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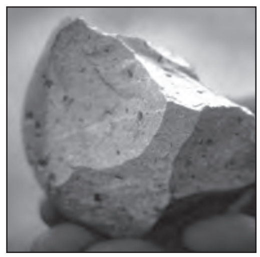
NUMBER 1

THE OLDOWAN:
Case Studies Into the Earliest Stone Age

Edited by Nicholas Toth and Kathy Schick



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Photographs of the Stone Age Institute. Aerial photograph courtesy of Bill Oliver.

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CHAPTER 2

The Oldest Stone Artifacts From Gona (2.6-2.5 Ma), Afar, Ethiopia: Implications for Understanding the Earliest Stages of Stone Knapping

By Sileshi Semaw

Abstract

Gona is key for understanding the earliest stages of ancestral human stone technology. Systematic investigations at Gona (1992-94) led to the discovery of EG10 and EG12, which yielded more than 3,000 surface and excavated artifacts. The artifacts are dated to 2.6-2.5 million years (Ma) by $^{40}Ar/^{39}Ar$ and paleomagnetic stratigraphy, and are the oldest yet documented from anywhere in the world. Thus, they offer the best opportunity for investigating the earliest stages of ancestral hominin stone technology, raw material preference and selection strategy. The evidence strongly indicates that the first toolmakers, though at the early stages of crossing over the threshold, had sophisticated control of conchoidal fracture, selected for raw materials with good flaking quality, and had remarkable skills in producing sharp-edged flakes. A handful of slightly younger artifact sites are known in East Africa including Omo and Hadar from Ethiopia, and Lokalalei from Kenya. Earlier descriptions alleged the Lokalalei 1 hominins to have been technologically less advanced, but to the contrary, excavated materials recovered from the contiguous Lokalalei 2C have shown that the toolmakers commanded excellent flaking control, further corroborating earlier observations made by Semaw *et al.* (1997). Bouri, from the Middle Awash has yielded the oldest cutmarked fossilized animal bones dated to 2.5 Ma, complementing the archaeology of Gona by showing unequivocally that the earliest artifacts were used for processing animal carcasses. Further, Bouri has produced *Australopithecus garhi*, probably the best candidate for making and using the earliest artifacts. The Oldowan was named for the 1.8 Ma non-standardized simple core/flake artifacts discovered from the Lower Beds of Olduvai Gorge, Tanzania. The Gona artifacts are the earliest examples of this "least effort" core/flake tradition, and it is argued here that the stone assemblages dated between 2.6-1.5 Ma group into the Oldowan Industry. The first intentionally produced sharp-edged stones made an abrupt entrance into the archaeological record by 2.6 Ma, and the same patterns of stone manufacture persisted for over a million years with little change suggesting a "technological stasis" in the Oldowan.

Key Words:

Gona, Earliest stone tools, Late Pliocene stone assemblages, Oldowan Industry

Introduction

Continued systematic archaeological investigations of the major East African Late Pliocene sites are shedding further light on the initial appearance and the earlier stages of stone technology, and the adaptive role tools played in the lives of ancestral hominins. The major sites including Gona, Bouri and Hadar are located within the main Afar Rift of Ethiopia (Kimbel *et al.*, 1996; Semaw, 2000; Semaw *et al.*, 1997; Asfaw *et al.*, 1999; de Heinzelin *et al.*, 1999), Omo, in the southern part of the Ethiopian rift (Chavaillon, 1976; Merrick, 1976; Howell *et al.*, 1987) and Lokalalei, at West Turkana, in northern Kenya (Kibunjia, 1994; Kibunjia *et al.*, 1992; Roche *et al.*, 1999). The stone assemblages and contextual data from these sites are providing major insights on the beginnings of stone technology and ancestral hominin tool use behavior. The earliest and the most informative of these are the stone artifacts excavated from the two East Gona sites of EG10 and EG12. Bouri is dated to 2.5 Ma, and Omo, Lokalalei and Hadar are from slightly younger deposits dated between 2.4-2.3 Ma.

Archaeological reconnaissance survey of the Gona deposits began in the 1970's, and initial fieldwork showed the presence of a low density of artifacts east and west of the Kada Gona River (Roche *et al.*, 1977, 1980; Harris, 1983; Harris & Semaw, 1989). Extensive and systematic investigations of the two sites between 1992-94 produced more than 3,000 surface and excavated artifacts. Based on a combination of radioisotopic ($^{40}Ar/^{39}Ar$) and paleomagnetic dating techniques, EG10 and EG12 were firmly dated between 2.6-2.5 Ma and the stone assemblages are the oldest yet known from anywhere in the world (Semaw, 2000; Semaw *et al.*, 1997). The EG10 and EG12 stone artifacts were deposited in fine-grained sediments and excavated within a primary geological context, therefore, offering the best opportunity for investigating the stone manufacture techniques and skills of the first toolmakers, and for understanding the overall behavioral repertoire of Late Pliocene hominins. Analysis of the EG10 and EG12 artifacts show that the first toolmakers had sophisticated understanding of the mechanics of conchoidal fracture on stones, that they selected for appropriate size and fine-grained raw materials with good flaking quality, and commanded superior control in stone working techniques than previously recognized. Based on the remarkable knapping skills shown at EG10 and EG12, Semaw *et al.* (1997) suggested that Late Pliocene hominins had a clear mastery and sophisticated understanding of stone flaking techniques comparable to Early Pleistocene Oldowan toolmakers. The recently excavated LA2C assemblages of West Turkana (Roche *et al.*, 1999) further corroborate this suggestion. The Gona assemblages are the earliest examples for the "least effort" core/flake Oldowan technology (Toth, 1982, 1985, 1987), which lasted between 2.6-c.1.5 Ma. This mode of stone manufacture persisted for over 1 million years with little change suggesting "technological stasis" in the earliest stone industry (Semaw *et al.*, 1997). The makers have yet to be identified at Gona, but the recent discovery made from the nearby contemporary site of Bouri, in the Middle Awash, indicates that *Australopithecus garhi* (2.5 Ma) may be the best candidate for inventing and utilizing the earliest sharp-edged stone implements (Asfaw *et al.*, 1999). Additionally, the fossilized animal bones associated with *Australopithecus garhi* bear evidence of cutmarks showing that the first stone tools were used for activities related to animal butchery (de Heinzelin *et al.*, 1999). Standardized artifacts made with predetermined shape and symmetry and characterized by large handaxes and cleavers appeared for the first time by c. 1.5 Ma with the advent of the Acheulean tradition in Africa (Isaac & Curtis, 1974; Gowlett, 1988; Asfaw *et al.*, 1992; Dominguez-Rodrigo *et al.*, 2001).

Detailed descriptions of the Gona stone assemblages and their geological context are provided in this chapter. In addition, the chapter offers the background archaeological information for comparing with the results currently available from the analysis of the first experimental replicative stone knapping conducted on water-worn ancient river cobbles sampled from Gona. The river cobbles were sampled from the conglomerate probably used as the source of the same raw materials used by the first toolmakers. The cobbles were brought to the U.S. under a permission granted by the Authority for Research and Conservation of Cultural Heritage (ARCCH) of the Ministry of Youth Sports and Culture of Ethiopia. The knapping experiments were carried out by Nicholas Toth and Kathy Schick (CRAFT Research Center, Indiana University), and by non-human primates (chimpanzees) from the Language Research Center in Atlanta, Georgia (Toth *et al.*, this volume).

Background: The Search for the Oldest Stone Tools in Africa

Early Half of the 20th Century

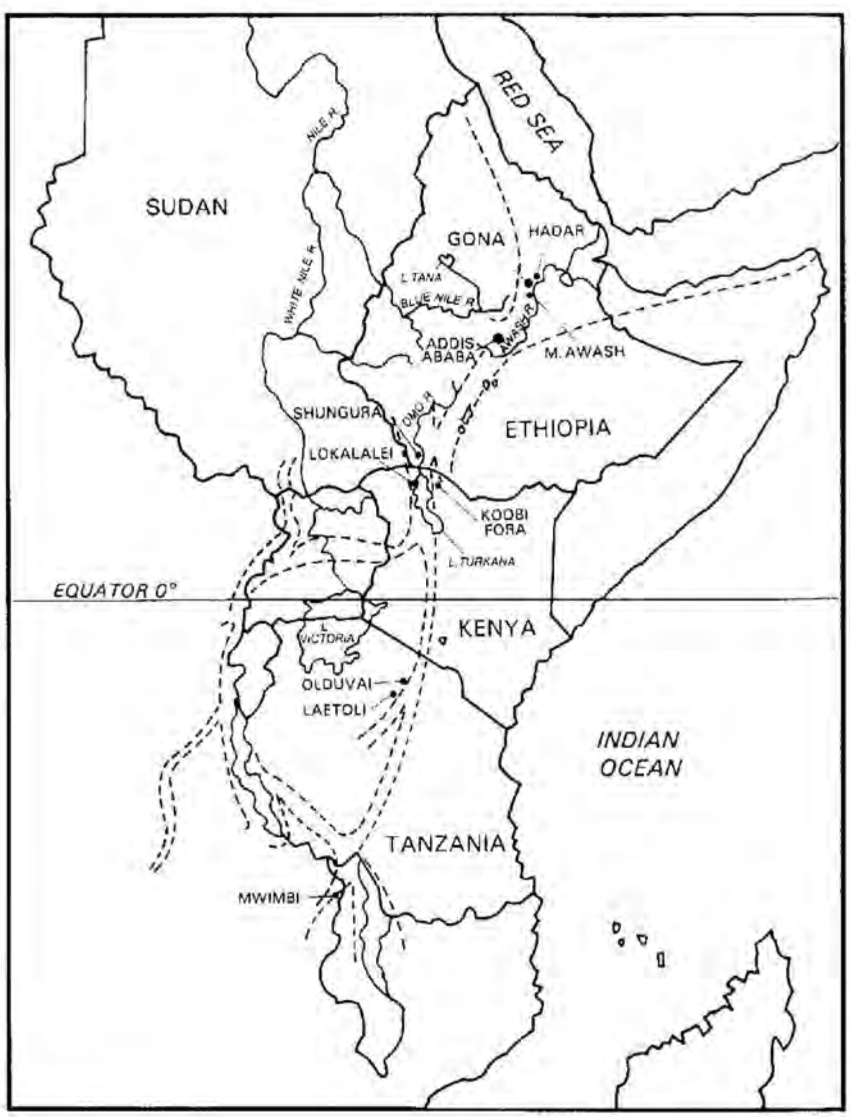
It is useful to present here a brief overview of earlier investigations undertaken in search of the oldest stone tools in East Africa to provide a historical link and a background for the major research activities and archaeological discoveries recently made at several Late Pliocene/Early Pleistocene sites. Comprehensive summary and details of important events on the history of archaeological research in Africa during the late 19th and the early parts of the 20th Century are provided in Gowlett (1990; see also Clark, 1976; Tobias, 1976). The initial search for early stone tools in Africa started during the late 19th Century, and the first archaeological explorations were those undertaken in the northern and southern parts of the continent within the countries which were then French and British colonies (Gowlett, 1990). The archaeological riches of the Eastern part of Africa were recognized beginning in the 1890's following artifact discoveries made by geologists who began collecting stone tools for a hobby (Gowlett, 1990). The explorations and archaeological collections made, for e.g., by E.J. Wayland in Uganda in the 1920's were among the earliest examples for the beginnings of systematic investigations. In the valleys of Kagera, Muzizi and Kafu, Wayland discovered crudely made "pebble tools" which at the time were believed to be the earliest artifacts ever to be documented from the African continent. These so called "pebble tools" were labeled as the "Kafuan Culture," named after one of the valleys in Uganda where these alleged artifacts were found (Wayland, 1934 in Gowlett, 1990). Subsequently, Wayland proposed an archaeological sequence in East Africa with the "Kafuan" as the original "pebble culture" and the oldest in the region (Gowlett, 1990).

Louis Leakey began extensive palaeoanthropological investigations in East Africa during the 1930's, and he was responsible for outlining the initial culture-sequence of the stone artifacts found at Olduvai Gorge, in Tanzania. At the time, the Kafuan was still recognized as the earliest "pebble culture" and Wayland's ideas greatly influenced the interpretations of older archaeological assemblages from East Africa. This was clearly exemplified with the evolutionary stages proposed by Louis Leakey for the culture-sequence /culture history of the Olduvai Gorge artifacts:

> "Following upon the Kafuan culture came a culture step which Mr. Wayland calls pre-Chellean and to which I have given the name of the Oldowan culture. I should have preferred to call it 'Developed Kafuan' but Mr. Wayland holds that it is quite distinct from even the most developed Kafuan" (L.S.B. Leakey, 1936, quoted in Gowlett, 1990, p.22).

Subsequently, the artifactual authenticity of these so called "pebble tools" was challenged by a number of researchers (for e.g., Van Riet Lowe, 1957), and the "Kafuan" was finally rejected in 1959 after it was proven that the majority were broken pebbles which occurred due to geological processes instead of being the results of deliberate fashioning by ancestral humans (Bishop, 1959). The Oldowan, as originally proposed for the assemblages of the Lower Beds of Olduvai Gorge, is still valid for classifying the earliest stone tools dated roughly between c.2.6-1.5 Ma (L.S.B. Leakey, 1936; M. D. Leakey, 1971; Semaw, 2000; Semaw *et al.*, 1997). The Oldowan artifact tradition was widespread between 2.0-1.5 Ma and well-documented from several sites distributed across Africa. In North Africa, Oldowan artifacts traditionally referred to as "pebble tools" (galets aménagés) are known from Ain Hanech in Algeria (Balout, 1955; Sahnouni, 1998; Sahnouni and de Heinzelin, 1998) and the Sidi Abderrahman from the Casablanca sequence in

Figure 1



1. *A map showing the Late Pliocene archaeological sites in East Africa.*

Morocco (Biberson, 1961; Clark, 1992). The major East African sites with the Oldowan include Melka Kontouré, Middle Awash, Gadeb and Fejej from Ethiopia (Chavaillon *et al.*, 1979; Clark & Kurashina, 1979; Clark *et al.*, 1984, 1994; Asfaw *et al.*, 1991), Koobi Fora and Chesowanja from Kenya (Isaac, 1976a & 1976b; Isaac & Isaac, 1997; Harris, 1978; Gowlett *et al.*, 1981) and Nyabusosi from Uganda (Texier, 1995). Early Pleistocene Oldowan sites from Southern Africa include Swartkrans Members 1 and 2 (Brain *et al.*, 1988), Sterkfontein Member 5 (Kuman, 1994a, 1994b, 1996, 1998) and Kromdraai (Kuman *et al.*, 1997). The stone artifacts from these sites are characterized mainly by the “least effort” core/flake industry of the Oldowan tradition.

Major Late Pliocene (c. 2.6-2.0 Ma) Artifact Discoveries Made in the Last 50 Years

The systematic explorations and discoveries made by Louis and Mary Leakey at Olduvai Gorge were instrumental for placing East Africa on the global map of prehistoric studies. East African archaeology took a major turn in the early 1960's following the discovery of Zinjanthropus (*Australopithecus boisei*), which brought great focus and attention to the field research being undertaken in that part of the continent. Newly developed dating techniques (for e.g., K/Ar, zicron fission track, etc.) clearly showed that the archaeological record of East Africa was much earlier in time than originally perceived and greatly assisted in asserting Africa's leading position in the study of human beginnings.

