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Raw material selectivity of the earliest stone toolmakers at Gona, Afar, Ethiopia

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Abstract

Published evidence of Oldowan stone exploitation generally supports the conclusion that patterns of raw material use were determined by local availability. This is contradicted by the results of systematic studies of raw material availability and use among the earliest known archaeological sites from Gona, Afar, Ethiopia. Artifact assemblages from six Pliocene archaeological sites were compared with six random cobble samples taken from associated conglomerates that record pene-contemporaneous raw material availability. Artifacts and cobbles were evaluated according to four variables intended to capture major elements of material quality: rock type, phenocryst percentage, average phenocryst size, and groundmass texture. Analyses of these variables provide evidence of hominid selectivity for raw material quality. These results demonstrate that raw material selectivity was a potential component of Oldowan technological organization from its earliest appearance and document a level of technological sophistication that is not always attributed to Pliocene hominids.

Keywords: Gona; Oldowan; Raw materials; Lithic technology; Pliocene; Cognition

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Introduction

Thanks to the hard work of several generations of researchers (Hay, 1976; Stiles, 1979; Jones, 1979, 1994; Clark, 1980; Isaac, 1984; Schick and Toth, 1994; Isaac et al., 1997; Sahnouni et al., 1997; Ludwig and Harris, 1998; Semaw, 2000), the importance of considering lithic raw materials in studies of Early Stone Age (ESA) technological behavior is now widely recognized. Raw material composition has been identified as a major source of assemblage-level technological variation (Jones, 1979; Isaac et al., 1981) as well as an important indicator of hominid ranging and stone transport activities (Stiles et al., 1974; Hay, 1976; Schick, 1987; Stiles, 1998). A somewhat smaller body of evidence has been accumulated regarding the degree of selectivity shown by ESA toolmakers for particular types or grades of raw material (Toth, 1985; Schick, 1987; Isaac et al., 1997). The research presented here contributes to this foundation by providing a systematic assessment of raw material selectivity in the earliest known archaeological assemblages (ca. 2.6 Myr) from Gona, Ethiopia.

For modern stone knappers, the location, identification and selection of suitable raw materials can be one of the more challenging aspects of production (Whittaker, 1994: 65; Stout, 2002). Although Oldowan toolmakers certainly did not display the high degree of raw material selectivity and transport seen later in prehistory (e.g. Féblot-Augustins, 1999), neither did they conform to patterns of resource exploitation and transport known in extant apes (e.g. Boesch and Boesch, 1984). Assessment of the technological and cognitive sophistication of Oldowan toolmakers requires that the details of their interactions with the environment be further specified.

Evidence from the East African sites of Olduvai (Hay, 1976), Koobi Fora (Isaac et al., 1997), Lokalalei (Kibunjia et al., 1992), Omo (Merrick and Merrick, 1976), Peninj (de la Torre et al., 2003), Kanjera South (Plummer et al., 1999) and Gona (Semaw et al., 1997; Semaw, 2000) reveals that Oldowan toolmakers typically used raw materials, including quartz, basalt, and other fine-grained lavas, that were abundant in local (<4 km) stream channels. The best-documented exceptions to this come from Olduvai Gorge, where phonolite, gneiss and quartzite were collected from bedrock outcrops and transported for distances up to 13 km (Hay, 1976), and where the periodic exposure of chert deposits occasioned the intensive exploitation of this material (Stiles et al., 1974). A portion of the artifacts (~15%) from the Late Pliocene KS1 and KS2 Beds at Kanjera South may also derive from non-local sources (Plummer et al., 1999).

In general, the stream channels and bedrock outcrops which served as raw material sources in the Oldowan would have been fairly obvious features on the paleo-landscape, and their discovery and exploitation by early toolmakers is not particularly surprising. More interesting are details regarding 1) the degree of technological acumen reflected in the selection of suitable materials from these sources, and 2) the extent of foresight and planning revealed by subsequent transport patterns. This latter question has been well addressed by research on the formation of Oldowan sites at Koobi Fora and Olduvai (Schick, 1987; Potts, 1991; Kroll, 1997). Technological analyses have shown that there was a substantial flow of artifacts both into and out of Oldowan sites (Toth, 1985; Schick, 1986, 1987), which are thought to represent attractive locations of repeated hominid activity on the landscape. Hominid activities leading to the formation of Oldowan sites clearly include a scope and intensity of resource transport unknown in non-human primates.

In contrast, published evidence of raw material selectivity among Oldowan hominids is more equivocal. At Koobi Fora, the high frequency of basalt in local conglomerates (i.e. ancient stream channels) is closely mirrored by its predominance in the artifact assemblages (Toth, 1985; Schick, 1987; Isaac et al., 1997). Although quartz, chert and glassy volcanics are "reasonably easily available" in the conglomerates, these material types do not appear to have been specifically selected for (Isaac et al., 1997: 268). On the other hand, Schick and Toth (e.g. 1993) do observe a degree of selectivity for raw material quality, noting that the Koobi Fora toolmakers systematically avoided vesicular lavas and cobbles with weathering flaws. Toth (1982: 121) concluded that "it is likely these hominids were able to discriminate between easily flaked, non-weathered material and less suitable rocks; however the actual selection of materials for their stone artifacts appears more opportunistic than selective with regard to specific rock type."

At Olduvai, the situation seems more complex. In Bed I times (1.85 – 1.70 Myr), the archaeological assemblages are dominated by volcanic cobbles from local streambeds. These cobbles appear to have been selected for size and composition in much the same way as those from Koobi Fora (Hay, 1976, Schick, 1987), and the occurrence of minimally reduced cores of low-quality, vesicular lava at some Bed I sites (DK, FLK) further suggests that these undesirable materials may have been tested and rejected by hominid toolmakers (Ludwig and Harris, 1998). In Bed II (<1.7 Myr), on the other hand, assemblages show a clear tendency toward the increased use of quartz (Schick and Toth, 1994) and exotic volcanic rocks (Hay, 1976). This trend, along with a temporary increase in the exploitation of chert in Lower Bed II, lies at the heart of the technological variation initially recognized by Mary Leakey (1971) in her typological distinction between Oldowan and Developed Oldowan assemblages.

