8. Variability in Raw Material Selectivity at the Late Pliocene sites of Lokalalei, West Turkana, Kenya

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Abstract

The current techno-economic study of two well-preserved Late Pliocene lithic assemblages from the Nachukui Formation, in the West Turkana region in North Kenya, provides new evidence of planning and foresight in raw material procurement, and management from 2.34 Ma onwards, testified to by the selection of specific raw materials. One of the most noteworthy results ensuing from this study, carried out in combination with geological surveys, petrographic analyses and lithic assemblage analyses, is the existence of substantial differences in raw material provisioning and management between Late Pliocene assemblages, geographically and chronologically close. These differences are related to the degree of selectivity for raw material sizes and morphologies as well as to the way they were processed, rather than to variations in resource availability.

8.1 Introduction

Since the 1970s, research addressing ancient hominin behavior in relation to lithic procurement has been particularly focused on hominin ranging and foraging behavior during the Early Pleistocene. This research has been carried out mainly in two regions of eastern Africa, Olduvai Gorge in Tanzania, and Koobi Fora, east of Lake Turkana in Kenya (e.g., Leakey, 1971, 1975, 1994; Hay, 1976; Isaac, 1977; Isaac and Harris, 1978; Jones, 1979; Clark, 1980; Toth, 1982, 1987). Undertaken at a regional scale, raw material studies have furthered the construction of Early Pleistocene hominin activity models (e.g., "home base hypothesis", Leakey, 1971; "routed foraging model", Binford, 1980; "favored places model", Schick, 1987; Schick and Toth, 1993), and have shown evidence of stone transport and management during the Early Pleistocene (Toth 1985; Schick 1987; Isaac et al. 1997). From 1.9 Ma onwards, the preferential use of a particular raw material is generally interpreted as a result of local abundance rather than choice on the part of the toolmakers (e.g. Merrick and Merrick 1976; Toth 1985; Schick 1987; Isaac et al. 1997), although site provisioning could involved distances of several kilometers (up to 13 km at Olduvai: Hay 1976; overview in Féblot-Augustins 1997). However, recent lithic studies based on raw material sourcing and characterization from a series of sites from the West Turkana region, Kenya, have provided a much more complex picture of resource availability management by Oldowan hominins, with evidence for selection patterns although a local procurement in stream channels and bedrock outcrops (Harmand 2005, in press). These involve a certain level of anticipation of the effects of raw material properties and further contradict the assumption generally made for the Early Stone Age of an opportunistic gathering of rocks. For the time being, published evidence for raw material transport and selectivity at Late Pliocene remains limited (Plummer et al. 1999; Hovers et al. 2002; Stout et al. 2005; Goldman-Neu-

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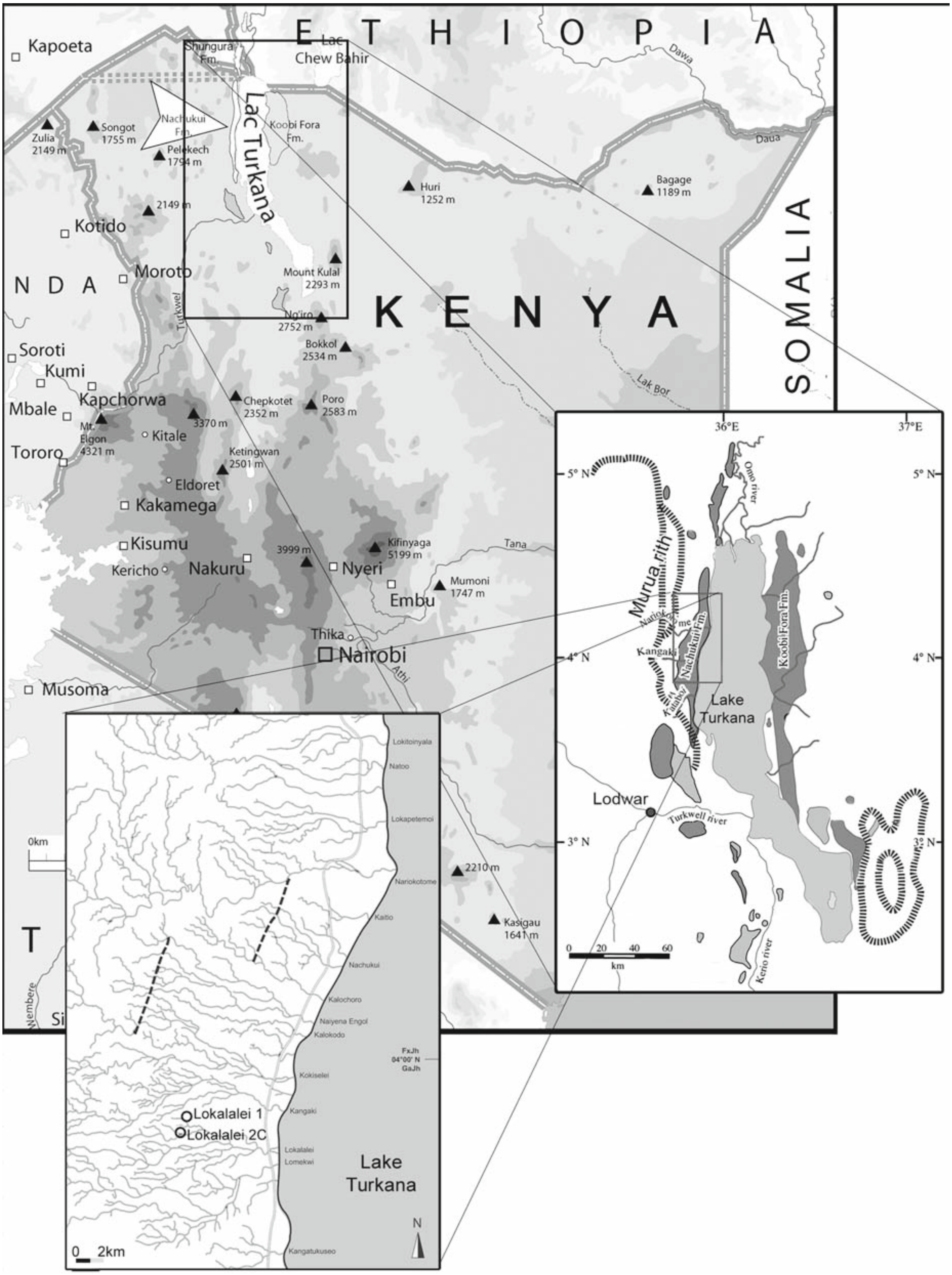

