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Oldowan hominin behavior and ecology at Kanjera South, Kenya

Thomas W. Plummer[1] & Laura C. Bishop[2]

1) Department of Anthropology, Queens College, CUNY and NYCEP, 65-30 Kissena Boulevard, Flushing, NY 11367 USA
e-mail: thomas.plummer@qc.cuny.edu

2) Research Centre for Evolutionary Anthropology and Palaeoecology, School of Natural Sciences and Psychology, Liverpool John Moores University, Byrom Street, Liverpool L3 3AF UK

Summary - *The Early Stone Age archaeological record does not become persistent and widespread until approximately 2.0-1.7 million years ago, when Oldowan sites spread across Africa and ultimately into Eurasia. However, good records of hominin behavior from this important time interval are uncommon. Here we describe recent findings from the two million year old Oldowan site of Kanjera South, on the Homa Peninsula of southwestern Kenya. Kanjera South is the oldest Oldowan site with large assemblages of stone artifacts and well-preserved archaeological fauna. Our research indicates that hominin activities were situated in an open habitat within a grassland dominated ecosystem, the first documentation of an archaeological site in such an open setting. Hominins selectively collected and transported stone materials (30% of the lithic assemblage) over longer distances (at least 10 km) than is typical for the Oldowan, reflecting their preference for hard, easily-flaked lithologies unavailable on the northern half of the Homa Peninsula. They deployed different technological strategies to more intensively utilize these hard, non-local raw materials. Artifacts were used for a variety of tasks, including butchering small antelopes probably obtained by hunting, working wood, working soft plant material, and processing underground storage organs. These data suggest that the Kanjera hominins utilized a technological system that allowed them to extract nutrient dense animal and plant foods from their environment. This shift towards the acquisition of nutritious, hard-to-acquire foods in packets large enough to be shared may have facilitated brain and body size expansion in the genus* Homo.

Keywords - *Lithic technology, Hominin adaptation, East Africa.*

Background to lithic technology

The oldest evidence for stone tool manufacture comes from the 3.3 million year old (Ma) site of Lomekwi 3, on the western shore of Lake Turkana, Kenya (Harmand *et al.*, 2015; Hovers, 2015). The context and behaviors associated with this early industry, named the Lomekwian, are still under investigation, but it is clear that flake production was generally carried out by hitting a stone against stationary anvils on the ground. How well established stone tool use was in the late Pliocene, the tasks the tools were used for, and the identity of the hominin (living humans and related fossil species) taxon (or taxa) that produced the earliest stone artifacts all require further investigation. One possible use of the tools was for animal butchery. While stone tool-modified bones have yet to be found associated with Lomekwian artifacts, linear marks on roughly coeval (3.39 Ma) surface fossils from Dikika, Ethiopia, may have been produced by hominins cutting meat off of bones using stone tools (McPherron *et al.*, 2010, 2011; though see

Dominguez-Rodrigo *et al.*, 2010, 2012 for a contradictory interpretation).

Beginning ca. 2.6 Ma, artifacts referred to the Oldowan Industry, within the Oldowan Industrial Complex (type site Olduvai Gorge, Tanzania) appear in the geological record of East Africa (Leakey, 1971; Plummer, 2004; Rogers & Semaw, 2009). In contrast to the Lomekwian, Oldowan artifact production was frequently carried out with stones held in both hands, using a method termed hard-hammer percussion. One stone, often a rounded "hammerstone," was used to hit another stone held in a fixed position in the opposite hand (a "core" or "flaked piece") in order to knock off "flakes," or "detached pieces." Hominins at most Oldowan sites were selective in the raw materials they used to make tools, suggesting at least a nominal appreciation for the material properties of different stone lithologies. Animal carcasses were also transported, at least by 2 Ma. It is the transport of materials, both stones and foodstuffs, which is one of the novelties of Oldowan hominin behavior (Potts, 1991; Plummer, 2004).

Research over the last several decades has produced a great deal of data, and sometimes contradictory interpretations, of Oldowan hominin behavior and the adaptive significance of early stone tools. It is clear that Oldowan hominins had a sophisticated sense of fracture mechanics by the time of the first appearance of the industry ca. 2.6 Ma at Gona, Ethiopia (Semaw *et al.*, 2003; Delagnes & Roche, 2005; Stout *et al.*, 2005, 2010; Toth *et al.*, 2006; Rogers & Semaw, 2009). Moreover, the concentration of artifacts at least a short distance from raw material sources indicates the appearance in the behavioral record of novel transport and discard behaviors, where materials with no nutritive value (rocks) were moved around the landscape in anticipation of activities requiring the use of stone tools.

It has been argued by some that there were important differences in the behavior of hominins forming the older sites (ca. 2.6-2.3 Ma) relative to the younger ones (ca. 2.0-1.7 Ma) attributed to this industrial complex (Harmand, 2009a,b; Goldman-Neuman & Hovers, 2012; Potts, 2012), with the gap in these time ranges reflecting a dearth of sites from ca. 2.3-2.0 Ma. The older Oldowan sites are more geographically restricted, appearing first in Gona, Ethiopia at 2.6-2.5Ma, and then between 2.36-2.32 Ma at Hadar and Omo, Ethiopia and Lokalalei, Kenya. These sites tend to combine variable degrees of raw material selectivity with short lithic transport distances (generally a few tens to hundreds of meters) (Stout *et al.*, 2005; Goldman-Neuman & Hovers, 2012). It is unclear what this variability in selectivity, ranging from simply choosing relatively homogeneous cobbles to choosing specific raw materials and specific cobble shapes, represents. Some researchers (e.g., Harmand, 2009a) entertain the possibility that it reflects differing levels of manual dexterity and/or technical skills between different groups (or species) of hominins. It is also possible that some variation represents different culturally transmitted social traditions, though there is currently no strong data to support this interpretation (Stout *et al.*, 2010). Another feature of the older set of sites is that they occur within confined stratigraphic intervals and a narrow range of geological settings (Quade *et al.*, 2004; Potts, 2012). The three well-studied sites at 2.58 Ma from Gona, for example, are found in the same stratigraphic interval in a fluvial fining upwards sequence above large cobble conglomerates (Stout *et al.*, 2010). Finally, the exact function of the stone artifacts is not entirely clear. While cutmarks have been found on bones from the surface of several Gona sites (Dominguez-Rodrigo *et al.*, 2005), there are no in situ assemblages of bones from any of the older sites that preserve definitive evidence of butchery (e.g., de Heinzelin *et al.*, 1999; Dominguez-Rodrigo & Martinez-Navarro, 2012). This has led some to argue that many Oldowan sites are palimpsests of hominin and carnivore activity, where hominins were primarily using stone tools for non-butchery related activities, such as plant processing (e.g., Dominguez-Rodrigo, 2009).

