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Oldowan: Rather more than smashing stones

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Treading Carefully: Site Formation Processes and Pliocene Lithic Technology

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Introduction

The appearance of Oldowan lithic technology as an integral part of the Pliocene-Pleistocene hominin record has long been perceived as an adaptive threshold in human evolution (Isaac 1986), because it expanded the ability of early hominids to exploit and modify a variety of raw materials and enhanced the accessibility of high-quality food resources. These resources supported the costly metabolic demands induced by encephalization (Aiello and Wheeler 1995), triggered by -and contributing to- complex social relationships (Humphrey 1988; Aiello and Dunbar 1993; Byrne 1997; Dunbar 1998). Various outcomes of the crossing of this adaptive threshold are modeled and/or tested by hypotheses derived from a plethora of scientific disciplines (e.g., Bunn and Kroll 1986; Speth 1989; Blumenschine 1991; Sept 1992; Aiello and Dunbar 1993; Bunn and Ezoo 1993; Blumenschine et al. 1994; Aiello and Wheeler 1995; Rose and Marshall 1996; Capaldo 1997; Brantingham 1998; McHenry and Coffing 2000; Plavcan 2000; Domiguez-Rodrigo 2002). But it is only from the study of the artifacts that the nature of early stone knapping, and the qualities of the human condition that were necessary to implement it, can be inferred.

Stone knapping is a sequential activity in which stages of reduction follow one another, resulting in artifacts with discrete characteristics. Sequence models are therefore a powerful tool for analyzing lithic production, offering a conceptual basis for linking apparently diverse objects (the discrete lithic artifacts) into patterns that reflect a process in time, and which can themselves be studied in behavioral, cultural or cognitive terms (Leroi-Gourhan 1943; Leroi-Gourhan 1945; Geneste 1985; Boëda 1991; Schlanger 1994; Bleed 2001).

Studies of Pliocene lithic technology apply the concept of sequence modeling, either explicitly or implicitly, when attempting to reconstruct the cognitive abilities of early hominids reflected in the realm of lithic technology.

The sequence of actions involved in lithic production encompasses what might be called strategic planning vs. tactical action. The first stage in the process involved purely abstract processes of decision making, using pre-conceived mental templates of the forms, materials, and imagined sequences of actions as the decision criteria (Pelegrin 1990:118, and references therein).

Whether such high faculties played a part in the lithic technology of early hominids is inferred from patterned variations which are interpreted to reflect depth of planning (e.g., acquisition of appropriate raw material, selection criteria based on shape and size), or from the physical reconstruction of the lithic reduction process by extensive refitting (e.g., Roche et al. 1999; Roche 2000).

On the other hand, tactical, target-specific planning comprises the [mental] structuring of the physical acts necessary for materializing these decisions. It is only at this stage of the knapping process that actual action upon matter takes place. Strictly speaking, the 'archaeological record' that we observe is the direct outcome of this stage of the cognitive process.

Clearly, comprehending lithic reduction at the level of tactical knapping skills bears on our inferences about the higher-level cognitive processes involved in lithic reduction. For this reason, knapping skills should be assessed and reconstructed before inferences about higher cognitive abilities can be attempted.

Lithic shatter and knapping skills of Plio-Pleistocene hominids

Two different types of human capacities, physical and mental, factor into the knapping skills inferred directly from the archaeological finds. Anatomical characteristics dictate the dexterity of a stone tool maker and his ability to manipulate raw materials of various shapes and forms, and to apply the correct force and direction of blows during the process of lithic reduction.

Technical knowledge, namely, the techniques used in order to implement a mode of lithic production (Roche 2000), sets the objectives towards which manual action is directed. Hence, knapping skills may be hampered by limitations on any or both of these two broadly defined domains.

Anatomical constraints may not have been a limiting factor for the knapping skills of Late Pliocene hominids at Hadar. Whether australopiths were anatomically capable of stone knapping, and if so -which species of australopiths had these abilities, is debatable (e.g., Susman 1991; Marzke 1997; Susman 1998). But early Homo appears to have many (if not all) of the specific elements of precision grip that are necessary for habitual tool-making (Marzke 1997). If the knapping skills of the early tools makers were limited to any extent, the crucial factor would be in cognitive abilities. But which are the archaeological correlates of those cognitive abilities?

Angular fragments as flaking debris

One category of artifact that has been discussed in this context is 'angular fragments'. Various authors, however, have perceived the term differently. M. Leakey (1971:8) used it to describe pieces "apparently derived from shattering blocks of raw material", which she then coined 'core fragments' in her typology.

From her tacit description it is not clear whether she referred to such items as the results of natural mechanical fracturing or of stone knapping. Isaac and Harris, in their analysis of the Koobi Fora sites, extended the definition of angular fragments to include all flaking debris lacking striking platforms and bulbs, but still attributable to detached pieces (in the terminology of Isaac and Harris 1978) and explicitly differentiated from core fragments (Isaac and Harris 1997:265, table 6.1; 285).