The increased use of chert at Olduvai around 1.65 Myr was clearly occasioned by the temporary exposure of rich sources of this material by the retreating waters of the paleo-lake (Hay, 1976). Hominid toolmakers at this time readily appreciated the superior flaking properties of chert, leading to the formation of the earliest known special-purpose quarry site at MNK CFS (Stiles et al., 1974; Stiles, 1998). Causes underlying the increased use of quartz over time are less clear-cut, and may include changes in hominid ranging patterns, tool-using behaviors and/or technological sophistication (Schick and Toth, 1994; Ludwig and Harris, 1998). The question of whether Bed II hominids actually sought out quartz for its unique technological properties, or simply adapted their technology to its expedient availability, remains open.

Quartz was also used by Late Pliocene toolmakers (ca. 2.3 Myr) in assemblages from Omo Shungura Member F, where its frequency is more clearly a reflection of local availability (Merrick and Merrick, 1976). Published accounts from the Late Pliocene sites of Lokalalei LA1 (GaJh 5) and LA2C similarly suggest that raw material selection reflected local availability (Kibunjia, 1994; Roche et al., 1999) at these sites, although recent reports from more systematic raw materials studies have indicated a bias toward the exploitation of phonolite (Harmand, 2004). Interestingly, Ludwig and Harris (Ludwig and Harris, 1998; Ludwig, 1999) have argued that "subtle raw material flaws" account for a high incidence of step fractures observed on cores from LA1, raising the possibility that toolmakers at this site were less attentive to cobble quality than those at LA2C, Koobi Fora and Olduvai. Further studies of raw material exploitation at Lokalalei are sure to yield interesting results.

For the time being, however, evidence of raw material selectivity among Oldowan toolmakers remains quite limited. This is especially true in Late Pliocene assemblages from Omo, Koobi Fora (KBS), and Bed I of Olduvai, where raw material composition closely parallels local availability and the only evidence of selection comes from qualitative observations of cobble suitability. Reports of exotic raw materials at Kanjera South (Plummer et al., 1999) may indicate some degree of selectivity and/or long range transport by Pliocene hominids at that site, but more detailed data regarding raw material availability in the region are needed for a definitive assessment. Taken together, evidence from these sites generally supports the parsimonious conclusion that patterns of Oldowan raw material exploitation were determined by local availability rather than choice on the part of the toolmakers.

In this context, recently described Pliocene archaeological sites from the Gona study area in Ethiopia (Semaw et al., 1997; Semaw, 2000; Semaw et al., 2003) provide an important counter-example. As at many of the sites discussed above, the Gona toolmakers obtained their raw materials from local channel gravels that are now preserved as cobble conglomerates in the modern study area. The Gona gravels are, however, distinguished by their greater representation of felsic volcanic rocks (trachyte, rhyolite, latite) as opposed to basalt (e.g. Olduvai, Koobi Fora) or quartz (Omo). As documented by Semaw et al. (1997), the Gona toolmakers showed a clear preference for these felsic volcanic rocks, using them in much greater proportion than would be expected from their representation in the gravels. Aphanitic (without phenocrysts) volcanic rocks, which are quite rare in the gravels, were also exploited in substantial numbers at Gona (Semaw, 2000; Semaw et al., 2003).

The strong pattern of raw material selection seen at Gona demonstrates that low levels of selectivity are not universal in the Oldowan. The fact that the assemblages from Gona are the oldest known in the world also argues against an overarching temporal trend toward increasing selectivity within the Oldowan. More detailed and specific explanations of the observed variation are thus needed, ideally based on robust, quantitative analyses of raw material availability and utilization at multiple sites and study areas. The age and distinctive character of the Gona assemblages makes them a particularly important focus for such investigation.

Background

The Gona Paleoanthropological Research Project (GPRP) study area (Fig. 1) encompasses more than 500 km^2 in the Afar Depression of the Ethiopian rift valley. Artifact and fossil-rich Plio-Pleistocene deposits of the Busidima Formation (Quade et al., 2004) lie exposed in a number of major drainages dissecting the eastern portions of the study area. These include the Kada Gona, Ounda Gona, Dana Aoule, Busidima and Asbole drainages, which are ephemeral tributaries of the Awash River (Fig. 1). Surface scatters of artifacts were first observed along the east side of the Kada Gona during the 1970s (Corvinus and Roche, 1976; Corvinus, 1976; Roche and Tiercelin, 1977), and the presence of *in situ* artifacts in sediments on both sides of this drainage was subsequently demonstrated by systematic excavations during the 1980s (Harris, 1983; Harris and Semaw, 1989) and 1990s (Semaw, 1997; Semaw et al., 1997; Semaw, 2000). This latter work, including excavations at the high density sites of EG (East Gona) 10 and 12, firmly established the great age (2.60 - 2.52 Myr) and typical Oldowan affinities of the Kada Gona artifacts.

The current phase of research at Gona, initiated in 1999, has pursued systematic geological (Quade et al., 2004), paleoenvironmental (Levin et al., 2004), paleontological and archaeological (Semaw et al., 2003) studies of the entire GPRP study area, resulting in the identification of numerous new paleonotological and archaeological localities. Among these are five Pliocene archaeological sites from the Ounda Gona and Dana Aoule drainages, including Ounda Gona South (OGS) 6 and 7 (Semaw et al., 2003), two unpublished excavations from the Dana Aoule North area (DAN1 and 2d), and a controlled surface collection from Dana Aoule South (DAS7), also unpublished. Data regarding raw material composition and local availability at these sites, as well as the previously identified Kada Gona site EG13 (Semaw, 1997), are presented here.

