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Chapter · June 2009

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From Nothing to Something: The Appearance and Context of the Earliest Archaeological Record

Michael J. Rogers and Sileshi Semaw

Abstract Before 2.6 million years ago (Ma), no archaeological record has been securely documented, and therefore there is no evidence of hominin tool use. Then, at 2.6–2.58 Ma, there is widespread evidence for tool manufacture and use at several archaeological sites, with undisputed stone tools and fossil fauna at Gona, Ethiopia. Additionally, the evidence from the earliest archaeological sites at Gona shows that the earliest stone tool makers were skilled flintknappers and were able to select high quality stone raw materials. The possible reasons behind this seeming abrupt transition from the absence of stone tools to the presence thereof include sampling biases, paleogeographic influences, gaps in the geological record, paleoenvironmental change, and changes in the record of hominin evolution.

Based on our observations at Gona, the earliest use of flaked stone tools is likely to be slightly older than 2.6 Ma. These stone tools represent a significant change in behavior that set the stage for subsequent hominin evolution. The paleogeographic and paleoenvironmental evidence points to the earliest use of stone tools in certain settings: usually (but not always) close to raw material sources, and ecotones between riparian woodlands and open grasslands. The earliest stone tool makers were proficient, selective, and flexible in their reduction strategies. The variability we see in Pliocene artifact

assemblages has much to do with different raw material sources.

Keywords Early Stone Age • Paleoenvironments • Gona • Oldowan • Pliocene • Stone tools

Introduction

Twenty-five years ago, the earliest archaeological record was known primarily through several excavated sites at Olduvai Gorge (Tanzania) and Koobi Fora (Kenya). Dated to 1.9–1.6 Ma, the stone artifacts found at these sites served as the basis for what we knew about the Oldowan, the simplest known hominin technology. Archaeologists had excavated a handful of other Oldowan sites—including those that were thought to be slightly older in Members E and F in the Shungura Formation (Chavaillon 1976; Merrick et al. 1973), and in the Kada Hadar Member of the Hadar Formation (Corvinus 1975; Harris 1983; Roche and Tiercelin 1980, 1977)—but these were small sites, sometimes with imprecise dating and/or uncertain context, and were therefore either brought into question or omitted from discussion of the earliest human behavioral traces (e.g., Isaac 1984; Leakey 1981; Toth and Schick 1993). Research undertaken in the last decade has shown that the Oldowan archaeological record represented at Olduvai and Koobi Fora is in fact 700,000–900,000 years *later* than the earliest archaeological record, now documented at 2.6 Ma at Gona, Ethiopia (Semaw et al. 2003, 1997). Recent work has also shown that this early record is more widespread than previously known, as research

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projects at West Turkana and Kanjera in Kenya, and Middle Awash, Hadar, and Gona in Ethiopia have all added to the late Pliocene evidence. As additional sites have been securely dated to pre-2.0 Ma, there has been more interest in speculating about the timing and causes of the earliest hominin use of technology (e.g., de Beaune 2004; Foley and Lahr 2003; Panger et al. 2002), linking the earliest use of stone tools with climate change (often explicitly or implicitly tied to the emergence of the genus *Homo* [e.g., Bobe and Behrensmeyer 2004; Bobe et al. 2002; Harris 1983; Potts 1998; Stanley 1992; Vrba 1985; Wynn 2004]), and explaining the apparent variability of this early stone technology (e.g. de la Torre 2004; de Lumley et al. 2005; Delagnes and Roche 2005; Plummer 2004; Roche 2000; Semaw 2006, 2000).

In this paper, we review what is now known of the (still) sparse late Pliocene archaeological record, with particular reference to the paleogeographic and paleoenvironmental context of the earliest archaeological sites. Our own research at Gona is highlighted here because of its early age as well as its large number of localities that have been investigated. We also briefly explore the reasons behind some of the differences that have been noted among some of the late Pliocene artifact assemblages. This overview is not meant as a comprehensive review of the Oldowan archaeological record and ongoing theoretical debates surrounding it, as Plummer (2004) has provided recently, but as a succinct synthesis of the earliest archaeological record, with the hope that this will put

future investigations into broad paleoecological and evolutionary perspective. We also hope that this brief discussion of arguably the most important archaeological transition—the transition from the apparent absence of a human/hominin tool-making tradition to the presence of such a tradition—will help to put all subsequent archaeological transitions described in this volume into broader perspective.

Summary of Archaeological Sites
>2.0 Ma

As a means of highlighting the gaps in our knowledge and the sparseness of the late Pliocene archaeological record, in Table 1 we have placed the known excavated sites from primary contexts in chronological order within 100,000-year time intervals from 2.6 to 2.0 Ma.

Tables 2 and 3 present what is known of late Pliocene archaeological sites. Table 2 summarizes the material evidence found at the sites, and Table 3 focuses on the paleogeographic and paleoenvironmental data that derive from the sites themselves and/or the beds in which the sites are found, contributing to regional paleoenvironmental reconstructions.

Due to the paucity of sites, as well as the vagaries of site dates and dating precision, it makes some sense to consider these late Pliocene sites in three temporal periods: 2.3–2.0 Ma, 2.4–2.3 Ma, and 2.6–2.5 Ma.