Recently, Semaw (1997:111, 161-163) and Ludwig (1999:43) adopted the latter definition, expanding it to include all fragmented portions of flakes, and any broken pieces on which the point of origin, or the direction, of the blow could not be discerned. Item size is not considered as one of the definitive criteria.

It stands to reason, however, that the majority of these pieces tend to be small (where publications provide sufficient data, the relevant size range appears to be <20 mm; e.g., Chavaillon 1976; Merrick and Merrick 1976; Semaw 1997: table 4.20).

The inclusiveness of the term 'angular fragments' as used by Semaw (1997) and Ludwig (1999) defies the purpose of classification of artifacts in relation to their generative processes. Until the term is redefined in the future, I use here, for the purpose of comparability, the broad definition employed by these two authors.

Angular fragments in Pliocene sites are considered by several workers as the outcome of flaking processes involving the tech-

nique of direct percussion with hard hammer. In the Omo localities, these pieces were perceived as the result of nearly random battering of nodules/cores (Chavaillon 1976:571; Merrick and Merrick 1976), a basic mode of lithic production that is integral to the technological repertoire seen in Pliocene lithic assemblages (Roche 2000:102).

Semaw (1997:111), too, includes angular fragments in his category of detached pieces, as do Isaac and Harris (1997), namely pieces that were detached from the core in the course of lithic reduction.

Angular fragments as the result of site formation processes

The presence and frequencies of angular fragments in Plio-Pleistocene sites are explained sometimes by invoking hydraulic processes. Where the sites' sedimentological make-up is suggestive of channel bed deposits, water action is claimed to have winnowed a locality of the small-fraction lithics, thus reducing the frequencies of angular fragments, the implication being that their presence on site reflects minimal post-deposition disturbance (e.g., Semaw 1997:161).

Conversely, high frequencies of small, size-sorted artifacts (as well as of bone fragments of similar sizes) may result from transportation by hydraulic agents to sediment traps in floodplains, where the pieces were then embedded (e.g., Merrick and Merrick 1976; Schick 1987; Isaac and Harris 1997:283-285).

The processes of formation of the angular fragments themselves are not necessarily specified in these models. Presumably, these could have been either flaking processes as discussed above, or some natural agency unrelated to human action.

Finds from A.L. 894 (Hadar, Ethiopia) and their implications

Recent excavations at the late Pliocene (>2.3 Ma) locality A.L. 894 (Hadar, northern Ethiopia), have revealed a few hundred bone fragments and several thousands lithic artifacts in silty-clay deposits of the floodplain of a low-energy stream, dispersed in a ca. 30-cm thick cluster. The lithic assemblage consists mostly of sharp-edged complete and broken flakes, and of angular fragments.

Fig. 1. A cracked flake in A.L. 894. Identification of these fragments as part of a single flake is possible due to minimal post-depositional disturbance. The actual separation of the frgments from one another occurred only when surrounding sediment was removed during excavation.

Fig. 2. A cracked flake in A.L. 894, before it was completely exposed in the excavation.

Fig. 3. A snapped flake in situ.

Cores and core tools are present in small numbers (Hovers et al. 2002). Raw materials are cobbles of various volcanic rocks, whose size in relation to the surrounding matrix indicates transport from a source located at least several meters away from the site.

No human remains have been found in A.L. 894. To date, only one hominid taxon, Homo aff. *H. habilis*, has been recovered in the uppermost Kada Hadar Member, at A.L. 666 (Kimbel et al. 1996; Kimbel et al. 1997), which is penecontemporaneous with the A.L. 894 artifact assemblage.

Figures 1-3 document examples of flakes broken in situ as found during the excavation at A.L. 894. They could be recognized as such only because post-depositional disturbance was minimal and did not cause removal of the smaller fragments away from the initial location of breakage. Had this been the case, each of these pieces might have been inventoried several times, as distinct and broken flake(s) and/or as angular fragment(s), unrelated to one another.

The break of the artifact seen in Figure 2 may be an old one, as attested by the silt-filled cracks. The artifacts seen in Figures 1 and 3 had been cracked post-depositinally, but not completely shattered. Removal of the silty sediment at the time of excavation elevated the pressure that had held the pieces together and caused widening of the cracks and final breakage of the artifacts. These photos document, then, examples of formation of angular fragments through purely natural processes, completely unrelated to flaking skills.

Three natural mechanisms may be invoked to explain the occurrences of these (and other similar) items: cracking due to shearing by pedogenic processes (e.g., in clays), cracking and fracturing due to compaction in the sediments, or breakage due to trampling by humans and/or animals.