A large number of substantive and informative discoveries have been made through extensive field and laboratory studies conducted mainly within the last five decades. These include findings regarding the physical and behavioral evolution of ancestral hominins, systematic archaeological investigations of the initial stages on the techniques of stone knapping and their function, and intensive studies on the stratigraphy, dating and palaeoenvironments of the major East African Plio-Pleistocene archaeological sites (e.g., M.D. Leakey, 1971; Isaac, 1976a & b; Isaac & Isaac, 1997; Chavaillon, 1976; Merrick, 1976; Roche & Tiercelin, 1977, 1980; Bunn *et al.*, 1980; Walter, 1980; Toth, 1982; 1985, 1987; Harris, 1978, 1983; de Heinzelin, 1983; de Heinzelin *et al.*, 1999; Clark *et al.*, 1984, 1994; Walker *et al.*, 1986; Howell *et al.*, 1987; Kaufulu & Stern, 1987; Feibel *et al.*, 1989; Schick & Toth, 1993; Brown, 1995; Asfaw *et al.*, 1991, 1992, 1999; Kibunjia *et al.*, 1992; Kimbel *et al.*, 1996; Semaw *et al.*, 1997; Roche *et al.*, 1999).

Despite considerable progress in field research, only a handful of Late Pliocene archaeological sites are known with secure radiometric dates and a high density of excavated artifacts (Chavaillon, 1976; Merrick, 1976; Merrick & Merrick, 1976; Howell *et al.*, 1987; Kibunjia, 1994; Kibunjia *et al.*, 1992; Roche, 1989; Roche *et al.*, 1999; Kimbel *et al.*, 1996; Semaw, 1997, 2000; Semaw *et al.*, 1997; Asfaw *et al.*, 1999; de Heinzelin *et al.*, 1999). The sites referred to in this text are shown in Figure 1. Except for Lokalalei, which is located in Kenya, all of the other Late Pliocene archaeological sites are documented in Ethiopia, and most of these are situated on the floor of the main Afar Rift. Gona is close to 2.6 Ma, Bouri c. 2.5 Ma, and the rest are from slightly younger deposits dated between 2.4-2.3 Ma. There are claims for the presence of Late Pliocene sites in the Western African Rift (Harris *et al.*, 1987, 1990), and the Malawi region (Kaufulu & Stern, 1987). However, both sites lack radiometric dates, and the ages of the Oldowan occurrences of the two regions are still problematic.

Omo, Shungura Formation, Southern Ethiopia

The first multidisciplinary scientific research team in palaeoanthropology was organized by F.C. Howell and colleagues in the early 1960's to investigate the fossiliferous deposits of the Omo, in southern Ethiopia (Howell, 1978). The new interdisciplinary approach contributed enormously to the research and set the standard currently adopted in the field, with multiple aspects of the problems to be addressed dealt with jointly by archaeologists, paleontologists, geologists, and others specializing in the various allied sub-disciplines. The stone artifacts from Upper Bed I and Lower Bed II from Olduvai were dated to 1.8 Ma by K/Ar (M.D. Leakey, 1971; Hay, 1971), and these were the oldest known until fresh archaeological discoveries were made in the Omo, within Member F of the Shungura deposits dated by K/Ar to 2.4-2.3 Ma (Chavaillon, 1976; Merrick, 1976; Merrick & Merrick, 1976; Howell *et al.*, 1987). Two groups (American and French) were involved in the archaeological excavations of the artifacts recovered from the Shungura Formation. The Omo artifacts were predominantly made of small-size quartz pebbles and mainly worked with the “bipolar” flaking technique. Thus, the artifacts were essentially smaller in size compared to the stone assemblages excavated from Olduvai, which were made of moderate size quartz and lava produced mainly by the hand-held percussion technique. Because of the simplicity of the artifacts, Chavaillon (1976) proposed the “Shungura facies” to differentiate the Omo from slightly younger assemblages of the Oldowan. Composition of the surface and excavated artifacts from Omo and the other major Late Pliocene sites in East Africa are shown in Table 1. There were no hominins directly associated with the excavated Omo artifacts, but *Australopithecus aethiopicus* and probably early *Homo* were contemporaneous with the Shungura 2.4-2.3 Ma artifacts (Howell *et al.*, 1987; Walker *et al.*, 1986; Suwa *et al.*, 1996). To date,

Table 1

Artifact Category	EAST GONA				WEST TURKANA				OMO									
	EG10		EG12		Lokalalei 1		Lokalalei 2C		FtJi1		FtJi2		FtJi5		Omo57		OMO123	
	Exc.	Surf.	Exc.	Surf.	Exc.	Surf.	Exc.	Surf.	Exc.	Surf.	Exc.	Surf.	Exc.	Surf.	Exc.	Surf.	Exc.	Surf.
Cores	2.19	1.09	2.02	1.30	11.99	6.12	2.61	2.91	0.26					3.90		3.68	1.56	2.37
Whole Flakes	23.37	17.80	32.58	30.52	17.51	12.24	16.88	27.71	4.50	7.00	1.35	4.60	4.20	7.80	23.34	25.15	38.86	34.12
Flake Fragments	14.16	6.13	11.46	12.66	55.63	81.64	57.14	55.62	2.10	11.10	1.79	10.80		1.30				
Angular Fragments	59.12	73.50	50.79	54.22	11.99		16.06	12.02	93.30	81.85	96.90	84.60	95.80	87.00	70.00	65.03	56.45	56.31
Retouched Pieces	0.58		0.90				0.44	0.78										
Piece*															6.66	9.81	0.26	0.30
Core Fragments	0.58	1.48	2.25	1.30			0.44	0.19							6.66	6.14	2.35	6.90
Hammerstones							0.82											
Modified Pebbles					2.88		3.34	0.78										
Unmodified Pieces							2.27											
Total number of artifacts	685	1551	445	309	417	49	2067	516	375	270	223	130	24	77	30	193	767	1014

Key: Exc., = Excavated, and Surf. = Surface artifacts

Source for the Omo artifacts, Howell et al. 1987, p. 679. Omo 84 is not included because the available data seems incomplete.

* *The meaning of this category is not clear, and exists only in the inventory of Chavaillon 1976 (Howell et al. 1987). The data for Omo 57 is much higher than 100%.*

Source for Lokalalei 2C, Roche et al. 1999, p. 59. Broken flakes and small flakes are included together, all the core categories are included together, & broken cores are listed as core fragments. Worked pebbles and broken pebbles are included together, Unmodified pebbles are listed under Unmodified Pieces.

Source for Lokalalei 1, Kibunjia 1994, p. 164. The Lokalalei Artifacts from both the 1987 and 1991 excavations are included together.

Data not yet available for the 2.3 Ma Hadar artifacts.

1. *Composition and percentages of artifact assemblages, the 2.6-2.5 Ma Gona and other Late Pliocene archaeological sites dated to 2.4-2.3 Ma (modified after Semaw, 2000).*

Australopithecus aethiopicus is the least favored by most anthropologists as the possible candidate for Late Pliocene artifact manufacture and use (but see Sussman, 1991).

Koobi Fora, East Turkana, Kenya

In the early 1970's claims were made for the presence of older artifacts dated to c. 2.6 Ma from the Koobi Fora Formation, East Turkana in northern Kenya (R.E. Leakey, 1970; Isaac, 1997). Initial radioisotopic dates yielded 2.6 Ma for the KBS tuff, and the artifacts were thought to be the oldest at the time (R.E. Leakey, 1970; Fitch & Miller, 1976; Isaac, 1997). However, the age of the KBS tuff was later revised to 1.89 Ma based on repeated K/Ar dates and comparative biochronological data gathered from Koobi Fora and the Shungura Formation in the Omo (McDougall et al, 1980; Fitch & Miller, 1976; Cooke, 1976; Isaac, 1997). The lava-dominated stone assemblages lacked spheroids and retouched pieces, artifact types known to occur within the Oldowan (mainly at Olduvai Gorge), and initially their absence at Koobi Fora was taken to imply greater antiquity, and the assemblages were assigned to the KBS Industry (Isaac, 1976a & b). Despite the similarities in the techniques of Late Pliocene-Early Pleistocene stone manufacture and use, assemblage variations could occur due to differences in the quality of the raw materials utilized (Isaac 1976a; Toth, 1982, 1985, 1987). Early on, Isaac recognized the role raw material variations could have played in influencing artifact morphology and he accepted that the stone assemblages originally assigned to the KBS Industry could be subsumed under the Oldowan (Isaac, 1976a).

The Lokalalei Sites, West Turkana, Kenya

Beginning in the mid-1980's, archaeological survey and excavations undertaken at West Turkana, in northern Kenya revealed the presence of Late Pliocene artifacts at the site named Lokalalei 1 (GaJh5) (Roche, 1989, 1996; Kibunjia, 1994; Kibunjia *et al.*, 1992). During the mid 1990's, continued archaeological investigations of the contiguous deposits produced an additional contemporary site named Lokalalei 2C (LA2C) (Roche *et al.*, 1999). The Lokalalei sites were discovered in ancient sediments that are contemporaneous with the adjacent artifact-bearing deposits of the Omo. Lokalalei 1 was excavated in 1987 and 1991, and LA2C in 1997. Both sites were placed stratigraphically above the Kalochoro tuff, a geochemical correlate of Tuff F of the Shungura Formation and dated between 2.4-2.3 Ma (Feibel *et al.*, 1989; Brown, 1995).

Lokalalei 1 produced close to 500 surface and excavated artifacts, and the LA2C site yielded more than 2,500 artifacts (Table 1). The Lokalalei artifacts were found within fine-grained sediments deposited in floodplain settings and they were in primary context. The assemblages of both Lokalalei 1 and LA2C consisted of cores, *débitage*, and pounded pieces, stone artifacts typical of the Oldowan Industry. There are a few instances of retouched pieces from LA2C, but none were recognized from Lokalalei 1. Possible cut-marked bones were found at Lokalalei 1, but none were reported from LA2C. The artifacts earlier excavated from Lokalalei 1 were described to be poorly-made, the makers alleged to be less-coordinated, less-skilled, and lacking in manual dexterity compared to the "better-skilled" hominins responsible for making the "elaborate" artifacts known from slightly younger Early Pleistocene Oldowan sites dated between c. 2.0-1.5 Ma (Roche, 1989, 1996; Kibunjia, 1994). More than 50 cores were recovered (both surface and excavated) at Lokalalei 1 which average close to 100 mm in size, with the majority having between 1-12 flake scar counts. "About 80% of the flaking scars on these cores was [sic] characterized by step fractures and only a few instances of complete flake removals were observed" (Kibunjia, 1994, p.165). According to Kibunjia, the majority of the cores were discarded because repeated flaking attempts produced nothing but step/hinge flakes. He concluded that "factors other than raw material account for the poor technology" (Kibunjia, 1994, p. 165). Furthermore, he argued that the Lokalalei 1 artifacts were substantially different and less exhaustively worked compared to the Oldowan cores that post-date 2.0 Ma, and the assemblages were assigned to the "Nachikui facies" (Kibunjia, 1994). The "Shungura facies," which was earlier proposed for the Omo artifacts by Chavaillon (1976) was accepted as a Late Pliocene "variant." In addition, the Gona assemblages were included with the so called "technologically less- advanced" Omo and Lokalalei, and the three assemblages were assigned to "the Omo Industrial Complex" and/or to the generic "Pre-Oldowan" to differentiate them from the Oldowan (*sensu stricto*) known within the deposits dated between 2.0-1.5 Ma (Kibunjia, 1994).

The artifacts recently excavated from the adjacent and contemporary site of LA2C were described to be more "sophisticated" and the "*débitage* scheme" different from any of the Oldowan assemblages known during the Pliocene (Roche *et al.*, 1999; Roche, 2001; Roche & Delagnes, 2001). Remarkably, c. 20% of the LA2C excavated artifacts included refitting pieces. Ten different raw material types in the regions were identified as potential raw material sources, but basalt (varying from coarse to fine- grained) and phonolite were the main types used for making the LA2C artifacts. Interestingly, the coarse-grained materials were not as intensively worked as the finer ones (Roche *et al.*, 1999). The authors claim that the large number of refitting pieces from the LA2C excavations makeup for the strongest case presented for showing Late Pliocene hominin "sophistication" in artifact making techniques (Roche *et al.*, 1999) (to be discussed further below).

The Senga 5a (Western Rift), DR of Congo, and the Mwimbi Site, Malawi

There were claims for the presence of Late Pliocene artifacts in the Western Rift of Africa at two sites named Kanyatsi and Senga 5a, in the eastern part of what is now the Democratic Republic of the Congo (Harris *et al.*, 1987, 1990). The Kanyatsi site was found by Jean de Heinzelin in the early 1960's and yielded several flakes made of quartz (Harris *et al.*, 1987). During the mid-late 1980's, the area was resurveyed and further artifacts were found at Senga 5a. The site was excavated and produced a high density of quartz artifacts including cores and a large number of flaking debris. Based on associated fossilized fauna, the Senga 5a artifacts were estimated to be between 2.2-2.3 Ma. However, subsequent investigations showed that the materials were in a derived geological context and of unsubstantiated age (Harris *et al.*, 1990).

Farther to the south, field investigations in the Malawi region yielded an archaeological site named Mwimbi stratified within the Chiwondo Beds, and the site was estimated to be of Late Pliocene age (Kaufulu & Stern, 1987). Excavations at Mwimbi produced a high density of artifacts made of quartz (mainly cores and flakes) and the site was estimated between 2.2-1.6 Ma based on stratigraphically associated fauna. Additional geological/geochronological studies are critical for substantiating the age of the Mwimbi artifacts before expanding the geographical range of Late Pliocene toolmakers to include the areas south of the Omo/Turkana basin.

Hadar, Afar, Ethiopia

The Hadar study area is located east of Gona. Beginning in the 1970's, for decades the field research at Hadar was primarily focused on searching for fossil hominins, and continuous palaeontological survey in the Hadar basin resulted in the discovery of hundreds of remarkable hominin specimens attributed to *Australopithecus afarensis* within ancient deposits dated between 3.3-2.9 Ma (Johanson *et al.*, 1982; Kimbel *et al.*, 1994 and references therein). A brief archaeological exploration carried out in the early 1970's produced Acheulean assemblages from the Denen Dora area (Corvinus, 1976) and Oldowan artifacts further west of the Hadar study area at Kada Gona (Corvinus & Roche, 1976; Roche & Tiercelin, 1977, 1980).

Archaeological investigations were continued at Hadar in the mid-1990's, and a reconnaissance survey undertaken in the younger deposits of the Upper Kada Hadar Member produced Oldowan artifacts and associated fossilized animal bones. The artifacts and fauna were dated to 2.3 Ma based on the $^{40}Ar/^{39}Ar$ age of the BKT-3 tuff (Kimbel *et al.*, 1996). The deposits also yielded a hominin maxilla attributed to early *Homo* in stratigraphic association with the artifacts.

Bouri, the Middle Awash, Afar, Ethiopia

Palaeolithic researchers for a long time (based solely on the evidence of stone artifacts) inferred that the first intentionally created sharp-edged stones were used for processing carcasses for meat (e.g., Vrba, 1990; Harris, 1983; Pickford, 1990). However, such early hominin practice remained archaeologically unproven for quite sometime because of the lack of empirical evidence. The recent field investigations of the Late Pliocene Hata Beds of the Bouri peninsula, in the Middle Awash yielded very well-fossilized excavated animal bones bearing evidence of definite stone tool cutmarks dated to 2.5 Ma (de Heinzelin, 1999). Bouri is located c. 90 Km south of Gona, and the cutmark data complements the archaeology by providing direct evidence for the function of the oldest artifacts. The excavations at Bouri failed to produce associated *in situ* artifacts, but the cutmarks for the first time unequivocally showed that the earliest stone tools were made and used for activities related to animal butchery. Furthermore, Bouri yielded stratigraphically associated fossilized remains of a hominin named *Australopithecus garhi*, probably the best candidate for inventing and using the first stone tools (Asfaw *et al.*, 1999; de Heinzelin *et al.*, 1999).