Table 1 Excavated, primary context archaeological sites $\geq$ 2.0 Ma

2.6–2.5 Ma	2.5 Ma	2.4–2.3 Ma	2.3–2.2 Ma	2.2–2.1 Ma	2.1–2.0 Ma
<i>Gona:</i> EG 10, 12, 13, 24; OGS 7, 6 DAN 1 BSN 6	<i>Middle Awash:</i> Hata Mb	<i>Omo:</i> FtJi 2, Omo 123 <i>West Turkana:</i> Lokalalei 1, 2C <i>Hadar:</i> AL 666, AL 894 <i>Gona:</i> WG 1	<i>Gona:</i> DAN 2		<i>Kanjera South:</i> Excavation 1 <i>Gona:</i> OGS 3, (OGN 3)

Table 2 Summary of materials found at excavated Oldowan sites older than 2.0 Ma

Site	Locality	Age (Ma)	Material evidence	Stone Raw Materials*	Paleogeography	Associated Hominins	Source(s)
Gona	OGS-6a	2.6–2.55	Lithics, fauna	T, AL, R, B, La, VV, QL	Floodplain of paleo-Awash	None	Semaw et al. (2003); Quade et al. (2004); Stout et al. (2005)
	OGS-7	2.6–2.55	Lithics, fauna	R, AL, La, QL, VV, T, B	Bank of paleo-Awash	None	Semaw et al. (2003); Quade et al. (2004); Stout et al. (2005)
	EG-10	2.6–2.55	Lithics	T, R, B	Proximal floodplain of paleo-Awash	None	Semaw et al. (1997); Semaw (2000); Quade et al. (2004)
	EG-12	2.6–2.55	Lithics	T, R, B	Proximal floodplain of paleo-Awash	None	Semaw et al. (1997); Semaw (2000); Quade et al. (2004)
	EG-13	2.6–2.55	Lithics, fauna	T, R, La, AL, B, QL, VV	Proximal floodplain of paleo-Awash	None	Quade et al. (1997); Semaw et al. (2005); Quade et al. (2004)
	EG-24	2.6–2.55	Lithics	T, R, B?	Floodplain of paleo-Awash	None	Quade et al. (2004)
	DAN-1	2.6–2.5	Lithics	T, R, AL, La, VV, QL, B	Proximal floodplain of paleo-Awash	None	Stout et al. (2005); Quade et al. (2004)
	Kada Gona 2-3-4	2.6–2.5	Lithics	B, T	Bank of paleo-Awash?	None	Roche and Tiercelin (1980); Roche (1996)
	DAN-2d	2.5–2.2	Lithics, fauna	T, R, AL, La, VV, QL, B	Proximal floodplain of paleo-Awash	None	Stout et al. (2005)
	WG-1	2.5–2.3	Lithics, fauna	B, T	Proximal floodplain of paleo-Awash	None	Roche and Tiercelin (1980); Roche (1996)
Middle Awash	Bouri, Hata	2.5	Cutmarked bones	None	Shallow lake margin	<i>A. garhi</i>	Harris (1983); Harris and Capaldo (1993); Quade et al. (2004)
	Member						de Heinzelin et al. (1999)
	FtJi 1	2.34–2.3	Lithics, fauna	Q, C, L	Braided channel—derived context	<i>A. aethiopicus?</i> <i>Homo sp.?</i>	Merrick and Merrick (1976); Howell et al. (1987)
Omo, Shungura	FtJi 2	2.34–2.3	Lithics	Q	Proximal floodplain of meandering proto-Omo	<i>A. aethiopicus?</i> <i>Homo sp.?</i>	Merrick and Merrick (1976); Howell et al. (1987)

Table 2 (continued)

Site	Locality	Age (Ma)	Material evidence	Stone Raw Materials*	Paleogeography	Associated Hominins	Source(s)
West Turkana	FiJi 5	2.34–2.3	Lithics, fauna	Q	Braided channel—derived context	<i>A. aethiopicus?</i> <i>Homo sp.?</i>	Merrick and Merrick (1976); Howell et al. (1987)
	Omo 57	2.34–2.3	Lithics	Q, C, L, Qt	Braided channel—derived context?	<i>A. aethiopicus?</i> <i>Homo sp.?</i>	Chavaillon (1976); Howell et al. (1987); de la Torre (2004)
	Omo 123	2.34–2.3	Lithics	Q, C, L, Qt	Proximal floodplain of meandering proto-Omo river, near ephemeral stream	<i>A. aethiopicus?</i> <i>Homo sp.?</i>	Chavaillon (1976); Howell et al. (1987); de la Torre (2004)
	Lokalalei 1	2.33	Lithics, fauna	L	Floodplain of axial river, near ephemeral stream	<i>Homo sp.?</i>	Kibunjia (1994); Prat et al. (2005); Quinn et al. (2008)
Hadar	Lokalalei 2C	2.33–2.23	Lithics, fauna	P, B	Floodplain of axial river, near ephemeral stream	<i>Homo sp.?</i>	Roche et al. (1999); Delagnes and Roche (2005); Prat et al. (2005); Quinn et al. (2008)
	AL 666	2.33–2.36	Lithics, fauna	B, C	Levee of paleo-Awashi; Crevasse splay of medial floodplain	<i>Homo sp.</i>	Kimbel et al. (1996); Hovers et al. (2002); Hovers et al. (2008)
Kanjera	AL 894	2.33–2.36	Lithics, fauna	L	Levee of paleo-Awashi; Crevasse splay of distal floodplain	<i>Homo sp.?</i>	Hovers (2003); Hovers et al. (2008)
	Kanjera South, Excavation 1	2.1–2.0	Lithics, fauna	(A), B, C, F, Fen, I, Li, M, N, P, Q, Qt, R, S	Near braided streams at lake basin margin	None	Plummer et al. (1999); Plummer (2004); Braun et al. (2008)

*Lithic raw materials: A, andesite; AL, aphanitic lava; B, basalt; C, chert; F, felsite; Fen, fenites; I, ijolite; L, lava unspecified; La, latite; Li, limestone; M, microgranite; N, nephelinite; P, phonolite; Q, quartz; QL, quartz latite; Qt, quartzite; R, rhyolite; S, sandstone; T, trachyte; VV, vitreous volcanic.

Sources: Following Plummer (2004) and Potts (1991).