Sites in the 2.0-1.7 Ma time interval are more geographically widespread, appearing for the first time in new regions of East Africa (e.g., the Homa Peninsula, Kenya), North Africa (e.g., Ain Hanech, Algeria) as well as in South Africa (e.g., Sterkfontein, Swartkrans), and across a wider variety of depositional settings and habitats (Potts, 1998, 2012; Plummer, 2004; Plummer *et al.*, 2009a; Magill *et al.*, 2013; Sahnouni *et al.*, 2013). The appearance of *H. erectus sensu lato*, and dispersal of hominins out of Africa into Eurasia also occurred during this time interval (Zhu *et al.*, 2004; Ferring *et al.*, 2011; Lordkipanidze *et al.*, 2013). In addition to this wider geographic spread, hominin activities appear more persistent temporally, for example occurring through consecutive layers in an almost 3 meter sequence of sediments at the 2.0 Ma locality of Kanjera South, Kenya, probably representing hundreds of years of deposition (Plummer *et al.*, 1999), or through levels of the FLK I locality representing thousands of years of deposition at Bed I Olduvai Gorge, Tanzania (Leakey, 1971; Hay, 1976). Relative to the older occurrences, sites in the 2.0-1.7 Ma time interval tend to combine generally complex raw material selectivity patterns with on average longer transport distances, with some evidence that particular raw materials were being collected for the production of specific artifact types (Plummer, 2004; Braun *et al.*, 2008; Harmand, 2009a,b; Goldman-Neuman & Hovers, 2012; Potts, 2012).

The zooarchaeological record also becomes more substantial in the 2.0-1.7 Ma time interval, with evidence of hominin processing of fauna recovered from multiple sites across Africa (e.g., Kanjera South and FwJj20, Kenya; FLK Zinj, Tanzania; Ain Hanech, Algeria, Swartkrans, South Africa) (Pickering *et al.*, 2008; Braun *et al.*, 2010; Ferraro *et al.*, 2013; Sahnouni *et al.*, 2013). These sites provide clear evidence of the routine transport of artifacts as well as delayed consumption and transport of food (animal carcasses, and possibly plant foods) across the landscape. This may reflect a socioeconomic shift towards more cooperative foraging and provisioning in hominin groups (Plummer, 2004; Swedell & Plummer, 2012). The most comprehensively studied Oldowan zooarchaeological assemblages are derived from Mary and Louis Leakey's pioneering work at Olduvai Gorge, Tanzania (Leakey, 1971; Potts, 1988; Dominguez-Rodrigo *et al.*, 2007), with interpretation of the faunal assemblage from FLK I Level 22 (FLK-*Zinjanthropus* or FLK Zinj) dominating the discussion of Oldowan hominin subsistence practices (Bunn & Kroll, 1986; Potts, 1988; Oliver, 1994; Blumenschine, 1995; Capaldo, 1997; Selvaggio, 1998; Dominguez-Rodrigo *et al.*, 2007; Pante *et al.*, 2012). Whether large mammals were acquired by hominins as fleshy or as largely defleshed carcasses with only marrow and head contents remaining has been a point of contention for some time (Binford, 1981; Bunn & Kroll, 1986; Dominguez-Rodrigo *et al.*, 2007; Pante *et al.*, 2012). The mode of carcass acquisition, frequency of meat consumption and evolutionary significance of animal tissue is still debated, with some researchers arguing that high quality plant foods (e.g, underground storage organs (USOs)) were of greater dietary and socioeconomic importance than meat (O'Connell *et al.*, 1999; Wrangham *et al.*, 1999). The intensity of competition between Oldowan hominins and carnivores is also debated, as is the competitive position of Oldowan hominins within the Plio-Pleistocene carnivore guild (Blumenschine, 1987; Bunn & Ezzo, 1993; Brantingham, 1998; Parkinson *et al.*, 2015). Finally, the interpretation of behaviors leading to site formation range broadly (Plummer, 2004), from hominins picking over bones at carnivore kill sites with no faunal transport (Binford, 1981), to extensive food and lithic transport and food sharing at secure positions on the landscape (Isaac, 1978; Rose & Marshall, 1996).

On-going research at Kanjera South, Kenya, provides excellent data sets for assessing the behavior of Oldowan hominins in this critical time interval. One of the primary goals of our research is to investigate the adaptive significance of Oldowan tools. Did stone tool use play an important but perhaps not always essential role in the foraging ecology of early humans, akin to chimpanzee tool usage, or was hominin foraging stone tool-dependent? Understanding how

Oldowan stone tools were manufactured, transported, used, and discarded across the landscape will tell us something fundamental about the behavior and cognitive sophistication of the oldest stone tool makers, and the importance of tool manufacture and use to their survival.

