

Environment and Behavior of 2.5-Million-Year-Old Bouri Hominids

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The Hata Member of the Bouri Formation is defined for Pliocene sedimentary outcrops in the Middle Awash Valley, Ethiopia. The Hata Member is dated to 2.5 million years ago and has produced a new species of *Australopithecus* and hominid postcranial remains not currently assigned to species. Spatially associated zooarchaeological remains show that hominids acquired meat and marrow by 2.5 million years ago and that they are the near contemporary of Oldowan artifacts at nearby Gona. The combined evidence suggests that behavioral changes associated with lithic technology and enhanced carnivory may have been coincident with the emergence of the *Homo* clade from *Australopithecus afarensis* in eastern Africa.

Paleoanthropological research in the Middle Awash study area has revealed a hominid-bearing succession spanning the past 6 million years. The African hominid record is particularly ample from 3.0 to 4.0 million years ago (Ma). Numerous fossils of *Australopithecus afarensis*, which is widely thought to be ancestral to *Homo*, have been recovered from both the Middle Awash and other sites in Ethiopia, Kenya, Tanzania, and possibly Chad. Abundant *A. africanus* fossils are now available from 2.0- to 3.0-million-year-old cave deposits in South Africa. However, the east African record is relatively sparse for this same time period—one that witnessed the emergence of lithic technology and *Homo*. Asfaw *et al.* describe the discovery of 2.5-million-year-old hominids from Bouri in a companion paper (1). Here, we describe behavioral and environmental evidence demonstrating that early hominids used stone tools to butcher large mammal carcasses in an open lake margin habitat, and we also provide a stratigraphic context.

Active tectonics in the southern Afar triangle

have shifted depocenters and drainages throughout the Plio-Pleistocene, creating a variety of habitats for hominid occupation and subsequently uplifting ancient sediments to modern erosional surfaces. The Bouri peninsula (Fig. 1) is a tilted fault block transverse (NNW-SSE) to the Quaternary rift zone (NNE-SSW) of the southern Afar. This horst diverts the modern Awash River southward, toward the Ayelu Mountain, forming a partial dam for modern Yardi Lake. The Bouri horst resulted from multiple, closely spaced normal faults that formed a series of segmented half grabens tilted at 5° to 10° to the southwest. The parallel transverse faults are long (>20 km), dip steeply, and produce 50-m-high scarps that step eastward. These faults represent an accommodation zone [for example, (2)] that is apparent laterally but has been terminated centrally by recent major axial faults and buried under pyroclastic and lava flows from the Ayelu silicic and the adjacent basaltic shield volcanoes.

Kalb (3) followed Taieb's pioneering 1960s work in the Middle Awash. He mapped and described Bouri sediments as late middle Pleistocene, part of what he named the Wehaietu Formation. In this formation, Kalb *et al.* (3) described the Dakanihylo Member as succeeding the Bodo Member. The latter yielded the ~0.6-Ma Bodo hominid cranium in 1976, east of the modern Awash (4, 5). Our subsequent work has demonstrated that the geological situation at Bouri is considerably more complex. The Daka Member (abbreviation of Dakanihylo), which contains early Acheulean artifacts, is older, not younger, than the middle Pleistocene Bodo deposits (4, 5). Furthermore, at Bouri, this member is unconformably atop the previously unrecognized faunal, archaeological, and hominid-bearing Hata Member (abbreviation of Hatayae) that dates to 2.5 Ma. Stratigraphic fieldwork, biochronological analysis of

collected faunas, assessment of archaeological remains, and radioisotopic dating of interbedded volcanic strata demonstrate that at least three discrete sedimentary packages spanning >2.5 million years crop out in the Bouri region. We name this succession the Bouri Formation, comprising three members with a combined thickness of ~80 m.

The youngest member of the Bouri Formation is the Herto Member, confined to the southwestern part of the Bouri horst. This member comprises ~15 m of silty clay, lacustrine limestone, beach sand with bentonite clasts, paleosols, and cross-bedded pumiceous sandstone. This member contains late Acheulean/Middle Stone Age artifacts, fauna, and hominid fossils. It has not yet been radioisotopically dated.

