

The Oldowan: The Tool Making of Early Hominins and Chimpanzees Compared

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Abstract

The Oldowan was the term first coined by Louis Leakey to describe the world's earliest stone industries, named after the famous site of Olduvai (formerly Oldoway) Gorge in Tanzania. The Oldowan Industrial Complex documents the first definitive evidence of early hominin culture as well as the earliest known archaeological record. This review examines our state of knowledge about the Oldowan and the hominin tool makers who produced this archaeological record and compares and contrasts these patterns with the technological and cultural patterns of modern apes, especially chimpanzees and bonobos. Of special interest are methodological approaches that can attempt to make direct comparisons between the early archaeological record and modern ape material culture, including a long-term collaborative experimental program in teaching modern apes to make and use stone tools.

Oldowan Industrial Complex: the earliest stage of human technology, consisting of simple percussors, cores, retouched pieces, flakes, and fragments (~2.6–1 Mya).

Hominin: member of the tribe Hominini, including the bipedal genera *Australopithecus* and *Homo*. Chimpanzees and bonobos are members of the tribe Panini

Tool: an object, modified or unmodified, that is used by an animal for a purpose or objective

Culture: in an ethological sense, refers to learned behavior that is shared by and transmitted among members of a community

Artifact: an object that is recognizably modified, intentionally or unintentionally, through manufacture or use

Chimpanzee: *Pan troglodytes*, found in West, Central, and East Africa. Closely related to bonobos, probably sharing a common ancestor ~2.5 Mya

Bonobo: *Pan paniscus*, sometimes called the pygmy chimpanzee, restricted to a core area of the Congo Basin

INTRODUCTION

The Oldowan Industrial Complex is the first definitive evidence for early hominin tool making and culture (**Figure 1**) and marks the beginning of the archaeological record. Palaeolithic research into aspects of early stone tools has now been carried out for well over 150 years (research into the Oldowan for more than 50 years), including excavation and documentation of early sites and stone artifact assemblages in Africa, Europe, and Asia, as well as a variety of laboratory and experimental studies exploring their significance. Awareness of chimpanzee tool use in the wild began to emerge approximately 50 years ago, after Goodall's (1964) initial documentation of such behaviors, and field and laboratory studies of chimpanzee tool-making and tool-using abilities have grown dramatically over the past few decades. After such concerted research and the development of a fairly extensive literature in each of these areas, it would seem an appropriate time and stage in the discipline to undertake a comparison of tool-related behaviors evident among early hominin tool makers and that now documented among our closest living relatives, the chimpanzees and bonobos.

Why Compare Oldowan and Chimpanzee Tool Makers?

The makers and users of Oldowan tools are now extinct, with no modern representatives of their mental and physical abilities and behaviors. The very earliest Oldowan sites emerge, in fact, prior to definitive evidence of any significant increase in brain size in early hominins and are contemporary with a small-brained, bipedal hominin form, *Australopithecus garhi* (Asfaw et al. 1999), whose cranial capacity (~450 cc) is within the range of modern apes.

Thus, we are devoid of modern representatives of the ancient species of tool makers, but we do have relatives, other living ape species, that show considerable tool-making and tool-using abilities, namely members of the genus *Pan* (the chimpanzees and the bonobos). It can be safely argued that chimpanzees exhibit the

most elaborate set of tool-related behaviors of any existing nonhuman species. Because the chimpanzee's cranial capacity is roughly equivalent to that of a potential candidate for the earliest tool maker, and in consideration of the chimpanzee's documented propensity to make and use tools, it can be extremely useful to examine the similarities and differences between chimpanzee and early hominin tool-related behaviors.

Such comparisons can help inform the fields of paleoanthropology and primatology as well as anthropology as a whole. These may help provide models for other possible tool behaviors of early hominins, which may be archaeologically invisible in the material record; they may highlight behavioral adaptations among early hominins that go beyond behavior patterns observed among other apes and which may have had significance in our species' evolutionary success; they can likewise highlight aspects of modern primate behavior that show parallels with the behavioral transformations in the evolutionary lineage that led to *Homo sapiens*, or conversely, provide insight into important differences in the evolutionary trajectory of apes; and overall they may help provide a more refined view of how well, and in what ways, modern apes might serve as models for early hominin tool makers.

THE OLDOWAN: AN OVERVIEW

The earliest known assemblages of definite stone tools, consisting of stone artifacts that have been deliberately flaked through percussive blows, appear in the archaeological record at 2.6 Mya at Oldowan localities at Gona in Ethiopia (**Figure 1**) (Semaw 2006), and numerous sites bearing such tools have been found over the ensuing 1.5 My, first in Africa, then also in Europe and Asia. For other discussions of the Oldowan, see Isaac (1981, 1982, 1984, 1989), Harris (1983), Toth (1985), Toth & Schick (1986, 2005, 2006), Schick (1986, 1987), Potts (1991), Harris & Capaldo (1993), Schick & Toth (1993, 1994, 2001, 2006, 2009), Klein (1999), Martinez et al. (2003), de Beaune

(2004), Lewin & Foley (2004), Plummer (2004), Roche (2005), Pickering et al. (2007), Barsky (2009), Braun & Hovers (2009), Carbonell et al. (2009), de la Torre & Mora (2009), and Hovers & Braun (2009). Here we outline the hominin candidates for early tool makers, summarize the nature of Oldowan sites and their stone tool industries, and discuss possible behavioral and cognitive implications of these industries.