Gona is unique for providing the earliest and most informative assemblages for studying the stone manufacture techniques of the first toolmakers. Attempts are made in this chapter to analyze the earliest assemblages from Gona in light of current understanding of Late Pliocene-Early Pleistocene human behavior, and to address issues related to technical and coordination skills, raw material preference, and acquisition strategies of the first toolmakers. The Gona evidence is compared and contrasted with the archaeological information available from slightly younger 2.4-1.5 Ma sites, and inferences on Late Pliocene hominin behavior are drawn mainly from reports published on the comparable artifacts excavated from Lokalalei 1 & LA2C and the other contemporary sites (Chavaillon, 1976; Merrick, 1976; Merrick & Merrick, 1976; Isaac, 1976a & b; Kibunjia, 1994; Kibunjia *et al.*, 1992; Roche, 1989, 1996; Roche *et al.*, 1999; Piperno, 1989; Asfaw *et al.*, 1999; de Heinzelin *et al.*, 1999).

Earlier Research at Gona

Maurice Taieb (a French geologist) was the first to recognize the palaeoanthropological importance of the deposits exposed within the Afar Rift. His geological reconnaissance survey of the late 1960's along the Awash indicated the presence of laterally extensive artifact and fossil-rich Plio-Pleistocene deposits outcropping in the areas adjacent to the main course of the Awash and its tributaries. Subsequently, extensive field research programs were initiated in the region leading to the discovery of what are now recognized as the Hadar, the Middle Awash and the Gona study areas. Decades of fieldwork undertaken at these major sites have produced remarkable fossil hominins and archaeological materials which have provided great insights on the physical and behavioral evolution of ancestral humans and their surroundings (for e.g., Kalb *et al.*, 1982a & b, 1993; Johanson *et al.*, 1982; Clark *et al.*, 1984, 1994; White *et al.*, 1994; WoldeGabriel *et al.*, 1994; Kimbel *et al.*, 1994, 1996; Semaw, 1997, 2000; Semaw *et al.*, 1997; Asfaw *et al.*, 1999; de Heinzelin *et al.*, 1999; Haile-Selassie, 2001; WoldeGabriel *et al.*, 2001, and references therein).

During the early 1970's, G. Corvinus began archaeological survey in the Hadar deposits and documented Middle Pleistocene Acheulean artifacts (Corvinus, 1976). H. Roche later joined Corvinus and they extended explorations into the adjacent deposits exposed west of the Hadar study area. Their brief archaeological survey revealed the presence of Oldowan artifacts within the deposits exposed by the Kada Gona river, and surface artifacts were documented at localities named Afaredo-1, and Kada Gona 1, 2, 3 & 4 (Corvinus & Roche, 1976; Roche & Tiercelin, 1977, 1980). The artifacts were characterized by a low density of surface scatters located stratigraphically between two Cobble Conglomerates referred to as the Intermediate Conglomerate (*Conglomérat Intermédiaire*) and the Upper Conglomerate (*Conglomérat Supérieur*). Initially, four volcanic tuffs labeled as *Cinérites* (ashes) I-IV were recognized. Three of the *Cinérites* were later renamed as Artifact Site Tuffs (AST-1, -2 & -3) by Walter (1980). The three AST tuffs were useful for tephra chronology, but they were contaminated for radioisotopic dating techniques and have not provided absolute chronology for the artifacts (Aronson *et al.*, 1977, 1981; Walter, 1980, 1994; Walter & Aronson, 1982). Therefore, the 2.5 Ma age earlier reported for the Kada Gona artifacts was derived from estimates based on the higher stratigraphic position of the artifact-bearing sediments in relation to the BKT-2 tuff (dated to 2.9 Ma by K/Ar) known from the contiguous older deposits of the Hadar Formation (Roche & Tiercelin, 1977, 1980). The BKT-2 tuff also provided the minimum age for the *Australopithecus afarensis* specimens documented at Hadar, and the maximum age estimate for the Kada Gona artifacts (Corvinus & Roche, 1976; Roche, 1976; Roche & Tiercelin, 1977, 1980). Further, an age of 3.14 Ma was reported for the BKT-2 tuff (by Hall *et al.*, 1985) and the age of the Gona artifacts remained uncertain. The first *in situ* artifacts were systematically excavated in 1976 from a West Gona locality later renamed WG1 (Harris, 1983; Harris & Semaw, 1989). Again, the West Gona surface and excavated artifacts were low density concentrations, and the 2.5 Ma age for WG1 was an extrapolation based on the higher stratigraphic position of the artifact-bearing strata in relation to the BKT-2 tuff. Because of a moratorium passed by the government, there were no field activities in Ethiopia during the 1980's. After a long hiatus, the 1987

Gona field permit was the first to be issued by the then Ministry of Culture of Ethiopia. The deposits exposed on both sides of the Kada Gona were briefly surveyed and yielded two new archaeological localities named WG2 and WG3. The two sites were documented in close proximity to WG1, the site earlier excavated at West Gona (Harris, 1983; Harris & Semaw, 1989). The brief field survey indicated the great potential of the Gona region for future extensive palaeoanthropological investigations.

The importance of Gona was overlooked for a long time mainly because the artifact-bearing deposits investigated in the 1970's lacked radiometric dates. It was not clear from the published reports whether or not the artifacts reported by Roche *et al.* (1977, 1980) were retrieved from a sealed stratigraphic context. In addition, the artifact assemblages documented by Roche *et al.* (1977, 1980) and those excavated by Harris (1983) were relatively low density and perhaps of limited utility in characterizing the earliest assemblages. In addition, details have yet to be available for the surface artifacts from Afaredo 1, Kada Gona 1, 2, 3 and 4 of Roche *et al.* (1977, 1980).

The Gona Paleoanthropological Research Study Area: New Investigations

The Gona Palaeoanthropological Research Project (GPRP) study area is situated in the west-central part of the Afar Administrative Region of Ethiopia. The GPRP covers an area of 500 Km^2 badlands with fluvio-lacustrine fossiliferous and artifact-rich deposits. Cobble conglomerates and interbedded tuffaceous markers are prominent throughout much of the sequence. The GPRP study area stretches to the Mile-Bati road in the north and to the headwaters of the Asbole River in the south. The Hadar study area bounds Gona to the east, and exposures of the Western Escarpment of Ethiopia are the western limits of the Gona study area. The Western Margin deposits are rich with Late Miocene-Early Pliocene faunas. The largest portion of the study area to the east and to the south contain ancient sediments with a wealth of Plio-Pleistocene fossilized faunas, and stone artifacts spanning the time period between 2.6 Ma-c.500 Ka. The major rivers east to west, include Kada Gona, Ounda Gona, Dana Aoule, Busidima, Gawis Yalu, and Sifi. These rivers and associated tributaries drain the surrounding region and seasonally flow into the Awash, also cutting through the ancient sediments and exposing artifacts and fossilized fauna. The deposits outcropping in the GPRP study area are now providing windows of opportunities for systematic archaeological, palaeontological, and geological field studies. Recent field investigations (1999-2001) have produced a large number of new archaeological and palaeontological sites, including hominins sampling various critical time intervals during the Early Pliocene and the Early Pleistocene (Semaw *et al.*, 2002).

The East Gona Archaeological Localities of EG10 and EG12: An Overview

The first systematic and extensive archaeological and geological field studies at Gona were undertaken between 1992-94. Fossilized fauna and artifact rich deposits at Gona are being exposed by erosion and often washed away quickly due to the high relief and badlands topography of the region, and the 1992 survey was timely due to the very high density of freshly eroded artifacts found littering the ancient landscape. More than 12 new localities were documented on both sides of the Kada Gona river, and the two East Gona sites of EG10 and EG12 were excavated yielding more than 3,000 surface and *in situ* artifacts within fine-grained deposits securely dated between 2.6-2.5 Ma (Semaw, 1997, 2000; Semaw *et al.*, 1997). Figure 2 shows the photo of the excavations carried out at EG10. The location and stratigraphy of the major East Gona sites are shown in Figure 3a & 3b.

The EG10 and EG12 sites are situated on the eastern side of the Kada Gona c. 7 Km upstream from its confluence with the Awash River. Surface artifacts with abundant cores, flakes and fragments were also systematically sampled from several localities distributed within laterally extensive deposits exposed on both sides of the river. EG10 and EG12 were chosen for systematic excavation and detailed investigations because the two localities had the highest density of freshly eroded artifacts with cores, flakes, and flaking debris of all sizes found exposed on the surface. The three laterally extensive marker tuffs (AST-1, -2 & -3), the two additional new tuffs (AST-2.5 & AST-2.75), and the three prominent cobble conglomerates were found very well-exposed in close proximity to EG10 and EG12, aiding stratigraphic placement and age determinations of the excavated artifacts. Furthermore, the two localities were amenable for systematic excavations because of less overburden to deal with to expose the artifact-bearing horizon as well as ease of access to the sites by vehicle from the Kada Gona River.

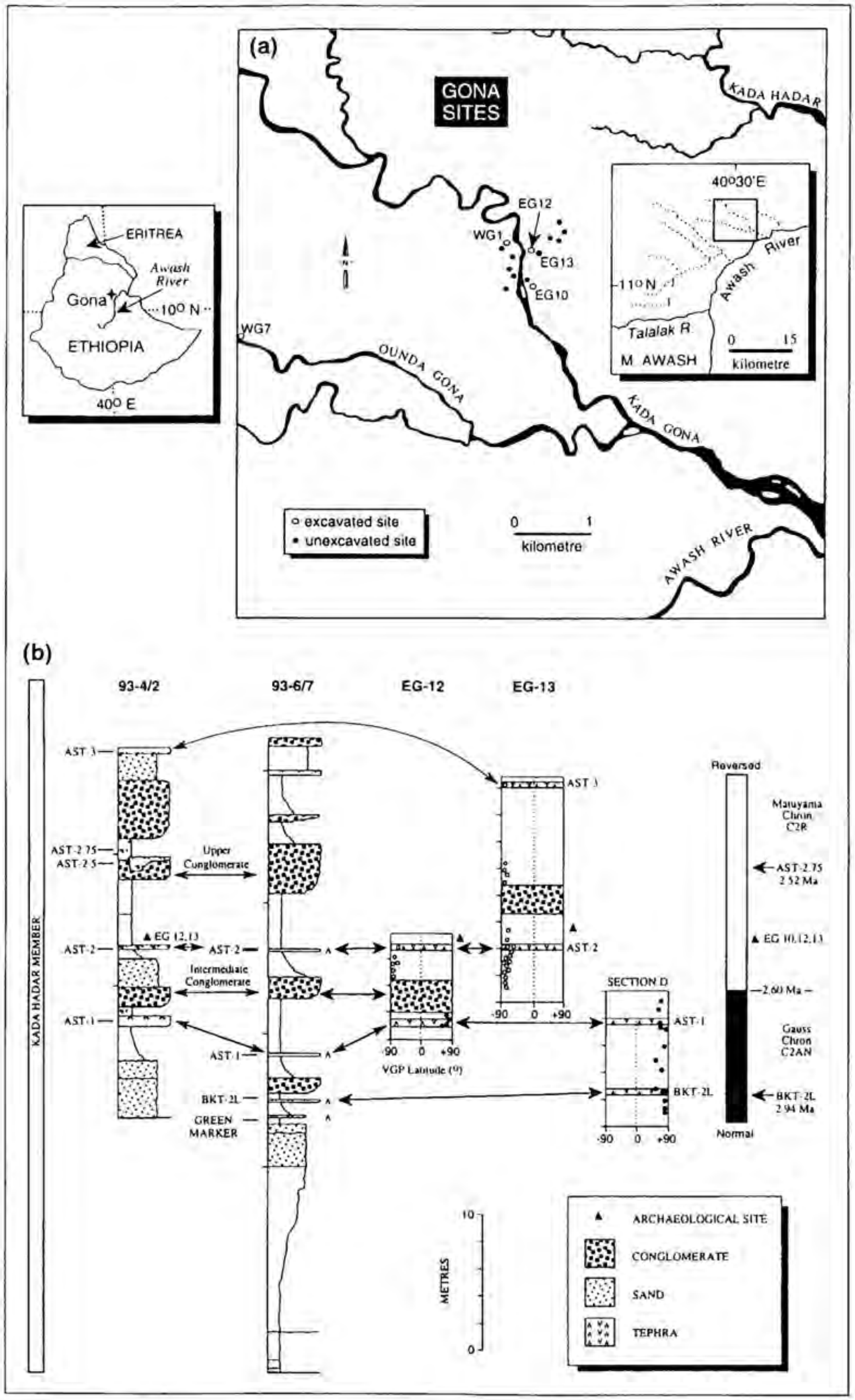
Stratigraphy and Dating

The EG10 and EG12 artifact-bearing horizons are stratified in fine-grained sediments of floodplain context situated within and immediately overlying the AST-2 marker tuff. The Intermediate Cobble Conglomerate (ICC) is situated less than one meter below the EG10 and EG12 excavations and is prominent within the stratigraphic section exposed near both sites, and as a marker horizon, it also extends laterally within the Kada Gona and associated drainages. Geological studies indicate that the ICC was the closest source of the stone raw materials used for making the EG10 and EG12 artifacts. The stratigraphic details and the dating of the EG10 and EG12 sites are shown in Figure 3b. The Kada Gona River has exposed a c. 50 meter-thick, upward-fining stratigraphic section near EG10 and EG12. From bot-

Figure 2

2. A photo showing view of the EG10 excavations.

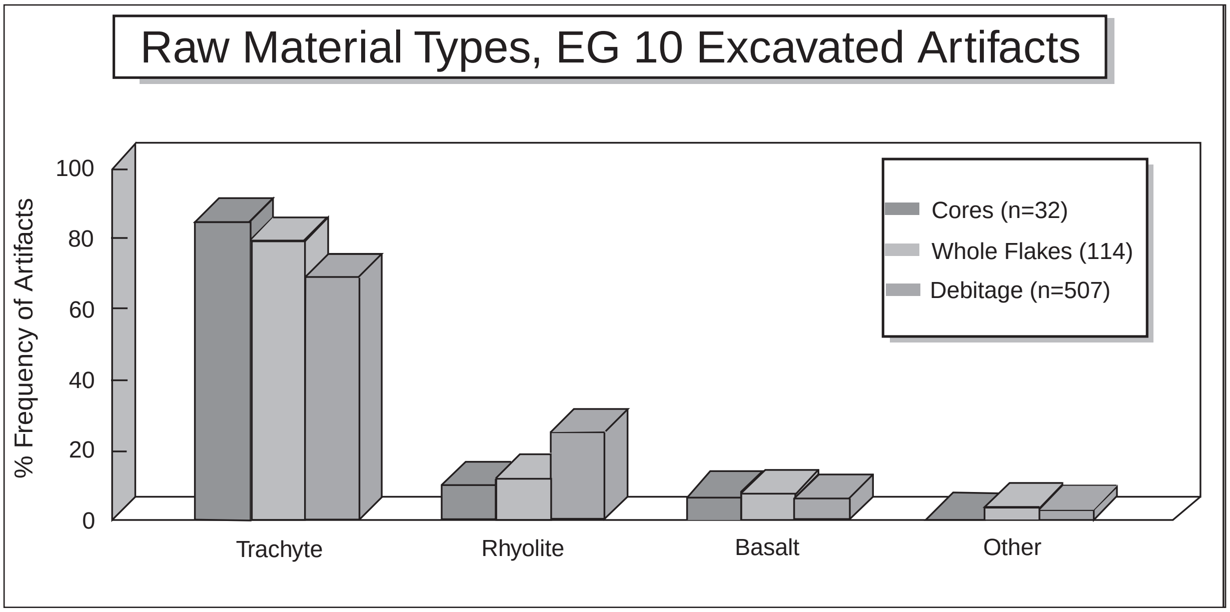
Figure 3



3a. A map showing the location of EG10, EG12 and other contemporary archaeological sites of East and West Gona.