The underlying Daka Member contacts the Herto Member across a fault through the middle part of the Bouri horst (Fig. 1). The Daka Member is ~30 m thick and generally confined to the southern half of the Bouri horst. Its basal fluvial deposit is cross-bedded pumiceous sandstone named the Hereya Pumice unit (HPU) (Hereya is Afar for "warthog"), a horizon dated to ~1.0 Ma. The Daka Member contains early Acheulean artifacts, fauna, and hominids.

Most lithostratigraphic units of the Bouri horst are Pliocene and belong to the underlying Hata Member. At its type locality (10°15.5792'N, 40°34.0735'E), this member comprises ~40 m of variegated silty clay and paleosols, zeolitic and bentonitic tuffs, pedogenic carbonates, sandstone with bivalve and gastropod shells, and mudstone. These units were mostly deposited by fluvial processes associated with floodplains along distributary deltaic channels close to a shallow fluctuating lake. Only the upper contact of the Hata Member is exposed; the base of the formation is buried by the modern Awash River's alluvial plain.

Three volcanic units of variable thickness were identified in the Hata type section. The most prominent is the Maoleem Vitric Tuff (MOVT) (Maoleem is Afar for "dragonfly") (Fig. 1). The relative scarcity of channel sand and the absence of shell beds in immediately superposed sediments indicate that it was deposited on flats surrounding the shallow lake. The MOVT is a yellow-green zeolitic tuff ~1 m thick. It contains patches of partially altered vitric material. It is exposed along strike for ~10 km and is mostly vitric in the northern part of the horst. A 6-cm diatomaceous tuff and a pinkish bentonitic tuff (4 cm thick) with abundant accretionary lapilli crop out at ~14 and 18 m above the MOVT, respectively. Both tuff layers are localized and discontinuous, are devoid of volcanic glass, and contain abundant Miocene feldspar xenocrysts. The upper Hata Member comprises poorly cemented yellow sandstone and dark-gray mudstone with bivalve fossils. This is capped by a 25-cm-thick, mas-

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sive yellowish-orange pedogenic carbonate marking a major angular unconformity. Biochronological evidence indicates that the hominid-bearing sedimentary units ~9 km north of the type Hata section at Esa Dibo [Bouri Vertebrate Paleontological locality 17 (BOU-VP-17)] are roughly contemporary.

The antiquity of Hata Member sediments has been established with radioisotopic dating, paleomagnetic determinations, and biochronology. Sixty-six sanidine grains from the MOVT were analyzed individually with laser-total-fusion $^{40}\text{Ar}/^{39}\text{Ar}$ methods (6). Three grains were xenocrysts and yielded ages of 7 to 8 Ma. The remainder yielded mutually indistinguishable ages, whose weighted mean is 2.496 ± 0.008 Ma, based on 27.84 Ma for the Fish Canyon sanidine standard (7).

Magnetostratigraphic data were obtained from 21 samples from a 24-m interval bracketing the MOVT [methods in (6)] (Fig. 1). Thermal demagnetization was performed in 12 to 15 steps per sample. Samples from this interval (Fig. 1) show normal polarity overprints residing in goethite at low temperatures, but reverse

polarity directions are shown above 350°C.

The age of ~2.5 Ma for the MOVT clearly identifies its reverse polarity as belonging to the Matuyama Chron [for example, (8)]. The absence of normal polarities below the MOVT indicates that the exposed 10.9-m Hata section below the MOVT is younger than the Gauss/Matuyama polarity transition, which is dated to 2.6 Ma. These observations indicate that the sub-MOVT stratigraphic interval represents ~100,000 years and, therefore, a sediment accumulation rate greater than 10.9 cm per 1000 years. The similarity of lithologies, lack of unconformities, and reversed polarities above the MOVT indicate that sedimentation rates above the MOVT were comparable to those below and therefore that the archeological, hominid, and faunal remains within 5 m above this tuff are likely to be no younger than 2.45 Ma (9).

Biochronological placement of the Hata Member fauna is in full accordance with the chronometric dating, paleomagnetic determinations, and sedimentological data. The presence of the bovids *Tragelaphus pricei*, *Beatragus*

whitei, and *Damaliscus adamasui* and the suids *Metridiochoerus andrewsi* and *Kolpochoerus limnetes*, all sensitive time indicators, provides further temporal correlation with Shungura Formation (southern Ethiopia) members C to E.