The Oldowan Site of Kanjera South, Kenya

Since 1995 an interdisciplinary team of palaeontologists, archaeologists, and geologists has been investigating the late Pliocene and Pleistocene deposits exposed at Kanjera South, which lies on the northern margin of the Homa Peninsula (Behrensmeyer *et al.*, 1995; Ditchfield *et al.*, 1999; Plummer *et al.*, 1999, 2009a,b; Bishop *et al.*, 2006; Braun *et al.*, 2008, 2009a,b; Ferraro *et al.*, 2013; Lemorini *et al.*, 2014) (Fig. 1). Centrally located on the peninsula, the peaks of the Homa Mountain carbonatite complex are ringed by sediments deposited in alluvial fans, and by streams and lakes. Fossil-bearing sediments extend back in time to at least 6 Ma, with the oldest well-dated archaeological occurrence being found at Kanjera South.

Magnetostratigraphy and biostratigraphy indicate that the archaeological sites at Kanjera South are approximately 2 million years old (Plummer *et al.*, 2009). The silts and fine sands at the locality were deposited in and around channels and floodplains near the foothills of Homa Mountain (Fig. 1). We have recovered multiple levels of stone artifacts and associated fauna successively through three beds (from oldest to youngest KS-1 through KS-3) spanning approximately three meters of sediment (Plummer *et al.*, 1999). The sands and sandy silts of the beds were deposited by variable water flow in unconfined ephemeral channels. Thin conglomerate lenses represent brief intervals of more rapid water flow. Except for the conglomerate lenses, hominin activity was the primary agent of accumulation of the Kanjera archaeological materials (Plummer *et al.*, 1999; Ferraro *et al.*, 2013). The 169 m² Excavation 1 is the largest excavation to date, and has yielded approximately 3700 fossils and 2900 artifacts with 3D (N, E, and Z) coordinates, exclusive of materials from spit bags and sieving. This represents one of the largest collections of Oldowan artifacts and fauna.

The environmental setting of hominin activities

It is important to document the spectrum of habitats that were available to hominins, and to understand hominin adaptation we need to determine whether they preferred particular habitats within the available range. Over larger timescales and geographic regions, patterns of environmental change can be related to hominin evolutionary patterns to investigate whether environmental change correlates with and potentially triggered evolutionary change (deMenocal, 1995). It seems likely, for example, that the spread of grassy habitats played an important role in the evolution and lifeways of species within the genus *Homo* (deMenocal, 2004; Cerling *et al.*, 2011; Dominguez-Rodrigo, 2014).

Hominin activities at Kanjera South occurred in a more open, grassy setting than is typically associated with Oldowan sites. On a local scale, analysis of the chemistry of soil carbonate nodules associated with the archaeological horizons provides information about the vegetation cover (proportion of grasses using the C_4 photosynthetic pathway versus plants such as bushes, shrubs, or trees using the C_3 photosynthetic pathway) at the time that hominins were making, using and discarding stone tools at the site. The Kanjera soil carbonates have $\delta\ ^{13}C$ values indicative of a very grassy setting (> 75% grass), within the range of open habitats such as wooded grasslands to open grasslands today (Plummer *et al.*, 2009b). Antelopes whose living relatives are found in open settings dominate the bovid sample, and fossil equids are also common (Plummer *et al.*, 1999; Bishop *et al.*, 2006). This fauna indicates that grassy habitats were well represented within the regional plant palaeocommunity, and not simply located in the immediate vicinity of the site. Stable carbon isotope analysis of enamel indicates that these animals had diets composed predominantly of C_4 plants, again reflecting the dominance of grass in the vegetation community (Plummer *et al.*, 2009b).

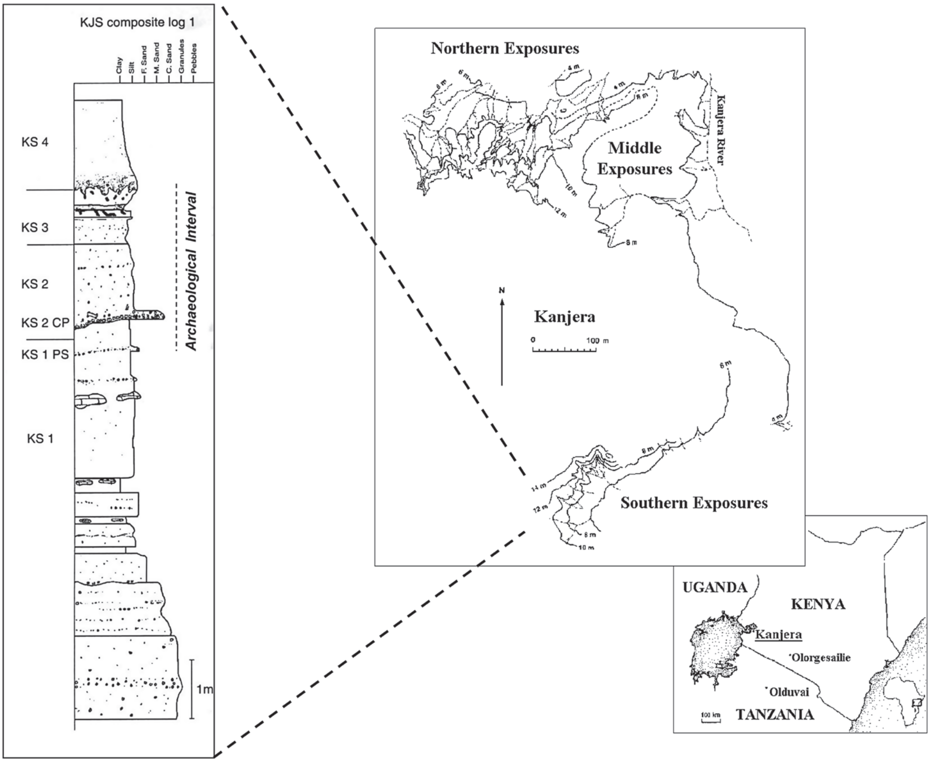

Fig.1 - The location of Kanjera in southwestern Kenya and of the Southern Exposures at Kanjera where the Oldowan occurrences are found. The composite stratigraphic log shows the basal three beds of the Southern Member of the Kanjera Formation (from oldest to youngest KS-1 to KS-3) and the base of KS-4. Spatially associated artifacts and fossils are found as diffuse scatters and also in more vertically discrete concentrations from the top of KS-1 through KS-3, with KS-2 providing the bulk of the archaeological sample. After Lemorini et al. (2014), Figure 1.