Geological and paleogeographic context

The geological context of the Gona Oldowan has recently been described by Quade et al. (2004) and the relevant features are summarized here. Sediments in the lower portion of the Busidima Formation at Gona are characterized by fining upward sequences (Fig. 2) of basal conglomerates, coarse sands, bedded silts and vertic paleosols that represent the channel, bank and floodplain deposits of the ancestral Awash River. All of the Oldowan sites known from Gona occur in silts and paleosols of these fining upward sequences. These silts are over-bank flood deposits of the ancestral Awash River and the associated paleosols represent pedogenesis that post-dates artifact deposition. Following Walther's law of correlation of facies (Walther, 1894), the vertical association of silts and underlying gravels seen today implies that the Gona Oldowan sites were in close spatial proximity (within 10's to 100's of meters) to a river channel and exposed cobble bars (Fig. 3) from which raw materials would have been readily available. These gravels provide the only local source for the large (>10 cm), well-rounded cobbles exploited by Pliocene toolmakers at Gona. Although it is not possible to identify exact sections of conglomerate that would have been exposed during the formation of particular sites,

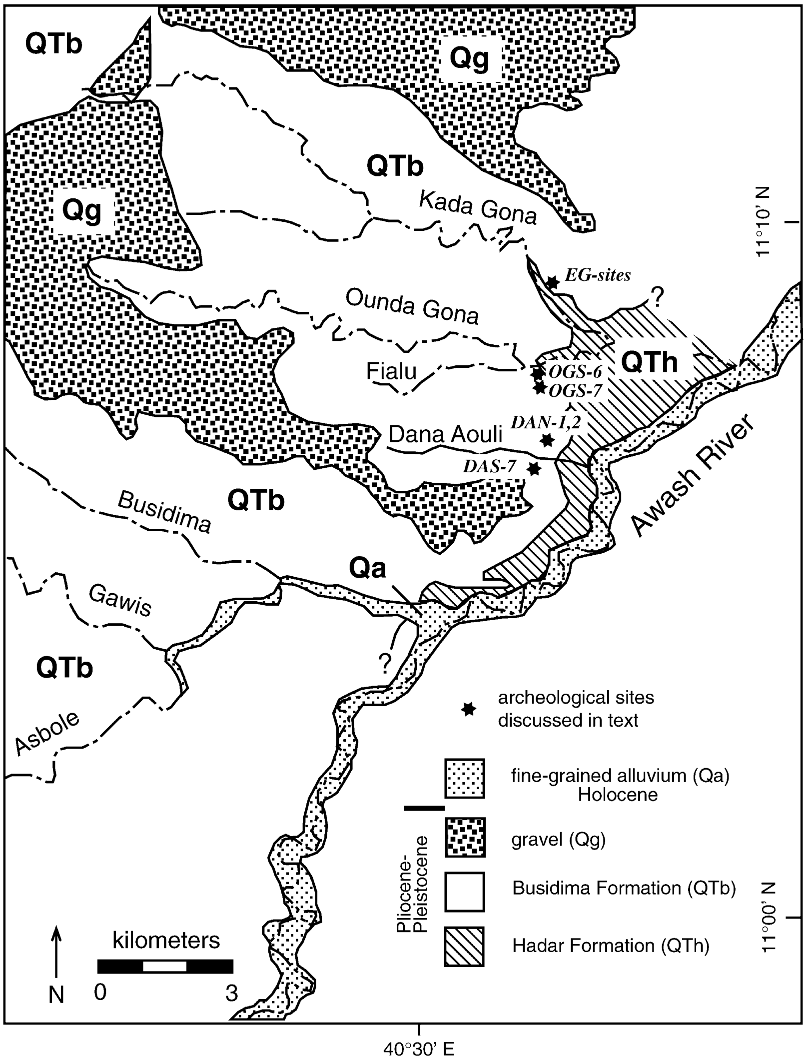

Fig. 1. The Gona Paleoanthropological Research Project study area is located in the Afar region of Ethiopia. The easternmost portion of the study area is shown here, including the six Pliocene archaeological sites discussed in the text. After Semaw et al. (2003).

stratigraphically associated conglomerates do record the overall character of paleo-Awash river gravels in the region at the time of site formation. This situation provides an excellent opportunity to assess the raw material selectivity of the earliest stone toolmakers at Gona.

Methodology

In this study, hominid raw material selectivity was assessed through a systematic survey of raw material composition in six Pliocene archaeological assemblages and their associated conglomerates (Table 1).

The archaeological sample

The archaeological sample consists of artifacts recovered in excavations and controlled, 100% surface collections conducted between 1999 and 2003 at the sites of EG13, OGS6a, OGS7, DAN1, DAS7 and DAN2d. Five of these sites date to the

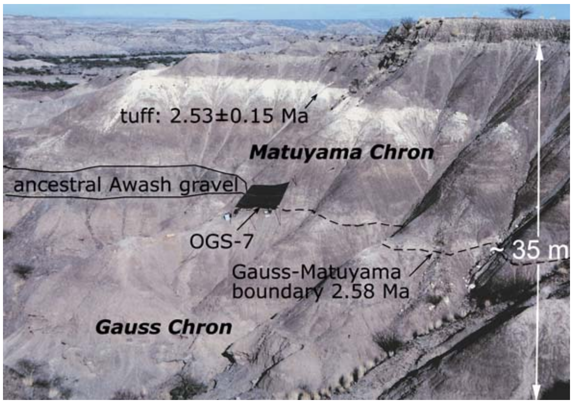

Fig. 2. A representative fining upward sequence as seen at the OGS-7 locality. This site is located at the contact between an alluvial sand bank and overlying floodplain silts, stratigraphically above an ancestral Awash River gravel. Data from Semaw et al. (2003).