FIGURE 8.1. Lake Turkana Basin, Nachukui Formation, and location of the Lokalalei 2C, and Lokalalei 1 sites, modified after Roche et al. 2003.

man and Hovers 2009; Harmand in press). Recent investigations at the sites of Gona have provided evidence for selection patterns as early as 2.6 Ma (Semaw 2000; Stout et al. 2005), and evidence for selection patterns was documented also at the somewhat later site A.L. 894 in Hadar (Goldman-Neuman and Hovers 2009). At Kanjera South (Late Pliocene sites from KS1 and KS2 Beds), a small portion of the raw materials could also indicate a degree of selectivity and provisioning patterns from non-local sources (Plummer et al. 1999; Braun et al. 2008). In this context, further detailed studies of raw material, considered from the viewpoint of their provenance and use, are thus needed for a better assessment of raw material procurement and exploitation behaviors at Late Pliocene.

This chapter focuses on the results of a comparative techno-economic study that addresses the lithic procurement and exploitation patterns brought into play in the two earliest known archaeological assemblages in Kenya (ca. 2.34 Ma), the Lokalalei sites west of Lake Turkana. Besides providing renewed data on the emergence of early technological developments, the Lokalalei assemblages offer the opportunity to compare raw material procurement activities at early Oldowan (Late Pliocene) archaeological localities found in temporal and geographical proximity, and to document potential differences in lithic provisioning and exploitation in ancient contexts.

8.2 Geographical, Geological and Chronological Contexts

The geographical area covered by our study is part of the Lake Turkana Basin, namely the Nachukui Formation. It stretches on the western shore of the lake to the Labur and Murua Rith escarpments (Figure 8.1).

This Formation is characterized by Plio-Pleistocene sedimentary deposits that reach a thickness of about 730 meters and are exposed in an area of about 700 km^2. The Nachukui Formation comprises eight members (from 4 to 0.7 Ma), using widespread volcanic tuffs as bed markers (Harris et al. 1988; Feibel et al. 1989, 1991). This sequence is one of the longest and more complete in East Africa, and has yielded very rich and well-preserved archaeological sites of great antiquity, occupied by hominins between 2.34 and 0.70 Ma (Kibunjia et al. 1992; Roche and Kibunjia 1994; 1996; Roche et al. 1999, 2003). These sites were excavated by the West Turkana Archaeological Project, a joint project led by H. Roche (*Mission Préhistorique au Kenya*, France) and M. Kibunjia (National Museums of Kenya).

The Lokalalei archaeological sites are located in the South of the Nachukui Formation, one km apart (Fig. 8.1). Excavated in 1991 (Lokalalei 1), 1996 and 1997 (Lokalalei 2C), they are the oldest sites known so far in Kenya and belong to the very few African Pliocene sites (Roche et al. 2003). Locally, Lokalalei 1 and Lokalalei 2C are correlated by a mollusc-packed sandstone, which occurs beneath both sites. This marker was used as the local boundary between the Lokalalei and Kalochoro Members. The Kokiselei and Ekalalei Tuffs lying below the Lokalalei 1 and Lokalalei 2C sites are correlated with Tuffs E and F1 of the Shungura Formation, respectively. The Kokiselei Tuff has a stratigraphically scaled age of 2.4±0.05 Ma, while the Ekalalei Tuff is slightly younger than 2.34±0.04 Ma. An age of 2.34±0.05 Ma is thus estimated for the Lokalalei archaeological sites. The stratigraphical position of Lokalalei 2C, while slightly higher in the section than Lokalalei 1, is judged compatible with a chronological attribution within the same time interval (see Delagnes and Roche 2005; Tiercelin et al. in prep.).

8.3 Analytical Approach

The raw material provisioning and exploitation patterns at the Lokalalei sites are inferred from the techno-economic analysis of the lithic assemblages (e.g. Geneste 1989, 1991), which aimed more particularly to highlight the relationship between raw materials and tool production processes. This approach is linked to the notion of *chaîne opératoire* (e.g. Leroi-Gourhan 1964, 1971), whereby artifacts are analyzed as the result of a process, that is to say the strategies of reduction and the technical skills involved in tool-production. The implemented techno-economic analysis involved several stages of investigation. It required the systematic sourcing, mapping and sampling of raw materials by field surveys so as to determine their geographical provenience and to assess the opportunities for procurement according to the evolution of the geological and the post-depositional geomorphological environment and in relation to the geographical position of the sites. Petrographic analyses were carried out in order to evaluate the diversity of the raw materials available, and to assess the relative abundance of each type of rock in relation to their petrographic, structural and granular patterns. The natural morphologies and sizes of the collected boulders and cobbles were recorded to appraise the range of shapes and sizes available in the potential sources. Rock mechanics tests through knapping experiments were conducted in the field on rocks similar to those found in the archaelgoical assembalges. These aimed to estimate the importance of the constraints imposed by the different properties of the various raw materials found at sites (here referred to as rock qualities). These knapping experiments were conducted according to the knapping techniques (direct hard hammer percussion) and the strategies of core reduction documented at Lokalalei (no preparation of the cores, natural striking surfaces and angles used). For each rock types (~50 cobbles), an average of ten flakes were removed from the initial cobbles using different lava cobble hammerstones (Harmand 2005). The flakes produced through the knapping tests were used for plant and goat processing to obtain precision on edge efficiency and durability. Table 8.1 presents the results of the raw material characterization.