The ca. 2.0 Ma sediments at Kanjera South thus provide some of the best early evidence for a grassland dominated ecosystem during the time period of human evolution, and the first clear documentation of human ancestors forming archaeological sites in such a setting. The presence of artifacts and archaeological fauna both low and high in the KS-2 sequence and in the underlying KS-1 and overlying KS-3 indicates that hominins repeatedly visited this grass-rich area on the landscape for hundreds of years. This is significant for several reasons. The open setting contrasts with the more wooded settings associated with other Oldowan sites (Plummer *et al.*, 2009a,b; Braun *et al.*, 2010). This suggests that by 2 Ma, the hominins forming Oldowan sites were using a broad spectrum of habitats during their foraging. Activities in open settings may have correlated with hominin utilization of plant or animal resources that were specific to those habitats. Moreover, the formation of sites in an open setting provides one line of evidence that hominins, in at least some palaeoecosystems, were able to effectively compete with large carnivores. This is an important finding, as there is clear evidence that Oldowan hominins were consuming animal carcasses, and this dietary shift would have increased the frequency that hominins and carnivores came into contact, perhaps in competition for the same carcass.

The importance of lithic technology

The Homa Peninsula and its immediate environs have a complex geological history, so that a diverse array of rocks are exposed in outcrops or as cobbles in conglomerates (Braun *et al.*, 2008; 2009a, b). This raw material diversity is reflected in the artifact assemblages at Kanjera South, which were made using a greater variety of raw materials than typically found at other Oldowan sites (Braun & Plummer, 2013).

Extensive raw material surveys both on and off the Homa Peninsula combined with petrological and geochemical characterization of samples collected from primary outcrops and ancient stream and river conglomerates have been used to build a lithological data base for sourcing most of the rocks used in artifact manufacture. We thus have a good idea of how far the artifacts were transported away from their sources prior to their discard at Kanjera South (Braun *et al.*, 2008). Moreover, these rocks vary in physical properties (e.g., hardness) that can be quantified, with the harder, and often more easily flaked raw materials originating from conglomerates off the Homa Peninsula, outside of the drainage system of Homa Mountain (Braun *et al.*, 2009a, b).

Hardness is an important variable, as experiments have shown that a flake of a hard raw material, like the quartzite found off of the Homa Peninsula 10 or more km away from the site, will maintain a sharp edge much longer than a flake of a soft raw material, such as the limestone that outcrops locally (Braun *et al.*, 2009b). The spatial distribution of raw materials varying in their physical attributes provides an opportunity to assess aspects of hominin decision making in the selection, transport, and flaking of stone. If stone tool manufacture was not a critical component of the foraging behavior of the hominins at Kanjera there would be little pressure to transport stone, and one would expect the artifact assemblage to be overwhelmingly dominated by locally available raw materials from the conglomerates in the radial drainage system off of Homa Mountain. What we found is that approximately 30% of the artifacts recovered from Kanjera were made on rocks that were transported to the site from conglomerates found at least 10-13 km away (Braun *et al.*, 2008). Moreover, these nonlocal raw materials were more extensively flaked, and flaked more efficiently (generating more cutting edge per unit volume) than were the local raw materials found on the peninsula (Braun *et al.*, 2009a,b) (Fig. 2). Large flakes of the nonlocal raw materials were sometimes used as cores, again as a way to increase the amount of cutting edge per unit of rock. Finally, flakes of some of the hard, nonlocal raw materials were occasionally retouched to resharpen their edges, an uncommon practice in the Oldowan. This suite of behaviors reflects the attention hominins paid to raw materials best suited for tool use. The finding that there are not nearly enough cores to account for all of the flakes at the site further hints that the artifact sample at Kanjera was part of a larger transport system (Braun & Plummer, 2013). It appears that cores were being carried by hominins, for use to dispense flakes as needed for various cutting tasks.

The fact that hominins were investing energy in the transport of hard raw materials, and more efficiently reducing these, suggests that artifact manufacture was of great importance in their day-to-day lives. But what was it that they were doing with these artifacts? One certain use was animal butchery (Lemorini *et al.*, 2014). Hominins were primarily acquiring small antelopes roughly the size of Grant's gazelles at Kanjera South (Ferraro *et al.*, 2013; Parkinson, 2013). The representation of the different bones of the skeleton indicates that complete carcasses of these animals were brought to the site. Analyses of dental eruption and long bone fusion indicate that many of these antelopes were immature when they died. Damage to the fossils indicates that hominins were using stone tools to slice meat off of bones, and to break bones open for their marrow. The acquisition and butchery of small, immature, largely complete bovid carcasses may very well be the oldest signal yet of hominin hunting. Low frequencies of carnivore toothmarks are found on the small bovid bones, showing that carnivores were also occasionally interested in the carcasses at the site. But the