3b. The stratigraphy and dating of the EG10 and EG12 sites. The composite sections (93-4/2, 93-6/7) are correlated with the results of the magnetostratigraphy of EG12 and EG13. Normal polarity is shown by filled circles, and reversed by open circles. The 40Ar/39Ar dates are shown with units of the magnetic polarity timescale (MPTS) on the right (Figure modified after Semaw et al., 1997).

Figure 4



4. *The raw material types used at EG10. Note: data based on* in situ *artifacts. Only the surface and excavated cores/choppers are combined.*

tom to top, major stratigraphic layers include the Green marker tuff (a geochemical correlate of the Kada Hadar BKT-2 tuff sampled beneath EG10, and dated to 2.9 Ma), the Basal Cobble Conglomerate, the AST-1, the ICC, the AST-2, the AST-2.5, the AST-2.75, the Upper Cobble Conglomerate, the AST-3 tuff and slightly younger fossil and artifact-bearing deposits of the capping strata. Two of the new tuffs, the AST-2.5 and AST-2.75 were sampled in 1993, and the latter proved amenable for $^{40}Ar/^{39}Ar$ dating, and provided the critical data needed for resolving the age of the Gona artifacts. The AST-2.75 tuff was sampled just above locality EG13 and dated to 2.52+ 0.075 by the $^{40}Ar/^{39}Ar$ dating technique (Semaw *et al.*, 1997). The tuff was located c. 200 m north of EG10 and stratigraphically less than 5 meters above EG10, EG12 and EG13. Paleomagnetic calibrations of the sediments sampled along the stratigraphic sections exposed near EG10 and EG12 placed the Gauss-Matuyama transition, dated to 2.6 Ma (McDougall *et al.*, 1992), within the ICC. Hence, the 2.52 Ma $^{40}Ar/^{39}Ar$ date provided a minimum age for the excavated sites, and the paleomagnetic transition identified below the sites provided a maximum age for the artifacts. In addition, the paleomagnetic calibrations corroborated the 2.52 Ma minimum age derived from the $^{40}Ar/^{39}Ar$ analyses of the overlying tuff. Therefore, the EG10 and EG12 artifacts are firmly dated between 2.6-2.5 Ma, and they are the earliest documented archaeological occurrences yet identified in Africa (Semaw, 2000; Semaw *et al.*, 1997).

Raw Materials

The EG10 and EG12 artifacts were predominantly made of trachyte and rhyolite cobbles (Figure 4). The stone raw materials were acquired from nearby gravels, and the ICC was the most likely source of the cobbles used for making the artifacts. Geological studies have indicated the presence of ancient channels that carried the cobbles in close proximity to the sites. The ICC contains water-worn rounded trachyte and rhyolite cobbles suitable for making the EG10 and EG12 stone tools, suggesting that the toolmakers had to travel only short distances (c.100-200 m) to select and acquire these stone raw materials.

Moreover, preliminary geological studies have shown that the raw materials used at EG10 and EG12 were similar to the cobbles that are now eroding from the ICC. The raw materials selected and used by the hominins appear to have been fist-sized water worn rounded cobbles. The ICC is currently eroding into the Kada Gona River and being exposed near EG10 and EG12, providing a wonderful opportunity for sampling and analyzing the cobbles from present day settings. During the 1993 fieldwork, a total of 103 cobbles eroded from the ICC were picked randomly (near EG10) and sorted by raw material types. The cobble samples consisted of 48% trachyte, 24% rhyolite and the remaining were identified as chalcedony, breccia, basalt and other types (Semaw 1997). The trachytes used at Gona were of fine-grained quality varying from light grey to brown, often with inclusion of phenocrysts, and their cortical surface mostly dark brown in color. Measurements taken on the maximum dimensions of the cobbles ranged between 60-170 mm (mean 105mm, s.d. 29), size classes optimal for making the Oldowan artifacts of EG10 and EG12 (Semaw, 1997).

As is shown in Figure 4, more than 75% of the EG10 and EG12 excavated artifacts were made of trachyte, c. 20% of rhyolite, and the remaining of basalt, chalcedony and other raw materials. Comparison of the

Table 2

	EG 10		EG12	
	Surface	Excavated	Surface	Excavated
All Lithics (n)	1549	686	309	445
All Artifacts (n)	1549	685	308	445
Manuports (Unmodified Stones)	0	0	0	0
Split Cobbles	0	1	1	0
Cores/Choppers or Tools (Flaked Pieces)	1.1	2.19	1.3	2.03
Débitage (Detached Pieces)	98.9	97.81	98.7	97.97
Utilized Material (Battered & Pounded Pieces)	0.00	0.00	0.00	0.00
% Artifacts	100.00	100.00	100.00	100.00
Cores/Choppers (Flaked Pieces) (n)	17	15	4	8
Cores/Choppers	88.24	73.33	100.00	88.89
Discoids	5.88	20.00	0.00	0.00
Core Scrapers	5.88	6.67	0.00	11.11
% Total	100.00	100.00	100.00	100.00
Débitage (Detached Pieces) (n)	1532	670	304	436
Whole Flakes	18.01	24.48	30.92	33.94
Angular Flakes	74.28	60.45	54.93	51.83
Split Flakes	5.42	8.36	12.17	9.86
Snapped Flakes	0.72	3.43	0.66	2.06
Split & Snapped Flakes	0.07	2.69	0.00	0.00
Core/Cobble Fragments	1.50	0.59	1.32	2.31
% Total	100.00	100.00	100.00	100.00
Utilized Materials (Battered & Pounded Pieces) (n)	0	0	0	0

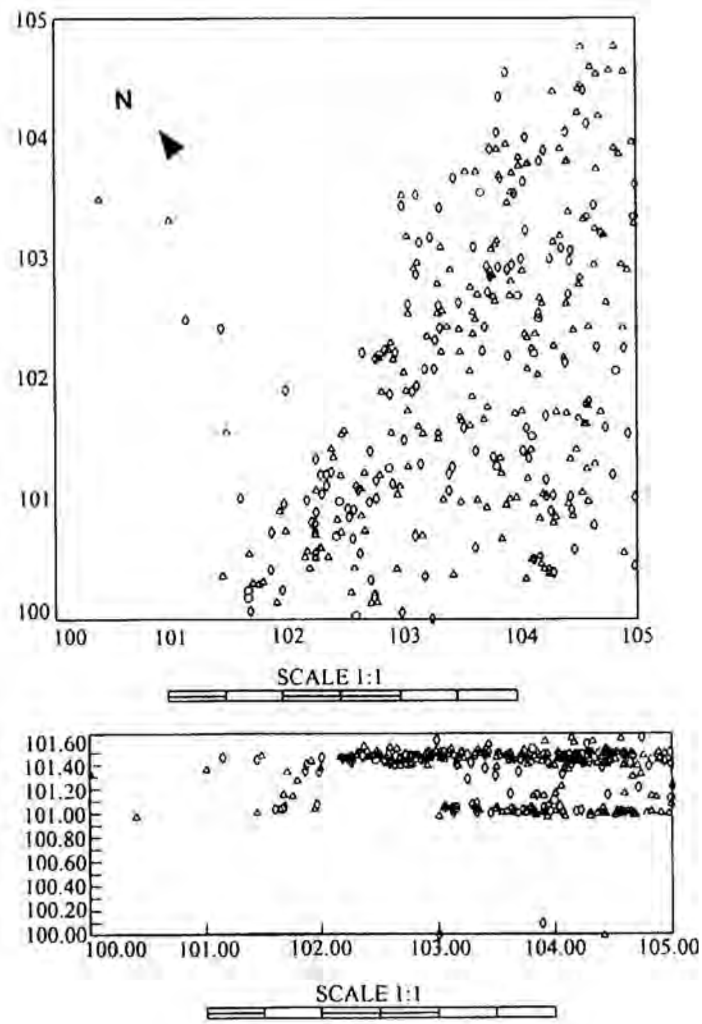
2. Percentage composition of all the surface and excavated artifacts from EG10 and EG12. Data modified after Semaw (1997). The description of the artifacts follows terminologies introduced by M.D. Leakey (1971). Isaac et al.'s (1981) artifact categories are shown in parentheses.

raw materials used at EG10 and EG12 with the types identified from the samples picked within the ICC show that trachyte was the most abundant as well as the most preferred. Recently discovered contemporary archaeological sites located c.10 Km away from the EG sites are confirming that the hominins practiced even more systematic raw material selection strategies and preference for finer-grained raw materials (like chert), further reinforcing the fact that the first toolmakers were more selective in their decision-making and stone-crafting behavior than previously recognized (personal observation.).

East Gona 10 (EG10)

EG10 is the most informative of all the East Gona sites with the highest density of surface and excavated stone artifacts. The composition of the surface and excavated artifacts from EG10 and EG12 are shown in Table 2. Fresh artifacts comprising of cores, and *débitage* were found eroding down a slope situated above the ICC. All sizes and classes of artifacts were found freshly eroding out of fine-grained sediments indicating the great potential of EG10 for yielding a high density of *in situ* artifacts. A total of 1, 549 surface exposed artifacts (including plotted and surface-scraped) were collected from the 38m^2 grid established down the slope to the level of the ICC. There were several fossilized bones found on the surface, but none from the excavations, and the evidence was not adequate to make any behavioral associations between the fauna and the artifacts. A total of 13m^2 area was excavated following the edge of the outcrops, and 686 artifacts were recovered *in situ*. The excavated materials consisted of cores, broken flakes (with majority of split and snapped), broken cores and a high density of angular fragments. As shown in Figure 5, two artifact-bearing levels separated by c. 40 cm of nearly sterile deposits were documented at the site. The artifacts from the two levels were tightly clustered and restricted, each within a 10 cm layer of

Figure 5



5. *Horizontal and vertical distributions of the EG10 excavated artifacts. (○ = Cores, ◇ = Whole Flakes and △ = Angular Fragments.)*

deposits, suggesting absence of vertical dispersion or minimal disturbance as a result of geological processes. The presence of two discrete levels suggests possible repeated occupation of the site, and that the area may have been favored by the toolmakers due to its close proximity to raw materials and ancient streams with fresh water.

The artifacts were excavated in fine-grained, consolidated brown clays that appear to have distinctive characteristics of swelling and cracking that occur during different moisture regimes. The paleosols also indicate marked seasonality during the time of the deposition of the artifacts. Glass shards of the contaminated AST-2 tephra were chemically identified within the artifact-bearing sediments. A majority (>99%) of the surface and excavated artifacts were exceptionally fresh, and only a fraction of the cores and flakes show edge-damage that may be attributable to utilization. There were no preferred orientations recorded for the excavated artifacts implying excellent site integrity and absence of disturbance by water. The overall evidence is in favor of a quick burial after discard. However, the absence of utilization damage is intriguing when considering the time and energy expended for seeking out raw materials and making the artifacts.

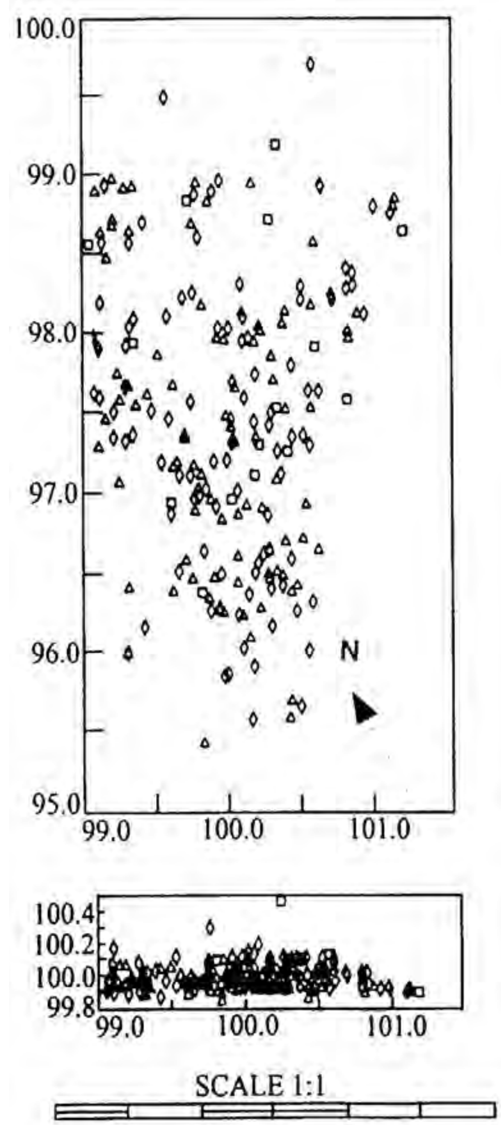
The excavation was extended into a geological trench to the north and dug c. 3 meters down the sequence to the level of the ICC, and no artifacts were found from the geological test-trench. The latest survey (1999-2001) of EG10 has shown the presence of freshly exposed artifacts eroding out of the sediments left unexcavated, and there is high potential for the presence of further artifacts still buried within intact sediments beneath the overburden (personal observation).

East Gona EG12

Locality EG12 was discovered within the Aybayto Dora stream, c. 300 meters north of EG10. The stream flows west into the Kada Gona, also exposing Late Pliocene sediments. The stratigraphy of EG12 is similar to EG10 because the same deposits extend laterally, and very well exposed for c. 2-3 km along the Kada Gona and feeding streams. Therefore, the Green Marker, the AST-1, -2 & -3 marker tuffs and interbedded cobble conglomerates are prominently featured in the stratigraphic section exposed near EG12. The AST-2.75 tuff is located c. 100 meters east of EG12, and stratigraphically situated c. 0.5 meters above the excavation. The same artifact-bearing horizon extends east and surface artifacts were sampled at EG13, located less than 5 meters directly below the AST-2.75 tuff. Based on their stratigraphic position in relation to the $^{40}Ar/^{39}Ar$ dated AST-2.75 tuff, and the magnetostratigraphy of the nearby sediments (identified as the Gauss-Matuyama transition), the EG12 and EG13 localities are firmly dated between 2.5-2.6 Ma (Figure 3a).

At EG12, a high density of very fresh stone artifacts was found exposed on a steep slope and eroding down into the Aybayto Dora stream. The artifact-bearing horizon was located on a small flat ridge mid-way up the steep section and the area difficult to reach for excavation. An area of 26 m^2 was gridded over the tilted slope down the sequence to the level of the ICC and a total of 309 artifacts (including surface plotted and surface scraped) were systematically collected. An area of 9m^2 was excavated atop the flat ridge and yielded a total of 444 artifacts *in situ* within fine-grained sediments. The vertical and horizontal distribution of the EG12 excavated artifacts is shown in Figure 6. The artifacts were clustered within 40 cm thick well-consolidated brown clays, and their sedimentary context was very similar to EG10. The AST-2 tephra was located c. 0.5 meters below the EG12 excavated horizon. Composition of the artifacts, both surface and excavated, was similar to

Figure 6



6. *Horizontal and vertical distributions of the EG12 excavated artifacts. (○ = Cores, ◇ = Whole Flakes and △ = Angular Fragments.)*

EG10, and all of the artifacts were in mint condition. There were no fossilized bones associated with the surface or the excavated artifacts. EG12 was resurveyed during the recent rounds of fieldwork and high density concentrations of freshly exposed stone artifacts were found eroding at the site of the 1992 excavation. As was the case with EG10, it is likely that two artifact-bearing levels may be present at EG12. The surface exposed artifacts were collected, but no further excavations were undertaken due to time constraints.