Table 3 Paleogeographic and paleoenvironmental context of excavated Oldowan sites older than 2.0 Ma

Site	Locality	Age (Ma)	Paleogeographic analogy/depositional environment	Fossil Fauna	Pedogenic carbonates	Other paleoecological data/regional reconstruction	Source(s)
Gona	OGS-6a	2.6–2.55	Open grass or ecotone near paleo-Awash	Cut-marked equid calcaneum on surface	Increase in % C ₄ grass further from paleo-Awash	C ₄ biomass averages 48% in 2.6–2.5 Ma time interval	Semaw et al. (2003); Quade et al. (2004); Levin et al. (2004)
	OGS-7	2.6–2.55	Riparian woodland adjacent to paleo-Awash	Fragments; bone flake; medium-sized upper leg midshaft	See above	See above	Semaw et al. (2003); Quade et al. (2004); Levin et al. (2004)
	EG-10	2.6–2.55	Riparian woodland or ecotone close to paleo-Awash	None	See above	See above	Semaw et al. (1997); Quade et al. (2004); Levin et al. (2004)
	EG-12	2.6–2.55	Riparian woodland or ecotone close to paleo-Awash	None	See above	See above	Semaw et al. (1997); Quade et al. (2004); Levin et al. (2004)
	EG-13	2.6–2.55	Riparian woodland adjacent to paleo-Awash	Persussion-marked medium-sized rib on surface	See above	See above	Semaw et al. (1997); Quade et al. (2004); Levin et al. (2004)
	EG-24	2.6–2.55	Open grass or ecotone near paleo-Awash	None	See above	See above	Quade et al. (2004); Levin et al. (2004)
Middle Awash	DAN-1	2.6–2.5	Riparian woodland or ecotone close to paleo-Awash	Not available	See above	See above	Quade et al. (2004); Levin et al. (2004)
	Kada Gona 2.3–4	2.6–2.5	Close to or in paleo-Awash	None	See above	See above	Roche and Tiercelin (1980); Roche (1996)
	DAN-2d	2.5–2.2	Riparian woodland or ecotone close to paleo-Awash	Cutmarked bones on surface	See above	See above	Quade et al. (2004); Levin et al. (2004)
	WG-1	2.5–2.3	Riparian woodland or ecotone close to paleo-Awash	fragments			Harris (1983); Harris and Capaldo (1993); Quade et al. (2004)
	Bouri, Hata Member	2.5	Open lake margin/deltaic	Cutmarked alcelaphine mandible and <i>Hipparion</i> femur and tibia midshaft; Abundance of alcelaphine antelopes			de Heinzelin et al. (1999)
Omo	Fuji 1	2.34–2.3	Secondary context—braided stream system				Merrick and Merrick (1976); Howell et al. (1987)
	Fuji 2	2.34–2.3	Distal edge of levee of meandering proto-Omo; behind gallery forest at edge of open savanna				Merrick and Merrick (1976); Howell et al. (1987)
	Fuji 5	2.34–2.3	Secondary context—braided stream system				Merrick and Merrick (1976); Howell et al. (1987)
	Omo 57	2.34–2.3	Secondary context—braided stream system				Chavaillon (1976); Howell et al. (1987); de la Torre (2004)

Table 3 (continued)

Site	Locality	Age (Ma)	Paleogeographic analogy/depositional environment	Fossil Fauna	Pedogenic carbonates	Other paleoecological data/regional reconstruction	Source(s)
	Omo 123	2.34–2.3	Distal edge of levee of meandering proto-Omo; behind gallery forest at edge of open savanna				Chavaillon (1976); Howell et al. (1987); de la Torre (2004)
West Turkana	Lokalalei 1	2.33	Alluvial plain of proto-Omo	Taxa include: <i>Theropithecus</i> , Colobinae, <i>Elephas</i> , <i>Hipparion</i> , <i>Notochoerus</i> , <i>Kolpochoerus</i> , <i>Antilopini</i> , <i>Aepyrocerotini</i> , <i>Alcelaphini</i> , <i>Reduncini</i>	Mixed vegetation with some gallery forest		Kibunjia (1994); Brugal et al. (2003); Quinn et al. (2008)
	Lokalalei 2C	2.33–2.23	Proximal floodplain near intersection of marginal channel with meandering proto-Omo	Taxa include: <i>Ceratotherium</i> , <i>Hipparion</i> , <i>Gazella</i> , <i>Alcelaphini</i> , <i>Reduncini</i> , <i>Hippotragini</i>	Mixed vegetation with some gallery forest	Open habitat with patches of bush and/or forest	Roche et al. (1999); Delagnes and Roche (2005); Brugal et al. (2003); Quinn et al. (2008)
Hadar	AL 666	2.33–2.36	Paleosol in medial floodplain, with open bush vegetation bordering paleo-Awash	Taxa include: <i>Theropithecus</i> , <i>Tragelaphus</i> , <i>Raphicerus</i> , <i>Gazella</i> , Muridae		Maka' amitalu Basin fauna: 33% of bovids are Alcelaphini or Antilopini, <i>Thryonomys</i> See above	Kimbel et al. (1996); Hovers et al. (2002); Hovers et al. (2008)
	AL 894	2.33–2.36	Paleosol in distal floodplain—with open bush vegetation bordering paleo-Awash				Hovers et al. (2002); Hovers (2003); Hovers et al. (2008); Kimbel et al. (1996)
Kanjera	Kanjera South, Excavation 1	2.1–2.0	Lake margin, near channel	Abundant equids, alcelaphines	Wooded grassland to open grassland		Plummer et al. (1999); Plummer (2004)

2.3–2.0 Ma Sites

Kanjera South

Plummer and colleagues (Bishop et al. 2006; Plummer et al. 2001, 1999; Plummer 2004) have excavated the largest single site predating 2.0 Ma at Kanjera South, western Kenya. At Excavation 1, they uncovered about 4,500 stone artifacts, made from several different raw materials, associated with more than 3,000 fossil bone fragments, dated to sometime before the Olduvai Subchron, or about 2.1–2.0 Ma. Importantly, both the archaeofauna (with a high proportion of alcelaphine bovids and equids) and associated paleosol carbonates (with highly positive $\delta^{13}\text{C}$ levels translating into abundant C_4 grasses) indicate that the area was dominated by open grassland at the time hominins accumulated the stone debris and faunal remains. Also, the fossils found at Excavation 1 have a large number of small gazelle- and impala-sized individuals, prompting Plummer (2004) to suggest that this represents the hunting of small mammals. Ongoing analyses and future work at Kanjera will certainly add to our knowledge of hominin stone tool use, technology, ranging patterns, and foraging behavior.