We collected >400 vertebrate fossil specimens from the Hata Member (Table 1). Almost all of these come from within 3 m of the MOVT; most were found immediately above this unit. This assemblage largely reflects a mixture of grazers and water-dependent forms, which is broadly typical of later hominid-bearing Plio-Pleistocene occurrences and consistent with the sedimentological interpretation of the deposits as primarily lake marginal. Alcelaphine bovids are abundant and diverse. All indicators point to a broad featureless margin of a shallow freshwater lake. Minor changes in lake level, which were brought about by fluctuating water input, would probably have maintained broad grassy plains leading to the water's edge. As discussed below, hominids were active on this landscape.

Nearly contemporary deposits at Gona, only 96 km to the north, produced abundant surface

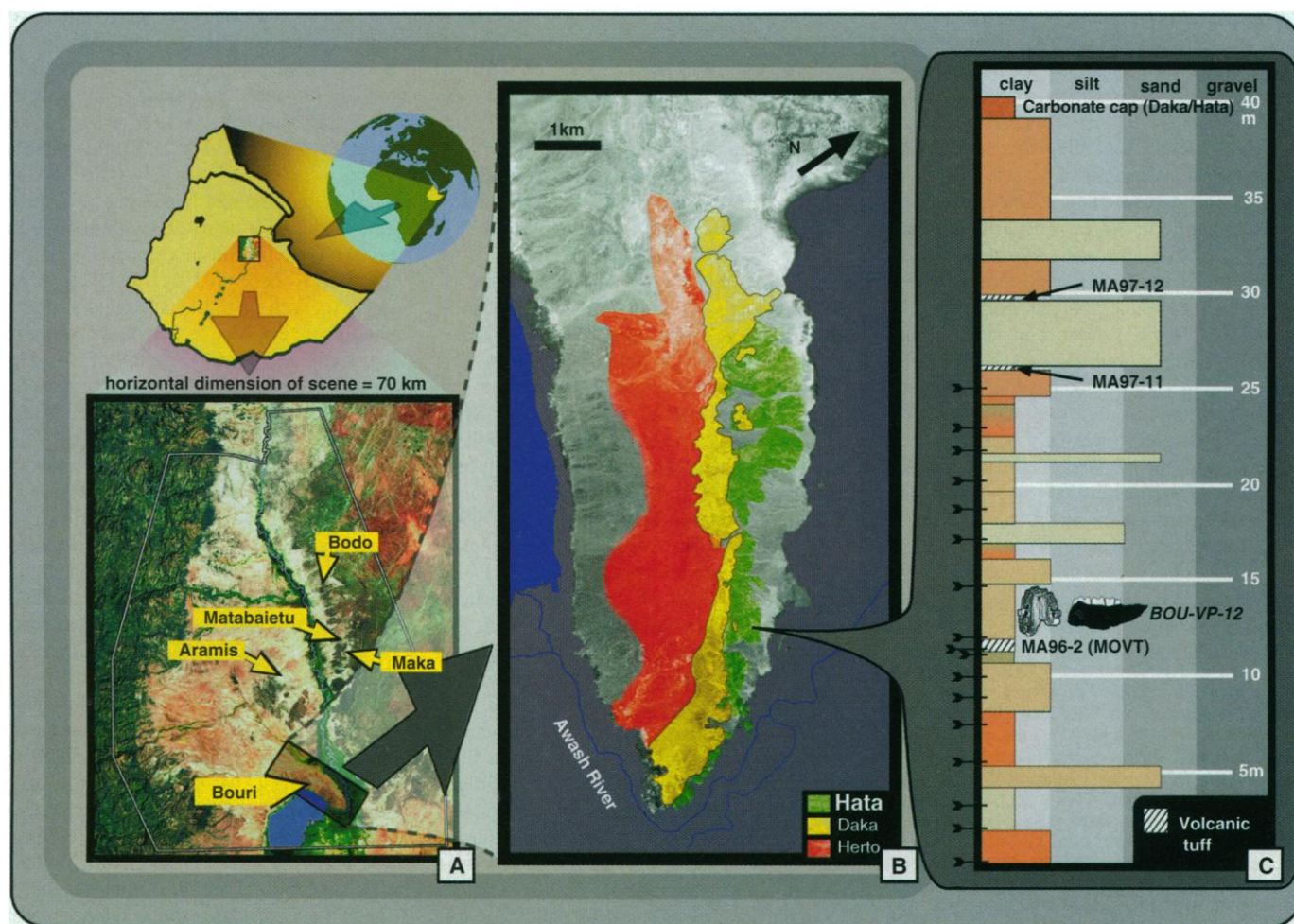


Fig. 1. Geography and geology of the Bouri peninsula. (A) Landsat Thematic Mapper image showing the study area's most important fossil hominid localities. (B) Air photograph mosaic of the Bouri peninsula overlain by a geological map of the three members of the Bouri Formation. Faults are not