Characteristics of the Gona Stone Assemblages

The EG10 and EG12 artifacts are broadly similar to the Oldowan assemblages known from archaeological sites dated between 2.4-1.5 Ma. The surface and excavated artifacts consist of a large number of unifacially-flaked cores, and *débitage* including whole flakes, and a high density of flaking debris (split and snapped flakes, and angular fragments). The composition of the EG10 and EG12 artifacts and the types of raw materials used are summarized in Table 2. Water worn rounded cobbles, mainly trachyte, rhyolite, basalt, and in some instances rare raw materials such as chalcedony and chert were used. Retouched pieces are rare, but present. There were no spherical cobbles with evidence of pitting or battering marks identified as typical hammerstones. In addition, spheroids and subspheroids, known at other Early Pleistocene sites (for e.g., at Olduvai) are totally lacking at Gona.

The Gona assemblages were classified by using the typology devised by M.D. Leakey (1971) for describing the artifacts excavated from the Lower Beds at Olduvai Gorge. None of the Gona artifacts were identified into the elaborate Oldowan tool types of M. Leakey such as proto-handaxes, awls, burins, etc. Despite the feasibility of doing so at Gona, these tool types were not included in the inventory of EG10 and EG12 because it would be unlikely for any of the Plio-Pleistocene toolmakers (2.5-1.5 Ma) to have had such functionally elaborate artifacts planned in their "toolkits."

By using a simple technological approach, Isaac *et al.* (1981) designed a system of classifications that minimizes the functional implications associated with M. Leakey's typology. Isaac *et al.* (1981) classified Plio-Pleistocene Oldowan artifacts into major categories including *Flaked Pieces* (the various choppers/ core forms and retouched pieces), *Detached Pieces* (the *débitage*), *Pounded Pieces* (the hammerstones and battered cobbles), and *Unmodified Pieces* (the manuports). Their scheme is useful, but very broad and general for detailed comparative study of Oldowan stone assemblages and for investigating possible changes in the tool manufacture behavior of Late Pliocene-Early Pleistocene hominins. Artifacts from Gona and the major Late Pliocene-Early Pleistocene sites in East Africa were analyzed and described by using the typology outlined by M. Leakey (1971), and her classifications are still vital for comparative studies of Oldowan assemblages.

The EG10 and EG12 artifacts were reanalyzed in 1999 and the descriptions of the artifacts presented here are based on the recently collected data. All of the surface and excavated cores from both EG10 and EG12 were described. All of the excavated whole flakes from EG10 and a sample of the whole flakes from EG12 were reanalyzed for this study. The brief summary of the measurements for the remaining *débitage* category (broken flakes, and angular and core fragments) is reliant on the excavated artifact data collected from EG10.

The Cores/Choppers

A majority of the cores/choppers at Gona were recovered from the surface and the excavations at EG10, and they provide the best representative samples for characterizing the stone knapping behavior of the first toolmakers, particularly those who inhabited the area around Kada Gona. The excavated cores/choppers include 15 specimens from EG10, and 7 from EG12, accounting for c. 1% of the total excavated assemblages (Table 3). Most of the EG10 cores (60% surface and 69% excavated) and close to half (44%) of the EG12 excavated cores were flaked only on one face, and the remaining bifacially worked. Only a small percentage were exhaustively-reduced, but most cobbles were flaked around much of the circumference, and the overall evidence clearly shows that the Late Pliocene/Early Pleistocene toolmakers understood conchoidal fractures on stones, sought acute angles when striking the cobbles and had excellent coordination and motor skills to successfully remove large flakes off the cores. Unifacial side choppers made of trachyte cobbles dominate the assemblages and only a few of the specimens were identified as discoids (Table 4). However, there were also

Table 3

	EG 10		EG12	
	Surface	Excavated	Surface	Excavated
No. of Cores/Choppers	17	15	4	7
Raw Materials				
Trachyte	94.12	73.33	100.00	42.86
Rhyolite	5.88	13.33	0.00	28.57
Basalt	0.00	13.33	0.00	0.00
Other	0.00	0.00	0.00	28.57
% Total	100.00	100.00	100.00	100.00
Length				
Mean	76.88	83.33	72.25	74.45
Std	6.82	10.34	2.39	8.72
Range	(64-87)	(69-105)	(69-75)	(58-93)
Breadth				
Mean	62.20	60.90	62.50	59.73
Std	6.01	9.18	3.91	8.06
Range	(51-71)	(44-80)	(57-68)	(49-77)
Thickness				
Mean	46.59	45.27	49.00	43.73
Std	9.25	12.36	2.92	7.74
Range	(31-63)	(30-69)	(45-53)	(25-53)
Total Scars				
Mean	8.76	10.27	11.00	8.91
Std	2.67	3.74	2.12	3.45
Range	(4-13)	(6-21)	(8-13)	(3-15)
Largest Scars				
Mean	45.47	48.07	52.25	45.45
Std	8.63	11.79	8.39	8.40
Range	(30-63)	(30-65)	(40-60)	(33-60)
B/L				
Mean	0.81	0.73	0.87	0.77
Std	0.05	0.08	0.00	0.09
T/B				
Mean	0.73	0.74	0.79	0.71
Std	0.08	0.16	0.00	0.14

3. Summary of the basic attributes for the EG10 and EG12 surface and excavated cores/choppers.

Table 4

	EG 10				EG12			
	Surface		Excavated		Surface		Excavated	
	Uni	Bi/Multi	Uni	Bi/Multi	Uni	Bi/Multi	Uni	Bi/Multi
Total no. of Artifacts	9	6	11	4	3	0	4	5
Side Choppers	3	2	8	0	1	0	4	1
End Choppers	3	0	0	0	1	0	0	0
Side & End Choppers	2	2	2	1	0	0	0	3
Discoids	1	0	1	3	1	0	0	0
Core Scrapers	0	2	0	1	0	0	0	1
% Total	60.00	40.00	68.75	31.25	100.00	0.00	44.44	55.55

4. Composition of the unifacially and bifacially/multifacially worked EG10 and EG12 surface and excavated cores/choppers. Uni=unifacial, Bi=bifacial, and Multi=multifacial. Note: Multifacial flaking here refers to working of the core around much of the circumference.

several multifacially worked and exhaustively reduced cores with evidence of many generations of flake removals from EG10, EG12, EG13, and other contemporary sites. The EG10 excavated cores have an average length of 83.33 mm (s.d. 10.34) and those of EG12 average 74.45 mm in length (s.d. 8.72). Detailed measurements of the basic attributes for the surface and excavated EG10 and EG12 cores are provided in Table 3. The average size of the Gona cores accords with the measurements of the cobbles sampled (in 1993) from the ICC (range between 60-170 mm, average 105mm, s.d. 29) (Semaw, 1997). The EG10 excavated cores have an average of 10 scar counts (range between 6-21 scar counts, with s.d. 3.74). The average size of the Gona cores is relatively smaller compared to the c. 105 mm average reported for Lokalalei 1 (Kibunjia, 1994). In addition, the pattern at Lokalalei 1with the number of flake scars (between 1-12) seem to correspond with the less exhaustively flaked nature of the core forms. It may be that the cores were not as heavily reduced because of the lower quality of the raw materials used at Lokalalei 1, and repeated attempts may have failed to produce workable flakes, as suggested by Kibunjia (1994).

Only two of the excavated cores/choppers from EG10 show typical hammerstone battering marks characteristic of flaking attempts, and none were recorded for the cores from EG12. As surface-exposed trachyte artifacts exfoliate because of weathering and can superficially mimic battering/pounding marks, only excavated artifacts were included in the analysis of pitting and bruising marks, and special caution was taken to distinguish actual pitting from such exfoliation. Analysis of the Gona specimens show that at least one step/hinge has been recorded on nearly 80% of the cores. The percentage frequency of the steps/hinges recorded for the Gona cores is shown in Figure 7. Some researchers attribute the high incidence of steps/hinges on cores as an indication of low level of technical skills (Kibunjia, 1994; Ludwig, 1999). Based on observation of the Gona assemblages and experimental knapping studies, Ludwig (1999) argues for a relatively low level of skills for the Gona and Lokalalei 1 toolmakers compared, for example., to the hominins responsible for the Oldowan assemblages known from the Lower Beds at Olduvai. His experimental studies were based on argillite blanks collected from river gravels in New Jersey, and it is debatable whether or not the materials he used approximate the flaking properties of the trachyte utilized at Gona, and if direct comparisons can be made between the two different raw materials. Nonetheless, the question of how many of the steps/hinges were influenced by raw material characteristics (e.g., quality of flaking, internal flaws, or shape) vs. the level of skills of the knapper (novice/ experienced) require careful investigations, and need to be further determined by extensive knapping experiments using comparable raw materials. Furthermore, recent experimental studies show that there appear no clear relationships between the preponderance of steps/hinges in an assemblage and the level of the skill of a knapper (see Toth *et al.*, this volume).

Despite the mastery and control of flaking shown by the hominins, a majority of the EG10 cores were flaked only on one face. The preponderance of unifacial working at EG10 might be explained by the abundance of large-size cobbles readily available from the nearby ancient streams for producing flakes for immediate use as “expedient tools,” or the sites may represent activity loci where the hominins acquired raw materials, did casual flaking and transported selected specimens for use elsewhere. However, all the cores made of exotic raw materials such as chalcedony and chert were heavily reduced and several examples of diminutive cores are known from EG13 and across Kada Gona at WG2 and elsewhere in the study area (Figures 8 and 9). Nonetheless, the overall evidence clearly indicates that the earliest toolmakers understood the properties of conchoidal fractures, and they have already mastered stone-on-stone flaking techniques as early as 2.6 Ma.

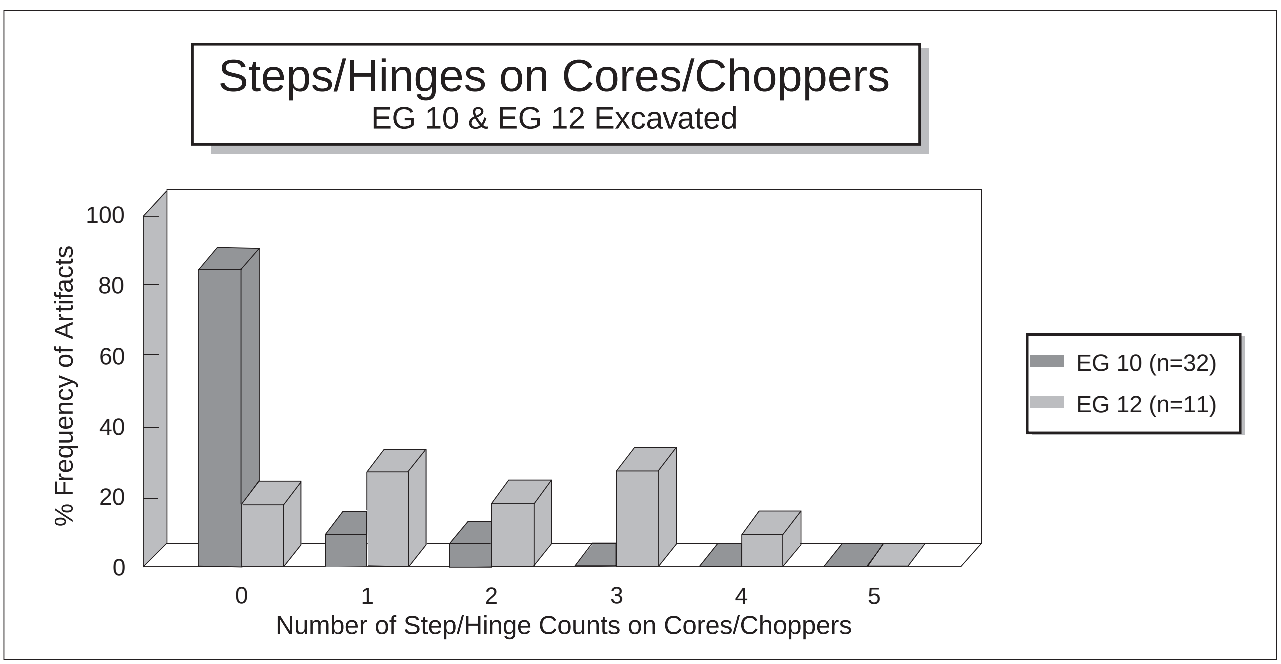
The Débitage

Following the criteria outlined by M.D. Leakey (1971), the whole flakes and resultant flaking debris produced during the process of reduction of the cores were classified as *débitage*. The *débitage* includes whole flakes, broken flakes, angular and core fragment often accounting for the highest percentage of the artifacts in the Oldowan. Over 97% of the total assemblages from EG10 and EG12 fall into this category. The whole flakes provide important information on the technical skills of early stone knappers and they are discussed in more detail. The flaking debris including split and snapped flakes, angular and core fragments are described in greater details in Semaw (1997), and only a brief summary of the measurements are provided here.

Artifacts with obvious platforms, diagnostic bulbs of percussion, and clear release surfaces were classified as whole flakes. A total of 110 specimens from EG10 and 58 from EG12 are included in this study. The whole flakes account for 25% of the EG10, and close to 34% of the EG12 excavated artifacts (Table 5). Like the cores, a majority (80%) of the EG10 whole flakes were made of trachyte, 11% of rhyolite and the remaining on basalt and other raw materials. EG12 also shows a similar trend with 69% of the whole flakes made of trachyte, 17% of rhyolite, and the remaining of basalt and other types of raw materials. Remarkably, most of the Gona whole flakes exhibit very prominent bulbs of percussion and show that the toolmakers practiced bold flaking and had excellent coordination and control over the core reduction processes (Figures 9 & 10). In maximum dimensions, the whole flakes from EG10 average to 42.18 mm (range between 85-20 mm, s.d. 15.56), and the EG12 average to 40.94 mm (range between 20-71 mm, s.d. 13.85). Basic measurements of the excavated whole flakes for the two sites are provided in Table 5. The angles of striking platforms for EG10 average to 109.30° (range between 80°-135°, s.d. 12.89), and for EG12 average to 107° (range between 80°-130°, s.d. 11.40). Although no average and s.d. available, the range of striking platforms (between 70°-129°) documented for Olduvai FLK N levels 1 & 2 (M.D. Leakey, 1971, p. 83) compare with the values recorded for EG10 and EG12.

