African Archaeological Review, Vol. 22, No. 4, December 2005 (© 2006)
DOI: 10.1007/s10437-006-9002-5

Levallois Lithic Technology from the Kapthurin Formation, Kenya: Acheulian Origin and Middle Stone Age Diversity

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Published online: 19 August 2006

The earliest fossils of Homo sapiens are reported from in Africa in association with both late Acheulian and Middle Stone Age (MSA) artifacts. The relation between the origin of our species during the later Middle Pleistocene in Africa and the major archaeological shift marked by the Acheulian-MSA transition is therefore a key issue in human evolution, but it has thus far suffered from a lack of detailed comparison. Here we initiate an exploration of differences and similarities among Middle Pleistocene lithic traditions through examination of Levallois flake production from a sequence of Acheulian and MSA sites from the Kapthurin Formation of Kenya dated to ∼200–500 ka. Results suggest that MSA Levallois technology developed from local Acheulian antecedents, and support a mosaic pattern of lithic technological change across the Acheulian-MSA transition.

Les premiers restes fossiles d'Homo sapiens sont rapportés d'Afrique aussi bien à des avec des outillages de l'Acheuléen final que du Middle Stone Age (MSA). La relation entre l'origine de notre espèce au Pléistocène moyen final d'Afrique et le changement majeur marquée par la transition Acheuléen-MSA est par conséquent un moment clé de l'évolution humaine qui a manqué jusqu'ici d'analyses comparatives détaillées. Nous nous proposons ici de commencer à explorer les différences et les similarités qui peuvent se faire jour au Pléistocène moyen dans les traditions

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techniques à l'examen des productions à éclats Levallois, dans une séquence de sites acheuléens et MSA de la formation de Kapthurin (Kenya), datée de 200–500 ka. Les resultants obtenus suggèrent que la technologie Levallois MSA s'est développée sur ce substrat acheuléen et renforce cette perception que l'on peut avoir d'une mosaïque de changements technologiques jalonnant la transition Acheuléen-MSA.

KEY WORDS: Levallois; Kapthurin Formation; Acheulian; Middle Stone Age; transition.

INTRODUCTION

Levallois flakes and cores are a defining feature of many Middle Paleolithic and Middle Stone Age (MSA) sites throughout Europe, parts of Asia, and Africa. However, the origin, or more likely, origins, of Levallois technology remains obscure. Continental-scale comparisons have suggested sporadic appearances and different regional trajectories in the development of Levallois flake production strategies (Rolland, 1995). These include the transformation of Acheulian bifaces into cores, seen in some French, Levantine, and northeast African sites (Caton-Thompson, 1946; DeBono and Goren-Inbar, 2001; Tuffreau, 2004), and an elaboration of existing, simpler strategies for the production of small flakes at some English sites (White and Ashton, 2003). Economizing behaviors related to changing mobility strategies, raw material conservation, and the need for flake blanks of specific shapes have all been suggested as causes for the adoption of Levallois methods of flaking (e.g., Brantingham and Kuhn, 2001; Chazan, 2000; Dibble, 1997; White and Pettitt, 1995). Throughout most of Africa, Levallois flake production apparently developed from existing Acheulian traditions of the manufacture of large blanks for handaxes and cleavers (e.g., Clark and Kurashina, 1979; Biberson, 1961; Dauvois, 1981; Isaac, 1977; McBrearty, 2001; Texier, 1996a; Toth, 2001; Van Riet Lowe, 1945; see also Madsen and Goren-Inbar, 2004). Cleavers are by definition large flake tools characterized by unretouched distal ends, whose production may require careful prior preparation of the core. Many of the earliest examples of Levallois technology in Africa are for the production of cleavers, suggesting a conceptual link between cleaver production and the development of Levallois flake manufacture in Africa (Alimen and Zuate y Zuber, 1978; Clark, 2001b; Dauvois, 1981; Inizan *et al.*, 1999; Roche and Texier, 1995; Tixier, 1957).

Our goal here is to clarify the origin and development of Levallois methods of flake production in Africa. Recent studies at primarily European and Levantine sites have demonstrated substantial variability *within* the Middle Paleolithic flake production systems encompassed by the Levallois concept (see papers in Dibble and Bar-Yosef, 1995), but comparable studies are largely lacking for most of the African continent (but see Chazan, 1995; Hublin *et al.*, 1987; Pleurdeau, 2003; Rose, 2004; Tryon, 2006b; Van Peer, 1992, 1998; Wengler 1995; Wurz, 2002). We begin to remedy this problem, which is particularly pronounced in eastern Africa. We emphasize the antiquity of Levallois technology in Africa, stress its Acheulian roots, and initiate comparisons among Levallois assemblages found at Acheulian and early Middle Stone Age (EMSA) sites. EMSA sites are defined by McBrearty and Tryon (2005) as those Middle Stone Age sites that antedate the last interglacial, and are therefore >130 ka. EMSA sites, which date to the Middle Pleistocene (∼ 130–780 ka; Baksi *et al.*, 1992; Cande and Kent, 1995) are critical for understanding the nature of post-Acheulian archaeological change, but such sites are rare in comparison to the richer and better documented MSA archaeological record of the Later Pleistocene (Klein, 1999; McBrearty and Brooks, 2000). Here, we focus on Acheulian and EMSA sites from the Kapthurin Formation of Kenya dated to between ∼ 200 ka and 500 ka. We examine raw material procurement and the manner in which flakes and tools were produced, a necessary first step to our eventual understanding of how these tools were used and how they reflect changing hominin adaptations in the later Middle Pleistocene.

The development of Levallois methods is a facet of lithic technological change that crosscuts the traditional divide between the Acheulian and Middle Stone Age, and may provide clues to local patterns of innovation and replacement during this period. The Acheulian-MSA transition is marked by the disappearance of handaxes, their replacement by regionally distinct forms of points, and an increased reliance on Levallois and other methods of flake and blade production (Balout, 1967; Clark, 1988, 1993; McBrearty and Brooks, 2000). Because of the longevity and widespread geographic distribution of the Acheulian (e.g., Petraglia and Korisettar, 1998), the appearance of MSA sites heralds a major technological change that occurred at different times in different regions of Africa, from ∼ 300 ka to perhaps as recently as 150 ka (Clark *et al.*, 2003; McBrearty and Brooks, 2000; Tryon and McBrearty, 2002). The quality of the relevant dates is variable, but the range of age estimates for the local appearance of MSA lithic industries may also be related to complex processes of small-scale population fragmentation, isolation, expansion, and replacement (Howell, 1999; Lahr and Foley, 1998). The timing of the Acheulian-MSA transition is broadly coincident with the age of the origin of our species, as suggested by both fossil and genetic data, and the appearance of a number of innovations that may suggest the origin of modern behavioral capacity (Clark *et al.*, 2003; Henshilwood and Marean, 2003; McBrearty and Brooks, 2000; McDougall *et al.*, 2005; Tishkoff and Williams, 2002; White *et al.*, 2003). Viewed from this perspective, MSA origins may record the signature of the emergence of *Homo sapiens*, and is the first archaeological evidence of regional differentiation (Clark, 1988). We explore the nature of these changes by focusing on the Kapthurin Formation, which preserves a succession of Acheulian and MSA sites.

ANALYSIS

Materials

We compare Levallois lithic technologies from four assemblages from the Kapthurin Formation, Kenya. These include two Acheulian sites, the Leakey Handaxe Area (LHA) and the Factory Site (FS), and two stratified EMSA levels from the site of Koimilot, Locus 1 and the overlying Locus 2. The Kapthurin Formation forms the Middle Pleistocene portion of the Tugen Hills sedimentary succession, exposed in the central Rift Valley west of Lake Baringo (see Fig. 1). The formation consists of alluvial, lacustrine, and variably reworked pyroclastic sediments (McBrearty, 1999; McBrearty *et al.*, 1996; Tallon, 1976, 1978).