Table 8.1 Characteristics and properties of the volcanic rocks found at sources and at sites at Lokalalei, inferred from classical petrological classification and knapping experiments

Rock type	Texture	Grain size	Colour	Mineral composition	Quality
Phonolite	Equigranular. Aphyric.	Medium grained (1 to 5 mm)	Often light black or grey.	Mainly composedof sanidine, amphibole and clinopyroxene. No quartz.	High quality rock, compact and homogeneous. Often rounded compact pebbles or cobbles. Parallel alignement of crystals. Advantage of breaking easily along foliation planes. Regular fracture and predictability of fracture orientation. Very suitable for obtaining durable and resistant sharp cutting edges.
	Equigranular. Aphyric.	Fine grained (crystals <1 mm).	Often light black or grey.	Mainly composed of san dine, amphibole and clinopyroxene. No quartz.	Often rounded pebbles or cobbles. Less control of the fracture. High frequency of fractured surfaces. Sharp cutting edges but fragile and no resistance. Low durability of the material.
	Inequigranular. Porphyritic.	Fine grained groudmass.	Often light black or grey.	Sanidine, amphibole and clinopyroxene. Sanidine and plagioclase phenocrysts.	Often rounded compact pebbles or cobbles. High frequency of medium crystals in the groundmass. Low predictability of fracture orientation.
Basalt	Equigranular. Aphyric.	Fine grained.	Often dark black.	Mainly composed of plagioclase feldsparand pyroxene.	Rounded compact pebbles or cobbles and often angular blocks. High density rock. Fracture resistant and difficult to break. Suitable for hammering.
	Inequigranular. Porphyritic.	Fine grained groudmass.	Often dark black.	Plagioclase feldspar, pyroxene. Olivine and pyroxene phenocrysts.	Rounded compact pebbles or cobbles and often angular blocks. High density rock. Fracture resistant and difficult to break. High frequency of large crystals in the groundmass. No predictability of fracture orientation.
Trachyte	Equigranular. Aphyric.	Fine to medium grained.	Usually pale in colour.	Mainly composed of alkali feldspar. Quartz in small amounts.	Often rounded compact pebbles or cobbles. Less compact and homogeneous rock. Tiny bubbles or vesicles. Irregular fracture and low fracture predictability. Friable edges. Low edge durability.
	Inequigranular. Porphyritic.	Finegrained groudmass.	Usually pale in colour. Banded or layered.	Alkali feldspar phenocrysts.	Often rounded compact pebbles or cobbles. High frequency of medium crystals in the groundmass. Irregular fracture and low predictability of fracture orientation. Friable edges. Low edge durability.
Rhyolite	Equigranular. Aphyric.	Very fine grained.	Often red.	Mainly composed of quartz and feldspar	Diaclasic angular blocks and fragments. High quality rock. Breaks with a conchoidal fracture like glass. Sharp cutting edges. Less homogeneous rock due to frequent internal fissures, vesicles and spherulites.
Syenite	Equigranular. Aphyric.	Coarse grained (>5 mm).	White or shades of grey.	Mainly composed of feldspars. Quartz in small amounts.	Diaclasic angular fragments. Poorly welded crystals. No fracture predictability. Tiny bubbles or vesicles. Friable edges. Low edge durability.

Ultimately, the relationship between raw materials and desired end products has been determined and analyzed based on the results of the technological study of the reduction sequences documented for the Lokalalei sites (Kibunjia 1994, 1998; Delagnes and Roche 2005; Harmand 2005)

8.4 Results

8.4.1 Geographical Provenience and Opportunities for Procurement During the Late Pliocene in the Nachukui Formation

Paleogeographic reconstructions of the Turkana Basin indicate that prior to 2.0 Ma, the Turkana Basin was dominated by a river system interpreted as the paleo-Omo, which flowed through the Basin from the north and exited east into the Indian Ocean (Figure 8.2) (Brown and Feibel 1988; Feibel et al. 1991; Rogers et al. 1994).

Lying in the southern area of exposure, the Lokalalei sites are enclosed within paleosols that formed in the alluvial plain of the Paleo-Omo fluviatile system, within the Kalochoro Member. The sandstones associated with these paleosols suggest that the sites were located in the proximal part of the alluvial plain where small East-flowing streams joined the main axial system (Figure 8.2) (Brown and Feibel 1988; Roche et al. 1999). Due to the development of these East-flowing streams, debris-flow outcrops were accumulated in the western margin of the Turkana basin.

Although it has not been possible to locate the exact point where the knappers collected their raw materials, specific debris-flow outcrops lying stratigraphically below the archaeological layers or within the same layers were identified and sampled according to the geomorphological framework previously established for the region (Brown and Feibel 1991; Rogers et al. 1994; Feibel 2001) and based on extensive survey of the surrounding sediments by the geologist (see Harmand 2005). These debris-flow outcrops are located at lateral distances a few meters away from the sites (150 m from Lokalalei 1 site; 30 m from Lokalalei 2C site) (see Harmand 2005). For each conglomerate, the raw materials were sampled according to a three dimensional pattern to assess the variability of rocks within a certain volume of sediments. The samples correspond to collecting areas of two meters in lateral extent and one meter deep to approximate the horizontal distribution of raw materials in the conglomerates. The thickness of the collecting areas is equivalent to the thickness of the conglomerates.