Who Were the Tool Makers? The Fossil Hominins

From the current evidence, the earliest stone tool-making hominins of the Oldowan were likely australopithecine-grade with smallish brains and large dentition. The discovery of *A. garhi* at approximately the same time as the Gona sites in Ethiopia and only 60 km to the south would suggest this species as a candidate for the maker of the very early tool industries at 2.6 Mya. This taxon is also roughly contemporaneous with *A. aethiopicus* in East Africa and *A. africanus* in South Africa.

Starting ~2.3 Mya, hominin remains have been assigned to the genus *Homo*, although good evidence for the beginning of the cranial expansion generally associated with this genus has not been documented until ~2 Mya. During the time span from 2.0 Mya to 1.0 Mya, the hominin taxa that have been identified that coexisted with stone tool assemblages include the robust australopithecines *A. boisei* in East Africa and *A. robustus* in South Africa and early members of the genus *Homo*: *H. rudolfensis*, *H. habilis*, and *H. erectus*.

It cannot be ruled out that more than one of these hominin forms could have had some involvement in stone tool manufacture and use, but it is apparent that members of the genus *Homo* (*a*) demonstrate a significant brain expansion during this period, between 2.0 and 1.0 Mya, likely correlated with a tool-making emphasis in their evolution; (*b*) also apparently carry this tool-making tradition out of Africa into Eurasia (Bar-Yosef & Goren-Inbar 1993, de Lumley et al. 2005, Diez-Martín 2006); and (*c*) continue this tradition beyond the time of

the extinction of the robust australopithecines by 1 Mya. Thus, the *Homo* lineage would represent the major progenitors of Oldowan tools and, subsequently, the Acheulean tools (hand axes, cleavers, picks) that also appear on the paleolandscape starting ~1.6–1.7 Mya (about the time of the emergence of *H. erectus*) and is contemporaneous with these simpler industries.

The Nature of Oldowan Sites and Stone Industries

Stone artifacts constitute nearly the entirety of the record of early hominin tool making and tool using because these are nearly impervious to the many destructive forces at work since these sites were occupied. If early hominins also had a tool repertoire involving organic materials such as wood, hide, or other materials, direct evidence of these is, for the most part, invisible in the archaeological record. A small number of polished and striated bones that may have served as digging tools have been reported, however, and may give valuable hints about some of the missing elements of the Oldowan hominins' tool kits (Brain 1981, 2007; d'Errico et al. 2001; d'Errico & Backwell 2003).

Fundamentally, early Oldowan stone artifacts are primarily products of hand-held percussive flaking, i.e., holding a stone hammer in one hand and hitting another stone cobble or chunk held in the other hand with a strong percussive blow to detach flakes (a procedure called knapping). Another technique seen in the Oldowan is bipolar technique, in which a core is placed on an anvil and struck from the top with a hammer. Although this is ostensibly a relatively simple activity, experiments have shown this is not such an easy task to master, particularly with regard to the placement, angle, and power of the percussive blow (discussed further below).

Early Oldowan archaeological sites consist, at a minimum, of quantities of stone artifacts and often also contain fossil animal bones, mostly from medium-to-large-size animals. A number of these bones bear evidence of cut marks made with stone tools as well as evidence

Acheulean (Industrial

Complex): the next stage of human technology, characterized by hand axes, cleavers, and picks, as well as Oldowan-like forms (~1.7–0.25 Mya)

Plio-Pleistocene:

time period straddling
the late Pliocene
(~3.0–1.8 Mya) and
Early Pleistocene
(~1.8–0.8 Mya)

of deliberate percussive pitting and fracture (e.g., Blumenschine & Peters 1998, Bunn 1983, Pickering & Domínguez-Rodrigo 2006), presumably to access marrow. A lively debate has centered on whether such butchery traces represent earlier, more primary access to animal remains through hunting and/or confrontational scavenging (Bunn 1983, Bunn & Kroll 1986, Domínguez-Rodrigo 2009, Domínguez-Rodrigo et al. 2007, Pickering et al. 2007, Pickering & Domínguez-Rodrigo 2006) or whether hominins had later, secondary access to carcasses by scavenging the remains of carnivore kills (e.g., Blumenschine 1986, 1989).