Acheulian sites LHA and FS both occur in a stratigraphic interval that is bracketed by tephra dated by $^{40}Ar/^{39}Ar$ to between 284 ± 12 and 509 ± 9 ka (Deino

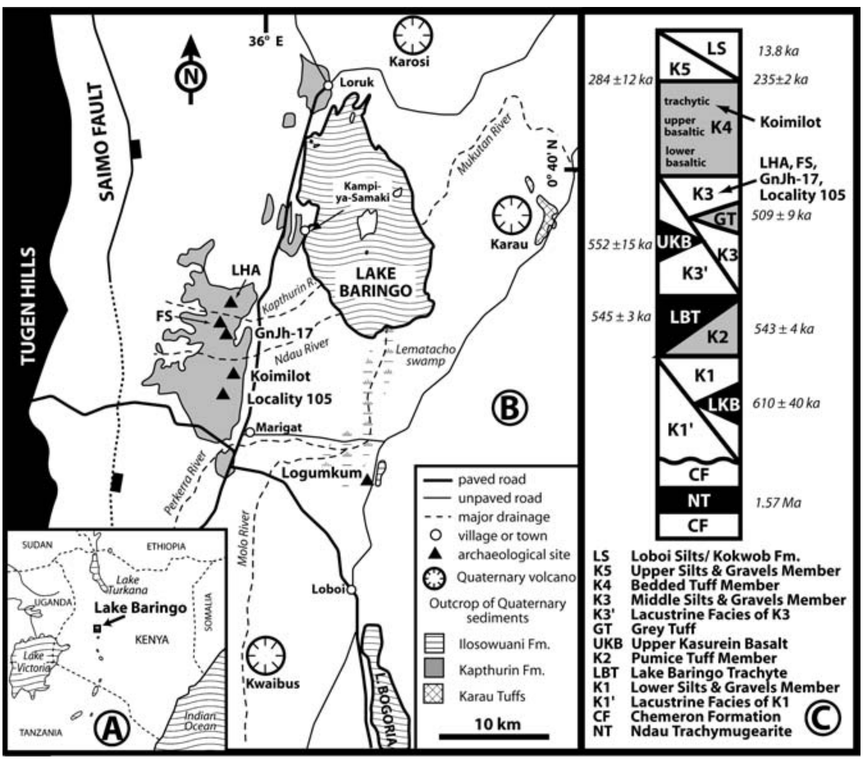

Fig. 1. Map of the major physiographic features and Pleistocene sediments in the Baringo basin and summary stratigraphic section of the Kapthurin Formation. Shown are the location and stratigraphic position of all Kapthurin Formation sites discussed in text. After Tryon (2003).

and McBrearty, 2002) (see Fig. 1). They are thus among the oldest dated examples of Levallois technology in Africa. These sites were discovered and first described by Leakey *et al.* (1969), and portions of the assemblages were later reanalyzed by Cornelissen (1992), Gowlett (1984; Gowlett and Crompton, 1994), McBrearty (1999; McBrearty *et al.*, 1996), and Texier (1996a, 1996b). At the Leakey Handaxe Area (LHA), the initial investigators recovered 1,376 artifacts from both surface and *in situ* excavated contexts within a well-defined stratigraphic interval. Surface collection was carried out over an area of 300 m^2, and excavations in fluviolacustrine sands and silts exposed an area of $\sim$70 m^2. Subsequent collection by McBrearty produced an additional $\sim$160 artifacts from surface context. Levallois flakes ($n = 18$) and Levallois cores ($n = 4$) form a small subset of an assemblage that also includes handaxes, cleavers, rare large non-Levallois cores, a number of small cores for the production of irregular flakes, and a distinct early blade industry. At the Factory Site (FS), 542 artifacts were initially found in and on poorly sorted conglomerates. They were collected from the surface as well as from the excavation of an area of 8.5 m^2 area (Leakey *et al.*, 1969). Sporadic collection by McBrearty at FS has added a further $\sim$25 artifacts to the specimens known from this site. A single Levallois flake and six Levallois cores from FS are examined here, gleaned from an assemblage comprised primarily of irregular flakes, large non-Levallois cores, and rare simple flake- and core-tools. Although Levallois boulder cores and large Levallois flakes are frequently observed on the surface and in the modern conglomerates of the Kapthurin Formation (e.g., Tryon, 2002), and occur as isolated examples from excavation at GnJh-17 (Cornelissen, 1992), we focus here upon LHA and FS because they provide the largest well-provenienced collections of Acheulian Levallois material from the Kapthurin Formation.

The archaeological succession at Koimilot is divided into an older Locus 1, and a younger Locus 2, separated by sterile sediments. Tephrostratigraphic correlation shows that the site of Koimilot overlies both LHA and FS, and provides an age estimate of $\sim$200–250, ka (Tryon, 2003; Tryon and McBrearty, 2006; Tryon, 2006a). Artifacts studied here are drawn from a sample of 3,782 artifacts from the 38 m^2 Locus 1 excavation, and a sample of 310 artifacts from Locus 2. The Locus 2 material was recovered from an excavated area of 26 m^2, and from a controlled surface collection of artifacts found immediately adjacent to, and judged to derive from, the excavated levels (see Tryon, 2003). Levallois cores ($n = 7$), Levallois flakes ($n = 11$) and associated flaking debris dominate both Koimilot assemblages, but these co-occur with simple cores for the production of flakes from one or two unprepared striking platforms. The Koimilot Locus 1 assemblage also contains several tested cobbles, as well as a single shaped, elongated cobble termed a "pointed uniface" after Villa (1983). The Locus 2 assemblage also includes an *in situ* blade core. Artifacts occur in medium to coarse sands that represent a distal alluvial fan depositional environment.

Methods

The Leakey Handaxe Area (LHA), the Factory Site (FS), and Koimilot Locus 1 and Locus 2, like most other known Kapthurin Formation sites, are open-air, rather low-density localities that produce relatively small sample sizes. We therefore employ a descriptive rather than a quantitative approach to assess the range of variation and to characterize the modes of Levallois flake production among Acheulian and MSA assemblages. This provides an initial basis to assess the differences or similarities in Levallois flake production among Acheulian and MSA sites. A qualitative approach is appropriate where sample size is small and includes surface-collected material, but lacks the analytical power of more quantitative inter-assemblage comparative methods possible with larger samples (e.g., Bordes, 1961; Tostevin, 2000, 2003). Following the *chaîne opératoire* approach and the archaeology of process in general, Levallois flake production is examined here as a sequence of varied technical actions and reductive phases, each of which may leave diagnostic traces, contributing directly to much of the archaeological variability present among Pleistocene archaeological sites (Boëda, 1991; Collins, 1975; Conard and Adler, 1997; Geneste, 1989, 1991; Inizan *et al.*, 1999).

Observed characters include raw material type and initial form, the pattern of preparation of the Levallois flake-release surface determined from core and flake dorsal scars, the shape and size of recovered Levallois flakes, and the presence and type of retouch. Inferred characters include flaking technique and method, as defined by Tixier (1967), Boëda (1994), Pelegrin (1995), and Inizan *et al.* (1999). The *technique* of flake detachment is the means by which mechanical force is applied in order to fracture stone. It is determined by examination of striking platform attributes and reference to experimental replications of large Levallois flakes using the phonolitic lava common to all assemblages studied here, described below. The *method* of Levallois flake production refers to the organization of flake removals, specifically the number and orientation of Levallois flakes removed from each prepared core surface. Cores and flakes are attributed to a particular Levallois method, defined below, on the basis of artifact refitting, the number of flake negatives preserved on cores, flake morphology, and the pattern of negatives of prior flake removals.