Gona

OGS-3 (Ounda Gona South) from Gona is a small excavated site that is probably 2.1–2.0 Ma, but the lithic assemblage has yet to be analyzed. For this reason, it is included in Table 1, but not in Tables 2 or 3. Another site from this time interval at Gona is OGN-3, found in deposits exposed north of the Ounda Gona drainage. Tens of artifacts and fossilized fauna were found freshly exposed on the surface at the site, but it has yet to be excavated. The OGN-3 site is associated with a tuff dated to ~ 2.1 Ma (Table 1).

The DAN-2d (Dana Aoule North) excavation at Gona is included in the 2.3–2.2 Ma time interval, although it could be older. Dozens of artifacts and several cutmarked bones were found here—mostly on the surface, but some artifacts *in situ*—stratigraphically below a tuff dated to 2.27 ± 0.14 Ma (Quade et al. 2004). The assemblage has yet to be fully analyzed.

2.4–2.3 Ma Sites

Omo

It has been long known that the Shungura Formation in the Lower Omo Basin of southern Ethiopia contains some of the earliest archaeological traces (e.g. Chavaillon 1970; Merrick and Merrick 1976; Merrick et al. 1973). Howell et al. (1987) put these sites into geochronologic and paleogeographic context, firmly placing them in Member F (2.34–2.32 Ma). Of the five Member F sites confirmed by excavation, three of them (FtJi 1, FtJi 5, and Omo 57) were found in shallow braided channel in-fills with abraded and rolled faunal remains, probably in secondary context. The other two sites (FtJi 2 and Omo 123) were located in low-energy overbank deposits of a meandering proto-Omo. The artifacts at all these sites are predominantly quartz.

In de la Torre's (2004) recent review of the Shungura Formation archaeology, he confirms the secondary nature of the Omo 57 deposit, showing that most of the quartz pieces from that site are simply naturally rolled pebbles. That said, he also argues that a few of the artifacts from both Omo 57 and Omo 123 show remarkable flintknapping skill on the part of the hominin manufacturer, especially considering the small size and brittle nature of the quartz raw material. There are still questions about the integrity of the Omo 57 site, however, so for now only Omo 123 and FtJi 2 should be considered for any comparative purposes. Unfortunately, neither of these sites contained faunal remains. Future investigations in the Shungura Formation should help to clarify the stratigraphic and paleoenvironmental context of these Member F archaeological occurrences and may provide more definitive information on the existence of stone artifacts in Members C–E.

Hadar

Kimbel et al. (1996) have reported on a small archaeological occurrence discovered in the upper Kada Hadar Member of the Hadar Formation while excavating in sediments close to where an early *Homo* maxilla (A.L. 666-1) was found.

Dated to about 2.33 Ma, the A.L. 666 archaeological site, which was heavily eroded, yielded about 160 stone artifacts, both on the surface and *in situ* (Hovers 2001; Hovers et al. 2008). Another archaeological site, A.L. 894, has also been found nearby in the same basin and within the same stratigraphic interval, about 3–4 meters above a cobble conglomerate (Hovers 2003; Hovers et al. 2008). These two sites were deposited on the levee of the paleo-Awash river, although the A.L. 894 was probably slightly further from the paleo-Awash than A.L. 666 (Hovers et al. 2008). A larger excavation yielding 4,828 stone artifacts (but only eight cores), the A.L. 894 locality will likely prove to be more informative than A.L. 666 in terms of hominin behavior when the site is fully published.

West Turkana

The Lokalalei 1 (Kibunjia 1994; Kibunjia et al. 1992) and Lokalalei 2C (Roche et al. 1999) archaeological sites, found in the Kalochoro Member of the Nachukui Formation at West Turkana, are the earliest documented sites in Kenya (Harmand 2007; Roche et al. 2003). In the Lokalalei 1 excavation, dated to 2.33 Ma, Kibunjia (1994) recovered hundreds of stone artifacts and thousands of fragmentary faunal remains, from a wide variety of taxa indicative of a mixed environment, but with substantial grassland (Brugal et al. 2003). Recently, a single lower first molar was found 100 meters from the archaeological site, morphologically similar to early *Homo* (Prat et al. 2005). Kibunjia (1994) has argued that the stone artifacts at Lokalalei 1 reflect hominins' poor understanding of fracture mechanics, based on the high number of step fractures and small size of the flake scars on some of the cores.

Ironically, the lithic assemblage from Lokalalei 2C, a site only one kilometer from Lokalalei 1, has been described as one that demonstrates "greater cognitive capacity and motor skills than previously assumed for early hominids" (Roche et al. 1999, 57). A smaller site than Lokalalei 1, it also appears to be slightly younger (Brown and Gathogo 2002), dating to 2.33–2.23 Ma. However, its importance lies in the number of refitting pieces that have been found there (Delagnes and Roche 2005): 11% of the 2,614 stone artifacts from both the surface and

the excavation have been conjoined to offer an unprecedented view of the steps taken and skill required by early hominins to create Oldowan stone flakes and reduce a core. In some cases, dozens of flakes have been refitted to their original core. Close to 400 faunal specimens were also found in association with the stone tools. The taxa represented include many that are indicative of open grasslands, though recent carbon isotope analyses on pedogenic carbonates suggest a mixed environment with significant gallery forest (Quinn et al. 2008). Both Lokalalei 1 and 2C were deposited within the floodplain deposits of a large axial (paleo-Omo) river.

2.6–2.5 Ma sites

Middle Awash

Like the A.L. 666 site at Hadar, the archaeological traces of the Hata Member (Bouri Formation), Middle Awash, were found as a result of a paleontological survey. However, the hominin taxon found in the ~2.5-Ma Hata deposits is not early *Homo*, but *Australopithecus garhi* (Asfaw et al. 1999). In addition, the deposits have not yet yielded *in situ* stone tools, only hominin-modified faunal remains. Several modified specimens were found, but only three have been reported *in situ* just above the Maoleem Vitric Tuff (MOVT), dated to ~2.5 Ma (de Heinzelin et al. 1999). These include an alcelaphine bovid mandible fragment with cut marks, a large bovid tibia midshaft with cut marks, chop marks, and percussion marks, and a *Hipparion* femur with cut marks. The marks on these bones indicate dismemberment, filleting, tongue removal, and marrow removal from a variety of large mammals.

