	8
	SP to CH to POLY	1
	SP to CH to IRP to POLY	2
	POLY to IRP to POLY	1
	CH to IRP to POLY	2
	CH to SP to CH to POLY	1
	CH to POLY	2
Irregular polyhedron	IRP to DI to IRP	1
	SP to IRP	10
	CH to IRP	5
	CAS to IRP	1
	IRP to CH to IRP	1
	IRP to SP to IRP	1
	SP to CH to IRP	1

Table 6. Experimental data. Variations in core shape through which experimental cores passed prior to achieving their final form, and the frequency with which these patterns of shape variation were seen. Data for quartz and quartzite combined, freehand experiments only. CH = chopper cores; DI = discoid; SP = single platform core; POLY = polyhedron; IRP = irregular polyhedron; CAS = casual; CHUNK = indeterminate/shapeless form.

Figure 1a

Figure 1b

Figure 1. Scatterplot comparing size distribution of experimental cores and the parent manuports from which they were made. Core and manuport size represented by volume ($L \times W \times Th / 10,000$ – see text for details); figure 1a bipolar data; figure 1b freehand data.

Figure 2. Scatterplot comparing maximum scar length in millimetres on cores with the amount of volume lost by the manuport (see text for details of calculation) while being knapped until suitable platforms for flake removal were exhausted and no more flakes could be detached. Freehand experimental cores only.

Figure 3. Scattergram of log transformed data for freehand cores, comparing the frequency of scars on a core with the amount of volume loss it experienced during knapping.

Figure 4. Scattergram comparing knapping intensity (measured by volume loss) with the size of the final core. Data for freehand cores only.

Figure 5. Boxplots showing the relationship between the amount of cortex left on a core and the volume lost during that core's knapping. Freehand data only, quartz N = 57, quartzite N = 57.