Following Boëda (1994, 1995), Levallois cores are defined and recognized by their two asymmetric, opposed surfaces, one (the upper, or Levallois surface) dedicated for flake production, and the other for striking platform preparation (see Fig. 2). Levallois flakes are removed sub-parallel to the plane dividing the lower and upper core surfaces, with a striking platform inclined at about 65° with respect to the plane defining the Levallois surface, and more steeply (less than, but close to 90°) at the point of impact (Boëda and Pelegrin, 1979; Texier, 1996a; Van Peer, 1992) (see Fig. 2). The technique is exclusively direct hard

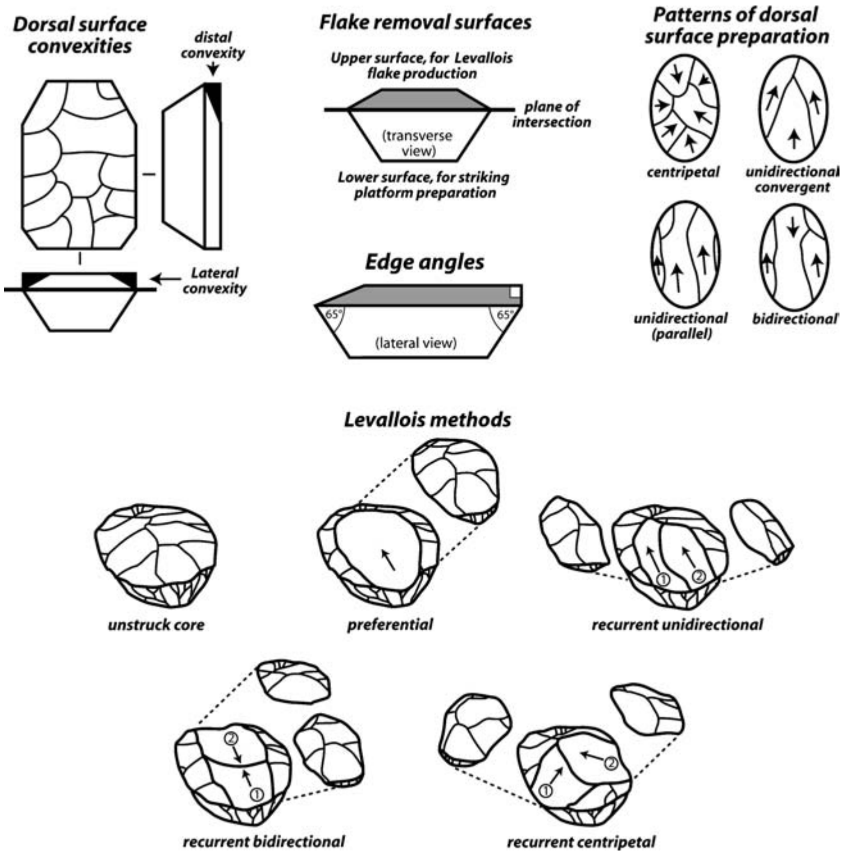

Fig. 2. Schematic illustrations of the Levallois concept. Shown are the location of the lateral and distal core convexities, edge angles, opposed flake removal surfaces, and patterns of upper surface preparatory flake removal. Also shown are the various preferential and recurrent Levallois methods. Drawings after Boëda (1994) and Schlanger (1996).

hammer percussion. The Levallois methods include the preferential method, in which a single flake is removed from each prepared surface, and various recurrent methods, in which a series of Levallois flakes are removed prior to repreparation of the Levallois surface (see Fig. 2). These recurrent methods include the recurrent centripetal, unidirectional, unidirectional convergent, and bidirectional methods (Boëda, 1994; Inizan *et al.*, 1999; Meignen, 1995). Several of these methods may be combined during successive phases of re-preparation of the Levallois surface throughout the reduction of a single core (Baumler, 1988; Texier and Francisco-Ortego, 1995). Although the lack of uniform criteria for the recognition of Levallois flakes is widely recognized (e.g., Copeland, 1995; Perpère, 1986; Van Peer, 1992), factors normally taken into account include the presence of multiple dorsal scars,

Table I. Attribute comparison of Acheulian and Middle Stone Age Levallois Technology from the Kapthurin Formation

Variable	Acheulian Levallois technology (LHA & FS)	EMSA Levallois technology (Koimilot Locus 1 & Locus 2)
Raw material	Selective use of a single type of phonolitic lava	Use of a range of fine-grained lavas
Levallois surface preparation	Centripetal	Centripetal or unidirectional
Technique	Hard hammer direct percussion, hammerstones 200–2,500 g	Hard hammer direct percussion, hammerstones 200–800 g
Method	Preferential	Preferential or recurrent
Flake morphology	Large (∼ 10–20 cm) elliptical flakes	Small (∼ 5 cm) elliptical or large (∼ 10 cm) triangular flakes/points
Flake modification	Either unretouched, ventrally thinned, or laterally retouched with scraper-like edges	none

steeply angled (∼ 90°) multi-facetted striking platforms, regularity of planform and profile, as well as the association with Levallois cores and characteristic flaking by-products.

Our interpretation of the archaeological data was guided by experimental replication of the Acheulian Levallois flakes by one of us (P.-J. T.). Experiments were conducted to determine the feasibility of producing Levallois flakes from locally available raw materials, to gain insights into their manufacture, and to provide a comparative reference for interpreting the archaeological evidence.

Results

Comparisons between Acheulian and early Middle Stone Age (EMSA) Levallois technology from Kapthurin Formation archaeological sites are summarized in Table I, with representative artifacts illustrated in Figs. 3 and 4.

Raw Material

Acheulian Levallois technology from the LHA and FS assemblages shows the use of locally available raw material, and selection of one type of lava. Primary forms include rounded cobbles and boulders derived from conglomerates deposited by ancient streams and rivers whose sources lie in the Tugen Hills to the West (see Fig. 1). There are more than 50 flows of lava with basaltic, trachytic, phonolitic, and intermediate compositions in the Tugen Hills (Chapman, 1971; Chapman *et al.*, 1978; Tallon, 1976). Cobbles and boulders from these flows are found in Kapthurin Formation conglomerates that crop out near all sites discussed here. Despite this variety, >95% of the artifacts from the Acheulian sites of LHA

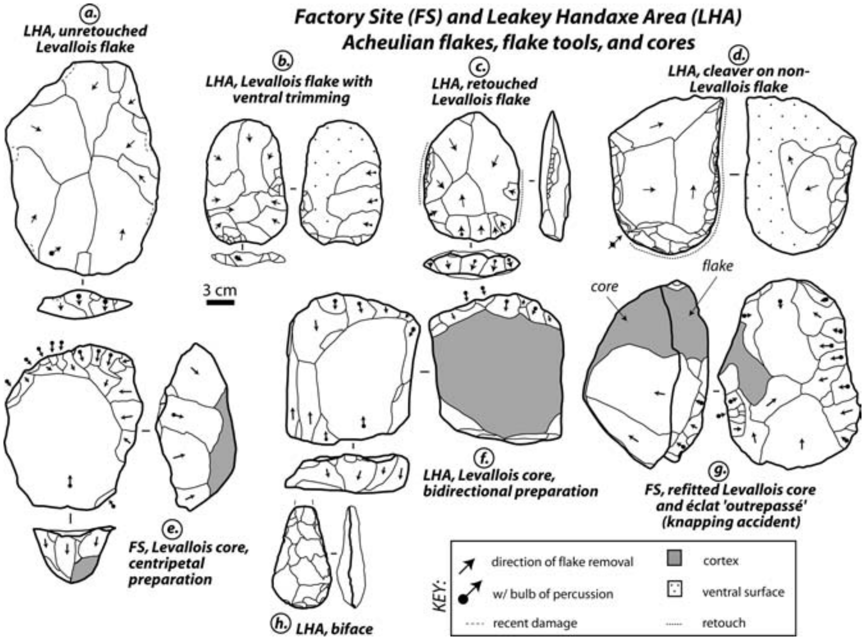

Fig. 3. Acheulian artifacts from the Leakey Handaxe Area (LHA) and the Factory Site (FS).

and FS are made from a single type of fine-grained phonolitic lava (raw material type 3 of Tryon, 2003). This was discovered by examining all Levallois flakes and cores, together with a random sample of complete and refitted flakes from both sites (LHA, $n = 185$; FS, $n = 109$). Examined artifacts represent 15% of all LHA artifacts, and 21% of all FS artifacts presently housed at the National Museums of Kenya, Nairobi.