The systematic sourcing of the poorly sorted debris-flow outcrops available in the vicinity of the archaeological sites indicates the predominance of rounded pebbles or cobbles of igneous and extrusive volcanic rocks (Table 8.1), all originating from flows of lava from the Murua Rith and Labur Miocene volcanic ranges which border the Basin to the West (Walsh and Dodson 1969; Feibel 2001) (Figure 8.2). These rocks, carried by the network of rivers, were grouped into several categories, differing in terms of color, grain, texture and homogeneity (Table 8.1). Five major volcanic rock types were identified in the Lokalalei study area based on classical petrologic classification (MacKenzie and Adams 1996): phonolite, basalt, trachyte, rhyolite, syenite (Table 8.1), and a few siliceous rocks. The raw material attribution was carried by eye identification. One artefact per major raw material group was devoted to a thin section for petrographic attributions. Each of the rock types was divided according to groundmass features (micro - to - cryptocrystalline), grain sizes (fine - to - coarse-grained fabrics), and textures (aphyric - to - porphyritic), resulting in distinct knapping and functional properties and varying initial morphologies and sizes (Table 8.1). For instance, the medium-grained phonolite displays good physical features in terms of its flaking qualities, the aphyric fine-grained basalt is difficult to break and more resistant to hard-hammer percussion.

At Lokalalei 2C area, 207 cobbles, pebbles and boulders were randomly collected from the different sampled gravel bars, out of which a total of 71 clasts of a diameter >40 mm were studied. These dimensions correspond to the smallest pebble used at the archaeological site (Table 8.2). At Lokalalei 1 area, a total of 173 cobbles, pebbles and boulders were randomly collected from the different sampled gravel bars (Table 8.3).

Each of the gravel bars sampled at both sites areas (Lokalalei 2C and Lokalalei 1) is located a short distance from the archaeological sites (both located near sources of raw materials, Roche et al. 1999) and includes a relatively large variety of raw materials of adequate size to make stone-tools. The shared range of volcanic rocks in the bars consists of phonolites, basalts, trachytes and rhyolites. Among them, trachytes repeatedly constitute the majority of the rock sampled, followed by phonolites, basalts and rhyolites (Table 8.2 and Table 8.3, see below).

The characteristics of the raw materials (types, sizes and cortical surfaces) found at archaeological sites and used for artefacts match with the ones sampled at sources (see below). This suggests that there is no reason to suppose that site provisionning at Lokalalei involved distances beyond a radius of 0.5 km. Raw material procurement at Lokalalei consisted of collecting and carrying raw materials from the local debris flow outcrops available in the immediate vicinity of the sites. As a result, the cost of search, acquisition and transport of raw materials was minimal.