Gona

Pliocene stone tools have been known in the Gona area for at least 25 years (Harris 1983; Roche and Tiercelin 1980), but the precise dating of the archaeological sites and the widespread distribution of early archaeological traces was not known until

recently (Quade et al. 2004; Semaw et al. 2003, 1997). Since the Gona Paleoanthropological Research Project began in 1999, several new 2.5–2.6 Ma archaeological sites have been found and sampled through excavation. We now know that Gona is the site of both the earliest archaeological traces documented, as well as the most extensive Pliocene archaeological record, in terms of the number of known localities. All of the archaeological traces found at Gona are found within the recently designated Busidima Formation (previously the upper Kada Hadar Member of the Hadar Formation), with dates constrained between 2.7 and <0.16 Ma (Quade et al. 2008, 2004). This change in nomenclature makes sense in terms of the great amount of time represented by the stratigraphy and the significant changes in lithology seen after the 2.9–2.7 Ma disconformity.

Few of the early archaeological sites at Gona have yielded faunal remains, but the small sample that has accumulated is significant. Bone fragments in the OGS-7 excavation (Semaw et al. 2003) have documented the earliest clear association of stone tools and animal remains. Also, several faunal specimens found on the surface, but clearly from 2.6–2.1 Ma sediments, have shown hominin modifications such as cut marks and percussion marks (Domínguez-Rodrigo et al. 2005).

All of the Gona localities have a consistent paleogeographic setting: they are all closely associated with the paleo-Awash River, which provided the cobbles from which the stone tools were made (Quade et al. 2004; Stout et al. 2005). While some localities were located on the bank or near a channel bar of the paleo-Awash (e.g., OGS-7), others were located up to a few hundred meters from the river in the adjacent edaphic grasslands (e.g., EG-24, OGS-6a) (see Levin et al. 2004; Quade et al. 2004). Pedogenic carbonates in vertisols have revealed both a regional trend towards increased grassland between 3.0 Ma and the present day (in particular between 3.0 and 2.5 Ma) (Quade et al. 2004), and increasing grassland contribution to the vegetation with increased distance from the paleo-Awash (Levin et al. 2004). The combination of these studies has led to the paleogeographic and habitat reconstructions for each Gona locality listed in Table 3.

The small excavated site of BSN-6 (Busidima North) is also located in the same paleogeographic

context as the other earliest sites at Gona and is included in Table 1. However, the lithic assemblage from the site has yet to be analyzed, and we feel that the stratigraphic placement needs verification; therefore, the site is not included in Tables 2 and 3.

The excavated locality of WG-1 (west of the Kada Gona drainage) was originally thought to be about 2.5 Ma (Harris 1983), but now seems to be slightly higher stratigraphically, dating to about 2.5–2.3 Ma (Quade et al. 2004).

General Observations of Recent Discoveries

From the summary above, we make the following general observations, followed by brief discussions of the toolmakers themselves and the paleoenvironmental context of the earliest archaeological traces, including the influence of raw material availability on technological variability.

- (1) Fifteen years ago, there were arguably only four excavated archaeological localities in primary context predating 2.0 Ma (WG-1, FtJi2, Omo 123, and Lokalalei 1). That number is now approaching 20, with most of the recent additions coming from Gona, but with important additions from Middle Awash, West Turkana, Hadar, and Kanjera.
- (2) Even with this dramatic increase in archaeological evidence, the record of the first c. 700,000 years of hominin stone technology is scarce. Gona is the only place with a confirmed record of stone tools that predates 2.36 Ma. This may be partly—but not entirely—due to the rarity of deposits in the 2.8–2.3 Ma time range in Africa. Furthermore, given the extent of the archaeological record at Gona at 2.6–2.55 Ma, it seems odd that this is the only place with stone tools of this age. We predict that this situation will change in the future as more attention is paid to late Pliocene deposits.
- (3) The first hominin-manufactured stone tools will likely be discovered >2.6 Ma, but probably <2.9 Ma. At Gona, there is a gap in the stratigraphic record between 2.9 and about 2.7 Ma. Soon after Busidima Formation deposition

begins—with the first of a series of paleo-Awash channel cuts and subsequent fining-up sequences—we find the first stone tools. This coincidence of a visible archaeological record with the onset of a particular depositional regime implies that stone tool manufacture began earlier than the first visible archaeological locality at Gona (Quade et al. 2004). Future research at Gona and elsewhere may identify earlier archaeological traces.

- (4) The Lokalalei, Hadar, and Omo sites are all dated to about 2.33–2.35 Ma. This coincidence may partly be explained by the existence of the same tuff (Tuff F-1 = Elkalalei tuff, dated to 2.34 Ma) being deposited in the Turkana Basin at both Lokalalei and the Member F sites of the Shungura Formation. The BKT-3 tuff found near A.L. 666 at Hadar is dated to 2.33 Ma, but has yet to be found elsewhere (Campisano and Feibel 2005). Future work may be able to sort out whether this temporal coincidence, and the 250,000-year gap between the Gona sites and these 2.33-Ma sites, is due to small sample size, different depositional histories among different study areas, and/or factors related to hominin adaptation and evolution. The occurrence of early *Homo* at both Hadar and West Turkana close to the 2.33-Ma archaeological sites may prove to be important.
- (5) Kanjera is the only confirmed archaeological site in primary context dated between 2.3 and 2.0 Ma, aside from the small sample at OGS-3 at Gona. Both Kanjera and OGS-3 are probably 2.0–2.1 Ma; therefore, there are no archaeological sites that can be confidently dated to 2.1–2.3 Ma. Future investigations at Gona and elsewhere will add to the sample in this time range, but this observation underscores the problems in drawing too many conclusions about the nature of the archaeological record, and hominin biocultural evolution, before 2.0 Ma.