Early Middle Stone Age Levallois technology from Locus 1 and Locus 2 at Koimilot also show the use of a variety of lava cobbles, procured from local streambeds adjacent to the excavations. However, as in the Kapthurin Formation Acheulian, there was apparent hominin selection of particularly fine-grained lavas for Levallois flake production. At Koimilot, the same fine-grained phonolitic lava that dominates the LHA and FS assemblages represents $\sim$55% of the Locus 1 and $\sim$79% of the Locus 2 lithic artifact totals. However, at least four other varieties of extremely fine-grained lava were used in the manufacture of Levallois flakes at Koimilot, including an aphanitic phonolite that in thin section is similar in texture and grain-size to some European flints. This lava (raw material type 9 of Tryon, 2003) comprises some 30% of the Koimilot Locus 1 lithic assemblage, but <2% of the Locus 2 material.

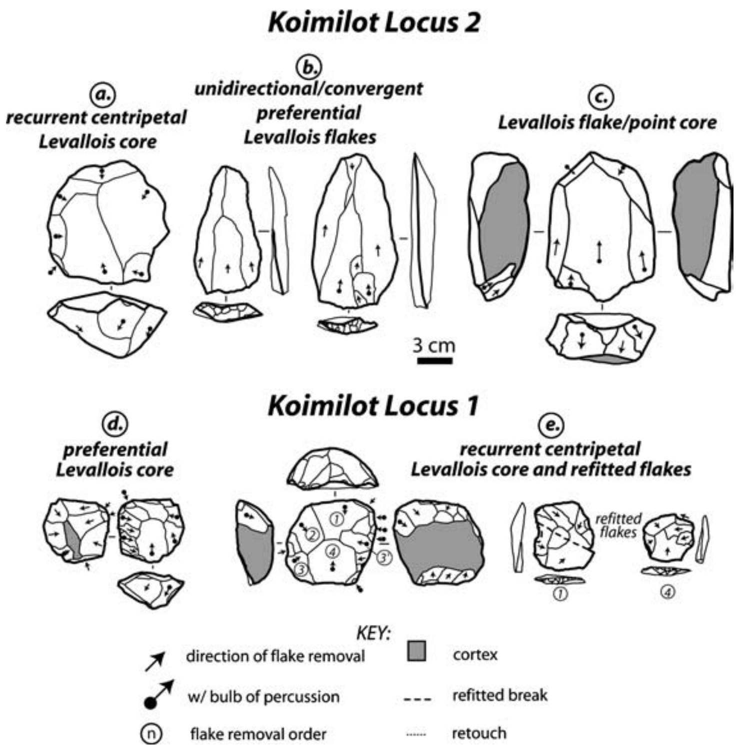

Fig. 4. Middle Stone Age artifacts from Koimilot Locus 1 and Locus 2.

Preparation of the Levallois Surface

Most Kapthurin Formation Acheulian Levallois flakes and cores preserve traces of a centripetal flake removal pattern. Bidirectional flaking was observed on only a single flake and core, the latter on a thin tabular lava boulder, whose form likely dictated the flake removal pattern (see Fig. 3f). Most cobbles and boulders in Kapthurin Formation conglomerates are rounded to sub-rounded in shape. Striking platforms are facetted.

All Levallois flakes and cores at Koimilot Locus 1 show centripetal preparation (Tryon, 2003, 2006a). This pattern of preparation is present at Locus 2 (see Fig. 4a), but the Locus 2 assemblage also contains five elongated Levallois flakes with dorsal scar patterns indicating unidirectional and slightly convergent flaking, some typologically similar to Levallois points (see Fig. 4b). A core that likely produced such flakes was found on the surface ~ 100 m west of Locus 2 at the same approximate stratigraphic level (see Fig. 4c). Together, this core and the Locus 2 flakes suggest the removal of elongated *éclats débordants* (core-edge flakes) from a single platform, shaping the upper core surface and simultaneously maintaining both lateral and distal core convexities (Beyries and Boëda, 1983). Striking platforms are facetted on all Koimilot Levallois flakes.

Flaking Techniques and Methods

The Levallois concept as defined by Tixier (1967) and Boëda (1994) includes only hard hammer direct percussion. Its use is confirmed here by the artifact replication experiments discussed below, and observations of well-defined impact cones on flakes, as well as flake striking platform angles and thicknesses (for discussion of these criteria, see Newcomer, 1971; Ohnuma and Bergman, 1982; Pelegrin, 2000). All Levallois flakes and cores at sites LHA and FS show exclusive use hard hammer direct percussion, and production according to the preferential method. In the preferential method, a single Levallois flake is removed from each prepared flaking surface, which lies parallel to the plane dividing the upper and lower faces of the core. The asymmetry of the two core surfaces and the angle of flake removal are particularly noticeable on two specimens from FS, a Levallois core recovered by Leakey in 1965 and a refitting flake found by McBrearty in 1993 (see Fig. 3g). The flake and core were likely discarded here by their makers due to a knapping accident that resulted in a type of *éclat outrepassé* (overshot flake) that removed the entire upper surface of the core. In the absence of more extensive refits, it remains unclear if successive Levallois flakes were removed from each core. The large sizes of some of the discarded cores (which weigh ~ 3 kg) and the final Levallois flake negatives (~ 13–15 cm in length) suggest that no smaller Levallois flakes were intended.

The hard hammer direct percussion technique was likely used at EMSA Koimilot Locus 1 and Locus 2. This is suggested by striking platform morphology and size, and the presence of three small cobbles that are interpreted as hammerstones. These are of a sufficient size and weight (0.2–0.3 kg) to function as hammers for production of Levallois artifacts, and exhibit localized pitting that appears to represent percussion damage. At Locus 1, Levallois cores and refitted flakes demonstrate the presence of both the preferential and recurrent methods (see Figs. 4d and 4e), the latter resulting in the production of multiple Levallois flakes from each prepared surface. These methods may represent different stages of a single core reduction strategy, as noted above. The symmetry of the elongated triangular flakes from Locus 2 in plan view and in profile, as well as the single large negative on the surface-recovered core (see Figs. 4b and 4c), suggest production by the preferential method.

Levallois Flake Morphology and Modification

Most Acheulian Levallois flakes from LHA and FS are elliptical in plan view, and those from LHA ($n = 18$) range from 10.4 cm to an exceptional 22.8 cm in

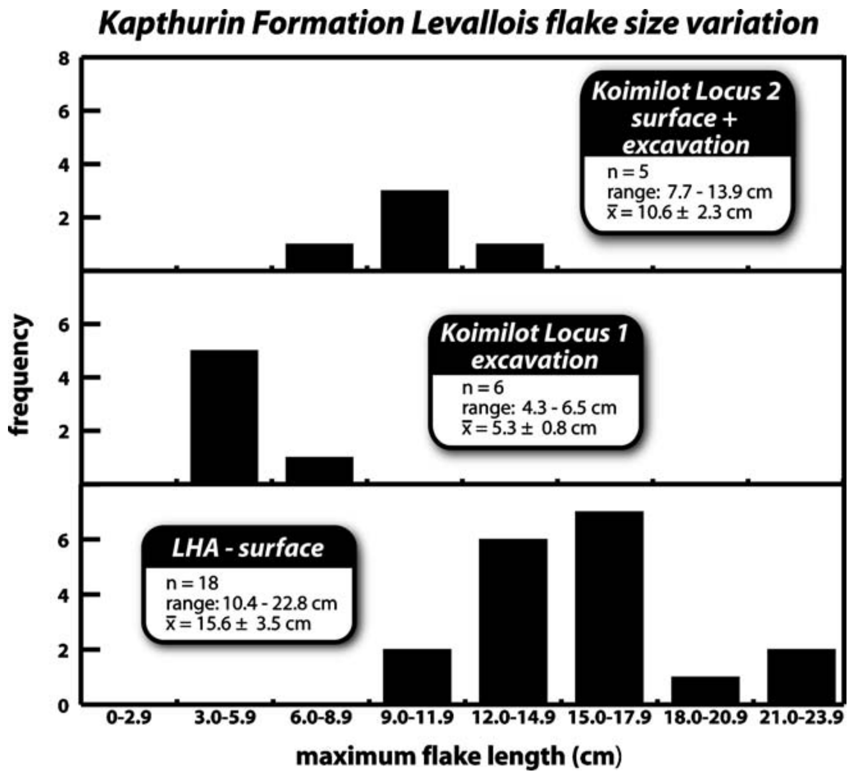

Fig. 5. Comparison of Levallois flake size from three Kapthurin Formation assemblages, shown in stratigraphic order.