Concentrations of hundreds or sometimes thousands of stone artifacts are typically found at many Oldowan sites, and sometimes these sites are clustered in major basins occupied by hominins and that were accumulating layers of sediment during the Plio-Pleistocene. Many of these sites are located in the Rift Valley of Eastern Africa, in karstic caves in South Africa, and in sedimentary basins in North Africa. Major localities include Gona (Semaw 2000, 2006; Semaw et al. 1997, 2003), Hadar (Kimbel et al. 1996), Middle Awash (de Heinzelin et al. 1999), Melka-Kunture (Chavaillon et al. 1979), Konso Gardula (Asfaw et al. 1992), Omo (Howell et al. 1987), and Fejej (Asfaw et al. 1991, de Lumley & Beyene 2004) in Ethiopia; East Turkana (Isaac & Isaac 1997), West Turkana (Delagnes & Roche 2005, Roche 2005, Roche et al. 1999), and Kanjera (Plummer et al. 2009) in Kenya; Olduvai Gorge in Tanzania (Blumenschine & Peters 1998; Leakey 1971, 1994; Peters & Blumenschine 1995, 1996; Potts 1988); Nyamabusosi in Uganda (Texier 1995); Sterkfontein and Swartkrans in South Africa (Field 1999; Kuman 1998, 2005); Ain Hanech and El Kherba in Algeria in North Africa (Sahnouni 1998, 2006; Sahnouni et al. 1997, 2002); and Dmanisi in the Republic of Georgia (de Lumley et al. 2005).

A typical Oldowan stone tool assemblage generally includes percussors (hammerstones, spheroids), simple core forms (choppers, discoids, polyhedrons, heavy-duty scrapers), retouched elements (scrapers, awls), and

debitage (flakes and fragments). After ~2 My, some sites exhibited higher proportions of artifact classes such as retouched forms and battered spheroids, which Mary Leakey called “Developed Oldowan” (Leakey 1971, pp. 1–8).

Oldowan artifacts, particularly the larger pieces or cores (so-called core tools), have often been categorized by various researchers according to their shapes and placed into inferred functional groupings such as choppers or scrapers. Experimental studies, however, have called into question whether such categories represent intentional end-products on the part of the hominin tool makers and also question the functional inferences often implied (Toth 1982, 1985). These experiments in manufacturing Oldowan artifact forms have demonstrated that the full range of typical core forms found at early sites can result as by-products of percussive flaking to produce a set of sharp flakes, although sharp-edged core forms could also be used for a range of chopping and scraping activities.

Raw materials used for stone artifacts tended to be found in the form of rounded cobbles from river gravels or angular chunks from primary rock outcrops. Depending on a given region, typical rock types included volcanic lavas (basalts, trachytes, rhyolites, phonolite, occasionally obsidians, etc.), ignimbrites (“welded tuffs”), quartzes, quartzites, limestones, and cherts.

A recurrent pattern at many Oldowan sites is evidence for transport of stone resources, including quantities of flaked materials, from place to place on the paleolandscape, as well as selectivity in choices of rock types and quality for tools (see Blumenschine et al. 2008; Braun et al. 2008, 2009a,b; Goldman-Neuman & Hovers 2009; Harmand 2009; Hay 1976; Negash et al. 2006; Piperno et al. 2009; Schick 1987; Stout et al. 2005; Toth 1982). At some sites, these transport distances were more than ten kilometers. At Olduvai Gorge, Tanzania, for instance, raw materials are quite often found several kilometers and sometimes 8–20 km from their sources, and at Kanjera, Kenya transport distances were up to 13 km.

Longer distance transport does not, of course, necessarily imply that hominins accomplished this in one event because raw materials may well have been moved on separate occasions from one site to another, and such movement of stone was likely embedded in their foraging patterns rather than special long-distance trips just for stone. From analysis of reconstructed cores and from technological analysis of the artifact assemblages, it is evident that hominins were often flaking cores prior to transporting them to a particular site, conducting further flaking at the site, and then subsequently transporting some of the artifacts away from the site. This indicates a level of behavioral complexity that has only recently begun to be appreciated.

One of the long-standing challenges of Palaeolithic archaeology is the determination of artifact function. For the Oldowan, most of the evidence is indirect—based on ethnographic analogy, experimental feasibility studies, and archaeological context (e.g., the association of stone artifacts with animal bones). We know that battered hammers and spheroids served as percussors for flaking stone, and roughly pitted stone hammers and anvils testify to their use in bipolar flaking. And, as previously mentioned, the processing of animal carcasses can leave diagnostic cut-mark traces from the stone knives used to skin, deflesh, and dismember, as well as produce diagnostic fracture patterns from breaking bones for marrow and brains. This evidence is particularly clear at the FLK Zinj site in Bed I at Olduvai (the “Woodstock” of Oldowan studies), but it should be noted that a number of Oldowan sites with associated stone artifacts and animal bones bear little or no evidence of hominin modification (e.g., Domínguez-Rodrigo 2009) and leave the probable function of these artifacts an open question.