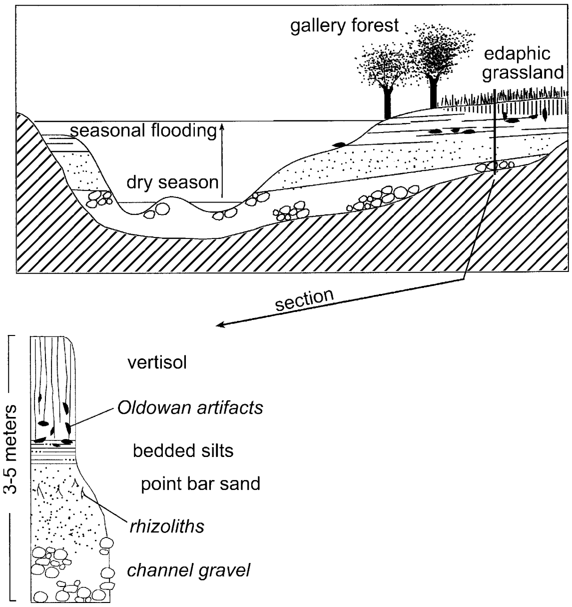

Fig. 3. The stratigraphic context of the Gona Oldowan sites indicates that they were deposited on the proximal floodplain of the paleo-Awash River. Raw materials from the paleo-Awash gravels would have been available from point bars in the main channel. After Quade et al. (2004).

period between 2.6 and 2.5 Myr while the sixth (DAN2d) is located stratigraphically above DAN1 and DAS7 and dates to between 2.58 and 2.27 Myr. All surface and *in situ* artifacts from these sites that were of sufficient size for analysis (generally >20 mm) were evaluated in terms of raw material type and quality (see below).

All of the sites presented here occur on steep modern erosion surfaces in silts or paleosols overlying large-cobble conglomerates. Erosion is very rapid in these deposits, and the surface collections reported here clearly derive from the sedimentary sequence where they were recovered. This conclusion is supported by multiple lines of evidence, including: 1) the remarkable freshness and locally high density of the artifacts, 2) the steepness of the topography and the high rate of artifact turnover observed from year to year, 3) refitting between surface and *in situ* materials (four refits between surface and *in situ* artifacts at OGS-7, including flake-on-flake and flake-on-core), and 4) the fact that the overlying sedimentary sequences at each of these sites have been mostly eroded away, removing any possibility of admixture from above. Small but statistically significant differences in material composition do exist between the surface and *in situ* samples reported here. However these differences do not affect the overall results of the study (see below).

Excavated areas range in size from 2 m^2 to 10 m^2 (Table 1). Although at least a portion of each site remains for future excavation, the lithic samples so far collected are large enough to provide high levels of statistical significance in the current study (e.g. Table 5). The samples presented here, though incomplete, are representative of the various sites investigated and there is no reason to suppose that they are systematically biased in any direction. Consistent patterns in raw material frequencies and characteristics across multiple sites in this study (see below) corroborate the representative nature of the samples, and reflect a lack of confounding intra-site variation.

The geological sample

Each of the sites included in this study is associated with a coarse-grained cobble conglomerate that contains the pene-contemporaneous material composition of the paleo-Awash river gravels. Random samples (n = ~100) of

Table 1
Archeological and Geological Samples

Locality	Age (Myr)	Archaeological sample	Excavated area	# artifacts analyzed	Geological sample
EG-13	2.6 − 2.5	1999 excavation, 2003 surf. coll.	2 m^2	surface: 152 *in situ*: 27 **Total: 179**	2000 (n = 100)
OGS-6a	2.6 − 2.5	2000 excavation	4 m^2	surface: 48 *in situ*: 52 **Total: 100**	2000 (n = 108)
OGS-7	2.6 − 2.5	2000 excavation	2.6 m^2	surface: 65 *in situ*: 188 **Total: 253**	2001 (n = 99)
DAN-1	2.6 − 2.5	2000 surf. coll., 2001 excavation	2.8 m^2	surface: 67 *in situ*: 45 **Total: 112**	2001 (n = 100)
DAS-7	2.6 − 2.5	2001 surf. coll., 2003 surf. Coll.	Surface only	surface: 190 *in situ*: 0 **Total: 190**	compared with DAN-1 sample
DAN-2d	2.58 − 2.27	2001 excavation	10 m^2	surface: 24 *in situ*: 36 **Total: 60**	2000 (n = 99) 2001 (n = 99)
Total	-	-	21.4 m^2	surface: 559 *in situ*: 335 **Total: 894**	**Total: 605**

approximately 10-20 cm diameter cobbles were collected from these conglomerates in the immediate vicinity (<30 m) of each archaeological site, with the exception of DAS7. Although DAS7 is separated from DAN1 by the modern Dana Aoule drainage, both sites appear to lie stratigraphically above the same gravel and were compared with a single cobble sample taken near DAN1. The gravel below the site of DAN2 was sampled twice, in 2000 and 2001, as a test of the sampling methodology. In all cases, cobble samples consisted of the first 100 cobbles of appropriate size collected from a particular section (~1-2 m) of conglomerate.