length, measured from the striking platform along the axis of percussion (see Fig. 5). Following the definitions of Isaac and Keller (1968), end-struck flakes are defined by width:length ratios <1; side-struck flakes have width:length ratios ≥ 1. All Kapthurin Formation Levallois flakes are end-struck, although a single core from the Factory Site suggests that some side-struck Levallois flakes were produced there. Thus the Kapthurin Formation Acheulian differs from South African Acheulian industries in which side-struck Levallois flakes, typically removed perpendicular to the long axis of the core, predominate (Kuman, 2001; McNabb, 2001; Van Riet Lowe, 1945). The functions of the Kapthurin Formation large Levallois flakes are uncertain, but we recognize three categories of flakes. Examples are illustrated in Fig. 3. They include (1) unretouched flakes, (2) flakes with ventral thinning, and (3) flakes with one or two retouched lateral margins. Unretouched Levallois flakes of the first category (see Fig. 3a) are rare at LHA ($n = 3$). There is only a single known example of the second category; it has multiple flake removals on the ventral surface to thin the bulb of percussion (see Fig. 3b). This specimen may represent the initial stages of biface production, using a Levallois flake as a blank, but testing this hypothesis is difficult. Handaxes and other bifaces from LHA have comparable sizes to the Levallois flakes (10.4 to 17.8 cm, measured along the axis of symmetry), but all of these derive from non-Levallois flakes, have been so extensively flaked such that determining the morphology of the original blank is impossible, or are made on cobbles.

The majority of Levallois flakes from LHA ($n = 14$) belong to the third category, having retouched proximal or medial portions of one or both lateral margins (see Fig. 3c); similar examples occur elsewhere in the Kapthurin Formation, including the site at GnJh-17 (Cornelissen, 1992) and Locality 105 (Tryon, 2003) (see Fig. 1). Following the terminology of Inizan *et al.* (1999), retouch on these specimens is direct (removals limited to the dorsal surface) and short (extending only a few mm from the margin). The distribution of flake removals within the retouched area is continuous, removals are sub-parallel to one another, and the retouched edge is convex and semi-abrupt, with edge angles between 45° and 60°. Distal margins are unretouched, which is a defining characteristic of cleavers (Inizan *et al.*, 1999; Texier and Roche, 1995; Tixier, 1957). Cleavers made on Levallois flakes from northwestern African sites are classified as Type III cleavers of Tixier (1957) and Alimen and Zuate y Zuber (1978), which lack prominent cleaver bits as a result of centripetal preparation. Cleavers with marginal retouch limited to the dorsal surface are termed “cleaver flakes” by Clark and Kleindienst (2001) in their analysis of material from Kalambo Falls, Zambia. Following Clark and Kleindienst (2001) we term the retouched Levallois flakes found at some Kapthurin Formation Acheulian sites “Levallois cleaver flakes.”

Early Middle Stone Age Levallois flakes from Koimilot Locus 1 are small and generally elliptical in plan view, with an average size of ~5.3 cm; those from Locus 2 are larger (~10.6 cm) and more elongated (see Figs. 4 and 5). All Levallois flakes are end-struck. No flakes of any sort at either Koimilot Locus 1 or Locus 2 have been retouched. The function of these pieces is unknown, although some of the elongated flakes from Koimilot Locus 2 are typologically comparable to artifacts identified as Levallois or Levallois-like points at sites in South Africa, the Levant, and Europe (*cf.* Bordes, 1961; Shea, 1997; Wurz, 2002). The possibility that such artifacts were designed to be hafted and used as hunting implements has been much discussed (e.g., Shea, 1997; McBrearty and Brooks, 2000; McBrearty and Tryon, 2005).

Observations from Experimental Replication

Texier conducted experimental replication of the large Levallois flakes recovered from the Acheulian sites of LHA and FS. Initial experiments were aimed at mastering the many variables controlled by the knapper during the production of large Levallois flakes of lava, many of which differ substantially from the manufacture of smaller Levallois flakes of flint. These include the weight and texture of the hammerstone used, the speed and trajectory of the flake-detachment blow, and the geometry and size of the core. Core geometry includes the distal and lateral convexities of the Levallois surface, and the angle and careful isolation of the striking platform, all of which affect the size and shape of the desired flake. The Levallois surface of these large cores was braced against the leg or other support to prevent movement of the piece during knapping, and to control the angle of the striking platform relative to the flake-detachment blow. Subsequent experiments, described below, explored the quality of available raw materials, examined the nature of the techniques used, and provide preliminary data on the nature of the reductive process from raw material selection until final core discard. Locally obtained lava cobbles, boulders, and blocks were used for all experiments. These were procured from the modern channels and ancient conglomerates exposed in the Ndau and Kapthurin Rivers (see Fig. 1). Although a variety of lavas were tested, much of the knapping focused on the phonolitic lava of which nearly all the Kapthurin Formation Levallois artifacts are made (raw material type 3 of Tryon, 2003), and which proved the best in the successful replication of large Levallois flakes.

These experiments confirm the inferences made from artifact observations: hard hammer direct percussion was the exclusive technique used in the manufacture of the Kapthurin Formation large Levallois flakes. However, the experiments also show that it is necessary to use a range of hammerstones of different weights and textures for the production of a single large Levallois flake, according to the variable circumstances and kind of core preparation locally required. Similar results have been described elsewhere for the manufacture of Levallois flakes from flint cores, and the production of a range of lava flakes and tools, including handaxes (*cf.* Boëda and Pelegrin, 1983; Jones, 1994; Newcomer, 1971; Toth, 1997). The particular hammerstone used in large Levallois flake production varied according to the different stages of core reduction, the size and shape of the core and striking platform, and the size of the desired flake removal (*cf.* Dibble and Pelcin, 1995; Pelcin, 1997; Speth, 1981). Four different hammerstones were used here, divided by weight, material, and provenance:

1. Very heavy hammerstone (2,745 g) of basalt (Ndau River, Baringo District, Kenya).
2. Heavy hammerstone (1,626 g) of quartzitic microdiorite (Estérel, France).
3. Medium hammerstone (1,270 g) of quartzitic microdiorite (Estérel, France).
4. Light hammerstone/abrader (169 g) of sandstone (Antibes, France).

Texier's use of basalt cobbles collected from the Ndau River for use in direct percussion establishes the availability of suitably durable material for use as hammerstones in the Kapthurin Formation conglomerates. Further experimentation is necessary to explore the range of local lithologies suitable for use as hammerstones.

The first stage of production includes locating lava boulders of the appropriate size and raw material without major flaws. The "roughing out" stage of the large Levallois core necessitates the use of either a heavy or very heavy hammerstone, according to the size of boulder being worked. This stage is devoted to testing the quality of the raw material and removal of major imperfections, such as cracks of other planes of weaknesses affecting the shape and internal structure of the piece. The starting weight of the boulders or blocks selected for experimental use varied between 15.7 and 19.6 kg. Testing and initial shaping frequently removed up to 60% of the initial weight. Preparing the lateral and distal convexities of the Levallois surface of the core consumed a further ∼30%, and was accomplished using the medium hammerstone. This same hammerstone is also effective for obtaining Levallois flakes that approach ∼15 cm in length and 600 g in weight, the average dimensions for the large Levallois flakes observed in the archaeological assemblages (see Fig. 5). Extrapolating from these experimental results, manufacture of the largest archaeological Levallois flake (∼22.8 cm in length, weighing 1,550 g) would have required a very precise strike against a large core weighing perhaps as much as 8–10 kg, using a hammerstone weighing between 2.5 and 3 kg. In all cases, the light hammerstone/abrader was used in the preparation of the striking platform and the removal of small surface irregularities.