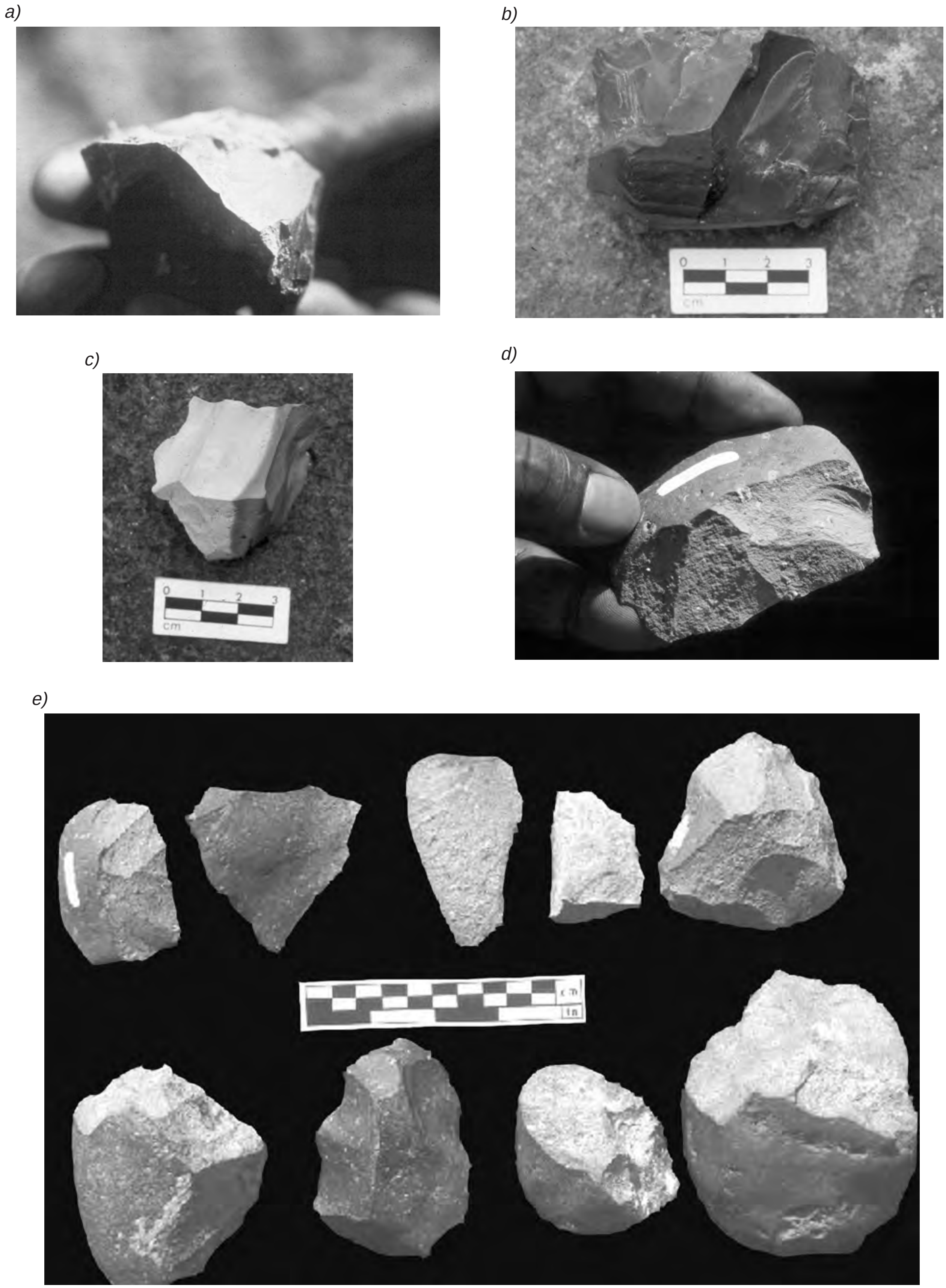
The flake type system devised by Toth (1982) was adopted to look at the stages of flaking represented at EG10 and EG12. Following intensive examination of the Koobi Fora assemblages, Toth (1982, 1985, 1987) recognized six major flake types based on the presence/absence of cortex on the platform and on the dorsal surface of the whole flakes. As is shown in Figure 11, a majority of the EG10 and EG12 whole flakes were flake types 2 and 3. The preponderance of these flake types with cortical platforms corresponds with the unifacial mode of flaking prevalent at Kada Gona (Toth, *pers. com.*). Because of their immediate proximity to sources of raw materials, it may be that EG10 and EG12 represent focal points for flaking activities, and usable flakes may have been preferentially selected and removed for utilization at different locations of the ancient Gona landscape (Toth *et al.*, this volume). The

Figure 7



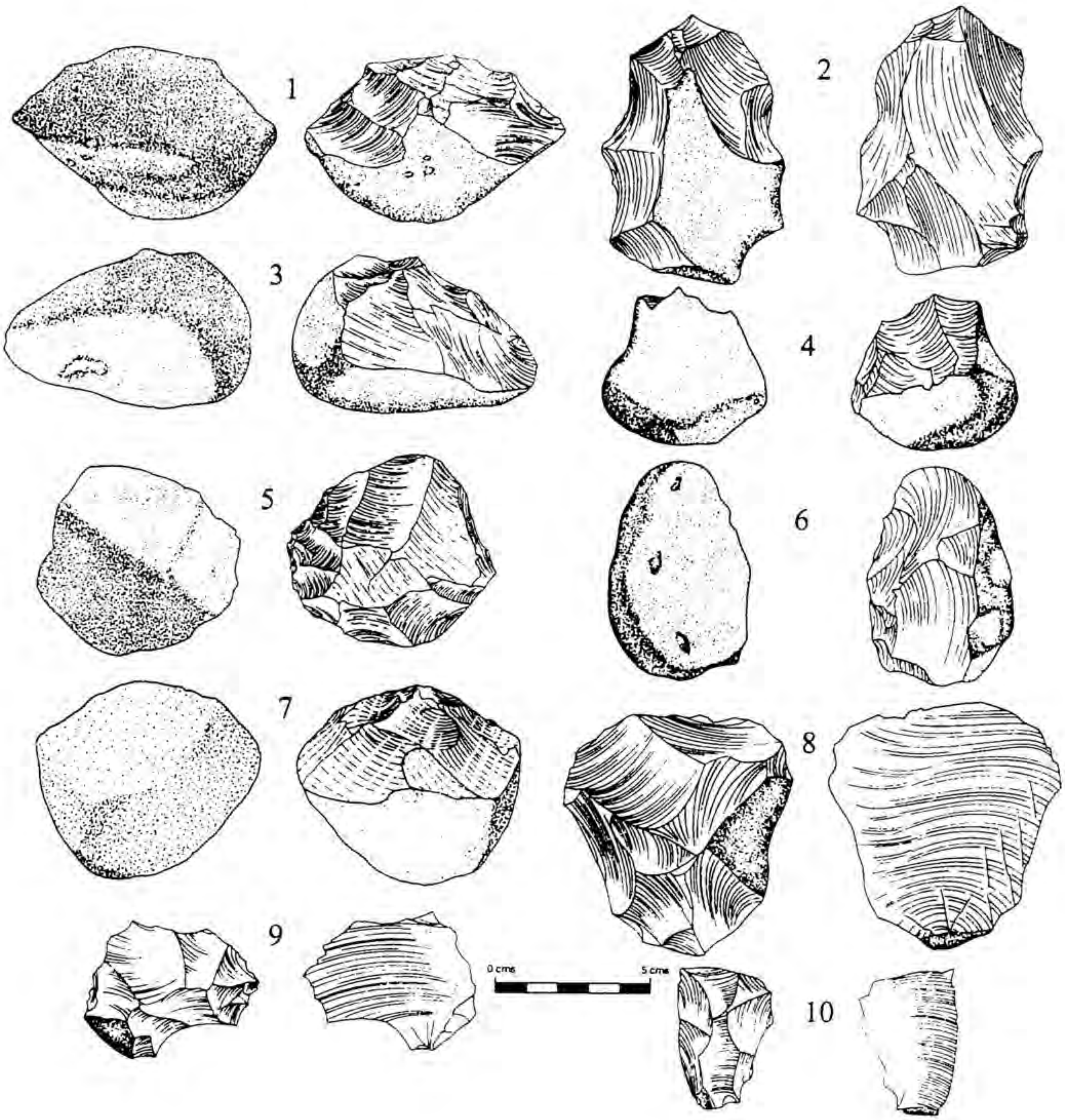
7. Steps and hinges counted on the excavated EG10 & EG12 cores/choppers.

Figure 8



8. Photo showing the Gona stone artifacts, a) bifacial core/chopper made of trachyte, b) bifacial core/chopper made of chert, c) exhaustively worked chalcedony core/chopper, d) a whole flake and e) cores and whole flakes from EG10 and EG12. (Photo d, © David Brill; Photo e, Tim White)

Figure 9



9. Drawings of the EG10 and EG12 excavated artifacts. 1) unifacial side chopper, 2) discoid, 3) unifacial side chopper, 4) unifacial end chopper, 5) partial discoid, 6) unifacial side chopper, 7) unifacial side chopper, and 8-10) whole flakes.

Table 5

	EG10	EG12
No. of Artifacts	114	62
Raw Materials		
Trachyte	78.95	66.13
Rhyolite	11.40	17.74
Basalt	7.02	6.45
Other	2.63	9.68
% Total	100.00	100.00
Maximum Dimensions		
Mean	42.18	40.94
Std	15.56	13.85
Range	(20-85)	(20-71)
Length		
Mean	37.38	34.50
Std	15.34	12.84
Range	(14-78)	(15-66)
Breadth		
Mean	34.63	35.55
Std	13.74	13.23
Range	(14-77)	(19-66)
Thickness		
Mean	13.18	12.13
Std	6.26	5.76
Range	(3-33)	(4-30)
Dorsal Scars		
Mean	3.07	3.00
Std	1.72	1.54
Range	(0-10)	(0-8)
Platform Breadth		
Mean	22.86	24.56
Std	11.37	13.27
Range	(4-60)	(5-58)
Platform Thickness		
Mean	10.21	10.10
Std	6.04	5.65
Range	(2-34)	(2-29)
Platform Scars		
Mean	0.32	0.37
Std	0.70	0.80
Range	(0-4)	(0-4)
Bulb Range		
Mean	109.30	107.00
Std	12.89	11.40
Range	(80-135)	(80-130)
Breadth/Length		
Mean	0.96	1.08
Std	0.26	0.30
Thickness/Breadth		
Mean	0.39	0.34
Std	0.11	0.11

5. Summary of the basic attributes of the EG10 and EG12 excavated whole flakes.

hominins were skilled in striking flakes off cores, but why they repeatedly used the cortical surface of only one face of the cores for a platform is unclear. This pattern of flaking is consistent both at EG10, EG12 and the other sites known around Kada Gona. The dorsal scar counts of the EG10 whole flakes average 3.07 mm (range between 0-10 mm, s.d. 1.72) and the EG12 average to 3 mm (range between 0-8 mm, s.d. 1.54) showing moderate to extensive flaking.

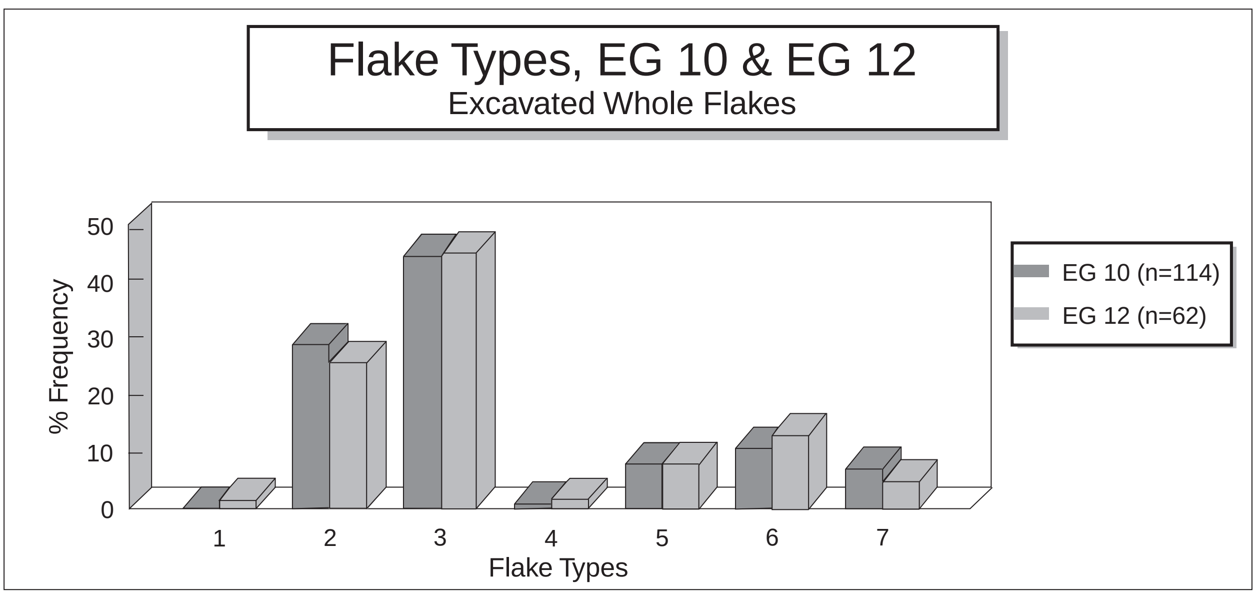
Table 6

Angular Fragments (n=405)	
Mean	20.12
Std	8.78
Range	(6-46)
Split Flakes, Left (n=26)	
Mean	31.81
Std	16.01
Range	(13-77)
Split Flakes, Right (n=30)	
Mean	37.77
Std	16.68
Range	(12-78)
Snapped Flakes, Proximal (n=15)	
Mean	27.33
Std	10.2
Range	(12-41)
Snapped Flakes, Distal (n=6)	
Mean	30.17
Std	6.82
Range	(18-38)
Split & Snapped Flakes (n=18)	
Mean	28.90
Std	9.34
Range	(13-47)
Core Fragments/Broken Cobbles (n=5)	
Mean	55
Std	12.70
Range	(35-73)

6. Maximum dimensions of the EG10 excavated débitage.

Angular fragments make up c. 65% of the excavated assemblages identified into the *débitage* category. The remaining, including broken flakes (split and snapped) and core fragments account for nearly 10% of the total excavated *débitage*. Because the majority of the artifacts fall into angular fragments, this class of artifacts is the best indicator of the types of raw materials used at Gona. About 68% of the angular fragments were made of trachyte, 24% made of rhyolite, 6% of basalt and the remaining of other raw materials, thus clearly showing trachyte to have been the most preferred and utilized raw material at EG10. A total of 405 angular fragments were analyzed, and in maximum dimensions average to 20.12 mm (range between 6-46 mm, s.d. 8.78). A total of 56 split flakes (26 left and 30 right), 23 snapped flakes (15 proximal, 2 medial and 6 distal), 18 split and snapped flakes, and 5 core fragments (one broken cobble) were identified. The maximum dimensions of these artifact categories are presented in Table 6.