Raw material analysis

One major problem confronting the study of hominid raw material selectivity is the difficulty of observing and quantifying technologically relevant material characteristics. For example, the formal petrologic classifications used by geologists (e.g. Travis, 1955; Philpotts, 1990; Klein and Hurlbut, 1993) have the advantage of being well established and highly replicable, but do not capture many of the variables that would have been relevant to ancient toolmakers. Proper petrologic assessment also requires destructive laboratory analyses (thin-sectioning) which may not be appropriate for artifacts, cannot be conducted in the field, and are generally not practical for the evaluation of variation within large samples. In contrast, qualitative assessments of lithic materials by experienced knappers deal directly with technological suitability and are relatively easy to produce, but suffer from being informal, difficult to replicate, and unsuitable for statistical analysis. In this study, an attempt was made to bridge the gap between these approaches by focusing on four specific variables related to raw material quality and composition: rock type, percentage of phenocrysts per unit area (of a fractured surface), average size of phenocrysts, and groundmass texture (Table 2). This approach is similar to that previously used by Brantingham et al. (2000) to assess raw material quality in a late Pleistocene

Table 2
Variables used in Raw Material Analysis

Variable	Values	Data type	Method of comparison
Rock Type	Trachyte, Rhyolite, Latite, Quartz Latite, Aphanitic lava, Basalt, Vitreous volcanic, Other	nominal	frequency distribution
Percentage of Phenocrysts	0, ≤5, ≤10, ≤15, ≤20, …	ratio	2-tailed t-test
Average size of phenocrysts (mm)	<1, 1, 2, 3, 4, 5, …	ratio	2-tailed t-test
Texture	Glassy, Smooth, Coarse, Chalky/Decayed	ordinal*	Mann-Whitney test

* when chalky/decayed (a small percentage of observations) is excluded.

assemblage from Tsagaan Agui cave, Mongolia. For reasons of practicality, all variables were assessed through the visual inspection of fractured surfaces using a hand-lens.

Rock type

Initial cobble samples collected during the 2000 field season led to the identification of eight major volcanic rock types in the Gona study area: trachyte, rhyolite, latite, quartz latite, aphanitic volcanic, basalt, vitreous volcanic and "other." These types are defined geologically by differences in mineral composition, texture, and the occurrence of phenocrysts (e.g. Travis, 1955; Klein and Hurlbut, 1993). It should be noted that, for the purposes of this study, the use of these categories does not reflect rigorous petrological analysis, but rather a pragmatic system of field identification based on visual inspection with a hand lens.

Basalt, for example, is a mafic rock that is easily identified in the Gona conglomerates by its fine grain, high density and dark color. Less dense, felsic rocks occur at Gona in four main varieties (trachyte, rhyolite, latite and quartz latite) that are defined by differing abundances of quartz and by potassium feldspar/plagioclase proportions (Table 3) and were identified for this study through careful examination of phenocryst mineral composition with a hand lens. Felsic rocks without phenocrysts were classified as either aphanitic volcanic or vitreous volcanic. "Vitreous volcanic" is the term that we adopt to describe high-quality glassy or cryptocrystalline aphanitic rocks with vitreous luster found in low frequencies in the Gona conglomerates. Much more rarely occurring materials such as volcanic breccias, ignimbrites and obsidian were grouped together under "other." The resulting nominal rock type data were used to construct frequency distributions for comparison across samples (Figs 4 and 6).

Table 3
Felsic Rock Classification System

Mineral composition	Potassium Feldspar to Plagioclase Ratio	
	≥ 2:3	2:3 − 1:3
>10% quartz	Rhyolite	Quartz Latite
<10% quartz	Trachyte	Latite

The eight-part classificatory system employed here is a refinement over preliminary studies of the Gona conglomerates (Semaw, 1997, 2000), which grouped all cobbles into four basic raw material types (trachyte, basalt, rhyolite and "other"). The increased number of types recognized in the new system provides more detailed information about the composition of conglomerates and artifact assemblages, although it yields rock type distributions that are not directly comparable with previous results. Despite this methodological difference, present and prior results both clearly reflect the same underlying pattern of hominid raw material selectivity at Gona.

The classificatory system used here, though simplified, allows for the practical and objective description of raw material composition among the Gona gravels and artifact assemblages. The description of rock types also captures some basic elements of technological suitability, for example in distinguishing vitreous volcanics from more fracture resistant basalt. On the other hand, there

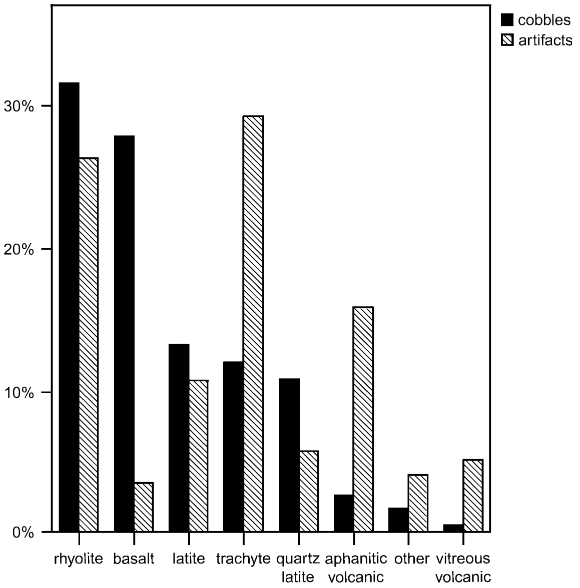

Fig. 4. Distribution of rock types in the artifact and conglomerate samples. Types are organized from left to right in order of their descending frequency in the conglomerates.

is a large degree of variation in material quality within categories, depending on factors such as texture, uniformity, weathering flaws, etc. Beginning in 2001, additional data on phenocryst and groundmass characteristics were collected in order to assess some of this variability. Future experimental research will be important in more precisely defining the influence of rock type, phenocryst and groundmass variables on the flaking properties (e.g. evenness of fracture) and practical utility (e.g. edge durability) of various raw materials.

