# Searching for the emergence of stone tool making in eastern Africa

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Modern humans rely entirely on technology for their subsistence, and the interaction between technological and biological adaptations has played a key role in the evolution of our lineage. When exactly technology emerged in the fossil record and thus started to shape primate evolution, has appealed researchers since the beginnings of paleoanthropology as a discipline and, as Braun et al show in PNAS (1), is still today a source of important discoveries.

Our closest relatives at present, the chimpanzees, have a rich material culture that varies geographically (2) and that includes the use of a wide variety of raw materials such as leaves, clubs, sticks, stones and others. While our ancestors most likely used an array of organic materials as well, stones are usually the only artifacts preserved in the record and therefore are key to trace the emergence of technology in human evolution. For nearly a century, the Oldowan defined by Louis Leakey (3) at Olduvai Gorge in Tanzania has remained the most solid evidence of earliest stone-tool making in our lineage. Originally thought to be around half a million years old, since the 1960s through the present the age of the Oldowan has been pushed back steadily (4), with the Gona sites in Ethiopia at 2.58 million years ago (Ma) being, until Braun et al (1)'s discovery, the oldest evidence of this technology (5). The new site of Bokol Dora 1 (BD 1) at the paleoanthropological area of Ledi-Geraru, also in Ethiopia, is slightly older than Gona at 2.61-2.58 Ma (1) and contributes to establishing the age of ~2.6 Ma as a firm date for the earliest Oldowan.

But the Oldowan might have not been the first archaeologically-visible technology in the paleoanthropological record. In recent years, two discoveries –Dikika and Lomekwi– have sparked fresh debate about the potential existence of stone tool technologies much further back in time, at ~3.4 Ma. At Dikika, Ethiopia, some bones bear traces interpreted as cutmarks (6), which would evidence that Pliocene hominins were using stone tools to process animal carcasses. Although no stone tools have yet been reported in Dikika, the site of Lomekwi 3 (Kenya) has yielded several lithic artefacts that are attributed to 3.3 Ma sediments (7), thus complementing the indirect evidence of stone tool use proposed for Dikika.

Whilst the evidence >3 Ma is not exempt of controversy –see recent reviews in (8, 9)–, Braun et al (1) compare the lithic assemblage of BD 1 with that of Lomewki and conclude that differences are significant enough to maintain a separation between the Lomekwian culture –the name given by Harmand et al (7) to the new discovery in Kenya– and the Oldowan, for which BD 1 is now the earliest site. Acceptance of this scenario would imply reconsidering some long-standing paradigms in paleoanthropology.

For instance, an influential view established coalescence between the emergence of the Genus *Homo*, the earliest stone tools, and climatic change towards aridification at 2.9-2.6 Ma (10). The earliest fossils of *Homo* have been recently discovered in the same area of Ledi Geraru as the Oldowan site reported by Braun et al (1) and, although such human remains are 200,000 years older (11) than BD

1, given the fragmentary character of the paleoanthropological record they do not necessarily challenge the scenario associating climate change with speciation and cultural responses. Accepting the validity of archaeological evidence at ~3.4 Ma, however, changes substantially the scenario and decouples such association, as no significant climate changes have been detected in that particular interval, and hominins in both the Dikika (*Australopithecus afarensis*) and Lomewki (*Kenyanthropus platyops*) areas are less derived than early *Homo*.

Another intriguing implication is the ~0.5 Ma gap detected between Lomewki and BD 1. Basic lithic technologies such as the Lomewkian and the Oldowan may have been discovered, then disappeared and reinvented again in the course of human evolution (12), in a fragmented sequence of cultural gains and losses that could potentially explain why no archaeological evidence is found between 3.3 and 2.6 Ma. In my view, however, a scenario of independent inventions, disappearance and rediscovery of stone tool flaking does not fit well with the evidence available for the Oldowan record of East Africa from 2.6 Ma onwards, as the tight chronological clustering between Ledi-Geraru (1), Gona (5) and all the sites that follow in the temporal sequence (Figure 1), indicate continuity in the archaeological record and consistency in the patterns involved.