Pedogenic activity in vertic soils, such as those at AL 894, tends to shear artifacts (or bone) embedded in the sediment, which are then offset along the soil fracture planes (Craig Feibel, pers. comm.). The examples shown here from A.L. 894 are effected by breakage rather than shearing, and the fragments of any single item do not show such dislocation relative to one another.

Several experiments examined the effects of trampling on lithic artifacts made on flint and obsidian. The experiments have shown that breakage is more frequent on harder surfaces, such as the substratum of relatively compact loams and silts (Villa and Courtin 1983; Gifford-Gonzalez et al. 1985; Pryor 1988; Nielsen 1991). Villa and Courtin (1983:279) also noted that elongated pieces had snapped transversally.

Such observations are consistent with finds and with the type of sediment at A.L. 894 (e.g., Figure 3). However, all the trampling experiments documented the formation of edge damage, sometime to the degree that it could be mistaken for intentional retouch (Gifford-Gonzalez et al. 1985; Nielsen 1991; McBrearty et al. 1998).

At A.L. 894, the flakes and angular fragments rarely show secondary modifications. To date, retouch has not been recognized in this site. Possibly, trampling was not the only, or the main, post-depositional process to have caused the presence of angular fragments on the site. To test such ideas, it is necessary to experiment with trampling with the specific raw materials used at A.L. 894 itself.

While one cannot specify at this point the exact nature of the processes leading to breakage and formation of anuglar fragments, the various lines of evidence and reasoning suggest that the occurrence of angular fragments at A.L. 894 is related to natural processes. In this particular site, for one, knapping skills may have played only a secondary role in the occurrence and deposition of angular fragments.

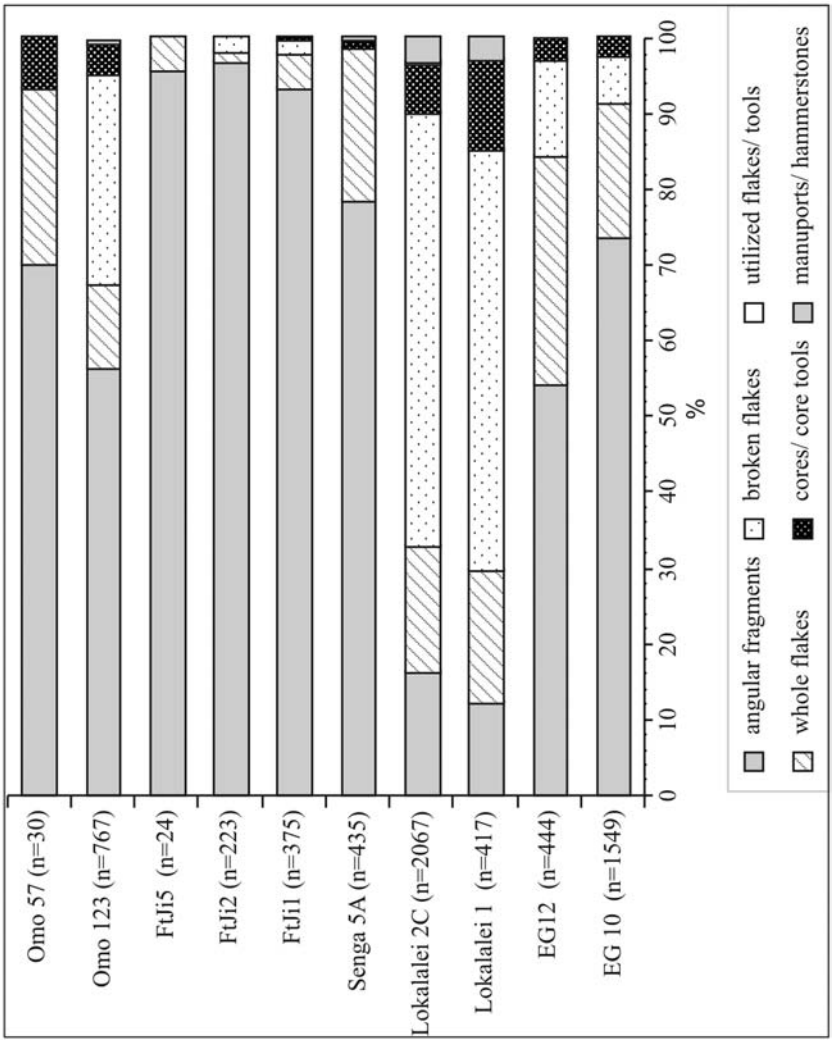

Fig. 4. Compositions of early lithic assemblages (surface collections not shown). Sources: Omo data after Chavaillon 1976, Merrick and Merrick 1976, Howell et al. 1987. The "Piece" mentioned in the original texts added here to manuports; Senga 5A - data from Harris et al. 1987; Lokalalei 2C -data after Roche et al. 1999. Broken flakes and small flakes originally classified together. Modified pebbles and broken cores are counted here with the cores, unmodified pebbles counted with the manuports; Lokalalei 1 - data from Kibunjia 1994. Broken flakes and fragments larger than 1 cm counted together, only fragments smaller than 1 cm included in angular fragments; Data for Gona from Semaw 2000.