These experiments establish the use of locally available raw materials for the production of Acheulian large Levallois flakes, the substantial reduction of large boulders during their manufacture, and the necessity to use a range of hammerstones for different stages of core preparation. Comparable processes, at smaller scales, likely affected the Koimilot assemblages.

Synthesis and Comparison

Levallois flake production is a shared feature among Acheulian and EMSA sites in the Kapthurin Formation. However, Acheulian and EMSA sites show important differences among most of the technological variables examined here (see Table I). We suggest that many of these differences are driven by a series of interconnected functional demands related to the abandonment of Acheulian large cutting tools and the increased emphasis on flake-based tools characteristic of the Middle Stone Age in general. Extrapolation from usewear analyses of European and Levantine Mousterian artifacts suggests that this may be due to the development of hafting and the creation of composite tools. Direct evidence for hafting is presently lacking from African sites older than ∼100 ka (but see Donahue *et al.*, 2002–2004; Lombard *et al.*, 2004; Yellen, 1998). Basal thinning on points and the presence of backed pieces, however, argues for composite tools in Africa as early as ∼200 ka (Barham, 2001, 2002; Wendorf and Schild, 1993). We identify four primary differences between Acheulian and MSA Levallois technology in the Kapthurin Formation. We interpret these as differences of degree rather than kind, and suggest that MSA Levallois technology in the Kapthurin

Formation is a development from local Acheulian technological antecedents. The explanations for these differences suggested here are best viewed as directions for future research.

1. *Flake size:* Among our limited sample, EMSA Levallois flakes are smaller than Acheulian Levallois flakes (see Fig. 5), although there is considerable variation and some overlap in size between MSA flakes from Koimilot Locus 2 and Acheulian flakes from LHA. EMSA flakes range from 5.3 to 13.9 cm in length as measured from the striking platform along the axis of percussion; Acheulian examples vary from 10.4 to 22.8 cm in length.
2. *Appearance of recurrent methods:* Acheulian Levallois flakes from LHA and FS were produced exclusively by the preferential method, while both preferential and recurrent methods are present in the MSA assemblages from Koimilot. The use of recurrent methods allows for the production of a greater number of Levallois flakes per core, and can be argued to be a more efficient flake production strategy. However, recurrent methods are impractical, if not impossible, for the production of large flakes of the size of those found at the Kapthurin Formation Acheulian sites. The required cores would be too large for the controlled preparatory flaking needed to shape the Levallois surface. The preferential method is likely required if Acheulian Levallois cleaver flakes are the desired end product. The appearance of recurrent methods at MSA sites may thus be related to the need for small flake blanks, rather than to raw material economy.
3. *Raw materials:* Acheulian Levallois flakes were made almost entirely of a single variety of phonolitic lava, whereas the EMSA material shows use of wider range of lavas, some of them finer grained. Comparable shifts to a reliance on fine-grained or vitreous raw materials is a characteristic that has been found to distinguish Acheulian and MSA assemblages at a number of other localities throughout Africa (Clark, 1980, 2001a; Merrick *et al*., 1994; Raynal *et al*., 2001). To an extent, some fine-grained raw materials are better suited to Levallois flake production than others, and they may allow the full expression of the variability inherent in Levallois flake production (Jaubert and Farizy, 1995). However, functional contrasts provide an alternate explanation for the observed differences in raw material. African Acheulian implements are typically made of durable rocks, and are effective for a range of tasks because of their long cutting edges, large sizes, and substantial weights (e.g., Jones, 1994; Noll, 2000). The shift to finer-grained raw materials that hold a sharper edge, seen at MSA sites, may represent a design choice more suitable for the manufacture of smaller, lighter tools. The combination of hafting and sharp edges may compensate for reduced size, although considerable research remains to be done on raw material properties, reasons for the selection

of particular varieties, and the mechanical advantages afforded by hafting (*cf.* Kamminga, 1982; Noll, 2000; Rots, 2003).

4. *Flake shape and retouch*: Acheulian Levallois flakes from LHA are typically elliptical in shape, and have a centripetal pattern of dorsal scars. They may be unretouched, ventrally thinned, or have unifacially retouched lateral margins, with unmodified distal ends, a variant we identify as Levallois cleaver flakes. Early MSA flakes from Koimilot include both elliptical forms, often with centripetal dorsal scars, and elongated, triangular flakes produced by unidirectional and convergent flaking, some of which may be classified as Levallois points. None of the Levallois flakes at Koimilot exhibit retouch. Greater variability in flake shape and the methods of Levallois flake production, combined with the lack of retouch, suggests that the production of flakes with specific shapes that could be used without further modification was the aim of the makers (*cf.* Delagnes, 1991). A similar observation has been made for the convergent flakes and flake-blades characteristic of the Klasies River MSA sequence (Singer and Wymer, 1982; Wurz, 2002).

However, a preliminary analysis of the site of Logumkum (Farrand *et al.*, 1976; Tryon, 2003), located in the Ilosuowani Formation south of Lake Baringo (see Fig. 1), suggests that site function and proximity to lithic raw material sources may also be factors to consider. The MSA assemblage from Logumkum is one of the few in the Baringo region that contains many retouched Levallois flakes. The site lies near the axis of the Rift, whereas all the Kapthurin Formation sites examined here are located near the Rift margin, where coarse clastic deposits provide ready sources of stone raw material. Production sites may thus be spatially segregated from areas of tool use and final discard, resulting in distinct artifact assemblages produced by a single hominin population (*cf.* Geneste, 1989, 1991; Pétrequin and Pétrequin, 1993; Roebroeks *et al.*, 1995). Differences in Acheulian and MSA patterns of tool transport, resharpening, and discard, are central topics for future investigation that can be explored using the widespread tephra deposits of the Kapthurin Formation as a means of correlation among sites (Tryon, 2003; Tryon and McBrearty, 2002; Tryon and McBrearty, 2006).

DISCUSSION

Evidence from two Kapthurin Formation Acheulian sites, the Leakey Handaxe Area and the Factory Site, show the production of large end-struck Levallois blanks by the preferential method from boulder-sized cores of phonolitic lava shaped by centripetal flaking. Flake production conforms to the Levallois concept as defined by Boëda (1994) in terms of exploitation of a single Levallois flake production surface, maintenance of core surface convexities, angle of flake removal, and use of hard hammer direct percussion. Although some may have served as blanks for biface manufacture, most Acheulian Levallois flakes were modified by unifacial retouch on one or both lateral margins. In these latter examples, no flakes of any size are removed from either the distal end or ventral surface. These tools, which we classify as Levallois cleaver flakes, are a distinguishing feature of the Kapthurin Formation Acheulian. Similar methods of manufacture and retouch are reported from late Acheulian contexts at Kalambo Falls, Zambia (Clark and Kleindienst, 2001), from several sites in Ethiopia, including those at Arba and in the Upper Herto Member of the Bouri Formation (Clark *et al.*, 2003; Kurashina, 1978; Schick and Clark, 2003) (see Fig. 6). Comparable artifacts have also been described from surface contexts in Algeria (Alimen and Zuate y Zuber, 1978). Otherwise, large retouched Levallois flakes are not commonly reported from African Acheulian sites. They co-occur at the Leakey Handaxe Area (LHA) in the Kapthurin Formation with other typical African large cutting tools (LCTs), including handaxes and more extensively retouched cleavers on non-Levallois blanks (see Fig. 3d and 3h). In general, the Kapthurin Formation Acheulian Levallois flakes and cleaver flakes are similar to other African LCTs in terms of shape and size, but serve to highlight the diversity within the late Acheulian large cutting tool category, as recently emphasized by Clark (2001b; Clark and Kleindienst, 2001; see also Gowlett and Crompton, 1994: 28–39).