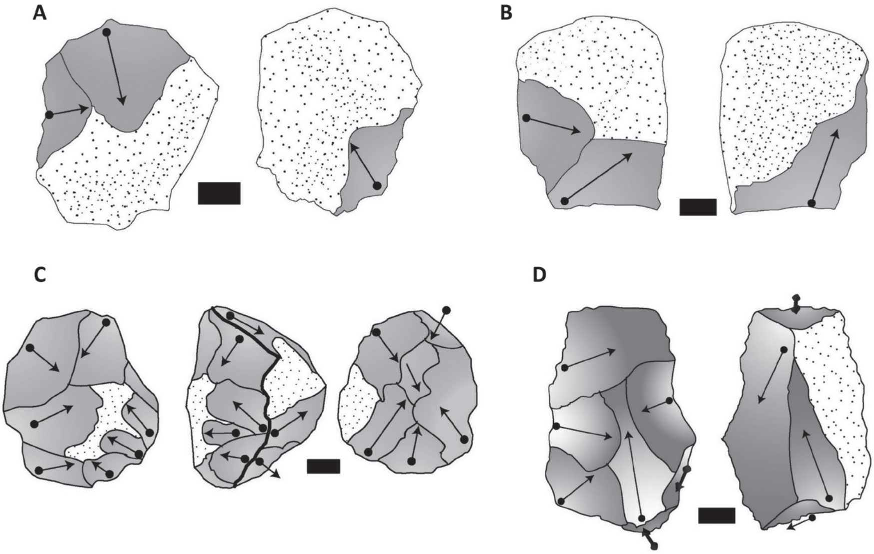

Fig. 2 - Cores from Kanjera South exemplifying the relative reduction of local versus nonlocal raw materials. A and B are cores made from fenetized andesite locally available at Kanjera South. C and D are cores made from Nyanzian rhyolite that was transported at least 10 Km to the site from the Paleo-Awach river system. Core D was a rhyolite flake that was knapped to produce additional flakes. All scale bars are 1 cm. After Braun & Plummer (2013), Figure 2.

carnivore damage largely follows the hominin damage, and appears to represent scavenging of the leftovers of the hominin meals.

In contrast to the small bovids, the skeletal part distribution of medium (e.g, wildebeest-sized) bovids is suggestive of both early and late access, most likely reflecting some degree of scavenging of medium and larger-sized mammals. Because the artifacts and fauna are stratified in three beds through several meters of sediment, the zooarchaeological analysis provides evidence of hominins having repeated access to largely complete small bovid carcasses as well as at least intermittent access to fleshy carcasses of larger animals over hundreds of years (Ferraro *et al.*, 2013; Parkinson, 2013). This provides the oldest evidence of sustained hominin involvement with carcasses, and indicates that by 2 Ma hominins at Kanjera South practiced persistent carnivory.

Artifact use-wear analysis provides another avenue for assessing the range of activities carried out by ancient hominins. We produced flakes of the same raw materials used by the Kanjera hominins, and used these experimentally produced tools to work a variety of materials, such as soft and hard wood, grass, wild tubers, animal skin and animal flesh. This use-wear reference collection was then available for diagnosing what hominins were cutting and scraping based on the use-wear of the quartz and quartzite tools found at the archaeological site (Lemorini *et al.*, 2014). Analysis of use-wear demonstrates that artifacts were used for butchery, corroborating the zooarchaeological evidence for animal butchery by hominins. However, the more important result was the evidence for plant processing, which would have been archaeologically invisible without the use-wear analysis. Roughly two thirds (16 out of 23) of the artifact edges with interpretable use-wear were used to process plants, including herbaceous plants, USOs and wood, the latter potentially for making wooden tools. Documentation of wood-working at Kanjera South may provide the oldest evidence of a multi-step production of tools, where hammerstones were used to strike stone flakes from cores, which in turn were used to make wooden implements. USOs are a collected resource that can be bundled and transported, and may have played a key role in the evolution of central place foraging and provisioning (Isaac, 1978; O'Connell *et al.*, 1999; Wrangham *et al.*, 1999). Despite the prominence of USOs in the discussion of hominin diets, there has been very little archaeological evidence supporting hominin acquisition and consumption of them prior to the Kanjera artifact use-wear study.

Conclusions

Research at Kanjera has informed us a great deal about the habitat use and behaviors of Oldowan hominins in one region of East Africa, and about the potential importance of stone technology to the lives of our ancestors living 2 Ma. Hominins were foraging in a variety of habitats, from grasslands to woodlands, and on the Homa Peninsula at least, processing plant and animal foods with stone tools. Tool use seems to have been adaptively significant, as hominins preferentially utilized and transported stones that were hard, and because of this produced flakes that held a sharp edge for a long time. Hominins consumed foods including animal carcasses and USOs that would have required stone tool use to acquire and/or process, were of high nutritional value, and in the case of whole gazelle carcasses and dense patches of tubers came in packets large enough to be shared. The fact that these behaviors are found throughout 3 meters of sediment indicates that they were not ephemeral, but were sustained activities by multiple generations of hominins in the vicinity of Kanjera South over decades to centuries (Ditchfield *et al.,* 1999; Ferraro *et al.,* 2012).

Given the paucity of archaeological sites with stone tools and well-preserved zooarchaeological samples from equivalent and earlier time intervals, the degree to which the Kanjera results are generalizable to early *Homo* populations existing ca. 2 Ma can be debated. But there are pockets of evidence to suggest that the behaviors discussed here are not unique to the hominins forming the Kanjera assemblages. The roughly coeval site of FwJj20 in Kenya also evinces utilization of high quality foods requiring stone tool processing, including large mammals and aquatic fauna (fish, turtles and crocodiles) (Braun *et al.,* 2010). The slightly younger sites of Ain Hanech, Algeria, FLK Zinj, Tanzania and Swartkrans, South Africa provide documentation of early access to fleshy carcasses of medium-sized mammals (Dominguez-Rodrigo et al., 2007; Pickering *et al.*, 2008; Sahnouni *et al.*, 2013). At FLK Zinj at least, these may have been hunted (Bunn & Gurtov, 2014).

By approximately 1.89 Ma early *H. erectus* appears in Africa. This taxon has a larger average body size and a larger absolute brain size than previous hominin species, and by 1.85 Ma is the first hominin to disperse outside of the continent (Antón *et al.*, 2014). *H. erectus* was large and wide-ranging, had a high total energy expenditure, and required a high-quality diet (Antón *et al.*, 2002; Pontzer, 2012). Food sharing was probably practiced by this species as a way to decrease the daily variance in foraging returns for high quality, patchily dispersed resources, as well as to assist reproductively active females and offspring unable to meet their own nutritional requirements (Aiello & Key, 2002; Plummer, 2004; Isler & van Schaik, 2012; Swedell & Plummer, 2012). The behaviors evidenced at Kanjera, just prior to the first appearance of *H. erectus*, may be the archaeological expression of this shift towards the tool-dependent foraging of high quality foods within a cooperative group context.