shown at this scale, for clarity. (C) Stratigraphic column at the type locality of the Hata Member, showing the placement of the radiometrically dated MOV and other volcanic markers (MA year, sample number), paleomagnetic sample locations (left arrows), hominid fossils, and hominid-modified bones.

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and in situ 2.6-Ma Oldowan artifacts (10). In contrast, surveys and excavations of the Hata beds have so far failed to reveal concentrations of stone artifacts. Rare, isolated, widely scattered cores and flakes of Mode I technology appearing to have eroded from the Hata beds have been encountered during our surveys. Most of these surface occurrences are single pieces. Where excavations have been undertaken, no further artifacts have been found. However, our surveys and excavations have demonstrated that early hominids were actively using stone tools on the Pliocene Hata landscape. It is not currently possible to positively identify the creators of the earliest stone tools here or at Gona, even though *A. garhi* is currently the only recognized hominid taxon recovered from Hata sediments (1).

The first indication of hominid tool use in Hata times came during surface collection and

excavation at the BOU-VP-12/1 partial skeleton locality (1), within 1 m above the MOVT. Here, several pieces of mammalian bone showed cut marks and percussion marks made by stone tools. Excavation revealed the left mandible of a medium-sized alcelaphine bovid with three successive, curvilinear striae on its posteromedial surface; these striae are unambiguous cut marks made by a sharp stone flake, presumably during tongue removal (Fig. 2). At the same stratigraphic horizon 195.7 m to the south, fragments of a large bovid's tibia were found eroding from the surface. Reassembly across post-fossilization breaks showed a robust tibial midshaft segment without articular ends and with ancient fractures at both ends. The shaft bears cut marks, chop marks, and several diagnostic hammerstone impact scars on the external surface, as well as inner conchoidal scars proximally (Fig. 2). Further excavation at that locality resulted in

the recovery of a fairly intact, in situ *Hipparion* (three-toed horse) femur 1 m from the tibia. The femur bears stone-tool cut marks indicative of dismemberment and filleting. Our identification of these bone modifications follows procedures outlined elsewhere (11).