And which are those patterns? All early archaeological assemblages contain clusters of stone tools in lake margins or riverine settings, which often correspond to more open environments than those inhabited by earlier hominins and the majority of non-human living primates. Most early archaeological assemblages also yield fossils, although in many –like the one reported by Braun et al (1)–, their association with lithic artifacts is only spatial and not necessarily contextual –for example, in the form of anthropogenic marks on fossils demonstrating an effective link between stone tools and bones–. In some other assemblages, fossils are not present (Figure 1), but their absence may be due to taphonomic bias against bone preservation. In some rare –and controversial (8)– instances, reported cutmarks in bones without a clear association with lithic assemblages –e.g., Dikika and Bouri– serve to emphasize the main purpose of early stone tools, which is deemed to be the production of cutting edges (13), most likely to aid early humans accessing animal carcasses.

In addition to cutting-edge production, stones were most likely used in other tasks; percussive activities involved in processing organic materials are common among several primates (14) and may potentially have preceded stone tool knapping during the initial stages of hominins' exploitation of animal resources (9). However, most early archaeological sites from Figure 1 contain few battered artefacts other than those related to flake production, with the latter being the primary goal in all assemblages. As Braun et al (1) emphasize, nonetheless, technological variability associated to such flake production may have been considerable. When the Gona assemblages were thought to be the earliest evidence of stone tool knapping, researchers were puzzled about the high quality of flaking production, as parsimony dictated that there would be an incremental process of skill acquisition through the Oldowan. Braun et al (1) indicate that the slightly older assemblage of BD 1 is also slightly less sophisticated technologically than Gona, which makes tempting to return to a gradualist approach of technological evolution during the Oldowan. As shown in Figure 1, three main techniques were employed to produce flakes in the earliest archaeological sites; the block-on-block technique has only been reported in Lomewki, involves the production of much larger flakes than the ~2-5 cm products typical of the Oldowan, and is one of the features put forward to differentiate the Lomewkian from the Oldowan (7). However, bipolar and freehand techniques are found across the early Oldowan record (Figure 1), and quality of flaking products may be strongly influenced by raw material (15) and site (16) particularities. Thus, for now it might be safest to highlight –and Braun et al (1) do so– that there is substantial technological variability among the earliest Oldowan sites, without attributing time trends to such variability.

From that perspective, the overarching features shared by most of the earliest sites in Figure 1 would be the clustering of artifacts –and often also bones– obtained through conchoidal fracture. Mastering of the conchoidal fracture has long stood as a defining character of human technology (17), and artifact clustering has been associated to behavioral changes by early hominins that enabled archaeological visibility of their activities (18).

But are these features really unique to hominins and the earliest archaeological sites they produced? Findings in the brand-new discipline of primate archaeology (19) seem to say otherwise; for example, chimpanzee nut-cracking activities are now observed to produce significant concentrations of artefacts, in many ways mimicking spatial patterns typical of the Stone Age record (20). Even more surprisingly, capuchin monkeys have recently been shown to obtain conchoidally-fractured flakes through recurrent use of hammerstones (21). Albeit capuchins produce such lithic assemblages unintentionally, these distant relatives in our evolutionary lineage indicate that large brains and human-like hands are not, after all, indispensable requirements for stone knapping.

Primate archaeology findings are blurring the line of what is unique to early human technology, and opening new perspectives into the comparative analysis of archaeological assemblages made by hominins and non-human primates. It now seems clear that lithic technology has appeared independently in various lineages of primates, and may potentially have been discovered and disappeared several times through the Pliocene and early Pleistocene; by pushing a bit further back in time the emergence of the Oldowan, Ledi-Geraru (1) contributes to both exploring the roots of lithic technology and to characterize the internal variability of early stone tool assemblages. It is hardly an exaggeration to state that, today, the field remains as vibrant as when Louis Leakey (3) defined the Oldowan nearly a century ago.

Figure 1. Earliest archaeological sites in eastern Africa. (a) Dikika research area, Ethiopia (b) West Turkana, Kenya (c) Ledi Geraru, Ethiopia (d) Gona, Ethiopia (e) Bouri, Ethiopia (f) Hadar, Ethiopia (g) Omo, Ethiopia (h) Kanjera, Kenya (i) Koobi Fora, Kenya (j) Fejej, Ethiopia (k) Olduvai Gorge, Tanzania. Block-on-block technique: flakes are produced by striking the core against a stationary anvil. Bipolar technique: a core resting over a stationary anvil is struck with a hammerstone. Freehand technique: a handheld core is knocked off with a hammerstone.

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