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References

Aiello L.C. & Key C. 2002. Energetic consequences of being a *Homo erectus* female. *Am. J. Hum. Biol.*, 14:551-565.

Antón S.C., Leonard W.R. & Robertson M.L. 2002. An ecomorphological model of the initial hominid dispersal from Africa. *J. Hum. Evol.,* 43: 773-785.

Antón S.C., Potts R. & Aiello L.C. 2014. Evolution of early *Homo*: An integrated biological perspective. *Science*, 345: 1236828.

Behrensmeyer A.K., Potts R., Plummer T.W., Tauxe L., Opdyke N. & Jorstad T. 1995. The Pleistocene locality of Kanjera, Western Kenya: stratigraphy, chronology and paleoenvironments. *J. Hum. Evol.,* 29: 247-274.

Binford L.R. 1981. *Bones: Ancient Men and Modern Myths*. Academic Press, New York.

Bishop L.C., Plummer T.W., Ferraro J.V., Braun D., Ditchfield P.W., Hertel F., Kingston J.D., Hicks J. & Potts R. 2006. Recent research into Oldowan hominin activities at Kanjera South, Western Kenya. *Afr. Archaeol. Rev.,* 23: 1572-9842.

Blumenschine R.J. 1987. Characteristics of an early hominid scavenging niche. *Curr. Anthropol.,* 28: 383-407.

Blumenschine R.J. 1995. Percussion marks, tooth marks, and experimental determinations of the timing of hominid and carnivore access to long bones at FLK *Zinjanthropus*, Olduvai Gorge, Tanzania. *J. Hum. Evol.,* 29: 21-51.

Brantingham P.J. 1998. Hominid-carnivore coevolution and invasion of the predatory guild. *J. Anthropol. Archaeol.,* 17: 327–353.

Braun D.R., Plummer T.W., Ditchfield P., Ferraro J.V., Maina D., Bishop L.C. & Potts R. 2008. Oldowan behavior and raw material transport: perspectives from the Kanjera Formation. *J. Archaeol. Sci.,* 35: 2329-2345.

Braun D.R., Plummer T.W., Ditchfield P.W., Bishop L.C. & Ferraro J.V. 2009a. Oldowan technology and raw material variability at Kanjera South. In E. Hovers & D.R. Braun (eds): *Interdisciplinary Approaches to the Oldowan*, pp. 99-110. Springer, Dordrecht.

Braun D., Plummer T. W., Ferraro J., Ditchfield P. & Bishop L. 2009b. Raw material quality and Oldowan hominin toolstone preferences: Evidence from Kanjera South. *J. Archaeol. Sci.,* 36: 1605–1614.

Braun D.R., Harris J.W.K., Levin N. E., McCoy J.T., Herries A.I.R., Bamford M.K., Bishop L.C., Richmond B.G. & Kibunjia M. 2010. Early hominin diet included diverse terrestrial and aquatic animals 1.95Ma in East Turkana, Kenya. *Proc. Natl. Acad. Sci. USA,* 107: 10002-10007.

Braun D.R. & Plummer T.W. 2013. Oldowan technology at Kanjera South: technological diversity on the Homa Peninsula. In M. Sahnouni (ed): *Africa: Cradle of Humanity: Recent Discoveries,* pp. 131-145. CNRPAH, Algeria.

Bunn H.T. & Kroll E.M. 1986. Systematic butchery by Plio/Pleistocene hominids at Olduvai Gorge, Tanzania. *Curr. Anthropol.,* 27: 431-452.

Bunn H.T. & Ezzo J.A. 1993. Hunting and scavenging by Plio-Pleistocene hominids: Nutritional constraints, archaeological patterns, and behavioural implications. *J. Archaeol. Sci.,* 20: 365-398.

Bunn H.T. & Gurtov A.N. 2014. Prey mortality profiles indicate that Early Pleistocene Homo at Olduvai was an ambush predator. *Quat. Int.*, 322: 44-53.

Capaldo S.D. 1997. Experimental determinations of carcass processing by Plio-Pleistocene hominids and carnivores at FLK 22 (*Zinjanthropus),* Olduvai Gorge, Tanzania. *J. Hum. Evol.,* 33: 555-597.

Cerling T.E., Wynn J.G., Andanje S.A., Bird M.I., Korir D.K., Levin N.E., Mace W., Macharia A.N., Quade J. & Remien C.H. 2011. Woody cover and hominin environments in the past 6 million years. *Nature,* 476: 51-56.

de Heinzelin J., Clark J.D., White T., Hart W., Renne P., WoldeGabriel G., Beyene Y. & Vrba E. 1999. Environment and Behavior of 2.5-Million-Year-Old Bouri Hominids. *Science,* 284: 625-629.

deMenocal P.B. 1995. Plio-Pleistocene African climate. *Science,* 270: 53-59.

deMenocal P.B. 2004. African climate change and faunal evolution during the Pliocene-Pleistocene. *Earth Planet Sci. Lett.,* 220: 3-24.

Ditchfield P., Hicks J., Plummer T.W., Bishop L. & Potts, R. 1999. Current research on the Plio-Pleistocene deposits north of Homa Mountain, Southwestern Kenya. *J. Hum. Evol.,* 36: 123-150.

Domínguez-Rodrigo M., Pickering T.R., Semaw S. & Rogers M.J. 2005. Cutmarked bones from Pliocene archaeological sites at Gona, Afar, Ethiopia: implications for the function of the world's oldest stone tools. *J. Hum. Evol.,* 48: 109–121.