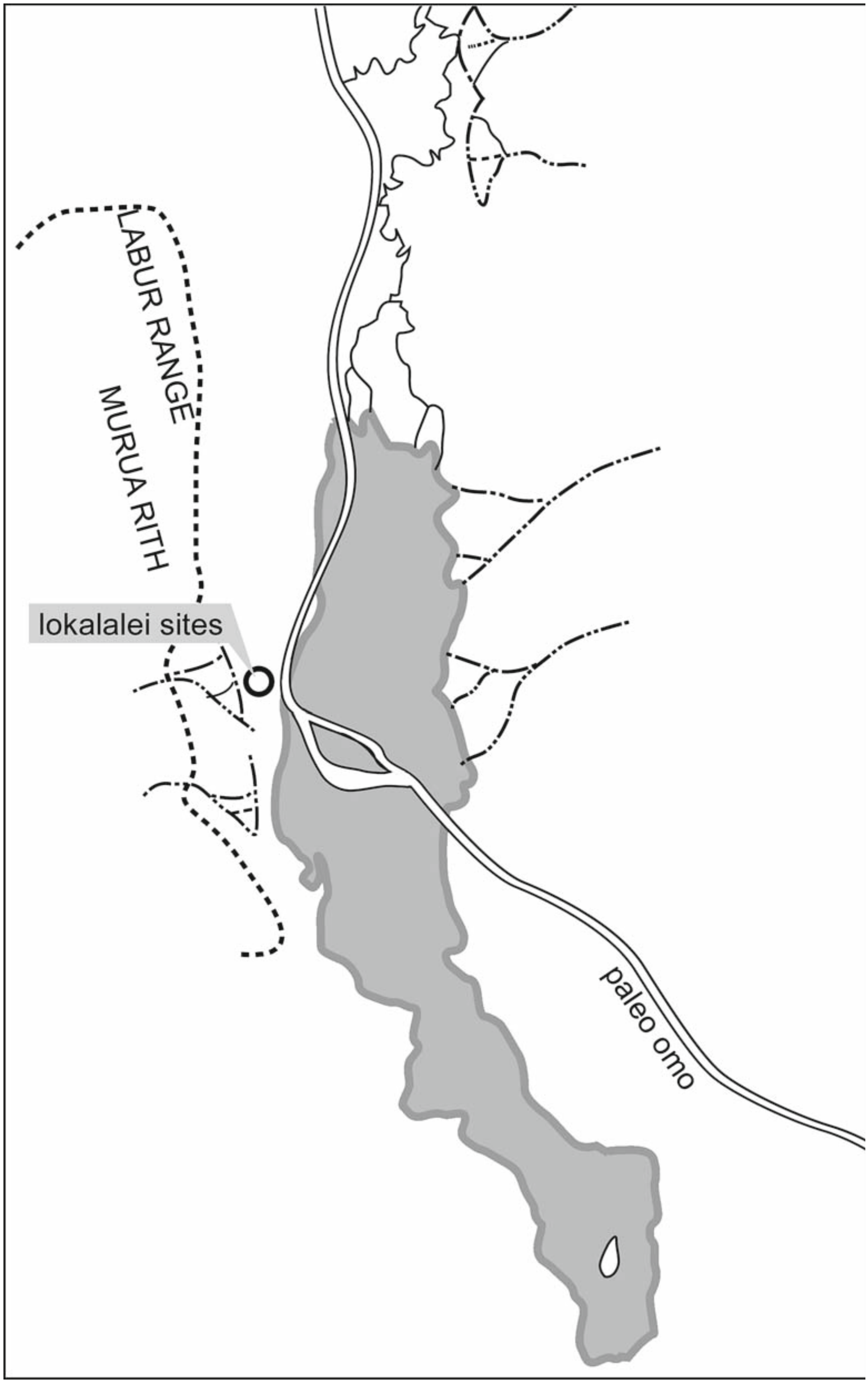

FIGURE 8.2. Paleogeographic setting of the Lokalalei sites at ca. 2.4 – 2.3 Ma, modified after Brown and Feibel 1988.

TABLE 8.2. Distribution of rock types in the lithic assemblage components at Lokalalei 2C and in the sampled outcrop

	Lokalalei 2C site						geological sample	
	débitage (cores, flakes, flake fragments)		hammerstones		unmodified or split cobbles		pebbles, cobbles, boulders*	
	N	%	*N*	%	*N*	%	*N*	%
Phonolites	1916	77.63	2	11.11	43	31.16	20	28.17
Basalts	350	14.18	3	16.67	20	14.49	17	23.95
Trachytes	175	7.09	13	72.22	66	47.83	26	36.62
Rhyolites	5	0.20	0	0.00	2	1.45	4	5.63
Syenites	1	0.04	0	0.00	0	0.00	0	0.00
Non det.	21	0.86	0	0.00	7	5.07	4	5.63
Total	2468	100.00	18	100.00	138	100.00	71	100.00

* from a total of 207 pebbles, cobbles and boulders collected, only the ones displaying a diameter >40 mm were studied. They correspond to the smallest pebbles used at the archaeological site (see Harmand 2005:136).

8.4.2 Raw Material Procurement and Exploitation Patterns at Lokalalei Sites

8.4.2.1 Lokalalei 2C

The randomly sampled outcrop in the Lokalalei 2C vicinity is dominated by cobbles and pebbles of a light brown aphyric trachyte (36.6%) (Figure 8.3).

Cobbles and pebbles of a dark gray aphyric phonolite account for 28% of the rocks sampled on the outcrops at Lokalalei 2C (Figure 8.3). Among the phonolites, cobbles and pebbles of a medium-grained type are predominant (24% of the raw materials). Cobbles and pebbles of a dark black porphyritic or aphyric basalts account for 24% (Figure 8.3) of the rocks sampled on the outcrop at Lokalalei 2C which comprises also smaller proportions of red rhyolites (5.6%, Figure 8.3).

At Lokalalei 2C, the excavation covered an area of 17 m^2 from which an abundant *in situ* lithic assemblage (n=2624) has been recovered, including cores, whole or broken flakes, a very few possibly retouched pieces, unmodified split cobbles and hammerstones (Table 8.2).

Although the archaeological deposit is partly truncated by erosion, the remaining part of the site shows evidence of good preservation, as indicated by a high ratio of very small elements and the freshness of the artifacts (Delagnes and Roche 2005). The high proportion of small elements (length <2 cm), the significant quantity of cores and flakes, and the presence of hammerstones are consistent with knapping activities carried out on site (Table 8.2), where an estimate of 190 cobbles or fragments of cobbles along with a few unmodified split cobbles were introduced from nearby sources (Harmand 2005). As documented by Delagnes and Roche (2005), the assemblage is remarkable in many respects, including the use of specific morphologies to conduct organized and highly productive *débitage*[1] sequences. These result in extensive production of relatively well-standardized flakes.

Regarding petrography, the knappers favored the medium-grained phonolite (52% of the on-site raw materials, Figure 8.3). This raw material displays a parallel mineral orientation that gives the rock a natural foliation. The rock has the mechanical advantage of breaking easily along the foliation plane when direct hard-hammer percussion is used, and therefore offers a measure of predictability in terms of fracture orientation (Table 8.1) (Harmand 2004, 2005). This type of raw material was thus most suitable in terms of flaking quality as well as cobble morphology for the production of large amounts of flakes. Medium-grained phonolite is also very suitable for obtaining potentially functional active edges (sharp cutting edges). At the source, the procurement patterns involved selecting phonolites in general over basalts and trachytes (Figure 8.3). The frequency of medium-grained phonolite is higher in the assemblage (~ 52% of the on-site raw materials of which 45 cores and a total of 745 flakes or flake fragments) than in the local conglomerates (~24% of the raw materials at source) (Figure 8.3). In comparison, the frequencies of trachytes and basalts are higher in the local conglomerates (respectively ~36.6% and ~24% of the raw materials at source) than in the assemblage (trachyte ~9.7% of the on-site raw materials of which only 8 cores and core fragments of trachyte; basalt ~14% of the on-site raw materials of which only 9 cores and core fragments not reduced extensively). The low frequencies of rhyolites and syenites in the assemblage (0.3% of the on-site raw materials) reflect their low frequencies in the local conglomerates (~5.6% of the raw materials at source).

Furthermore at Lokalalei 2C, medium-sized angular cobbles or fragments of cobbles (12 cm maximum dimension) of the medium-grained phonolite with naturally serviceable striking

[1] The word débitage is used in its original French meaning as a reflection of a specific reduction process, not as the residue of production (Inizan et al. 1995).