Experiments in the use of a range of Oldowan artifact forms for a variety of possible tasks substantiate the effectiveness of simple flake edges in cutting tasks, particularly in animal butchery (Jones 1994; Toth 1982, 1985). Microscopic usewear analysis on a sample of Oldowan artifacts from East Turkana has

indicated use of a number of flakes for cutting meat as well as use of some others for cutting soft plants (perhaps grasses for bedding) and for scraping wood (Keeley & Toth 1981). This latter evidence may suggest the use of stone tools to produce tools in other materials, e.g., perhaps the shaping of wood into spears or digging sticks, but such direct evidence is so far absent in the Oldowan.

The Oldowan documents one of the major phases of hominin brain evolution, with cranial capacities increasing from ~450 cc in *A. garhi* to up to 900 cc in early *Homo erectus*. Holloway et al. (2004) suggests that this period of brain evolution is correlated with increased language abilities, social complexity, tool standardization, hunting, and the development of home bases. Recently, brain-imaging studies (Stout et al. 2009) have shown that brain activity during the manufacture of Oldowan (and Acheulean) tools partially overlaps with areas associated with language, suggesting a possible coevolution of these two systems. For overviews and further discussions of the possible cognitive implications of early stone tools, see Parker & Gibson (1979), Isaac (1986), Wynn (1989, 2002), Gibson (1986), Dunbar (1993), Gibson & Ingold (1993), Toth & Schick (1993), Aiello & Wheeler (1995), Gowlett (1996), Joulain (1996), Mellars & Gibson (1996), Mithen (1996), Noble & Davidson (1996), Deacon (1997), Parker & McKinney (1999), Ambrose (2001), de la Torre et al. (2003), Holloway et al. (2004), de la Torre & Mora (2005), Pelegrin (2005), Roux & Bril (2005), Stout (2006), Stout & Semaw (2006), Stout et al. (2006, 2009), and Renfrew et al. (2009).

Summary: Implications of Oldowan Sites

Some important inferences that bear on possible cognitive abilities of the early hominin tool makers can be drawn from the Oldowan patterns:

1. Stone tool manufacturing skill: Even very early stone artifacts at the earliest sites at Gona demonstrate remarkable skill and control in flaking stone;

Material culture:

learned behavior that is manifested in objects, notably tools

2. Forethought and transport: Hominin tool makers showed considerable forethought in multiple aspects of their tool manufacture and use, including transport of raw materials and tools to and from different site locales;
3. Selectivity in use of raw materials: Hominin tool makers were aware of and responsive to signs of raw material quality that would affect ease and control of fracture as well as tool effectiveness;
4. Concentrating artifacts: Hominin behaviors tended to concentrate substantial amounts of tool materials at certain locations, possibly indicating repeated use or large social group use of these locales;
5. Acquisition of animal resources: Evidence indicates that hominins were often engaged in accessing meat resources from fairly sizeable animals using stone tools to deflesh carcasses and to fracture bones to access marrow. They may also have been actively involved in transporting these animal parts and concentrating them at some site locations, presumably for amenities such as shade, shelter, or protection or water. Consistent acquisition of such food sources would have placed them in more direct competition with active predators and scavengers and likely increased their risk factors from predation as well.

CHIMPANZEE TOOLS AND TECHNOLOGY

Studies of Wild Chimpanzee Tools

The range and instances of documented wild chimpanzee technology have increased dramatically during the past few decades of research. This increase likely is largely the result of the growing number of habituated chimpanzee populations combined with the number of long-term, committed projects investigating chimpanzee populations in different parts of Africa. The number of articles and chapters discussing chimpanzee technology and cultural

traits far exceeds the citation limit of this review, so here we focus on the references that attempt a synthesis of our state of knowledge. A number of researchers from different backgrounds and perspectives have addressed the relevance of chimpanzee technology to human evolutionary studies, including Beck (1980) (animal tools), Bonner (1980) (animal culture), Goodall (1986) (general), Foley (1987) (tool phylogeny), Wynn & McGrew (1989) (primate and hominin tool use), Sept (1992, 1998) (nesting patterns), McGrew (1992, 1993, 2004) (general), Berthelet & Chavaillon (1993) (primate and hominin tool use), Wrangham (1996) (general), Whiten et al. (1999, 2009) (chimpanzee cultural traits), Stanford (2001) (general), Panger et al. (2002) (evolutionary history of technology), Matsuzawa (2002) (general), van Schaik et al. (2003) (ape cultural traits), Hunt (2006) (sex differences in tool use), Lycett et al. (2007) (cladistics of chimpanzee cultural traits), and Carvalho et al. (2008) (chaînes opératoires).