Domínguez-Rodrigo M., Barba R. & Egeland C. 2007. *Deconstructing Olduvai: a taphonomic study of the Bed I sites.* Springer, Dordrecht.

Domínguez-Rodrigo M. 2009. Are all Oldowan sites palimpsests? If so, what can they tell us of hominid carnivory? In E. Hovers & D.R. Braun (eds): *Interdisciplinary Approaches to the Oldowan*, pp. 129-148. Springer, Dordrecht.

Domínguez-Rodrigo M., Pickering T.R. & Bunn H.T. 2010. Configurational approach to identifying the earliest hominin butchers. *Proc. Natl. Acad. Sci. USA,*107: 20929-20934.

Domínguez-Rodrigo M., Pickering T. R. & Bunn H.T. 2011. Reply to McPherron *et al.*: Doubting Dikika is about data, not paradigms. *Proc. Natl. Acad. Sci. USA,* 108: E117-E117.

Domínguez-Rodrigo M. & Martinez-Navarro B. 2012. Taphonomic analysis of the early Pleistocene (2.4 Ma) faunal assemblage from AL 894 (Hadar, Ethiopia). *J. Hum. Evol.,* 62: 315-327.

Domínguez-Rodrigo M. 2014. Is the "savanna hypothesis" a dead concept for explaining the emergence of the earliest hominins? *Curr. Anthropol.,* 55: 59-81.

Ferraro J.V., Plummer T., Pobiner B., Oliver J.S., Bishop L., Braun D.R., Ditchfield P.W., Seaman III J.W., Binetti K.M., Seaman Jr. J.W. *et al.* 2013. Earliest Archaeological Evidence of Persistent Hominin Carnivory. *PLoS One*, 8: e62174.

Ferring R., Oriol O., Agustí J., Berna F., Nioradze M., Shelia T., Tappen M., Vekua A., Zhvania D. & Lordkipanidze D. 2011. Earliest human occupations at Dmanisi (Georgian Caucasus) dated to 1.85–1.78 Ma. *Proc. Natl. Acad. Sci. USA,* 108: 10432-10436.

Goldman-Neuman T. & Hovers E. 2012. Raw material selectivity in late Pliocene Oldowan sites in the Makaamitalu Basin, Hadar, Ethiopia. *J. Hum. Evol.,* 62: 353-366.

Harmand S. 2009a. Variability in raw material selectivity at the late Pliocene sites of Lokalalei, West Turkana, Kenya. In E. Hovers & D.R. Braun (eds): *Interdisciplinary Approaches to the Oldowan*, pp. 85-97. Springer, Dordrecht.

Harmand S. 2009b. Raw materials and techno-economic behaviors at Oldowan and Acheulean sites in the West Turkana Region, Kenya. In B. Adams & B.S. Blades (eds): *Lithic Materials and Palaeolithic Societies*, pp. 3-14. Blackwell, New York.

Harmand S., Lewis J.E., Feibel C.S., Lepre C.J., Prat S., Lenoble A., Boës A., Quinn R.L., Brenet M., Arroyo A. *et al.* 2015. 3.3-million-year-old stone tools from Lomekwi 3, West Turkana, Kenya. *Nature,* 521: 310-315.

Hay R.L. 1976. *Geology of the Olduvai Gorge*. University of California Press, Berkeley.

Isaac G.L. 1978. The Food-sharing Behavior of Protohuman Hominids. *Sci. Amer.,* 238: 90-108.

Hovers E. 2015. Archaeology: Tools go back in time. *Nature,* 521: 294-295.

Isler K. & van Schaik C.P. 2012. How our ancestors broke through the gray ceiling. *Curr. Anthropol.*, 53: S453-S465.

Laden G. & Wrangham R. 2005. The rise of the hominids as an adaptive shift in fallback foods: plant underground storage organs (USOs) and australopith origins. *J. Hum. Evol.,* 49: 482-498.

Leakey M.D. 1971. *Olduvai Gorge: Excavations in Beds I and II, 1960-1963*. Cambridge University Press, Cambridge.

Lemorini C., Plummer T.W., Braun D., Crittenden A., Marlowe F., Bishop L.C., Ditchfield P., Hertel. F., Oliver J., Schoeninger M. *et al*. 2014. Old stones song: functional interpretation of the Oldowan quartz and quartzite assemblage from Kanjera South (Kenya). *J. Hum. Evol.,* 72: 10-25.

Lordkipanidze D., de León M.S.P., Margvelashvili A., Rak Y., Rightmire G.P., Vekua A. & Zollikofer C. P. 2013. A complete skull from Dmanisi, Georgia, and the evolutionary biology of early *Homo*. *Science,* 342: 326-331.

Magill C.R., Ashley G.M. & Freeman K.H. 2013. Ecosystem variability and early human habitats in eastern Africa. *Proc. Natl. Acad. Sci. USA,* 110: 1167-1174.

McPherron S.P., Alemseged Z., Marean C.W., Wynn J.G., Reed D., Geraads D., Bobe R. & Béarat H.A. 2010. Evidence for stone-tool-assisted consumption of animal tissues before 3.39 million years ago at Dikika, Ethiopia. *Nature,* 466: 857-860.

McPherron S.P., Alemseged Z., Marean C., Wynn J.G., Reed D., Geraads D., Bobe R. & Béarat H.A. 2011. Tool-marked bones from before the Oldowan change the paradigm. *Proc. Natl. Acad. Sci. USA,* 108: E116.

O'Connell J.F., Hawkes K. & Blurton Jones N.G. 1999. Grandmothering and the evolution of *Homo erectus*. *J. Hum. Evol.,* 36:461-485.

Oliver J.S. 1994. Estimates of hominid and carnivore involvement in the FLK *Zinjanthropus* fossil assemblage: some socioecological implications. *J. Hum. Evol.,* 27:267-294.