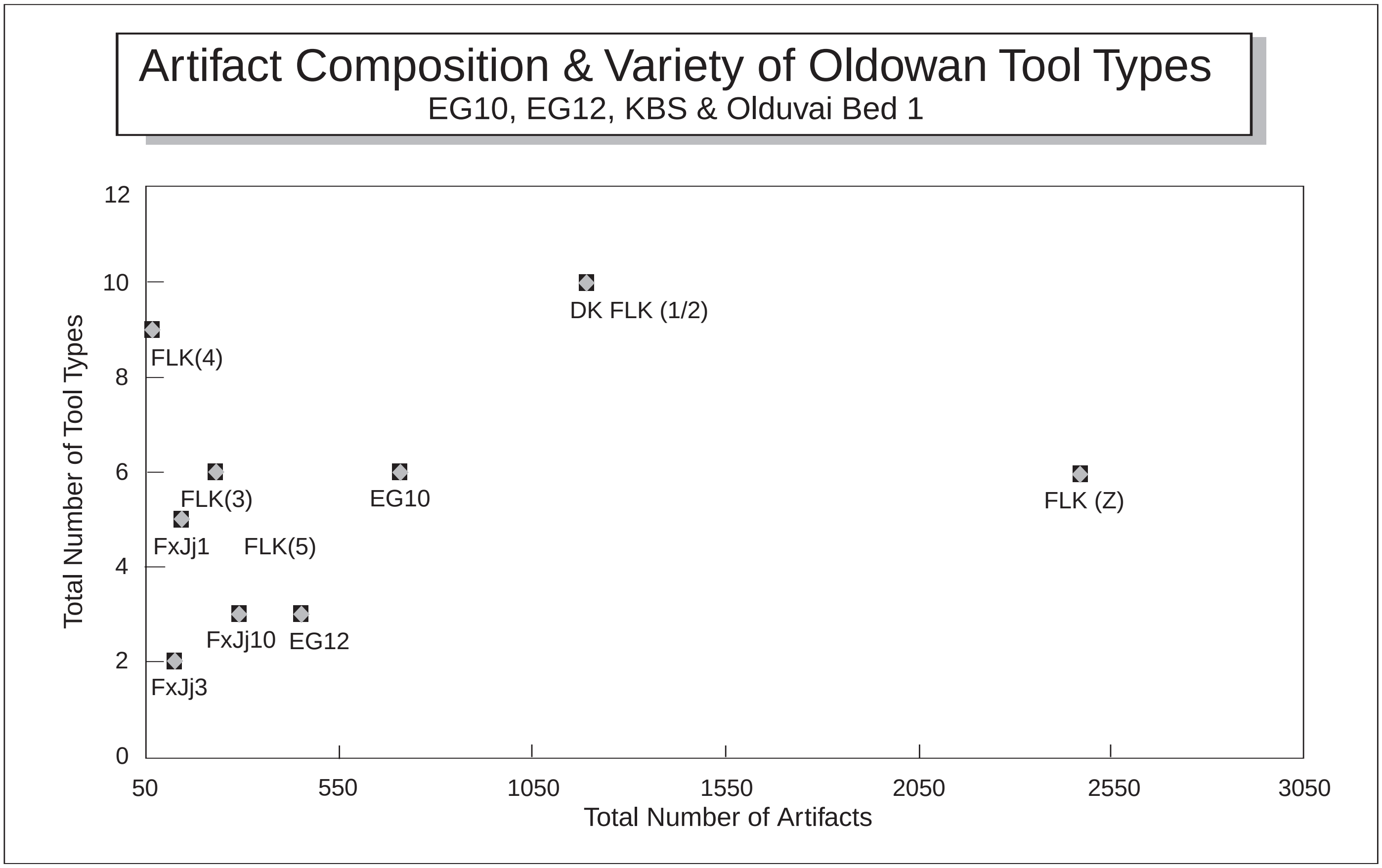
Figure 10



10. Flake types of EG10 and EG12 excavated whole flakes.

Key (after Toth, 1985):
1 = All cortex platform all cortex dorsal
2 = All cortex platform, part cortex dorsal
3 = All cortex platform, no cortex dorsal
4 = No cortex platform, all cortex dorsal
5 = No cortex platform, part cortex dorsal
6 = No cortex platform, no cortex dorsal
7 = Indeterminate

Figure 11



NOTE: Artifact types such as protobifaces, awls, burins, spheroids, laterally trimmed flakes, sundry tools, etc. are excluded. Artifacts identified into these types were very few in numbers at Olduvai, and represented only in one or two sites. Furthermore, none of these artifacts seem to have been part of the tool repertoire of Oldowan hominids, and their exclusion seems justified.

11. *Comparison of the variety of tool types, EG10, EG12, the KBS sites and the Olduvai Bed I and Lower Bed II assemblages. Artifact data for EG10 and EG12 are based on both the surface and excavated cores/choppers. Data for the KBS sites after Isaac & Harris (1997), and for Olduvai after M.D. Leakey (1971).*

Discussion

The Earliest Stone Technology

Despite years of intensive surveys, the older Gona deposits (c. 2.9-2.6 Ma) have not yet yielded any evidence of stones or fossilized bones modified by a hominin agent. Current understanding of the state of Palaeolithic research in East Africa indicates that flaked stone technology made an apparently abrupt entrance into the archaeological record by c. 2.6 Ma. As pointed out by G. Isaac (1976a, p. 491), "…the empirical discovery of the effects of conchoidal fracture was a threshold." The sudden appearance of thousands of flaked stones at Gona and the subsequent widespread manufacture and use documented over broader parts of Plio-Pleistocene Africa confirm his suggestions. Once the initial discovery was made, ancestral hominins engaged in intensive flaking activities making thousands of artifacts, and the practice of stone tool production and use appears to have disseminated quickly, especially in areas in close proximity to raw material sources. The presence of numerous archaeological localities at Gona with abundant artifacts by 2.6 Ma, and their absence in older deposits is intriguing. The mastery and control of stone working shown c. 2.6 Ma points towards the likelihood that the direct forebears of the first toolmakers may not be complete technological novices, and suggests that they probably practiced manipulating tools by regularly using unmodified stones and such perishable items as wooden clubs, tree branches, etc. in their various day-to-day activities (see McGrew, 1993). Unfortunately, these materials do not preserve and leave fossil signatures as well as do flaked stones, and the evidence for Early Pliocene hominin tool use may remain difficult to prove archaeologically.

The Oldowan was initially proposed by Louis Leakey, and later defined by M.D. Leakey (1971) based on her meticulous and detailed analysis of the Upper Bed I & Lower Bed II assemblages of Olduvai Gorge. The Oldowan tradition is characterized mainly by simple cores/choppers and *débitage*, battered hammerstones or spheroids, and occasional retouched pieces. The final shape of the stone artifacts was often dictated by the shape, size and flaking-quality of the original cobbles, and the extent of core reductions accomplished during the reduction of the cores (Toth, 1985, 1987; Schick and Toth, 1993). Currently, there are a large number of Plio-Pleistocene sites with Oldowan assemblages dated between 2.6-1.5 Ma, and all the artifacts of this tradition are non-standardized. The probable exception may be the so called "Karari" (c. 1.5 Ma), mainly differentiated by the preponderance of heavy duty scrapers/ cores, whereby the hominins knocked flakes off sequentially from "prepared platform cores," a technique argued to be effective for maximizing flake outputs and for making optimal use of raw materials (Harris, 1978; Ludwig, 1999). The Karari temporally overlaps with the Acheulean, and its status in terms of artifact tradition is still unclear.

M.D. Leakey defined the Oldowan primarily based on the morphology of the "tools," and some of the terminologies introduced in her descriptions were intended to reflect their function. She inferred that many of the various tool forms, such as choppers, scrapers, heavy duty/light-duty tools etc., were intentionally shaped for specific activities, while others were described and classified based on their morphology as spheroids, polyhedrons, discoids, etc. In particular, the artifacts identified as spheroids/subspheroids and proto-bifaces (which become relatively abundant above Middle Bed II) were considered to be more advanced compared to the core/chopper dominated assemblages of the Lower Beds. M.D. Leakey proposed the "Developed Oldowan" to accommodate these "evolved" forms. However, experimental knapping by Schick and Toth (1994) showed that the spheroids/subspheroids were largely made of quartz, and that intensive use of quartz chunks as hammers over several accumulated hours of flaking could result in these forms taking spherical shapes. They concluded that the abundance of spheroids/subspheroids probably reflects intensive activities with more "habitual" use of tools, and the preponderance of quartz as the main raw material type used at Olduvai during the Early Pleistocene. Thus, overall results from knapping experiments indicate that the final shape of Plio-Pleistocene Oldowan artifacts emerge as byproducts of the core reduction processes instead of resulting from deliberate fashioning by ancestral toolmakers.

In addition, the number of artifacts labeled as protobifaces, awls and burins were very few even within the assemblages of the Lower Beds at Olduvai. Experimental knapping studies have shown that the flaking quality of the raw materials, distances traveled to sources, the original size and morphology of the cobbles available for Plio-Pleistocene hominins, and the extent of core reductions carried out at the sites had a major influence on the final shape and composition of Oldowan artifacts (Toth, 1982, 1985, 1987). Moreover, the primary intent of the toolmakers was the production of simple sharp-edged implements used primarily for cutting up carcasses, and probably for breaking bones for extracting marrows (for e.g., de Heinzelin *et al.*, 1999; Blumenschine & Selvaggio, 1988; Bunn & Kroll, 1986). Until the need by Late Pliocene-Early Pleistocene hominins for such elaborate tools as protohandaxes, awls and burins and their possible functions are demonstrated through experimental studies, it can be argued that the variety of "tool" types identified in the Lower Beds at Olduvai were quite overstated. As shown in Figure 12, the EG10 and EG12 artifacts, and tool types fall within the range of Olduvai Bed I and the

KBS artifacts after the protobifaces, awls, burins, etc. are excluded.

Because of the excellent knapping skills and control exhibited by the Gona toolmakers, and the similarity illustrated with Early Pleistocene assemblages in artifact making techniques, the EG10 and EG12 assemblages are assigned to the Oldowan Industry. Semaw *et al.* (1997) suggested a "technological stasis" for the Oldowan (2.6-1.5 Ma) based on the following simple observations:

a) The earliest toolmakers had remarkable control and mastery of conchoidal fracture of stone, and the Oldowan persisted with little technological change, the hominins continuing to make simple tools by adopting similar stone working techniques up to c. 1.5 Ma,

b) Plio-Pleistocene Oldowan toolmakers were primarily after sharp-edged cutting implements made with the "least effort" strategy, and the final shape of the artifacts were dictated mainly by the availability and flaking quality of the raw materials, and the extent of the reduction of the cores carried out at the sites (Toth, 1982, 1985, 1987),

c) Current archaeological evidence suggests that the artifacts were used mainly for processing animal carcasses (for e.g., Blumenschine & Selvaggio, 1988; Bunn *et al.*, 1980; Bunn & Kroll, 1986; Beyries, 1993; de Heinzelin *et al.*, 1999), and probably also for processing plant foods (for example, Keeley & Toth, 1981).

d) Compared to the Late Pliocene/earliest Pleistocene, later in the Early Pleistocene relatively higher density concentrations of artifacts and associated fossilized fauna with evidence of cutmarks are observed, along with a marked increase in the intensity of hominin activities (plus more exhaustive core reductions and greater proportions of retouched pieces), but still within a continuum and with no significant departure in the techniques of stone working,

e) Large artifacts made with controlled design, predetermined shape, and symmetry were essentially unknown within the Oldowan, and bifaces with such forms as handaxes and cleavers emerged by c. 1.5 Ma in the archaeological record with the advent of the Acheulean tradition in Africa (Isaac & Curtis, 1974; Gowlett, 1988; Asfaw *et al.*, 1991; Dominguez-Rodrigo *et al.*, 2001).

Therefore, it is appropriate that all the core/flake assemblages dated between c. 2.6-1.5 Ma be subsumed under the Oldowan artifact tradition as defined by M.D. Leakey (1971; Semaw, 2000; Semaw *et al.*, 1997). Because of the similarity in the manufacture techniques utilized, the stone assemblages dated c. 2.6-1.5 Ma group into the Oldowan.

Late Pliocene/Early Pleistocene (2.6-1.5 Ma) Artifact Tradition(s)?

There is an excessive number of Late Pliocene artifact industries/facies introduced into the archaeological literature, including the "Shungura" for the Omo (Chavaillon, 1976), the "Nachikui" for the Lokalalei 1 (Kibunjia, 1994), and the generic labels including the "Pre-Oldowan" and the "Pre-Classic Oldowan," both proposed for accommodating the stone assemblages that are older than 2.0 Ma (Roche, 1989, 1996; Piperno, 1989; Ludwig, 1999). Further, these industries/facies were subsumed under the broader "Omo Industrial Complex" (Kibunjia, 1994) to separate them from the conventional "Oldowan Industry" (*sensu stricto* of M.D. Leakey, 1971) known between 2.0-1.5 Ma. The basic premise underlying the so called "Pre-Oldowan" appears to be the firm conviction by the researchers that Late Pliocene assemblages should look very crude since the earliest toolmakers understood conchoidal fracture on stones only conceptually, but were still novices not fully adept in stone knapping skills (Chavaillon, 1976; Roche, 1989; Piperno, 1989; Kibunjia, 1994; but see also Roche *et al.*, 1999). Additionally, these facies/industries were proposed entirely based on preliminary observations, and detailed descriptions of the respective assemblages are still lacking. Further, no experimental knapping studies were undertaken using raw materials comparable to Plio-Pleistocene assemblages to investigate if the variations in Late Pliocene-Early Pleistocene assemblage characteristics were related to raw material differences. In addition, there are no convincing cases suggested by any of the researchers for supporting the significance of the various facies/industries, and why the 2.0 Ma date was used as a boundary to differentiate the core/flake Oldowan tradition that existed between 2.6-1.5 Ma.

The Omo assemblages reported by Chavaillon (1976) and Merrick (1976) were excavated from artifact horizons stratigraphically placed within Member F of the Shungura Formation (2.4-2.3 Ma). A great majority of the artifacts were made of vein quartz, and most identified as flaking debris resulting from shattered quartz pebbles or chunks made primarily by the 'bipolar' flaking technique. Chavaillon was convinced that the simplicity of the Omo artifacts sets them apart from the conventional Oldowan to merit a separate designation that he named the "Shungura." During Member F times, the closest source of the raw materials, small quartz chunks and pebbles, were ancient stream channels located 20-30 Km east of where the artifacts were made and discarded. "This material definitely does not flake as regularly as lava or other materials might and this may account for the size and the simplicity of the Member F artifacts" (Merrick, 1976, p.480). Thus, for Merrick, the simplicity and small size nature of the artifacts resulted from constraints imposed by the raw materials and distances traveled to sources, and apparently the Omo assemblages did not warrant a new industry other than the Oldowan.

Plio-Pleistocene toolmakers inhabited various parts of the ancient landscape with access to a limited variety of raw materials. Despite the similarities in the techniques of manufacture employed, raw material constraints certainly had major influence on the morphology and composition of contemporary assemblages. Ignoring the role of the various raw materials available for early hominins and their influence on the final form of the artifacts seem to have encouraged researchers to name further industries/facies and perpetuate redundancy for otherwise technologically homogeneous traditions. The following was a cautionary note Isaac forwarded a quarter of a century ago:

> "Distinctive features of stone artifact assemblages can be attributed to differences in the traditions or cultures of the hominins that made them. Clearly before this is done it is desirable to distinguish features which may have been induced largely by *differences in raw materials*, and difference which may reflect *varied activities* by the same people at different times and places. The distinctiveness of the Shungura industries *vis-à-vis* Olduvai and Koobi Fora may be an example of differences induced by contrasting raw materials, which therefore cannot be interpreted as necessarily indicative of other cultural or developmental stage differences."(Isaac, 1976a, p. 496, *original emphasis*).

Two distinct assemblages were recognized at West Turkana, the "less elaborate" from Lokalalei 1 and the "sophisticated" artifacts recently excavated from LA2C (Kibunjia, 1994; Roche *et al.*, 1999). The LA2C "*débitage* scheme" is argued to be exceedingly sophisticated compared to Lokalalei 1 and other Pliocene assemblages (Roche *et al.*, 1999, 2001; Roche & Delanges, 2001). Why such differences in "sophistication" between the Lokalalei 1 and the LA2C assemblages? The major evidence put forward to substantiate this claim was the high incidence of refitting pieces excavated at LA2C. The researchers concluded that, "...the variation observed probably reflects technical solutions to different environments and needs, as well as differences in cognitive and motor skills among early hominin groups characterized by non-synchronous evolutionary processes." (Roche *et al.*, 1999, p. 59). The "non-synchronous evolutionary processes" proposed by Roche *et al.* (1999) entail more than one hominin group as candidates for the two assemblages, and two groups of hominins with different level of technical skills responsible for designing the two "distinct assemblages." The presence of diverse quality of raw materials (coarse to fine-grained) was recognized, and that the heavy reduction of the cores made of the fine-grained raw materials was acknowledged, but the impact of the varying quality of the raw materials available for the hominins and the influence on the reduction stages of the cores represented at the two Lokalalei sites were not adequately explored as possible factors contributing for the assemblage differences.