Studies of chimpanzee tool use afford us much more fully textured insight into the range of material culture employed by these populations than is possible for Oldowan tools (e.g., Goodall 1986; McGrew 1992, 1993). McGrew (1993) has argued effectively for an intelligent, flexible, problem-solving use of tools among chimpanzees and, moreover, that tool use is the norm among wild chimpanzee populations. The range of tools used may differ among populations, but tool use is observed daily in any well-habituated population. Chimpanzee tool use involves a variety of organic materials that do not tend to be preserved in the archaeological record, and furthermore, it is possible to observe directly a wealth of detail regarding many aspects of tool use.

The variety of details that can be obtained from studies of chimpanzee tool use among wild populations can include preparation or processing of the tool, specifics regarding how it was used and on what sort of material(s), potential reuse of a tool, the use of tool sets combining a sequence of tools for a specific purpose, the frequency of observed uses of a tool, possible age or sex differences in tool use, the process of

learning tool use, fine-grained information regarding transport of tools and other materials, seasonal or ecological factors affecting tool use, contemporary regional or population similarities and differences, possible details regarding the locale of tool use (shade or protection, food or other resources, etc.), and potentially other activities also conducted at the site. These data can provide a wealth of information not directly available to the Palaeolithic archaeologist.

McGrew (1992, 2004) has provided broad overviews of material culture as well as culture writ large among chimpanzee populations, particularly among wild chimpanzees. As he has noted, most observations of habitual chimpanzee tool use are oriented toward subsistence activities, obtaining or processing materials for consumption, especially social insects such as termites or ants and nuts. Typical tool use for subsistence would include fishing for termites with twigs or grasses, using leaf sponges to scoop brains from a cranium or fruit from a husk, or using stone or wood hammers and anvils to crack open hard-shelled nuts. One report (Mercader et al. 2007) has suggested that a locality in the rainforest of Côte d'Ivoire dated to 4300 years ago may be a chimpanzee nut-cracking site, which would indicate some longevity for this practice if chimpanzees were responsible for the apparent activities here. In addition, in Senegal, chimpanzees appear to have used stone anvils to smash open baobab fruits (Marchant & McGrew 2005).

Another category of tools consists of materials used as weapons, such as sticks and stones thrown at other chimpanzees or at baboons competing for the same food, behaviors that are well known but not systematically studied. Although chimpanzee males are known to prey on smaller animals such as monkeys and small antelope, they generally have been observed to carry out the hunt and the consumption of the animal without the use of tools. An exception to this pattern with regard to hunting has recently been documented in Senegal by Pruett & Bertolani (2007), who observed a number of chimpanzees, particularly females and including immature individuals, on several occasions

shape wooden branches into pointed tools to try to jab and extract prosimians from tree cavities; they observed one successful kill in 22 bouts of observations.

Besides such use of stone hammers and anvils, another chimpanzee activity that could have archaeological visibility is their consumption of prey animals, which can leave toothmarks on bones, including tooth scoring, canine punctures, and damage to bone ends. This practice has been observed in the wild (Plummer & Stanford 2000) as well as in an experimental setting (Pickering & Wallis 1997). [Toothmarks on bones from Oldowan sites are often assumed to be produced by carnivores, although there is a growing appreciation that Oldowan hominins could also be responsible for some of these (White & Toth 2007)].

Some sex differences have been noted among chimpanzees in terms of tool-related behaviors. Notably, fishing for termites and dipping for ants are important subsistence activities conducted with tools that are preferentially associated with females, who have been observed to pursue these activities much more often than do males. McGrew (1992) has observed that these activities require prolonged and systematic persistence using a tool to extract predictable resources and that they are, in a sense, akin to gathering. Hunt (2006) has observed that not only do female chimpanzees use tools more frequently than do males, but they do so especially for lower-return food items requiring significant processing. Hunt further notes that females also use tools during arboreal feeding, whereas males use technology to harvest terrestrial resources. Among the nut-cracking chimpanzee populations in West Africa, investigators have observed that females are more apt and efficient than are males in opening the harder-shelled varieties. As mentioned above, hunting of smaller mammals is a predominantly male activity, albeit without the use of tools.

A number of researchers have compiled evidence and analyses from a number of chimpanzee study areas and discerned that chimpanzee material culture and nonmaterial culture show some regional patterning,

indicating the potential role of cultural transmission in spreading and maintaining regional patterns of behavior (Whiten et al. 1999, 2001). Such a pattern might be expected because many shared behaviors among chimpanzees appear to be learned, often transmitted through observation and a trial-and-error learning curve. Much of this transmission seems to be from mother to offspring, sometimes with a prolonged period of apprenticeship (Boesch & Boesch-Achermann 2000, Goodall 1986, McGrew 2004).