Who Made Stone Tools in the Pliocene?

This question is easy to answer, but the answer is problematic: We don't know. The candidates include early *Homo*, *Australopithecus garhi*, and

Au. aethiopicus. *Au. garhi* has been found in the same Hata Member deposits as hominin-modified bones at Bouri in the Middle Awash (Asfaw et al. 1999), and no other hominin has been found there. On the other hand, the A.L. 666-1 maxilla found next to stone tools at Hadar has been classified as early *Homo*, perhaps *Homo habilis* (Kimbél et al. 1996). In addition, a molar found close to Lokalalei 1 at West Turkana has also been classified as early *Homo* (Prat et al. 2005).

Both *Au. aethiopicus* and early *Homo* have been identified in the Member F deposits in the Shungura Formation (Suwa et al. 1996), but not in direct association with the archaeological localities. Hominin remains have yet to be found at Gona or Kanjera in the same deposits encasing the early archaeological sites.

While it is possible to suppose that *Au. garhi* made the earliest 2.6–2.5 Ma stone tools and then evolved into stone tool-making early *Homo* by 2.35 Ma, we feel that the situation was probably more complex than this scenario suggests. Although there is no reason to exclude any 2.5-Ma hominin from the capability of making stone tools, the suggestion that *Au. aethiopicus*/*Au. boisei* made the earliest stone tools because of the coincidental stability of both this hominin lineage and Oldowan technology from 2.6 to 1.6 Ma (Wood 1997) fails to convince us from both logical and evidential points of view.

Regardless of the taxonomic resolution of the earliest stone tool makers, it is possible that the paleoanthropological record in the late Pliocene will eventually tell another story of (1) mosaic evolution in hominin evolution, this time decoupling the origins of stone tool manufacture from the origins of marked encephalization, and/or (2) multi-lineal hominin evolution, this time with respect to behavior.

Paleoenvironmental Context of the Earliest Sites

Since identifying the manufacturer(s) of the earliest stone tools is problematic, it is also difficult to address questions related to the paleoecology of the earliest stone tool makers. However, by examining the paleogeographic and paleoenvironmental contexts of the earliest archaeological sites, we

may begin to generate hypotheses related to the adaptive significance of the first stone tool use and the environmental constraints and opportunities that were important for the earliest stone tool makers.

Table 3 summarizes what is known of the paleoenvironmental context of the Pliocene archaeological record by listing the contextual data by category: (1) paleogeographic reconstruction gleaned from depositional environment and sedimentology, (2) fossil fauna found in direct association with the archaeological material (or *is* the archaeological material), (3) pedogenic carbonates found at the archaeological locality or within the same stratigraphic interval as the site, and (4) other paleoecological data, which could include palynology or other regional reconstructions based on faunal remains, isotopes, and/or stratigraphy. By presenting the data this way, we emphasize the piecemeal nature of the paleoenvironmental information we have and the need for multiple lines of evidence in order to increase confidence in our paleoenvironmental inferences. All of the sites in Table 3, except the Omo localities, have more than one line of evidence to support their paleoenvironmental reconstructions.

In general, archaeological sites >2.0 Ma are found in mixed environments with a strong component of open grassland. Small sample size does not allow for an assessment of temporal change or lack thereof, although the paleoenvironmental settings seem fairly consistent from one site to another. The primary differences among sites relates to paleogeographic setting. The sites that are associated with a large axial river system, whether it be paleo-Awash or paleo-Omo (i.e., Gona, Hadar, Omo, West Turkana), all have somewhat mixed environments, probably because the rivers themselves are providing a certain amount of riparian woodland along their banks. The two lake margin sites (Middle Awash and Kanjera), on the other hand, are dominated by open grasslands and seem to have minor woodland components (de Heinzelin et al. 1999; Plummer 2004). The paleogeography of the Gona sites, however, provides a reminder of the dangers in inferring general patterns from single localities.

At Gona, the Oldowan localities are consistently located in association with a large, perennial

paleo-Awash River, which provided the source of the stones for flintknapping (Quade et al. 2004). Some localities were located immediately adjacent to the paleo-Awash (e.g., OGS-7, EG-12, and EG-13), while others were located up to a few hundred meters away from the river (e.g., OGS-6a, EG-24). Using the modern Awash River as an analog, the riverbank localities were probably located in riparian woodlands, while others were set in open edaphic grasslands. Pedogenic carbonates sampled laterally from the paleo-Awash in the lower Busidima Formation support the paleoenvironmental reconstruction of more grassland as one moves further from the paleo-Awash channel (Levin et al. 2004). Excavation of a single site, or even of a few sites, at Gona could give the mistaken impression of a narrow geographic setting for stone tool-making, whereas a larger sample has shown that archaeological traces were left in a variety of settings. However, this variety is constrained by the paleo-Awash and its active floodplain.

Presumably, the Hadar localities were located in similar paleogeographic settings to those at Gona, since both localities were found in paleosols (Hovers 2003) within similar fining-up sequences to those seen at Gona, with cobble conglomerates at the base (Kimbel et al. 1996). The setting of the A.L. 666 locality seems analogous to the floodplain localities of EG-10 and EG-12, whereas the A.L. 894 locality may be more distal (Hovers et al. 2008), similar to the settings of EG-24 and OGS-6a. The fauna at A.L. 666 is representative of a mixed grassy/woodland environment, and seems similar to the overall faunal assemblage from the Maka'amitalu basin at Hadar.

The Omo and West Turkana localities were all deposited within fluvial sediments associated with the paleo-Omo river. Howell and colleagues (1987) placed the archaeological sites of the Shungura Formation in the proximal floodplain of either a meandering (in the case of FtJi 2 and Omo 123) or a braided (FtJi 1, FtJi 5, Omo 57) paleo-Omo. The context of both FtJi 2 and Omo 123, then, is similar to what we see at Gona. However, the raw materials for stone tool-making at these localities do not seem to come from the paleo-Omo, but from some distance to the east, as the quartz was brought from the basin margin by small alluvial

channels. Similarly, the raw materials for the West Turkana sites came from high energy basin margin streambeds from the west, not far from the sites themselves.