These observations are consistent with evidence from other African sites indicating that Levallois technology is a late or final Acheulian phenomenon dating to the later portions of the Middle Pleistocene (see Fig. 6). Within the Atlantic coastal Moroccan sequence, Levallois production of handaxe and cleaver blanks is described from Biberson's (1961) "Middle Acheulian," now dated to ~300–350 ka by bracketing ESR age estimates at the Grotte des Rhinocéros and by OSL at Cap Chatelier (Raynal *et al.*, 2001; Rhodes *et al.*, 1994). A similar age is estimated for rare examples of handaxes transformed into Levallois or Levallois-like cores from the mound-spring site of KO10 at Kharga Oasis, where U-series dates on tufa of ~300–400 ka are reported (Caton-Thompson, 1946, 1952; Churcher *et al.*, 1999; Smith *et al.*, 2004). $^{40}Ar/^{39}Ar$ dates indicate a minimum age of 157 ka for handaxes and cleavers made on Levallois flakes from the Upper and Lower Herto Members of the Bouri Formation in the Middle Awash of Ethiopia, apparently associated with fossils attributed to *Homo sapiens* (de Heinzelin *et al.*, 2000; Clark *et al.*, 2003). South African sites with large Levallois cores such as the Cave of Hearths, as well as Canteen Koppie, site DB3 and others in the Vaal River basin remain undated, although fauna from the uppermost Acheulian levels at the Cave of Hearths is consistent with a late Middle Pleistocene age (Mason, 1988; McNabb, 2001; Kuman, 2001; Van Riet Lowe, 1945; Vrba, 1982). Neither the large Levallois cores and associated handaxes from Hargesia, Somalia (Clark, 1954), nor the large Levallois flakes and cores from Kamoa, Democratic Republic

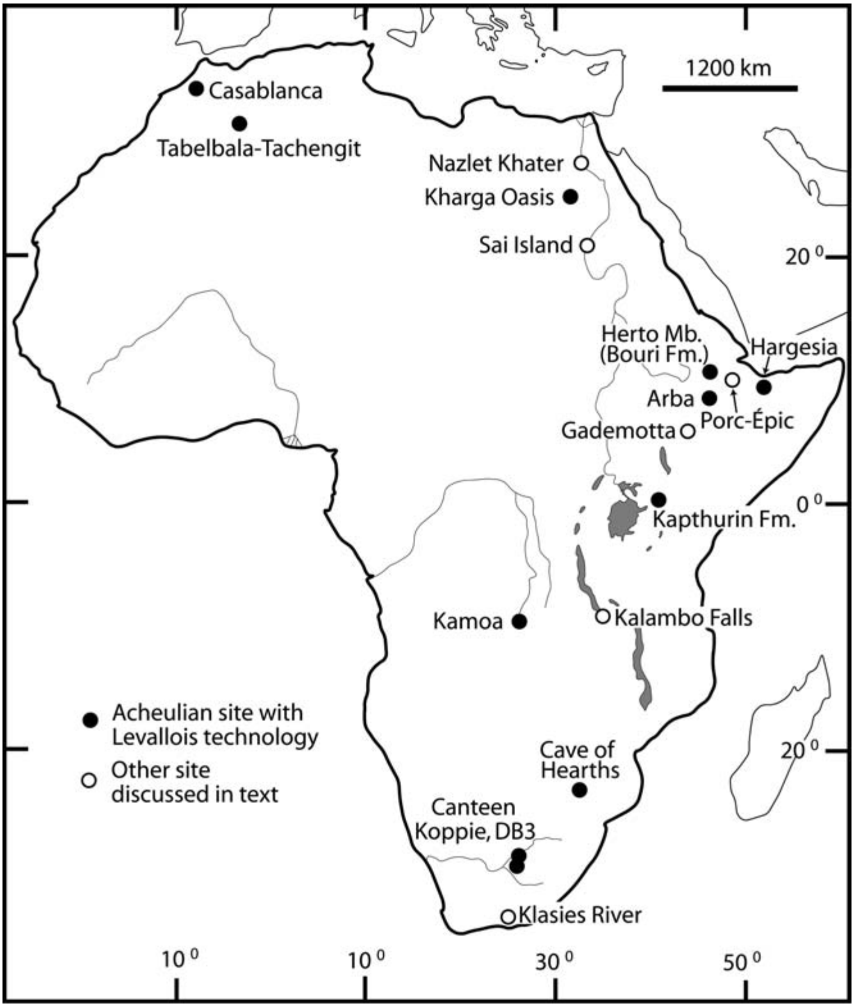

Fig. 6. Schematic map showing key African archaeological sites with Levallois technology.

of the Congo, have been dated. Many of the latter have been transformed into cleavers (Cahen, 1975).

The Tabelbala–Tachengit method appears limited to the northwestern Sahara, where it is used to produce cleavers of a very specific shape from centripetally prepared specialized Levallois cores (Alimen and Zuate y Zuber, 1978; Clark, 2001b; Tixier, 1957). Similarly, the almond-shaped, side-struck *hoenderbek* cores and distinctive flakes of the Victoria West industry that may have served as naturally backed knives, are characteristic of southern Africa (Cahen, 1975; Kuman, 2001;

McNabb, 2001; Van Riet Lowe, 1945). The regional differences in African Acheulian methods of Levallois flake production outlined here are important, because geographically distinct traditions of artifact manufacture are generally thought to have appeared in the Middle Stone Age (Clark, 1988).

In the Early Middle Stone Age (EMSA) Levallois technology found at Locus 1 and Locus 2 at Koimilot in the Kapthurin Formation, Levallois flakes of various sizes and shapes were struck from prepared cobbles of a range of fine-grained lavas, using both the preferential and recurrent methods. At Locus 1, small elliptical Levallois flakes were struck from centripetally prepared cores; the Locus 2 material includes larger elongated, triangular Levallois flakes or points that show unidirectional and convergent preparatory flaking. No flakes were retouched at Koimilot.

The variation in Levallois technology from Koimilot is important in part because it dates to ~200–250 ka. Such variability is rarely documented in Africa at sites older than 130 ka (see Fig. 6). The MSA levels at Klasies River, South Africa, for example, characterized by recurrent unidirectional Levallois flake, blade, and point production, and rare preferential centripetally prepared Levallois cores, are dated to ~60–115 ka by a variety of methods (Singer and Wymer, 1982; Vogel, 2001; Wurz, 2002). Similarly, MSA deposits from Porc-Épic Cave, Ethiopia, contain evidence for a variety of flake, blade, and point production methods, including centripetally prepared recurrent and preferential Levallois cores. These deposits have been dated to >61–77 ka on the basis of obsidian hydration (Clark *et al.*, 1984; Perlès, 1974; Pleurdeau, 2003). The sites at Nazlet Khater, Egypt, where Van Peer (1992, 1998) describes preferential Levallois flakes struck from centripetally prepared cores as well as point production from specialized Nubian Levallois cores, are dated to the Late Pleistocene on geomorphological grounds. A greater age is indicated for MSA sites at Gademotta near Lake Ziway, Ethiopia, where prior K/Ar age estimates of >180 ka have been revised to >235 ka (Wendorf and Schild, 1974; Wendorf *et al.*, 1975, 1994). Multiple Levallois approaches for flake and point production are likely present at site ETH-8-B at Gademotta, although this assemblage requires reanalysis in light of recent ideas concerning the nature of Levallois technology. Brief preliminary reports suggest the presence of recurrent and preferential Levallois cores at a similar time depth at site REF-4 at Kharga Oasis, Egypt, in assemblages underlying a tufa dated by U-Series to 220 ± 20 ka (Hawkins *et al.*, 2001).

Our understanding of patterns of lithic technology predating 130 ka remains limited by the rarity of sites of this age and by their poor documentation. Increased sample sizes are required to determine whether the Koimilot succession of flakes from centripetally prepared cores overlain by Levallois point-like triangular flakes with unidirectional/convergent preparation mark a true temporal trend in local MSA Levallois technology. The large triangular flakes at Locus 2 in particular hint at the presence of a locally distinct tradition of flake manufacture at the onset of the MSA. If confirmed, this has important implications for better defining the timing and nature of post-Acheulian regionalization, which is presently defined largely on the basis of retouched point styles (Clark, 1988, 1993; McBrearty and Brooks, 2000).