TABLE 8.3. Distribution of rock types in the lithic assemblage components at Lokalalei 1 and in the sampled outcrops

	Lokalalei 1 site						geological sample	
	débitage (cores, flakes, flake fragments)		hammerstones		unmodified or split cobbles		pebbles, cobbles, boulders (diameter > 40 mm)	
	N	*%*	*N*	*%*	*N*	*%*	*N*	*%*
Phonolites	238	68.19	2	28.57	25	69.44	69	39.88
Basalts	9	2.58	0	0.00	1	2.78	20	11.56
Trachytes	100	28.66	5	71.43	8	22.22	77	44.51
Rhyolites	0	0.00	0	0.00	0	0.00	2	1.16
Syenites	0	0.00	0	0.00	1	2.78	5	2.89
Siliceous	2	0.57	0	0.00	1	2.78	0	0.00
Total	349	100.00	7	100.00	36	100.00	173	100.00

surfaces and angles (n=95)[2] were preferentially selected for their suitability to be knapped without any preparation (Delagnes and Roche 2005). Flakes, cores and fragments are mainly made on these angular specimens of medium-grained phonolite (60% of the flakes and flake fragments, n=745). Selection at the sources was high, since such morphologies are poorly represented in the nearby sources, the medium-grained phonolite occuring mainly as rounded to subrounded cobbles, more rarely as angular cobbles (see Harmand 2005). The low representation of such specimens at the sources is probably one of the reasons for the deliberate breakage of large-sized (length >15 cm) to medium-sized (8 to 15 cm in length) rounded cobbles of medium-grained phonolite into several pieces to obtain suitable blanks for flaking, with serviceable striking platforms. This probably took place prior to transport and perhaps at the source, where the raw material was collected (Delagnes and Roche 2005; Harmand 2005). To maximize the reduction sequences, poorer quality cobbles of porphyritic phonolites and porphyritic basalts (Table 8.1) were exceptionally selected for their large dimensions (length >16 cm). Those were obviously partially flaked off-site prior to their transport (Delagnes and Roche 2005).

The initial selection of a specific morphology from a high-grade raw material (medium-grained phonolite), from which a large amount of flakes could be easily obtained, enabled the knappers to maximize the reduction sequences through a *débitage* system. As a result, the amount of flakes produced is relatively high (up to 80 for a single block) and they display sharp cutting edges, serviceable without any transformation by retouch (Delagnes and Roche 2005).

To a lesser extent, a more heterogeneous *débitage* by multidirectional removals was conducted on thick and globular cobbles mainly of medium-grained phonolite (6 cores) or on poorer quality cobbles or fragments of cobbles of porphyritic phonolites, aphyric trachytes or porphyritic basalts (8 cores, Figure 8.3). The presence of numerous phenocrystals of olivine and pyroxene within the porphyritic basalts significantly lessens the predictability of flake sizes and morphologies (Harmand 2005). In the same way, trachytes display low fracture predictability and generate low durability cutting-edges (Table 8.1). As a result, the cores display numerous knapping accidents from which only a small amount of small flakes were produced (Delagnes and Roche 2005).

In addition, a series of unmodified cobbles (n=54), mostly rounded cobbles (tested or not) of medium-grained trachyte or fine-grained basalt, were also brought to the site and probably stockpiled as resistant, massive, and difficult to break "manuports". Thirteen heavy and medium-sized rounded cobbles of a resistant medium-grained trachyte bear signs of percussion damage and are interpreted as hammerstones (Table 8.2) used for knapping most of the cores flaked at the site (Delagnes and Roche 2005). These hammerstones were selected from the cobbles most appropriate for percussion in terms of mass, size and shape, within the supply of raw materials brought to the site (Harmand 2004, 2005).

8.4.2.2 Lokalalei 1

The randomly sampled outcrops in the Lokalalei 1 area are also dominated by cobbles and pebbles of a light brown aphyric trachyte (44.5%) (Figure 8.4).

Pebbles and cobbles of a dark gray aphyric phonolite account for almost 40% of the rocks sampled (Figure 8.4). Among the phonolites, the medium-grained type is predominant (21% of the raw materials at source). Pebbles and cobbles of dark black porphyritic or aphyric basalts account for only 11.5% of the rocks sampled on the outcrops at Lokalalei 1 area (Figure 8.4). Various other rocks occur in smaller proportions: red rhyolites (1%), and a large-grained syenite (2.8%, Figure 8.4).

Compared to the Lokalalei 2C site, the Lokalalei 1 lithic assemblage is quite small (n=392). The excavation covered an

[2] Original shapes inferred from the refitting groups and documented by the study of the slightly modified cobbles (see Delagnes, Roche 2005).