Size and frequency of phenocrysts

The felsic rocks found in the Gona gravels are dominantly hypocrystalline, and range from aphanitic, where few to no phenocrysts are visible, to porphyritic, where variable proportions of macroscopic phenocrysts or spherulites are encased in a fine-grained groundmass. Depending on their size and frequency, such phenocrysts can create uneven fracture patterns that detract from a material's technological suitability, although this is not always the case. In this study, data on phenocryst size and frequency were collected through the visual examination of hand specimens. The average size of phenocrysts was estimated to the nearest millimeter, using a scale as a guide, and the percentage of phenocrysts per unit area was estimated to the nearest 5%. Because phenocrysts can be uneven in their distribution, percentage estimates were based on the entire exposed surface. These estimations provide a systematic, practical and reasonably accurate means of assessing raw material characteristics of potential relevance to knapping quality. Phenocryst size and percentage data were compared across samples using Student's t-tests. Consensus reached by multiple researchers on rock type identifications (NL, JQ and DS) and phenocryst percentages (JQ and DS) helped to ensure the consistency of results.

Groundmass texture

Another important factor influencing raw material quality is the texture of the groundmass surrounding the phenocrysts. Although most rocks at Gona exhibit groundmasses that are "fine grained" in a geological sense (crystals <1 mm), there is nevertheless a substantial amount of technologically relevant variation. In this study, individual samples were placed into one of four texture categories: glassy, smooth, coarse, and chalky/decayed. "Glassy" included materials like vitreous volcanics with no discernable grain (but probably cryptocrystalline, not vitrophyric), whereas "smooth" was applied to materials with an even fracture and a fine but noticeable grain. Materials with a more irregular fracture and groundmass crystals approaching 1 mm in size were termed "coarse," and heavily weathered samples (usually artifacts) were classified as "chalky/decayed."

Results

Comparison of the geological and archaeological samples presented here clearly demonstrates the high degree of raw material selectivity exercised by the Oldowan toolmakers at Gona. Pooled rock type frequency distributions show marked differences between the artifact assemblages and cobble conglomerates, most notably in the avoidance of

Table 4
Comparison of pooled phenocryst data (Student's t-test)

	All cobbles	Artifacts	Mean difference	2-tailed significance
Mean % phenocrysts	16 % *n = 553*	**all**: 6 %, *n = 858*	10 %	$p < 0.001$
		surface: 6%, *n = 540*	10 %	$p < 0.001$
		in situ: 5%, *n = 318*	11 %	$p < 0.001$
Mean phenocryst size	2.8 mm *n = 249*	**all**: 1.6 mm, *n = 618*	1.2 mm	$p < 0.001$
		surface: 1.7 mm, *n = 425*	1.1 mm	$p < 0.001$
		in situ: 1.4 mm, *n = 193*	1.3 mm	$p < 0.001$

basalt and preferential exploitation of trachyte, vitreous volcanics and other aphanitic clasts (Fig. 4). Material quality data similarly show that cobbles selected by hominids had fewer, smaller phenocrysts (Table 4) and finer groundmasses (Fig. 5; Mann-Whitney asymptotic significance <0.001) than would be expected in a random sample from the conglomerates. There are observable differences between the surface and *in situ* artifact samples, but these are an order of magnitude smaller than the differences between artifacts and cobbles and do not affect overall results. Two-tailed t-tests show that surface materials display an average of 1.4 % ($t = 3.38$, $df = 856$, $p = 0.001$) more phenocrysts than *in situ* artifacts, and the mean size of these phenocrysts is 0.2 mm greater ($t = 2.49$, $df = 616$, $p = 0.013$). These statistical differences largely result from the fact that the surface sample includes 15% fewer aphanitic artifacts, and lose significance ($t = 0.938$, $df = 710$, $p = 0.348$; $t = 2.26$, $df = 609$, $p = 0.024$) if aphanitic artifacts are removed from the analysis.

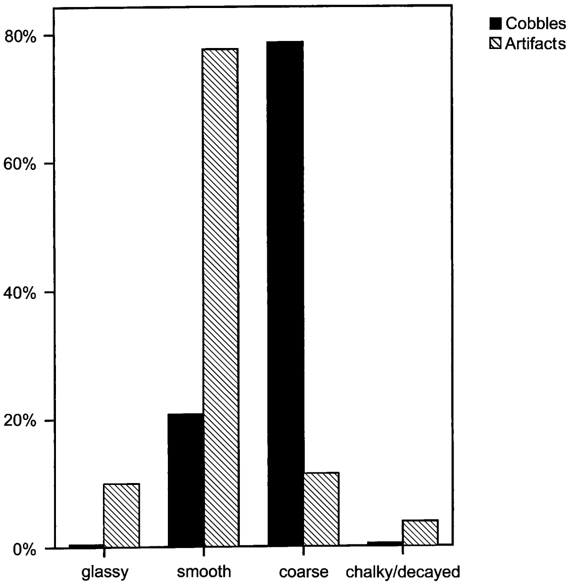

Fig. 5. Distribution of rock textures in the conglomerate and artifact samples.

The causes behind the under-representation of aphanitic artifacts in the surface sample are less clear. Currently available metric data (from OGS7, OGS6a and DAN1) do not show any size difference between aphanitic and other artifacts *in situ* that might possibly lead to differential winnowing on the surface. Aphanitic artifacts do display the highest percentage of "chalky/decayed" groundmasses (7%), suggesting that weathering might differentially affect the survival and/or identification of aphanitic artifacts on the surface, but the extremely low incidence of such decay (1% overall) argues against this being a major factor. The reasons underlying the under-representation of aphanitic artifacts in the surface sample thus remain unclear. What is clear, however, is that this difference is of insufficient magnitude to affect the overall results of the study, and that discarding the surface data would only serve to *increase* the contrast between artifact and cobble samples.