Pante M.C., Blumenschine R.J., Capaldo S.D. & Scott, R.S. 2012. Validation of bone surface modification models for inferring fossil hominin and carnivore feeding interactions, with reapplication to FLK 22, Olduvai Gorge, Tanzania. *J. Hum. Evol.,* 63: 395-407.

Parkinson J.A. 2013. *A GIS image analysis approach to documenting Oldowan hominin carcass acquisition: Evidence from Kanjera South, FLK Zinj, and neotaphonomic models of carnivore bone destruction*. PhD diss., City University of New York.

Parkinson J.A., Plummer T.W. & Hartstone-Rose A. 2015. Characterizing felid tooth marking and gross bone damage patterns using GIS image analysis: An experimental feeding study with large felids. *J. Hum. Evol.,* 80: 114-134.

Pickering T.R., Egeland C., Domınguez-Rodrigo M., Brain C.K. & Schnell A. 2008. Testing the "shift in the balance of power" hypothesis at Swartkrans, South Africa: hominin cave use and subsistence behavior in the Early Pleistocene. *J. Anthropol. Arch.,* 27: 30-45.

Plummer T.W., Bishop L.C., Ditchfield P. & Hicks J. 1999. Research on Late Pliocene Oldowan Sites at Kanjera South, Kenya. *J. Hum. Evol.,* 36:151-170.

Plummer T.W. 2004. Flaked stones and old bones: biological and cultural evolution at the dawn of technology. *Yearb. Phys. Anthropol.,* 47: 118-164.

Plummer T.W., Bishop L.C., Ditchfield P.W., Ferraro J.V., Kingston J.D., Hertel F. & Braun D.R. 2009a. The environmental context of Oldowan hominin activities at Kanjera South, Kenya. In E. Hovers & D.R. Braun (eds): *Interdisciplinary Approaches to the Oldowan*, pp. 149-160. Springer, Dordrecht.

Plummer T.W., Ditchfield P.W., Bishop L. C., Kingston J.D., Ferraro J.V., Braun D., Hertel F. & Potts R.B. 2009b. Oldest Evidence of Toolmaking Hominins in a Grassland-Dominated Ecosystem. *PLoS One* 4: e7199.

Potts R. 1988. *Early Hominid Activities at Olduvai*. Aldine De Gruyter, New York.

Potts R. 1991. Why the Oldowan? Plio-Pleistocene toolmaking and the transport of resources. *J. Anthropol. Res.,* 47: 153–176.

Potts R. 1998. Environmental hypotheses of hominin evolution. *Yearb. Phys. Anthropol.,* 41: 93-136.

Potts R. 2012. Environmental and behavioral evidence pertaining to the evolution of early *Homo*. *Curr. Anthropol.,* 53: S299-S317.

Quade, J., Levin, N., Semaw, S., Stout, D., Renne, P., Rogers, M. & Simpson S. 2004. Paleoenvironments of the earliest stone toolmakers, Gona, Ethiopia. *Geol. Soc. Am. Bull.,* 116: 1529-1544.

Rogers M.J. & Semaw S. 2009. Something from nothing: the appearance and context of the earliest archaeological record. In M. Camps & P. Chauhan (eds): *Sourcebook of Paleolithic Transitions*, pp. 155-171. Springer, Dordrecht.

Rose L. & Marshall F. 1996. Meat eating, hominid sociality, and home bases revisited. *Curr. Anthropol.,* 37:307-338.

Sahnouni M., Rosell J., van der Made J., Vergès J.M., Ollé A., Kandi N., Harichane Z., Derradji A. & Medig M. 2013. The first evidence of cut marks and usewear traces from the Plio-Pleistocene locality of El-Kherba (Ain Hanech), Algeria: implications for early hominin subsistence activities circa 1.8 Ma. *J. Hum. Evol.,* 64: 137-150.

Selvaggio M.M. 1998. Evidence for a Three-Stage Sequence of Hominid and Carnivore Involvement with Long Bones at FLK Zinjanthropus, Olduvai Gorge, Tanzania. *J. Archaeol. Sci.,* 25:191-202.

Semaw S., Rogers M.J., Quade J., Renne P., Butler R., Dominguez-Rodrigo M., Stout D., Hart W., Pickering T. & Simpson S. 2003. 2.6-Million-year-old stone tools and associated bones from OGS-6 and OGS-7, Gona, Afar, Ethiopia. *J. Hum. Evol.,* 45:169-177.

Stout D., Quade J., Semaw S., Rogers M.J. & Levin N.E. 2005. Raw material selectivity of the earliest stone tool makers at Gona, Afar, Ethiopia. *J. Hum. Evol.,* 48: 365-380.

Stout D., Semaw S., Rogers M.J. & Cauche D. 2010. Technological variation in the earliest Oldowan from Gona, Afar, Ethiopia. *J. Hum. Evol.*, 58: 474-491.

Swedell L. & Plummer T.W. 2012. A Papionin multi-level society as a model for early hominin evolution. *Int. J. Primatol.,* 33: 1165-1193.

Toth N., Schick K.D. & Semaw S. 2006. A comparative study of the stone toolmaking skills of *Pan*, *Australopithecus* and *Homo sapiens*. In N. Toth & K. D. Schick (eds): *The Oldowan: Case Studies into the Earliest Stone Age*, pp. 155-222. Stone Age Institute Press, Bloomington.

Wrangham R.W., Jones J.H., Laden G., Pilbeam D. & Conklin-Brittain N. 1999. The Raw and the Stolen : Cooking and the Ecology of Human Origins. *Curr. Anthropol.,* 40: 567-594.

Zhu R. X., Potts R., Xie F., Hoffman K.A., Deng C.L., Shi C.D., Pan Y.X., Wang H.Q., Shi R.P., Wang Y.C. *et al*. 2004. New evidence on the earliest human presence at high northern latitudes in northeast Asia. *Nature,* 431: 559-562.