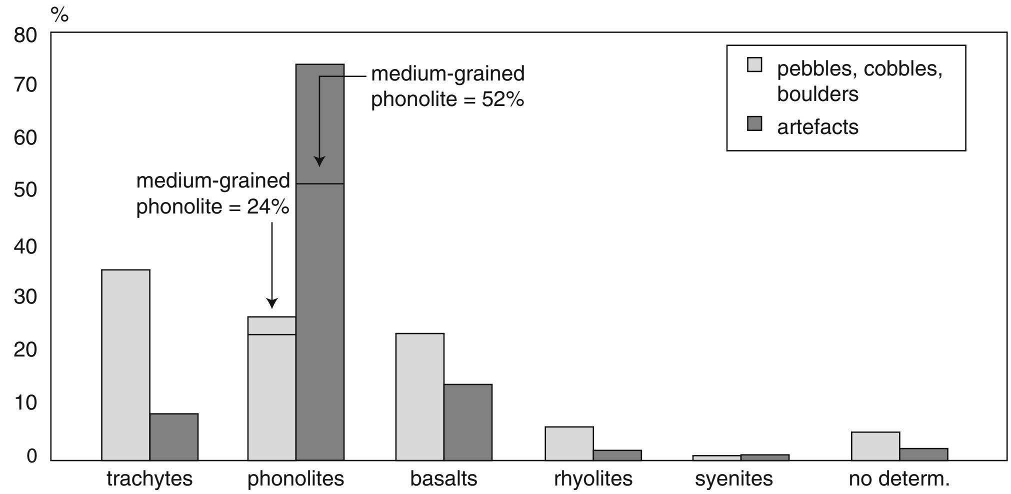

FIGURE 8.3. Distribution of rock types in the conglomerate samples (pebbles, cobbles, boulders) in the Lokalalei 2C area, and in the Lokalalei 2C assemblage (total of the artefacts). Rock types are organized from left to right in order of their declining relative frequency in the conglomerates. Note that the frequency of medium-grained phonolite is higher in the assemblage than in the local conglomerates. In comparison, the frequencies of trachytes and basalts are higher in the local conglomerates than in the assemblage. The low frequencies of rhyolites and syenites in the assemblage reflect their low frequencies in the local conglomerates.

area of 60 m^2 from which flakes and cores, unmodified split cobbles and hammerstones have been recovered (Table 8.3) (Kibunjia 1994, 1998; Roche et al. 2003; Harmand 2005). An estimated number of 110 boulders, cobbles or fragments of cobbles along with the few unmodified split cobbles were introduced into the site from a nearby source channel (Harmand 2005).

The selectivity towards raw material quality highlighted for the site of Lokalalei 2C is also documented for Lokalalei 1 site. At Lokalalei 1, the frequency of medium-grained phonolite is higher in the assemblage (~56.5% of the on-site raw materials) than in the local conglomerates (~21% of the raw materials at source) (Figure 8.4). The selectivity towards raw material quality at Lokalalei 1 can also be inferred from the avoidance of poorer quality rocks for the *débitage*: the frequencies of trachytes and basalts are higher in the local conglomerates (~44.5% and 12% respectively of the raw materials at source) than in the assemblage (respectively ~ 29% and 2.6% of the on-site raw materials). Furthermore, the over representation of the medium-grained phonolite in the archaeological assemblage is evident when looking at the cores: 43 cores of these particular rock versus only three cores or core fragments of trachyte and four cores of basalt not

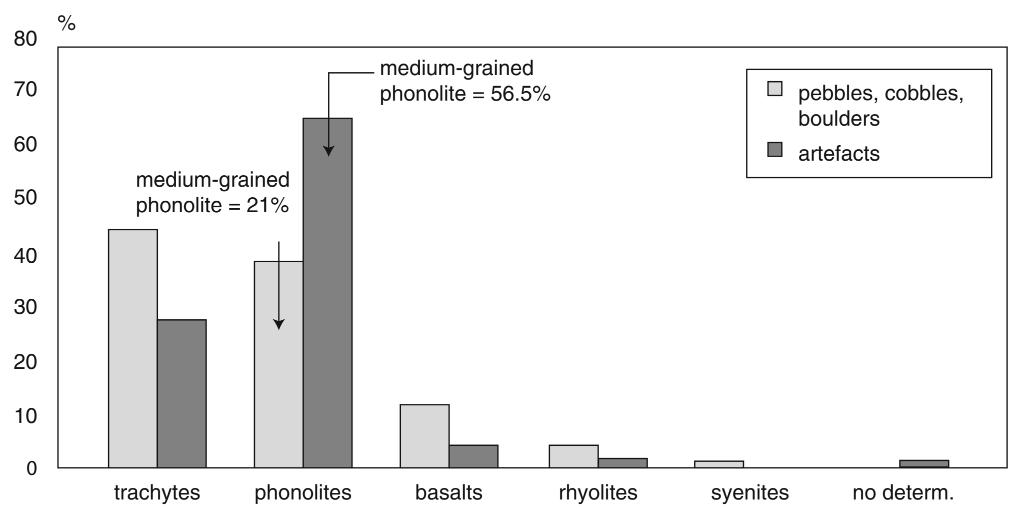

FIGURE 8.4. Distribution of rock types in the conglomerate samples (pebbles, cobbles, boulders) in the Lokalalei 1 area, and in the Lokalalei 1 assemblage (total of the artefacts). Rock types are organized from left to right in order of their declining relative frequency in the conglomerates. The frequency of medium-grained phonolite is higher in the assemblage than in the local conglomerates. The frequencies of trachytes and basalts are higher in the local conglomerates than in the assemblage. The low frequencies of rhyolites, syenites and siliceous in assemblage reflect their low frequencies in the local conglomerates.

reduced extensively. As noticed at Lokalalei 2C, the low frequencies of rhyolites, syenites and siliceous in the Lokalalei 1 assemblage (~ 1% of the on-site raw materials) reflect their low frequencies in the local conglomerates (~ 4% of the raw materials at source).

Nevertheless at Lokalalei 1, the selectivity of a raw material type has to be balanced when considering the evident opportunistic gathering of cobbles in terms of morphological types. The majority of the cobbles brought to the site are rounded, massive and globular in shape (medium to rather large thick, length >15 cm, width >10 cm). These cobbles are either of lower quality raw materials (aphyric phonolites and trachytes or porphyritic basalts) or of high-grade raw materials (medium-grained phonolite) but in any case, they display a scarcity of naturally serviceable striking surfaces (for 71% of the on-site cobbles). At Lokalalei 1, the initial selection of morphologies not suitable for carrying out *débitage* without any preparation led to low productivity reduction sequences. These consist of detaching small multidirectional flakes from two, three or more faces of the cores without any constant technical rules (as indicated by the direction and the number of negatives of removals on the cores). As a result, only a small amount of whole and serviceable flakes were produced: an estimate of 63 whole flakes of medium-grained phonolite removed for 43 cores; an estimate of 47 whole flakes for 18 cores made on other rocks (Harmand 2005).