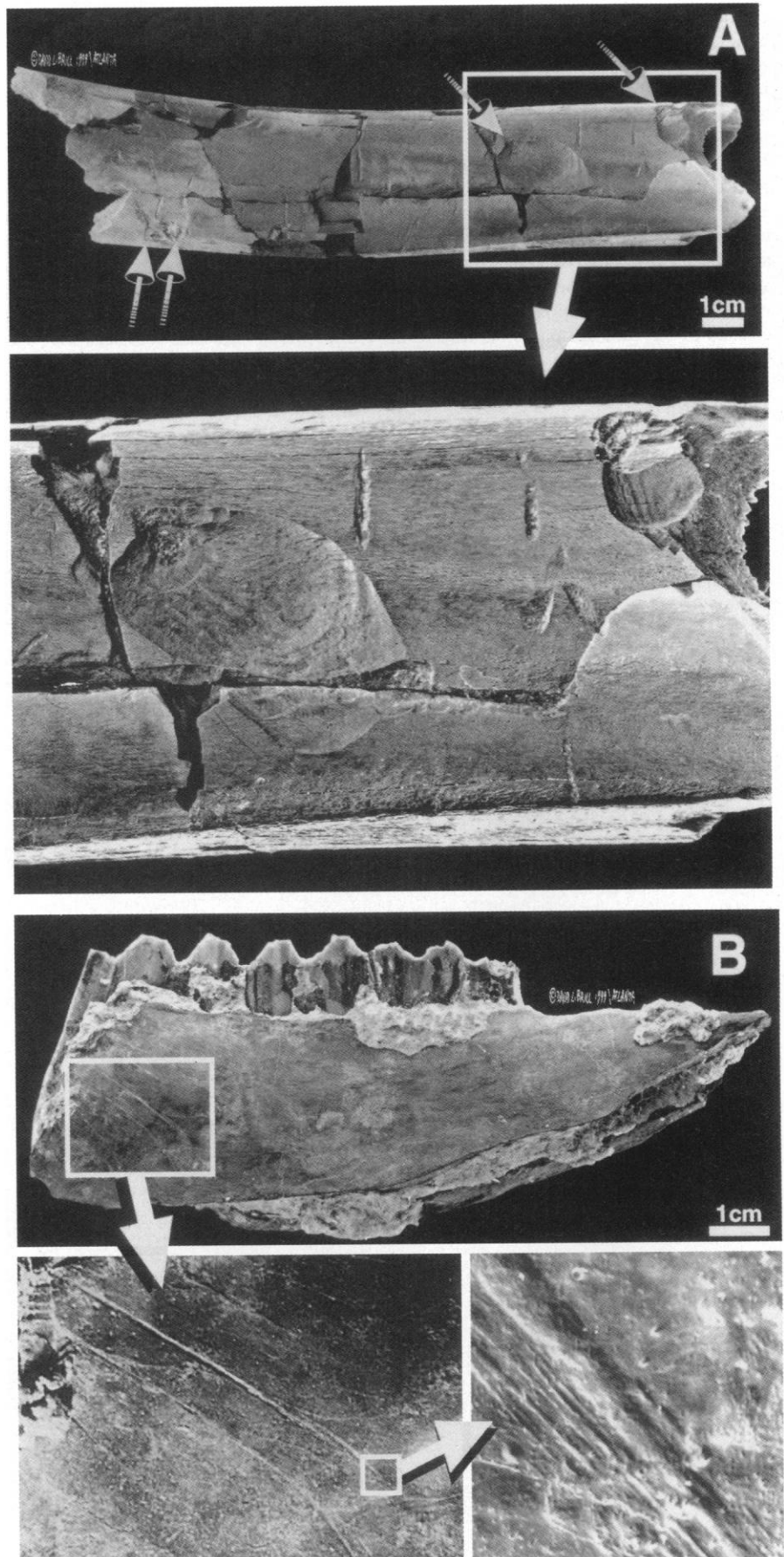
The bone modifications at these two excavated localities and at other localities from the same stratigraphic horizon across >2 km of outcrop demonstrate that stone tool-wielding hominids were active on the lake margin at 2.5 Ma. The bone modifications indicate that large mammals were disarticulated and defleshed and that their long bones were broken open, presumably to extract marrow, a new food in hominid evolution with important physiological, evolutionary, and behavioral effects. Similar patterns of marrow acquisition have been reported for younger sites such as Koobi Fora and Olduvai Gorge (12).

Table 1. Faunal list for the Hata Member, Bouri Formation.

Class	Order	Family	Tribe	Genus	Species
Aves					
Reptilia	Lacertilia				
	Crocodylia				
	Chelonia				
Osteichthyes	Siluriformes	Clariidae			
Mammalia	Artiodactyla	Bovidae	Aepycerotini	<i>Aepyceros</i>	
			Alcelaphini	<i>Beatragus</i>	<i>whitei</i>
				cf. <i>Numidocapra</i>	<i>crassicornis</i>
				cf. <i>Rabaticeras</i>	<i>arambourgi</i>
				<i>Connochaetes</i>	<i>gentryi</i>
				<i>Damaliscus</i>	<i>ademassui</i>
				<i>Megalotragus</i>	<i>kattwinkeli</i>
				<i>Parmularius</i>	<i>rugosus</i>
			Antilopini	<i>Antidorcus</i>	sp.
				<i>Gazella</i>	<i>janenschii</i>
			Bovini	<i>Pelorovis</i>	sp.
				<i>Syncerus</i>	sp.
			Hippotragini	<i>Hippotragus</i>	<i>gigas</i>
				cf. <i>Oryx</i>	sp.
			Neotragini		
			Reduncini	<i>Kobus</i>	<i>kob</i>
				<i>Kobus</i>	<i>sigmoidalis</i>
			Tragelaphini	<i>Tragelaphus</i>	<i>nakuae</i>
				<i>Tragelaphus</i>	<i>strepsiceros</i>
				<i>Tragelaphus</i>	<i>pricei</i>
		Giraffidae		<i>Sivatherium</i>	sp.
				<i>Giraffa</i>	sp.
		Hippopotamidae		<i>Hexaprotodon</i>	sp.
		Suidae		<i>Kolpochoerus</i>	<i>limnetes</i>
				<i>Metridiochoerus</i>	<i>andrewsi</i>
				<i>Notochoerus</i>	sp.
				<i>Homotherium</i>	sp. aff. <i>problematicum</i>
				<i>Genetta</i>	sp.
				<i>Aonyx</i>	aff. <i>capensis</i>
				<i>Hipparion</i>	sp.
				<i>Australopithecus</i>	<i>garhi</i>
				<i>Theropithecus</i>	sp.
				<i>Papio</i>	sp.
				<i>Deinotherium</i>	cf. <i>bozasi</i>
				<i>Elephas</i>	<i>recki shungurensis</i>
	Carnivora	Felidae			
		Viverridae			
		Mustelidae			
	Perissodactyla	Equidae			
	Primates	Hominidae			
		Cercopithecidae			
	Proboscidea	Deinotheriidae			
		Elephantidae			