To investigate large-scale chimpanzee cultural patterning, Toth & Schick (2007) examined the relationships between geographical proximity of different chimpanzee populations in West and East Africa and the number of shared cultural traits reported in the Whiten et al. (1999) study. At the species level, there was no significant pattern, but at the subspecies level (comparing West African groups to other West African groups of *Pan troglodytes verus* and comparing East African groups to other East African groups of *Pan troglodytes schweinfurthii*), a highly significant pattern appeared to emerge (Figure 2). The number of shared cultural traits between groups dropped by more than half (from eight shared traits to fewer than four) at a distance of ~700 km (about 450 miles).

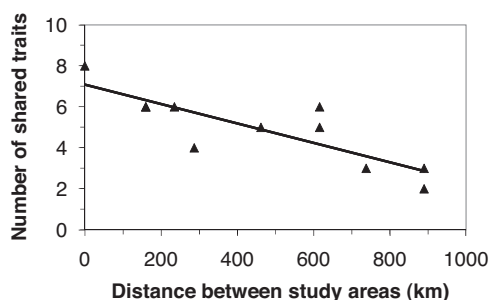


Figure 2

The relation between the number of shared chimpanzee cultural traits (habitual or customary, from the Whiten et al. 1999 paper) and distances between pairs of chimpanzee groups of the same subspecies. Note that groups in closer proximity tend to share more traits and that the number of shared traits drops by more than half (to fewer than four) at a distance of ~700 km. A Pearson r^2 value of 0.702 was derived for the 11 pairs of 7 groups; among the East African chimpanzee groups (10 pairs), Pearson $r = -0.829$, $r^2 = 0.687$, $p = 0.003$; Mantel test $p = 0.014$.

At the species level, with West African and East African populations separated by more than 4000 kilometers (more than 2700 miles), and perhaps two million years of time based on some genetic estimates, the results would appear to indicate some degree of convergence (independent invention) of cultural traits among disparate populations, without any clear evolutionary history. At the subspecies level, with a much more recent evolutionary history, there appeared to be some geographic patterning to the number of shared cultural traits by proximity to other chimpanzee groups. The drop-off of more than half the number of cultural traits in ~700 kilometers was used as a model for early hominin groups on the basis of known Oldowan archaeological sites (Toth & Schick 2007, Whiten et al. 2009). Such a subspecies patterning has also been independently suggested by Lycett et al. (2007) on the basis of a cladistic/phylogenetic analysis of chimpanzee cultural traits.

Thus, there is no universal chimpanzee culture in terms of tools but rather different clusters of tool-use behaviors in differing populations. One major difference noted between East African and West African populations is the prevalent (though not universal) use of hammers and anvils of stone or wood to crack open hard-shelled nuts in West African chimpanzee populations, a behavior that has not yet been documented among East African populations. Whiten et al. (2001) found that 39 behavior patterns, many of which involved tool use, variably observed among a group of 9 long-term chimpanzee study sites across Africa, showed patterning consistent with social transmission.

As might be expected, as quadrupedal, knuckle-walking animals, chimpanzees are not proficient at transporting materials. They do transport tools to tool-use sites, though generally over fairly short distances. Interesting patterns are observed in the tool transport behaviors for nutting activities in West Africa (Boesch & Boesch 1983, 1984, 1990; Boesch & Boesch-Achermann 2000; Boesch-Achermann & Boesch 1994). For the softer-shelled *Coula* nuts, wooden hammers are sometimes chosen

and taken up into a *Coula* tree to crack open nuts on a tree branch. For the harder, *Panda* nuts, however, stone hammers are sometimes carried short distances to the base of the *Panda* tree. The distance a stone or wooden hammer is transported may be relatively low in a single instance, but cumulative trips could accomplish greater distances.

Boesch & Boesch (1984) documented transport of wooden or stone hammers primarily over distances of less than 20 meters but with many transports evident over a distance of up to 500 m and, in very rare instances, more than 500 m. Their study indicated the chimpanzees could develop mental maps of resource locations and follow a least-distance rule in choosing stones to transport to nut tree locations, likely in response to the difficulty chimpanzees face in transporting heavier materials over longer distances. Chimpanzees also generally do not transport vegetable foods or invertebrates any great distance away from the food source. After a hunt, males may transport the kill (e.g., in the mouth or around the neck) to a safe or comfortable place for consumption, but with some difficulty in any case. Under such constraints, it is not surprising that, as McGrew has observed (1992), containers are not part of the tool equipment employed by chimpanzees.

Chimpanzees in the wild have not been observed to flake stone deliberately and thus do not produce materials that may be directly compared with Oldowan technology. Although Mercader et al. (2002) suggested that a West African nut-cracking locality presumably used by chimpanzees contained materials comparable to artifacts at early Oldowan sites, this material does not appear to represent the products of deliberate percussive flaking (unlike most Oldowan artifacts) but instead is only the by-product of nut-cracking (Schick & Toth 2006, pp. 24–26). Interestingly, no food-getting or other activity conducted by modern chimpanzees appears to require a reliance on cutting activities, and this may be the primary reason that a culture of flaked stone technology has apparently not developed among chimpanzees.