As mentioned, the Kanjera and Middle Awash lake margin sites have the strongest evidence for open grassland environments, although the archaeofauna sample size at Bouri is small (de Heinzelin et al. 1999). The open grassland signatures of these sites are perhaps due to the paucity of extensive riparian woodlands nearby, unlike the other sites discussed here. These two sites also have evidence for substantial transport of stone. At Bouri, the lack of stone tools and raw material sources nearby indicates that hominins transported stone to the lake margin setting. The stone tools at Kanjera were made from a variety of raw material sources, some local and some at least 10 km away (Braun et al. 2008). Raw material selection and transport will be discussed in more detail below.

The overall evidence for late Pliocene hominins using stone tools in environments with substantial open grassland is strong. Where there is evidence for woodland/forest in the paleoenvironmental reconstructions of early archaeological sites, this could be due simply to the pull of stone raw material sources in riverbeds with riparian forest (at Gona and Hadar) and/or fresh water supplied by a perennial river (Gona, Hadar, Omo, West Turkana). On the other hand, there is also strong evidence for the preferential use of environmental ecotones—habitats that are at the junction of woodland and grassland—that would have provided access to a variety of woodland and grassland resources. The evidence is consistent with the idea that early stone tool use was an adaptation that enabled the exploitation of resources in open grasslands *and* woodlands, with emphasis on the former, probably as a way of diversifying their diets. However, at present we cannot distinguish between early stone tool use as an adaptation to accessing resources in open grassland habitats versus accessing resources in a wider variety of habitats, including open grasslands.

The specific paleoenvironmental context alone may not be the most important factor in site location; tool function probably played a significant role as well. For example, if the earliest stone tools were made in order to access animal resources,

and if hominins had more animal resource encounters in ecotones and open grasslands (as opposed to in woodlands and forests), then you would expect the paleoenvironmental pattern that we have observed. The hominin-modified bones found at Bouri, Gona, Lokalalei, and Kanjera (Plummer 2004) are consistent with this idea.

There are problems with these paleoenvironmental interpretations, however, that need to be addressed, including: (1) The discussion of faunal evidence here has been limited to the analysis of presumed environmental preferences of certain taxa, whereas a taxon-free, functional morphological approach would increase confidence in the results. (2) All the paleoenvironmental data are time-averaged to varying degrees, so that we cannot know exactly what the specific habitat was like at the time of tool manufacture and use. The use of multiple lines of evidence helps in this regard. (3) Any analysis of habitat preference is also subject to the problem of negative evidence. That is, the absence of archaeological sites in heavily forested environments is not necessarily an indication that hominins did *not* use stone tools in those habitats; it could be that those environments have yet to be sampled by the known geological and paleoanthropological records. (4) Small sample sizes, as noted above, can influence our ideas of where sites are placed on paleolandscapes. (5) Finally, there is no reason to assume that the adaptational significance of stone tool use remained constant throughout the 600,000 years of time considered here. It is possible, for example, that paleogeographic location was more constraining on stone tool use behavior at 2.6 Ma at Gona than it was at 2.33 Ma at Lokalalei or at 2.1–2.0 Ma at Kanjera (see, for example, Rogers et al. [1994] for further discussion of the influence of paleogeography on Oldowan site distribution).

Origins of Stone Tool Use and Global Climate Change

Many scholars have argued or speculated that the origins of stone tool use, and/or the origins of our genus *Homo*, are causally linked with a global cooling and drying event in the late

Pliocene, sometime around 2.8–2.4 Ma. The general argument is that this global climatic event (or series of events) had the effect of reducing forest cover and expanding grassland in the African tropics, profoundly influencing the evolution of African terrestrial mammals, including hominins.

More specifically and relevant to this review, paleoanthropologists have presented several different scenarios within this broad framework relating the origins of stone tool use to climate change (e.g., Behrensmeyer 2006; Behrensmeyer et al. 1997; Bobe and Behrensmeyer 2004; Bobe et al. 2002; Harris 1983; Levin et al. 2004; Plummer 2004; Potts 2007; Quade et al. 2004; Stanley 1992; Vrba 1995; Wynn 2004). Most simply, the first use of stone tools is seen as a direct result of exploiting the expanded grasslands in East Africa. A corollary to this basic idea is that the earliest stone tools allowed hominins to expand their diet to include food items that were found in open habitats, but not to the exclusion of other habitats. Other environmental hypotheses of human evolution in the late Pliocene emphasize a change in environmental variability that hominins had to confront over the short-term (seasonality) or long-term (variability selection). Recent reviews have emphasized the complexity and difficulty in linking environmental change with evolutionary effects (e.g., Behrensmeyer 2006; Kingston 2007).

It is not our intention here to test or apply the savanna hypothesis to the origins of stone tool use, but to point out that sorting through various environmental hypotheses will be a significant challenge. Indeed, while it may appear at first glance that the paleoenvironmental settings of the earliest archaeological sites support the idea that stone tool-making was, at least in part, an adaptation to open grasslands (created by a late Pliocene global cooling event), we see problems with this argument, including:

(1) We still do not know if the origin of stone tool-making and global cooling are linked temporally. The earliest stone tools found at Gona are dated close to 2.6 Ma, but the disconformity in the stratigraphic record there suggests that the beginnings of stone tool use should eventually be found in the 2.6–2.9 Ma time range.

Also, there is considerable discussion about when exactly global cooling occurred and how this translated into ecological change on the African continent. Clearly, though, if a global cooling event is documented at, say 2.52 Ma, then this event is too late to have spurred the beginnings of stone tool use. Of course, we could also ask why *this* particular drying/cooling event? Why didn't a previous drying/cooling in the early Pliocene—e.g., the apparent expansion of grassland in the KH-2 submember at Hadar after 3.1 Ma (Carpisano and Feibel 2007)—lead to stone tool manufacture? Why not a later one?