Why does shatter matter?

The specific values of fracture mechanics parameters operating on lithic raw material during percussion flaking (see Faulkner 1972; Speth 1972; Speth 1974; Speth 1975; Cotterell and Kamminga 1979; Cotterell and Kamminga 1987; Pelcin 1997 for detailed discussions) are dependent on variables such as the quality of raw material and the size of raw material packages (Merrick and Merrick 1976; Ludwig 1999:107), and on the properties of the hammerstone used (Ludwig 1999:388).

This is seen in Pliocene lithic assemblages, where the knapping of quartz clearly generates high frequencies of angular fragments (Figure 4).

These patterns were related to both raw material properties and the small size of the original nodules, said to have required the application of breakage-prone bipolar flaking (Chavaillon 1976; Merrick and Merrick 1976; Harris et al. 1987; Ludwig 1999). In the case of the Gona assemblages, on the other hand, the occurrence of relatively high frequencies of angular fragments cannot be explained in the same way, since these assemblages were flaked from fair-sized cobbles of fine-grained trachytes (Semaw 2000:1207).

As a general rule, the more skilled a knapper is, the greater his cognitive ability to overcome problems resulting from a material's physical properties, which in turn dictate the material's propensity for breakage and/or shatter. Because the presence of angular fragments in late Pliocene sites can hardly be related to secondary modification by flaking, it bears implications for reconstructing the knapping skills of the early toolmakers. There are compelling indications that these hominids were capable of preplanning the reduction sequences and standardize them to a degree (Roche et al. 1999; Roche 2000).

But the proliferation of shatter in many of the early sites would suggest that early hominids were not highly accomplished in obtaining their knapping goals. The notion that angular fragments resulted from the flaking process in not easily compatible with the view that early hominins had sophisticated understanding of stone fracture mechanics (e.g., Semaw 2000).

If, on the other hand, we accept that the formation as well as frequencies of angular fragments in Pliocene archaeological occurrences are likely due to natural processes, the contradiction becomes more apparent than real. Angular fragments can hardly be considered as reflecting the knapping skills of their makers.

This distinction may seem trivial to the lithic analyst, but has far-reaching implications beyond lithics. In a recent study, Susman (1998) argued that precision grip of Paranthropus in Swartkrans allowed this hominid to use artifacts of various sizes, including very small ones. As an illustration of the smaller artifacts allegedly used by Paranthropus, few flakes and several angular fragments are illustrated (Susman 1998: figure 9). But if at Swartkrans, as in many East African early sites, these are the products of post-depositional processes, they are irrelevant to the question of precision grip in Paranthropus and cannot be relied on as support for this claim.

Similarly, the view that angular fragments originate primarily from natural, post-depositional processes is of interest for understanding the origins of tool making and tool use. In recent years, much evidence has accumulated which documents the diversity of tool-using and tool-making behaviors among chimpanzees in the wild (e.g., Whiten et al. 1999, and references therein; Boesch and Boesch-Achermann 2000).

One particular behavior, cracking of very hard nuts of Panda oleosa, leaves durable, detectable and clear spatial evidence of accidentally-formed lithic artifacts, among which angular fragments are the majority (Mercader et al. 2002a; Mercader et al. 2002b).

Noting the differences between the chimpanzee assemblage and some early Oldowan ones, Mercader et al. (2002b) emphasize nonetheless the similarities between the two assemblage types, indicating that "chimpanzees leave behind a stone record that mimics some Oldowan occurrences".

From here they go on to suggest the possibility that Oldowan assemblages might be interpreted as evidence of hard-object feeding by early hominids. It should be clear from the ongoing discussion that the similarity is more apparent than real, in that angular shatter is a predominant feature in the accidental knapping of chimpanzees but not necessarily a result of early hominid stone knapping as recovered from a prolonged and "dynamic" sedimentological record. To the extent that tentative evolutionary implications of the chimpanzee assemblage are inferred from the superficial similarity between this and hominid-made assemblages, they need to be re-evaluated carefully.

Above all, the previously unsuspected complexities involved in the understanding of the phenomenon of angular fragments in Pliocene sites underscore the importance of combining lithic analyses and refitting of the early stone assemblages with detailed studies of formation processes, sedimentological analyses, and experimental work. This is the only way by which meaningful insights into early lithic technology can be obtained and form the basis for understanding the adaptive impact of Oldowan lithic technology.

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