To explore the ability of this closely related ape to manufacture Oldowan-type artifacts, then by knapping, we conducted an experimental study.

An Experimental Study of Bonobo Stone Tool Manufacture

One major obstacle in attempts to compare and contrast Oldowan technology with the material culture of chimpanzees is that modern apes in the wild are not known to flake stones intentionally in the wild. Beginning in 1990, we embarked on a long-term experimental project to teach bonobos (*Pan paniscus*) to make and use flaked stone tools (Figure 3). In collaboration with cognitive psychologists Sue Savage-Rumbaugh and Duane Rumbaugh and their colleagues at the Language Research Laboratory of Atlanta and then the Great Ape Trust of Iowa, we began to investigate the tool-making and tool-using capabilities of bonobos in an experimental setting.

Pioneering work by Wright (1972) with a young orangutan demonstrated that a great ape could be taught to make and use a stone tool. Although this experiment used a flint core strapped to a stable board and did not continue beyond the first flake produced and used, it was nonetheless one of the inspirations behind this project. We produced a more naturalistic environment for the bonobos, where freehand, hard-hammer percussion was used to flake cobbles of quartzite, lava, and chert, and the sharp flakes produced were then used to cut a cord to open a box (or cut through the membrane of a drum) and retrieve a food reward. Our first bonobo subject, Kanzi, learned both the flaking and the cutting tasks through observing a human tool maker, began using flakes the first day of the experiment, and made his first tool within a month of the onset of the experiment. He has now been flaking stone for 18 years, and his sister Panbanisha is now also a practiced stone tool maker (Savage-Rumbaugh & Fields 2006; Schick et al. 1999; Toth & Schick 1993, 2006).

Recently we undertook a three-way comparison of stone tools manufactured (*a*) by very

early tool makers at Gona, Ethiopia (possibly *A. garhi*); (b) by bonobo (*Pan paniscus*) tool makers with several years experience in stone tool making; and (c) by modern *H. sapiens* very experienced in Oldowan tool manufacture (Toth et al. 2006), all using the same raw materials. These three populations of stone artifacts were then analyzed in detail and compared in terms of dozens of assemblage characteristics, particularly those that would indicate a level of tool-making skill.

For most of the traits attributed to skill, the bonobos tended to be the outgroup, with characteristics of the Gona artifacts either clustering with the modern human sample or intermediate between the bonobo and human samples. The bonobo cores tended to be heavier (the bonobos tended to select larger cobbles, probably because their hands were larger), less heavily reduced, and with fewer scars and a great deal of hammerstone battering on core edges from unsuccessful blows. The morphology of the bonobo cores and flakes appears to have been a function of less impact velocity (a probable biomechanical constraint) as well as less control as to where exactly to detach flakes from a cobble core (a possible cognitive constraint).

The Gona artifacts, however, show much better skill in cobble reduction than the bonobo artifacts do. Cores are more heavily reduced, with almost twice the number of flake scars, and exhibit significantly less battering from misplaced hammerstone blows. Biomechanical studies (Dapena et al. 2006, Harlacker 2009) of the arm swing during Oldowan flaking indicate that manufacture by modern humans produces a very rapid speed of the hammerstone, reaching a final velocity of up to 20 mph. The bonobo arm swing during tool making is considerably less, which may help account for the lower skill evident in their flaking and the considerable battering on the bonobo cores relative to the Gona artifacts and those produced by modern humans.

This study has demonstrated that our closest living relatives among the apes are definitely capable of stone tool manufacture. The apes in this study, however, are not as proficient

in stone tool making, even after many years of experience, as were the early hominin tool makers. As noted above, this difference in skill may be attributed both to cognitive processing and to the biomechanical constraints of the ape.

DISCUSSION AND CONCLUSIONS

In view of the significant technological repertoire of chimpanzees, there are valid arguments for using their behaviors as models for aspects of early hominin activities that are elusive or largely invisible to us. There are, however, also significant differences in chimpanzee biology, behavior patterns, and ecology that should temper us from basing our models of hominid behavior on modern chimpanzees too strictly or uniformly.

This overview has highlighted a number of elements of chimpanzee technology and behavior that appear to have, or may be likely to have, some counterpart in early hominin behavior and technology. These would include the concentrating of tools at sites of use, consumption of meat involving hunting activities and even group cooperation, carrying and transport of tools including stone, battering and bashing activities with stone, their use of probing sticks (which may have some counterpart in early bone tools), and even their tendency to gather together in groups on a daily basis (in nesting trees at night).

We could also infer that the cultural transmission of tool use within a group and between groups would have parallels between the chimpanzee mode (especially from mother to offspring) and early Oldowan hominins. We do not know if the sexual differences observed in chimpanzee tool use and behaviors had counterparts in early hominins, but the ape model does raise this question. Hunt (2006) suggests, based on chimpanzee analogies, that female Oldowan hominins were more frequent tool users than males. The use by chimpanzees of a great variety of tools in perishable, organic materials highlights the probability that early

hominins likewise had a much richer, more diverse, and varied tool kit than is visible in the archaeological record. Bipedal hominins would have had a considerable advantage in terms of transporting tools and foodstuffs around the landscape, and this practice could have been greatly enhanced with the use of containers.