- (2) Temporal correlation is not causation (e.g., Hill 1987; White 1995). Even if we can establish that the first stone tools appear at approximately the same time as a global climatic event, this does not mean that stone tool use was caused by such an event. First, it is difficult to establish a clear causal link between the global event and African terrestrial ecosystem change, and the studies that have attempted to assess this have indicated a complex interaction, with sometimes conflicting results. The key to the argument is in this complex interaction, though, since even if global climate change can be successfully tied to African environmental change, there still needs to be a causal mechanism that explains how a change in environment led to a change in hominin behavior (see, e.g., Kingston 2007).
- (3) The *lack* of temporal correlation does not necessarily mean a *lack* of causation. For instance, if the earliest stone tools are eventually dated to 2.8 Ma, and the evidence for a late Pliocene global cooling event suggests that this cooling happened in stages, but beginning at 2.7 Ma, this does not mean that global climate change had *no* role in influencing the evolution of early stone tool use. This is due, in part, to the complexities of global/regional interactions and the incompleteness of the geological record. However, it is also possible that an initial cultural/technological innovation (stone tool use) that was mediated by local/regional environmental conditions could subsequently be reinforced or sustained by later, global climatic changes.
- (4) In our view, in order to address adequately the issue of how climate and/or environmental

change influenced the origins of stone tool use, we need fine-grained paleoenvironmental data throughout the 2.9–2.3 Ma time interval from several different depositional basins, some with archaeological sites and some without (but with available raw material). Although progress has been made to fill this sampling gap, much additional work from many different sites will be required. It is also worth noting that accumulating the relevant data will require time-consuming survey and geological sampling of areas that do not appear to contain an archaeological record. Significant progress in this regard has been made recently in a few study areas (e.g., Campisano and Feibel 2007; Kingston et al. 2007).

Raw Material Transport and Selection

Raw material availability, along with the hominin selection, transport, and use of raw material for stone tool manufacture, is intimately tied to the paleoenvironment, as noted above, and seems to us a primary determinant in the appearance and characteristics of the earliest archaeological record. At Gona, an analysis of the types of raw materials available in the paleo-Awash and found at the archaeological sites has demonstrated that hominins were quite discriminating in their selection of stone type for tool manufacture, preferentially choosing higher quality raw materials (Stout et al. 2005). Raw material selectivity has also been observed at other sites such as Lokalalei and Kanjera.

Ongoing raw material investigations at Gona will examine how the raw material, shape, and size of the original cobbles may have influenced reduction strategies at different sites (e.g., EG sites versus OGS-7). It is our view that any discussion of Oldowan variability must first be informed by an in-depth knowledge of the types of stones available and the types chosen for tool manufacture. Once this is appreciated, then higher order explanations of technological variability can be explored. For example, many of the well-struck technical blades from OGS-7 at Gona were made from a fine-grained vitreous volcanic raw material (Stout et al. 2008). At West Turkana, the remarkable refitting of

dozens of artifacts at Lokalalei 2C has shown a certain skill level in organizing flake reduction, but it is also acknowledged that the more refined flaking is done on a higher quality phonolite (Delagnes and Roche 2005). Work at Kanjera has also explored this issue (e.g., Bishop et al. 2006; Braun et al. 2008).

Conclusions

The summary of the evidence from the Pliocene archaeological record is consistent with the idea that early stone tools were made and used to take advantage of open grassland settings, and probably a variety of settings. As we continue to expand our knowledge of the late Pliocene archaeological record, there is no reason to assume that there will be uniformity in this record. Variability in archaeological traces can be interpreted in a variety of ways (e.g., raw material availability and use, function of stone tools, different depositional settings, social learning patterns and abilities, different hominin species), but we are still trying to assess the nature and extent of this variability with regard to the earliest archaeological record. Testing higher order inferences regarding this variability remains a challenge.

The evidence shows that there is a significant sampling bias in the geological record 2.9–2.6 Ma, and that the earliest manufacture and use of stone tools may date to this time interval. However, hypotheses relating the appearance of the earliest stone tools simply to changes in the visibility of this record (cf. Panger et al. 2002) are not supported at this time, since we are in fact finding both low and high density occurrences at Gona. Hypotheses that relate the beginnings of stone tool use to throwing, pounding, and/or digging may be likely, but are not supported; at the moment, the evidence clearly suggests that the purpose of the earliest flintknapping was mainly to produce sharp flakes used for processing animal resources.

Future investigations of the evolutionary significance of the earliest use of stone tools will require filling in the many temporal and spatial gaps of the Pliocene archaeological record. Not only will we need to find more sites from different time

intervals, but we will also need to examine closely the geological, paleontological, and paleoenvironmental records of sites and regions that do *not* have stone tools and/or modified bones, but do have available stone raw material sources. We suspect that issues related to sampling and negative evidence may have a bearing on hypotheses concerning archaeological transitions from many different time periods, not just the first one from “nothing” to “something.”

Acknowledgments We would like to thank Parth Chauhan and Marta Camps for inviting us to contribute to this volume. We thank the ARCCCH of the Ministry of Culture and Tourism, and the National Museum of Ethiopia for permits and overall facilitation of our work at Gona. MJR would like to thank the SCSU School of Arts & Sciences for its support and acknowledges funding support from a Connecticut State University Research Grant. SS would like to thank the Stone Age Institute & Friends of CRAFT for overall assistance to the Gona Palaeoanthropological Research Project. Members of the Gona Project and colleagues have contributed greatly to our research on the earliest archaeological record in a number of ways, and we are grateful to Dietrich Stout, Jay Quade, Naomi Levin, Scott Simpson, Stephen Frost, and Tesfaye Kidane. Moreover, our work at Gona would not be possible without the help of our local Afar colleagues. We also appreciate the support and assistance of Tim White, Berhane Asfaw, Yonas Beyene, Giday WoldeGabriel, Alemu Admassu, the late Desmond Clark, and the late F. Clark Howell. We are grateful for an anonymous review of this manuscript.

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