At Lokalei, the contemporary hominins c. 2.3 Ma and possible candidates for the artifacts were early *Homo* or the immediate descendants of *Australopithecus garhi* and *Australopithecus aethiopicus* (Howell, 1978; Howell *et al.*, 1987; Walker *et al.*, 1986; Suwa *et al.*, 1996; Kimbel *et al.*, 1996; Asfaw *et al.*, 1999). Thus far, no conclusive evidence exists for the exclusion of anyone of these groups as candidates. The regional geographic and temporal overlap of *A. garhi* (at Bouri) and the Gona artifacts c. 2.5 Ma is well documented, and the archaeological evidence at Gona clearly shows that australopithecines had sophisticated understanding of stone flaking techniques (Semaw, 2000; Semaw *et al.*, 1997; de Heinzelin *et al.*, 1999). At Hadar, the 2.3 Ma artifacts are stratigraphically associated with early *Homo*, and the assemblages (although of moderate density) are typical of the Oldowan tradition with no marked sophistication shown compared to the other Pliocene/early Pleistocene assemblages known elsewhere in East Africa (Kimbel *et al.*, 1996). Therefore, attempts to attribute Late Pliocene Oldowan assemblages to distinct hominin groups and proving this archaeologically stands a very slim chance of success.

Therefore, experimental knapping studies of the various raw materials available at Lokalalei appear to be most appropriate and critical at this juncture to explain the reasons for the presence of "the sophisticated" LA2C and "the poorly-made" Lokalalei 1 artifacts at the two contiguous sites separated by only c.1 Km. The refitting data, however, is important evidence for the remarkable preservation and site integrity of LA2C, also clearly showing the intensive flaking activities undertaken at the site, and that the assemblages were not disturbed by post-depositional processes (Schick, 1986, 1987, 1997). The refitting pieces are also significant for understanding of the stages represented during the reduction of the cores, but the fact that the pieces conjoin back together is not necessarily strong supporting evidence for the sophistication of the techniques of flaking employed at LA2C, compared for example to Lokalalei 1, and the evidence may reflect variations in the flaking quality of the raw materials utilized at the two Lokalalei sites.

In a detailed study of the production techniques of Late Pliocene assemblages and investigation of the processes of core reductions based on experimental studies, Ludwig and Harris (1998) observed more stepped flakes with the "less-advanced" Lokalalei assemblages compared to EG10 and EG12. Based on their preliminary observations, Ludwig and Harris (1998) concluded that raw material flaws could have influenced the characteristics of the Lokalalei 1 artifacts. They did not recognize notable variations in the techniques of stone manufacture between Gona and Lokalalei, and questioned the validity of the "Pre-Oldowan." However, the same data was later interpreted showing more steps and hinges at Gona compared to other Pliocene sites, and Ludwig (1999), based on his knapping experiments (experienced vs. novices) on argillite blanks collected from gravels in New Jersey, suggested that the preponderance of steps/hinges at Gona means less-advanced technology by the toolmakers, an interpretation which is inconsistent with his earlier analysis of the same data. Recent knapping experiments on cobbles from the Gona conglomerates suggest that the meaning of steps/hinges has yet to be clearly understood, and it remains uncertain if the evidence can be used as a yardstick for discriminating between the technical skills of an experienced vs. a novice knapper. It appears that further knapping experiments of raw materials comparable to Plio-Pleistocene assemblages are needed to firmly address these questions (Toth *et al.*, this volume; Stout & Semaw, this volume).

Why Flaked Stones by 2.6 Ma?

The sudden behavioral shift in Late Pliocene hominins, the factors that triggered the abrupt appearance of flaked-stones in the archaeological record by c. 2.6 Ma, and the reasons why ancestral humans resorted to a novel means of adaptation by incorporating substantial meat in their diet at this juncture are among the least understood issues in Early Palaeolithic studies. Adequate data are needed to explain and establish the causal factors for these behavioral changes based on the archaeological, faunal and palaeontological record. Investigations are currently underway to understand if the changes c. 2.6 Ma in East Africa were tied to the climatic shifts documented globally (Shackleton, 1995). Some researchers point out that the onset of the build-up of ice sheets in the northern hemisphere beginning c.2.8-2.7 Ma may have had effects on the environments of East Africa and probably contributing to the behavioral changes seen in Late Pliocene hominins (Harris, 1983; de Menocal, 1995; de Menocal & Bloemendal, 1995; Vrba, 1995). Vrba relates the appearance of stone tools with these climatic changes and argues for drastic shifts in the African mammalian fauna (the “turnover pulse”) c. 2.5 Ma (Vrba, 1985, 1988, 1990, 1995; but see Hill, 1987; White, 1988, 1995). There is still uncertainty whether or not the changes in East Africa clearly indicate a punctuated event at c. 2.6-2.5 Ma, or if the faunal changes occurred gradually (White, 1995; Behrensmeyer *et al.*, 1997; Bobe *et al.*, 2002). Pollen and carbon isotope studies suggest gradual environmental shifts from humid and wetter regimes to cooler, drier and seasonal situations, and from forest to more open woodland regimes between c. 3.0-2.0 Ma (Bonnefille *et al.*, 1987; Levin *et al.*, 2001). Further, these changes also coincided with the major tectonic and volcanic activities documented in East Africa (Denys *et al.*, 1986; Pickford, 1990; Partridge *et al.*, 1995) and changes in the micromammalian fauna (Denys, *et al.*, 1986; Wesselman, 1995).

Based on the evidence of the proliferation of savanna-adapted animals in East Africa during the Late Pliocene, and the advent of marked seasonality in the geological record, one can surmise that environmental changes may have led to possible gradual disappearance of food items (plant matters?) that ancestral hominins subsisted on for a long time, and at the same time have helped lead to increased abundance of new dietary food items (meat) which had to be accessed by utilizing sharp cutting tools. The archaeological evidence from Gona coupled with the cutmark data from Bouri attest that the first toolmakers used sharp-edged flaked-stones for activities related to animal butchery, resources perhaps available seasonally. Further studies are needed to investigate the possible causal factors for the appearance of flaked stones c. 2.6 Ma and to understand better if the changes were ecologically driven and how Late Pliocene hominins were affected by these. These questions constitute a major focus of the ongoing field research at Gona.

Why are there thousands of flaked stones at Gona by 2.6 Ma? The Afar region was inhabited virtually continuously by ancestral hominins since the Late Miocene/Early Pliocene onward, and the region documents a great number of major biological and behavioral evolutionary events of the last c. 6.0 Ma (White *et al.* 1994; Kimbel *et al.*, 1994; Asfaw *et al.*, 1999; de Heinzelin *et al.*, 1999; Haile-Selassie, 2001 and references therein). The large number of localities with thousands of artifacts documented at Gona by 2.6-2.5 Ma, as well as the fossilized remains of *Australopithecus garhi* and the cutmark evidence from Bouri, clearly demonstrate that Gona and the adjacent areas were consistently inhabited by hominins throughout much of the Pliocene. Gona, and the surrounding areas were among the favored habitats probably due to the presence of ancient streams nearby that carried the cobbles used as raw materials, in conjunction with the availability of fresh drinking water, plant foods, and trees used for shade and refuge from predators. The geological and faunal evidence also show that the area that is currently dry and arid was well-watered and thriving with enormous variety of terrestrial and aquatic animals during the Plio-Pleistocene

The Makers of the Earliest Stone Tools

Early sites at Gona have well-documented toolmaking activities in the Afar Rift by 2.5-2.6 Ma, and the cutmark evidence from Bouri have now extended the known range of early toolmaking hominins at that time at least c. 90 km further south (de Heinzelin *et al.*, 1999). *Australopithecus garhi* from Bouri and *Australopithecus aethiopicus* from the Omo were contemporary with the earliest Gona artifacts. *Australopithecus garhi* was directly associated with the cutmarked animal bones and is the most likely candidate for the earliest stone artifacts (Asfaw *et al.*, 1999;

de Heinzelin *et al.*, 1999), although *Australopithecus aethiopicus* may not be excluded. Slightly later, c. 2.4-2.3 Ma, flaked-stones appear at Omo and in the Turkana basin (Howell, 1978; Howell *et al.*, 1987; Walker *et al.*, 1986). A number of sites in East Africa have produced fossilized specimens of early *Homo* dated to c. 2.3 Ma (Hill *et al.*, 1992; Schrenck *et al.*, 1993; Kimbel *et al.*, 1996; Suwa *et al.*, 1996), and pre-2 Ma *Homo* is considered by many as the most likely candidate for initiating the use of flaked stones. Despite that, stratigraphic association of early *Homo* with Oldowan artifacts is so far shown only at Hadar (Kimbel *et al.*, 1996). Nonetheless, both Late Pliocene australopithecines as well as early *Homo* appear to be possible candidates for the earliest tools, probably the lineage that produced *Homo* becoming a more dependent and "habitual" tool-user through time.

The cranial capacity of the hominins known c. 2.6-2.5 Ma shows no significant departure in size from the ancestral condition. *Australopithecus garhi* and *Australopithecus aethiopicus* had cranial capacities of c. 450 cc and 410 cc respectively, not significantly large compared to any of their immediate predecessors. The evidence seems to suggest that the advent of flaked stones probably acted as a catalyst and played a critical role in increase in hominin brain size through time (Isaac, 1976a; Walker *et al.*, 1986; Asfaw *et al.*, 1999; Schick & Toth, 1993).

Function of the Earliest Stone Tools

The discovery of conchoidal fracture on stones as a behavioral threshold, paved the way for Late Pliocene hominins providing them with the most effective means of access to critical food items, and opening unprecedented venues for control over a wide range of opportunities. As indicated by the cutmark evidence from Bouri, high calorie food sources like meat, which were minimally utilized or unexploited prior to 2.6 Ma became part of the ancestral human diet (de Heinzelin *et al.*, 1999). EG10 and EG12 yielded thousands of flaked stones, but there were no associated fossilized fauna recovered from the excavations. Behavioral information on Late Pliocene hominin diet was inferred for a long time based solely on the evidence of stone artifacts until the discovery of well-preserved fossilized fauna with evidence of cutmarks from the Bouri Peninsula within deposits dated to 2.5 Ma (de Heinzelin *et al.*, 1999). The cutmarked bones belonging to medium-size animals were excavated within fine-grained sediments, but with no associated artifacts. Experimental work and micropolish studies have also shown that some of the later Koobi Fora Oldowan flakes may have been used for processing plant matters (Keely & Toth, 1981).

Sources of raw materials were lacking near Bouri, and that in part may explain the absence of *in situ* artifacts in association with the excavated fossilized bones there. It is likely that the hominins carried with them stone artifacts preferred for certain tasks (cores or flakes with sharp cutting edges) and "manuports" used as cores for generating sharp-edged flakes as well as missiles used for defense against predators. The geological evidence shows that Late Pliocene hominins at Omo traveled long distances seeking raw materials, and the Bouri hominins appear to have experienced similar situations. Thousands of artifacts were made at Gona, but the absence of any associated *in situ* fossilized bones is intriguing, and investigations have yet to firmly show if this is a result of preservation bias or other factors.

Conclusions

The paucity and lack of continuity in the Late Pliocene archaeological record in Africa, both temporally and geographically, is puzzling. Small windows are open from time to time providing extraordinary and rare opportunities for a glimpse into hominin artifact manufacture and use, and well-documented cases are very scarce and restricted within the deposits dated between 2.6-2.5 Ma at Gona and Bouri, c. 2.3 Ma at Omo, Lokalalei, and Hadar. The record picks up again later c. 1.89 Ma at Koobi Fora and Fejej. Existing archaeological evidence shows that relatively continuous record and a high density of artifact occurrences in East Africa and elsewhere appeared in the archaeological record after c. 1.8 Ma, implying that the manufacture and use of stone artifacts becomes more "habitual" during the Early Pleistocene. Further archaeological and geological field investigations are crucial for understanding whether or not the paucity of artifact occurrences during the Late Pliocene was the result of preservation bias or other factors. The discovery of the deliberate manufacture of sharp-edged cutting tools on stones c. 2.6 Ma was a behavioral threshold. This major technological breakthrough sparked a novel means of adaptation and at the same time resulted in hominin dependency on technology. The appearance of artifacts in the archaeological record was abrupt and it expanded the breadth of dietary preferences and opportunities to include high calorie food items such as meat. This in turn may have created the stimuli for subsequent brain expansion through the feedback interplay of continued tool use.

The Gona archaeological discoveries have clearly shown that the first toolmakers had excellent mastery and control of the mechanics of conchoidal fracture on stones and produced thousands of artifacts even during the initial stages of artifact manufacture (Semaw, 1997, 2000; Semaw *et al.*, 1997). A majority of the EG10 and EG12 cores were flaked unifacially, but a significant number (over 35%) were also worked bifacially and around much of their circumference, and some were exhaustively reduced. Further, there appears no discernible trend at Gona or elsewhere in East Africa for Late Pliocene-Early Pleistocene core reduction strategies to have gradually evolved from unifacial to bifacial/multifacial stone working. The degree of core-reductions (minimal or exhaustive) conform to the "least effort" strategy of the production of simple sharp-edged cores and flakes used primarily for activities related to animal butchery, and the final shape of the artifacts were often highly influenced by the size, flaking-quality, abundance and distances traveled to sources of raw materials (Toth, 1982, 1985, 1987). The trachyte and rhyolite available from the conglomerates at Gona were of good flaking quality and suitable for making the simple Oldowan artifacts recovered at EG10 and EG12. The preponderance of unifacial flaking at EG10 and EG12 may be a result of the abundance and easy access to these raw materials, or due to other unexplained idiosyncrasies related to the core reduction norms practiced by the hominins around Kada Gona. Further, it is possible that some may be "test cores" resulting from flaking episodes generated while examining the flaking quality of available raw materials (Ludwig, 1999). A number of cases were documented at Gona whereby occasionally encountered fine-grained raw materials such as chalcedony and chert were multifacially and exhaustively reduced probably due to their exotic color and good flaking quality.

The composition and the techniques of manufacture of the Gona, Omo, Hadar and Lokalalei assemblages conform to the simple core/flake Oldowan tradition and no convincing cases have been put forward to justify the multiple Late Pliocene industries/facies existing in the current archaeological literature (Roche, 1989; Piperno, 1989; Kibunjia, 1994). The similarity in the techniques of manufacture and the simplicity of Plio-Pleistocene assemblages suggests a "technological stasis" in the Oldowan Industry (Semaw *et al.*, 1997). Similar conclusions were reached by other researchers following detailed studies of the Gona and other East African Plio-Pleistocene assemblages and referred by Ludwig (1999) as 700,000 years of "methodological stasis" in the Oldowan (2.6-1.7 Ma). His conclusions are agreeable, but the new label proposed seems a bit redundant with the "technological stasis" already proposed earlier by Semaw *et al.* (1997). What is commendable is more experimental work on comparable raw materials to East African Plio-Pleistocene artifacts and investigations of the knapping skills of the hominins to firmly understand the meaning of the variations in Oldowan assemblages.

Extensive areas have been surveyed recently within the Gona Paleoanthropological Research Project (GPRP) study area and new sites identified tens of kms away from the previously documented East Gona localities of EG10 and EG12. New sites recently excavated at Gona show that stone raw materials readily available from nearby sources were ignored by early hominins in favor of better quality materials (such as chert) sought from areas further away (sources still to be investigated), and the evidence seems to point towards a preference for better quality stone raw materials, foresight and planning, and a more sophisticated behavior for the earliest toolmakers than previously known (Semaw *et al.*, 2002). Investigations of the sources of raw materials, distances ancestral tool makers had to travel to acquire suitable stones, and experimental knapping studies of the stone raw materials available to early tool makers are important for understanding the technical skills of the first tool makers. The novel ancestral human adaptation that began with the creation of simple cutting stone tools c. 2.6 Ma underwent continual changes with more advanced artifact traditions emerging in spurts, and worked-stones playing major adaptive roles in the subsistence strategies of humans for the last two-and-half million years.

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