The emergence of the Oldowan around 2.6 Mya, at our present state of knowledge, appears to occur during an evolutionary stage involving relatively small-brained, bipedal australopithecines. The following one million years documents a period of dramatic encephalization with the rise and evolution of the genus *Homo*, a reduction in the size of hominin jaws and teeth, the first spread of hominins out of Africa and into Eurasia, and the earliest appearance of Acheulean industries.

Wild chimpanzees and Oldowan hominins, considering their material culture, would appear to share the following characteristics. First, stone is transported to and used at activity areas, making spatial concentrations of material culture. Second, stone tools become modified (battered and pitted) from their use as hammers and anvils.

As previously mentioned, it is likely that Oldowan hominins had a rich suite of cultural traits that leave little prehistoric visibility. Similarly, the majority of chimpanzee cultural traits and tool-related behaviors would leave little long-term archaeological record. Although their tool use is intelligent and flexible, chimpanzees tend to modify their tools with their bodies, e.g., stripping branches or pulling off bark with their hands or feet or even sharpening tips of branches with their teeth. Early hominins may well have accomplished some tasks in a similar fashion, but the human paleontological evidence suggests that a decrease in size of jaws and teeth over time may be correlated with the rise in extrasomatic tool use, with technology creating “synthetic organs” and gradually allowing hominins to move into niches traditionally occupied by other animals, such as the carnivore guild. We have called this phenomenon “techno-organic” evolution (Schick & Toth 1993).

Major differences in material culture between wild chimpanzees and Oldowan hominins would include the following traits observed in the Oldowan:

1. Skilled, forceful stone knapping by direct percussion with stone hammers, or bipolar flaking with stone hammers and anvils to create sharp edges that could be used for cutting, chopping, and scraping.
2. More selectivity and long-distance transport of lithic raw materials from their geological sources to activity areas (“sites”); concentrations of flaked and battered stone artifacts can number into the hundreds or thousands at a given locality, and transport distances can range from tens of meters to more than 10 kilometers.
3. The acquisition, processing, and consumption of large mammal carcasses (or parts of carcasses), assisted with technology (stone knives and percussors) to exploit meat, marrow, and organ foods, leaving recognizable traces on the bones in the form of stone tool cut marks and hammerstone-induced fracture.
4. Longer-term curatorial behavior of material culture over longer distances and probably longer time periods, suggesting a higher level of planning and anticipatory behavior.

It is likely, but less demonstrable, that during this period hominid populations developed more human-like characteristics, including the emergence of containers and carrying devices (e.g., of skin, shell, or bark); digging tools such as sharpened digging sticks to process underground plant resources; simple spears, throwing sticks or stone missiles, and clubs for predation; larger average group sizes and home ranges; food-sharing behavior; more sexual division of labor; more emphasis on central foraging places (home bases); more complex communicative skills; and the beginnings of symbolic behavior.

Future research into Oldowan archaeology will almost certainly continue to stress the role of technology in its ecological context and

explore new ways to study and test the significance and patterning of this technology during the course of human evolution. As new sites are discovered, our sample sizes of well-excavated stone artifact assemblages, associated animal bones and other materials, and associated hominin tool makers will allow more rigorous methodologies and more robust scientific results. Studies of our ape relatives in the wild will become increasingly crucial and urgent as their habitats dwindle and their populations be-

come endangered, and our disciplines will also gain a great deal of understanding from well-constructed studies of captive apes, who may become the surviving guardians of their genetic and behavioral legacy. Chimpanzees and bonobos are our closest living relatives. Each of our lineages has managed to survive for millions of years since we separated from a last common ancestor; we still have much to learn about them, and they still have much to teach us about ourselves.

DISCLOSURE STATEMENT

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Figure 1

The dawn of human technology. Stone artifacts made on lava river cobbles from Gona, Ethiopia, ~2.6 Mya (cm scale). (*Top row*) Three Oldowan cores. (*Bottom row*) Three flakes. Such artifacts represent the earliest known stage of hominin technology and herald the beginning of the archaeological record. Photo copyright © S. Semaw.



Figure 3

Kanzi, a bonobo or pygmy chimpanzee (*Pan paniscus*), knaps an Oldowan-like cobble-core by freehand, hard-hammer percussion in an experimental setting. Kanzi can produce percussors, cores and flakes that, in a prehistoric context, would easily be recognized as artifactual by archaeologists. Kanzi has now been flaking stone for almost two decades, and other bonobos at the Great Ape Trust of Iowa are now knapping as well. Photograph courtesy of the Great Ape Trust of Iowa.



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