Examination of individual assemblage and cobble sample data further show that overall differences between the archaeological and geological samples do not result from local anomalies in raw material availability and exploitation. In fact, there is relatively little variation in phenocryst and groundmass attributes from site to site or from conglomerate to conglomerate (Table 5). Statistical comparisons (t-tests) of phenocryst size

Table 5
Raw Material Attributes by Locality

	OGS-7		OGS-6a		EG-13		DAN-2d		DAN-1		DAS-7
	artifacts	cobbles	artifacts	cobbles	artifacts	cobbles	artifacts	cobbles	artifacts	cobbles	artifacts
Mean % phenocrysts	5.5	16.0	3.7	18.2	8.0	15.2	6.2	15.2/18.3*	5.0	16.3	5.5
Mean phenocryst size (mm)	1.1	3.0	1.5	not collected	1.4	not collected	2.8	2.5	1.7	2.9	1.9
% glassy groundmass	22.6	0.0	3.0	not collected	1.1	not collected	5.1	0.0	10.8	1.0	5.8
% smooth groundmass	75.8	11.6	90.0	not collected	93.8	not collected	71.2	21.1	63.1	29.0	68.8
% coarse groundmass	0.0	87.3	6.0	not collected	4.9	not collected	15.3	78.9	21.6	70.0	24.9
% chalky groundmass	1.6	1.1	1.0	not collected	0.2	not collected	8.5	0	5.5	0	0.5

* Two cobble samples were collected at DAN2, but only one (2001) included phenocryst size and groundmass texture data.

and percentage data between cobble samples revealed only three cases of significant ($p \leq 0.05$) difference (out of 18 comparisons): the OGS7 cobbles have (1) a lower percentage and (2) a greater mean size of phenocrysts than the DAN2 2001 cobble sample, and (3) the OGS6 cobbles have a higher percentage of phenocrysts than those from OGS7. In contrast, each locality shows the same characteristic pattern of difference between artifacts and cobbles (Table 5). The sole exception to this pattern is the unusually large mean size of phenocrysts in artifacts from DAN2d, which actually exceeds that in the underlying conglomerate.

Rock type frequencies observed at each locality show greater variation (Fig. 6), but reveal a similarly characteristic pattern of difference between artifact assemblages and their associated conglomerates. The close accord between separate cobble samples taken at the DAN2 locality during 2000 and 2001 also confirms the reproducibility of the sampling methods used in this study. Variations in local material availability do appear to affect assemblage composition in some cases, but this is always relatively minor compared to the influences of hominid preference. At OGS7, for example, unusually high concentrations of quartz latite in the conglomerate may explain the above-average representation of this material in the assemblage. More striking, however, are the preferential exploitation of locally scarce vitreous volcanic and aphanitic clasts, and the conspicuous avoidance of locally abundant basalt.

The avoidance of basalt is a common feature at every locality where data were collected, and is especially striking with respect to the basalt-rich conglomerates at DAN2 and OGS6. Hominid preferences are slightly more complex, in some cases being limited to vitreous volcanics and other aphanitic clasts (OGS7, DAN2d), but usually including a substantial bias toward phenocryst-poor trachyte as well (DAN1, EG13, DAS7). In any case, it is clear that hominid preferences were a major factor influencing raw material composition in each of the assemblages presented here.

Discussion

These results make it clear that Pliocene toolmakers at Gona were able to locate, identify and preferentially select materials with particular attributes. Hominids' evident preference for finer-grained, less porphyritic materials is most likely related to the influence of these variables on fracture patterns and technological suitability, but this hypothesis will need to be tested experimentally. The same may be said with respect to the selection of vitreous volcanics and other aphanitic clasts and the avoidance of basalt. Potential reasons underlying a preference for trachyte are less immediately obvious, but are likely related to the same factors. In fact, a comparison of the material attributes of the different felsic rock types found in the Gona conglomerates reveals that trachyte cobbles have the lowest mean size and percentage of phenocrysts, as well as a greater frequency of "smooth" groundmasses (Table 6). In sum, rock type, phenocryst and groundmass data all converge to show a high degree of raw material selectivity in the early Oldowan assemblages at Gona. The disproportionate representation