The analysis of Acheulian and MSA Levallois technology presented here complements our prior research on the Acheulian-MSA transition in the Kapthurin Formation, which has focused on the sequence of diagnostic tool types (e.g., handaxes, cleavers, and points). Sites containing diagnostic tools have been ordered stratigraphically on the basis of tephra correlation (McBrearty, 2001; McBrearty and Tryon, 2005; Tryon, 2003, 2006a; Tryon and McBrearty, 2002; Tryon and McBrearty, 2006). Our cumulative results may now be summarized as follows. (1) The earliest points date to >284 ka. (2) As described here, Levallois technology has an Acheulian origin. MSA variants are an elaboration of local technological antecedents. (3) Retouched points and Levallois flake production, elements that typically define MSA lithic technology, do no co-occur in all Kapthurin Formation MSA assemblages. (4) Handaxe and cleaver production persists after the introduction of points. These observations suggest that aspects considered the hallmarks of the MSA, including formal tools such as points, and the means of flake production, including Levallois methods, represent two independent elements of hominin tool-assisted adaptive behavior, each having its own distinct history of development (e.g., Boëda, 1991; Goren-Inbar and Belfer-Cohen, 1998). The Kapthurin Formation evidence also illustrates the methodological challenge in pinning down the precise timing of the Acheulian to Middle Stone Age transition, which we view as a process rather than an event. Our results suggest a mosaic or incremental pattern of change, and possibly, the geographic and temporal overlap of distinct artifact industries within a single depositional basin (*cf.* Chase and Dibble, 1990; Clark, 1999; McBrearty *et al.*, 1996). Similar spatial and chronological overlap among Acheulian and post-Acheulian industries has also been reported from assemblages on Sai Island, in the Nile Valley of Sudan, dated by OSL on sand to between 182 ± 20 and 223 ± 19 ka (Van Peer *et al.*, 2003, 2004).

The data from the Kapthurin Formation and Sai Island are important because major unconformities separate Acheulian and MSA levels at all other published sites where they occur in stratigraphic superposition, particularly in northern and southern Africa. These gaps render difficult any broader understanding of change at the end of the Acheulian, including the processes of diversification in Levallois technology. The unconformities may represent substantial portions of time and the obliteration of large portions of the archaeological record. Alternatively, as suggested by Marean and Assefa (2005; see also Deacon and Thackeray, 1984; Lahr and Foley, 1998; McBrearty and Brooks, 2000) the stratigraphic breaks between Acheulian and MSA levels may indicate periods of local abandonment and repopulation of these regions as a result of changing climatic conditions. Marean and Assefa (2005) note that in areas such as southern and northern Africa that may have become uninhabitable during cold, arid, glacial intervals, technological change is more likely to take form of replacement rather than *in situ* evolution, which they suggest to be more likely in areas of continuous hominin occupation such as equatorial eastern Africa or locations of perennial water availability such as the Nile Vally. The Kapthurin Formation archaeological record is consistent with an interpretation of persistent hominin occupation throughout much of the Middle Pleistocene, but confirmation of this hypothesis requires significantly more detailed reconstructions of local paleoenvironmental conditions, which are largely lacking for the late Middle Pleistocene in Africa.

CONCLUSION

The earliest examples of Levallois technology in the Kapthurin Formation of Kenya are found at two Acheulian sites, the Leakey Handaxe Area (LHA) and the Factory Site (FS), both dated to between ∼284 and 509 ka. At these sites, large (∼10–20 cm) Levallois flakes were struck from boulder cores. Many of these flakes were subsequently retouched on one or both lateral margins to form variants of Acheulian large cutting tools that we classify as Levallois cleaver flakes. Overlying assemblages from Koimilot, dating to ∼200–250 ka, show evidence for multiple production methods of Levallois flakes of various shapes that appear not to have been retouched on site. The Koimilot assemblages are important in demonstrating variation within Levallois technology at an early MSA site. Temporal changes among the Levallois assemblages studied here are likely to form part of a technological continuum that spans the Acheulian-MSA transition. MSA Levallois technology differs from that of the Acheulian in (1) the reduction in flake size, (2) increased variation in flake shape though different core preparation approaches, (3) the appearance of recurrent Levallois methods, (4) the selection of a range of finer-grained raw materials, and (5) the absence of retouch. Flakes may well have been retouched, however, if transported to locations farther from sources of lithic raw material. We interpret all these differences to reflect an increased emphasis on smaller flaked-based tools in the Middle Stone Age.

Levallois technology was clearly practiced by hominins not only in Africa, but also in the Levant, England, and continental Europe, where is first appears between 250 and 500 ka (DeBono and Goren-Inbar, 2001; Rink *et al.*, 2004; Tuffreau, 1995, 2004; Tuffreau *et al.*, 1997; White and Ashton, 2003). At this point we can only speculate as to where and why Levallois technology originated, and whether it was invented once or many times (*cf.* Foley and Lahr, 1997; Rolland, 1995). We suggest that large Levallois flake production derives from existing traditions of large flake manufacture characteristic of the Acheulian wherever durable raw materials are available as large boulders or blocks (e.g., Clark, 1980; Isaac, 1969; Petraglia *et al.*, 1999; Santonja and Villa, 1990; Saragusti and Goren-Inbar, 2001; Villa, 1981). We further postulate that cleavers in particular, by definition flake-based tools that may require careful preparation of the core to obtain large unretouched bits, are a likely candidate for the technological origin of Levallois methods of flake production in the African Acheulian. Whatever the reason for its invention, Levallois technology is likely to have been widely adopted because it provides the means to produce quantities of large, regularly shaped, relatively thin flakes, each bearing a substantial length of cutting edge. At European Middle Paleolithic sites, Levallois flakes were routinely selected for long-distance transport, suggesting that they represent an element of economizing behavior among highly mobile foraging populations (e.g., Brantingham and Kuhn, 2001; Dibble, 1997; Geneste, 1991; White and Pettitt, 1995). Similar studies need now be conducted for the African Middle Stone Age.

Our emphasis here has been upon differences in how Levallois flakes and flake-tools were manufactured. Ultimately, stone tools are adaptive devices, and it is how they were used and where they were discarded, rather than how they were made, that may prove a better reflection of changes in hominin behavior during the later Middle Pleistocene. The appearance of Levallois technology is a salient feature of the late Acheulian, and is important because of the otherwise sparse evidence of temporal change within the Acheulian. It may be significant that the period that witnessed the earliest appearance of Levallois technology, $\sim$250–500 ka, has been described as one of marked climatic instability. In Africa, this period witnesses the emergence of the modern suite of mammalian fauna, including species characterized by great habitat and dietary flexibility (Haradon, 2005; Potts, 1998, 2001). Further exploration of the causal links between environmental change, the emergence of Levallois technology, and increases in foraging range and resource breadth, is essential to clarify the archaeological and behavioral signature of early *Homo sapiens*. The mosaic and incremental nature of lithic technological change seen in the Kapthurin Formation suggests that the suite of behaviors practiced by Middle Stone Age hominins was the outcome of a number of adaptations and a result of long term evolutionary processes, rather than a single, punctuated event.

ACKNOWLEDGMENTS

Tryon's research was supported by a post-doctoral fellowship from the Fyssen Foundation (Paris), and the Smithsonian Institution (Human Origins Program, National Museum of Natural History), and dissertation improvement grants from the US National Science Foundation (BCS-0118345), the Wenner-Gren Foundation, the Leakey Foundation, the University of Connecticut Research Foundation, and the Bill Bishop Memorial Trust. McBrearty and Texier were supported by grants to McBrearty by the US National Science Foundation (BCS-0217728 and SBR-9601419). All field research at Koimilot was conducted under research permit MOEST 13/001/30C 229 from the Government of the Republic of Kenya, and an exploration and excavation license from the Kenyan Minister for Heritage and Sports, both issued to Tryon. McBrearty and Texier operated under a research permit (OP/13/001/C1391/1) and excavation license issued to Andrew Hill, as did Tryon during early stages of the project. We thank Andrew Hill, Rhonda Kauffman, Rick Potts and Hélène Roche for their comments and encouragement.

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