The Lokalalei 1 assemblage also includes a relatively small amount of cores (19 cores) testifying to a more organized *débitage* conducted on small to medium-sized angular blocks (length > 12.5 cm) mainly on medium-grained phonolite, and displaying small portions of flat surfaces, naturally serviceable as striking surfaces. Longer reduction sequences were conducted on these angular blocks (from one or two surfaces) than on the rounded and globular ones. As a result, more than 10 flakes for one block were produced. Yet the exploitation sequences at Lokalalei 1 do not reach the highly productive sequences documented by Delagnes and Roche (2005) at nearby Lokalalei 2C. This has been related to a lower level of technical elaboration at Lokalalei 1, as indicated by the way raw materials were processed. At Lokalalei 1, the large and plane surfaces of cobbles were used as striking surfaces, whereas at Lokalalei 2C the large surfaces served as the flaking surfaces (see Delagnes and Roche 2005:468). Another reason cited for the differences between the sites is a lower level of manual dexterity, as testified to by cores whose negatives of removal indicate numerous knapping accidents, and repeated impact damage from failed percussions (see Kibunjia 1994; Delagnes and Roche 2005).

The few hammerstones in the assemblage (n=7) are mainly medium-size (maximum length: 12 cm), compact and rounded cobbles of aphyric trachytes, and aphyric phonolites in smaller proportions, appropriate for hammering hard rocks (Table 8.3). In addition, the lithic assemblage includes 36 relatively large-size (maximum length: 15 cm) rounded cobbles (tested or not) mainly from aphyric phonolite or trachyte, possibly stockpiled to be knapped and to serve as resistant and massive "manuports" and/or hammerstones (Table 8.3) (Harmand 2005).

8.5 Conclusion

This study conducted on two Late Pliocene assemblages and based on raw material sourcing and characterization has provided evidence for selection patterns as early as 2.34 Ma despite a local procurement in stream channels and/or bedrock outcrops. Early hominin provisioning behaviors at both Lokalalei sites show the antiquity of decision-making testify to by the selection of a specific raw material for its flaking quality and for the durability of the sharp cutting-edge generated and by the avoidance of lower grade raw materials. They suggest sensitivity to the quality of raw materials, involving a certain level of knowledge and anticipation of the effects of raw material qualities.

This differential selection of raw materials brought to light in the Late Pliocene assemblages of Lokalalei is in keeping with the new and unexpected results obtained at the Early Oldowan localities of Gona and Hadar in Ethiopia, and Kanjera in Kenya (Plummer et al. 1999; Semaw 2000; Semaw et al. 2003; Plummer 2004; Stout et al. 2005; Goldman-Neuman and Hovers 2009) and contradict the assumption generally made for the Early Stone Age of an opportunistic gathering of rocks.

Our techno-economic analysis has highlighted significant differences in raw material procurement and management in the Late Pliocene of the Nachukui Formation, mainly related to the shape of the raw material brought onto the sites. While evidence of selectivity at Lokalalei 1 remains restricted to raw material quality, the procurement and exploitation strategies at Lokalalei 2C underscore a higher degree of planning and foresight. Those are testified to by the careful selection of advantageous rocks (high-grade rocks and particular morphologies) for the purpose of carrying out long reduction processes according to the level of skill the Lokalalei 2C knappers have mastered.

Since the raw material availability has no impact on artefact manufacture (similar high grade raw materials and similar morphologies available) and cannot explain the variation across the Lokalalei archaeological assemblages, the factors of assemblage diversity at Lokalalei are plausibly due to: (1) distinct patterns of hominin activity and site occupation or (2) unequal abilities to implement core reduction strategies (i.e. the way the raw materials were processed).

The first hypothesis favors a diversity related to specific tasks and needs. The Lokalalei 1 lithic assemblage may be the result of immediate needs of sharp cutting-edges expediently produced (lithic assemblage quite small in number, cores not reduced extensively) and used on site during short periods of occupation by a small group of hominins. At Lokalalei 2C, since the extensive reduction of cores does not reflect a high cost in terms of procurement energy, the assemblage may be the result of structured activities possibly during a longer period of occupation, and requiring planning and anticipation for greater needs for artefacts (long elaborate reduction sequences on advantageous rocks, cores discarded in significantly reduced states, high amount of cutting edges).

The second hypothesis favors the presence of contrasting levels of decision-making processes regarding raw material selection, along with different levels of manual dexterity and technical skills among Late Pliocene tool-makers. The latter, possibly robust Australopithecine (present at around 2.5 Ma in the West Turkana region; Walker et al. 1986) or Early Homo (found in close proximity to the Lokalalei sites, Prat et al. 2005) can then be identified as the main source of variation between the Lokalalei assemblages. For the time being, the question to know whether technological diversity at Late Pliocene is due to distinct patterns of site occupation or to unequal abilities is still an open issue and only further research in the future will help to solve this issue.

Our results lend strong support to recent investigations of African Early Oldowan lithic productions, which reveal a much more complex panorama of the first technical systems and their related behaviors, suggestive of temporal and spatial variability as early as Late Pliocene (Kimbel et al. 1996; Roche 2000; Hovers et al. 2002; Martínez-Moreno et al. 2003; Roche et al. 2003; de la Torre et al. 2003; de la Torre 2004; Delagnes and Roche 2005; Harmand 2005; Braun et al. 2008). At present, evidence of diversity in techno-economic patterns for Early Oldowan productions remains limited. More studies based on detailed and comparable techno-economic analysis from a larger number of sites are thus needed for a technological assessment of Early Stone Age assemblages, and ultimately to generate a clearer picture of potentially different responses to resource availability by Early Oldowan hominins in terms of raw material selection and management.

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