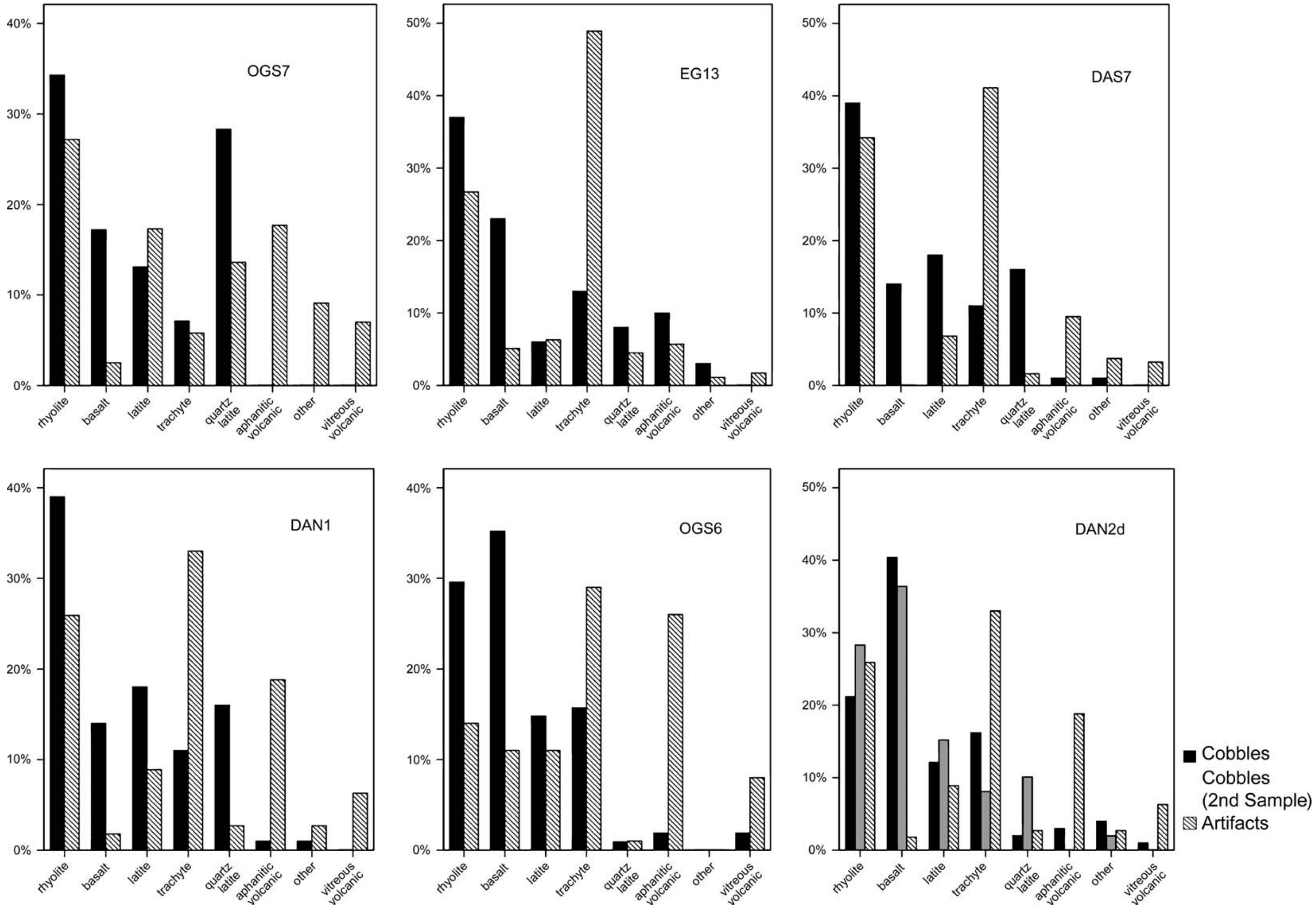

Fig. 6. Distribution of rock types in the artifact and conglomerate samples from each locality. Note that the DAS7 artifacts are compared with the DAN1 cobble sample (see text). Two cobble samples were collected at the DAN2 locality and both are depicted here.

Table 6
Attributes of Felsic Rocks in the Gona Conglomerates

	Trachyte	Rhyolite	Latite	Quartz Latite
Mean % phenocrysts	15.1 (n = 72)	19.8 (n = 189, $p < 0.01$*)	20.56 (n = 80, $p < 0.01$*)	20.85 (n = 65, $p < 0.01$*)
Mean phenocryst size (mm)	2.4 (n = 26)	2.7 (n = 101, $p = 0.20$*)	3.0 (n = 45, $p < 0.05$*)	3.2 (n = 54, $p < 0.02$*)
% Smooth	42	15	11	9
% Coarse	58	84	89	91
% Chalky/decayed	0	1	0	0

* p values are for 2-tailed t-tests vs. trachyte data.

of certain rock types, and preference for finer-grained, phenocryst-poor clasts must arise from the patterning of hominid technological activity, and cannot be attributed to any known taphonomic process.

Oldowan artifacts from Gona appear remarkably refined, especially given their early date (Semaw et al., 1997; Semaw, 2000; Semaw et al., 2003). Inspection of the artifacts themselves suggests that this apparent sophistication may be largely due to the quality of raw materials used. Not only is it easier to initiate and control fracture in fine-grained, isotropic rocks; such materials also tend to preserve more of the technological traces (e.g. flake scars, retouch, ripple marks, percussion bulbs) used by archaeologists to evaluate artifacts. The Gona artifacts do indeed provide evidence of well-developed flaking skills (Semaw et al., 1997; Stout and Semaw, in press), but are probably more remarkable for the materials from which they are made than for the specific techniques of their making. It is thus important to recognize that the dynamics of raw material procurement, selection, transport and use may be as revealing of technological and cognitive sophistication as are knapping plans and acquired perceptual-motor skills (Stiles, 1998; Inizan et al., 1999; Stout, 2002).

There are two complementary patterns of hominid activity which might plausibly have contributed to the pattern of raw material representation seen in Oldowan sites at Gona: 1) preferential selection at raw material sources, and 2) preferential transport to and/or discard at archaeological sites. Selection of materials at cobble bars would most likely have involved visual evaluation of cortex characteristics and at least some test flaking. Personal observation has shown that cortex characteristics such as color, texture, incipient fracture cones, and pits left by exfoliated phenocrysts can be good indicators of material quality. Any biases in subsequent patterns of material transport and discard on the landscape would likely have been based on direct experience actually flaking and/or using particular cores and flakes, although visual identification of desirable characteristics may still have been important if accumulated lithic scatters themselves served as secondary material sources (Schick, 1987).

Further research will be needed in order to define the relative importance of initial selection vs. subsequent transport and use. However, it is clear that both reflect hominid awareness of technologically desirable material characteristics. Even in modern, language-bearing humans, such practical technical knowledge is generally acquired through experience (Keller and Keller, 1996; Stout, 2002), and this would almost certainly have been the case with Oldowan hominids as well. The attention paid to raw material characteristics by the Gona toolmakers thus reflects the deliberate and well-practiced nature of their technological behavior.

Conclusion

Evidence from the earliest known archaeological sites at Gona clearly demonstrates that, in a situation where an assortment of raw materials was available, Pliocene toolmakers were capable of exercising a high degree of selectivity. The great age of the Gona sites indicates that such selectivity did not develop over time, but rather was a feature of Oldowan technological variation from its very inception. This selectivity reflects a level of technological understanding and sophistication among Pliocene toolmakers that is not always appreciated. Insofar as high-quality materials greatly facilitate knapping success and skill acquisition, it is even possible that the availability and selection of advantageous raw materials was an important factor in the initial invention and spread of Oldowan technology.

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