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Fig. 2. Hominid modification to bovid bones from the Hata Member. Photographs ©David L. Brill 1999\Atlanta. White boxes show enlargement size. (A) Successive enlargements illustrating bone modifications on a large bovid's right tibial midshaft (BOU-VP-11/14). Gray arrows indicate direction of hammerstone impact deduced from striae in percussion pits. Note the large external conchoidal flakes driven off by the distal percussor impacts and the adjacent cut marks. These are the earliest documented percussion marks made by hominids who were presumably processing these bones for contained fatty marrow. (B) Successive enlargements illustrating cut marks on the medial surface of a medium-sized alcelaphine bovid's left mandible (BOU-VP-12/11), presumably made during tongue removal. Note the multiple striae and shoulder marks in the SEM (used with permission by G. Richards and B. Plowman). These are the earliest documented cut marks made by hominids.



However, the absence of abundant lithic assemblages at these Hata archaeology sites requires explanation.

At the nearby Gona site, abundant Oldowan tools were made and discarded immediately adjacent to cobble conglomerates that offered excellent, easily accessible raw materials for stone-tool manufacture. It has been suggested that the surprisingly advanced character of this earliest Oldowan technology was conditioned by the ease of access to appropriate fine-grained raw materials at Gona (10). Along the Karari escarpment at Koobi Fora (13), the basin margin at Fejej (14), and the lake margin at Olduvai Gorge (12), hominids also had easy access to nearby outcrops of raw material. In contrast, the diminutive nature of the Oldowan assemblages in the lower Omo [made on tiny quartz pebbles (15)] was apparently conditioned by a lack of available large clasts.

The situation on the Hata lake margin was even more difficult for early toolmakers. Here, raw materials were not readily available because of the absence of streams capable of carrying even pebbles. There were no nearby basalt outcrops. The absence of locally available raw material on the flat featureless Hata lake margin may explain the absence of lithic artifact concentrations. The bone modification evidence demonstrates that early hominids were transporting stone to the site of carcass manipulation. The paucity of evidence for lithic artifact abandonment at these sites suggests that these early hominids may have been curating their tools (cores and flakes) with foresight for subsequent use. Indications of tool curation by later hominids have been found at the more recent Pleistocene sites of Koobi Fora [Karari escarpment versus Ileret (13)] and Swartkrans [polished bone tools in a single repository (16)].

Additional research into the Hata beds may allow a determination of whether the butchery is related to hunting or scavenging. The Bouri discoveries show that the earliest Pliocene archaeological assemblages and their landscape patterning are strongly conditioned by the availability of raw material. They demonstrate that a major function of the earliest known tools was meat and marrow processing of large carcasses. Finally, they extend this pattern of butchery by hominids well into the Pliocene.

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18. The Middle Awash paleoanthropological project is multinational (13 countries), with interdisciplinary research codirected by B. Asfaw, Y. Beyene, J. D. Clark, T. D. White, and G. WoldeGabriel. The research re-

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Australopithecus garhi: A New Species of Early Hominid from Ethiopia

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The lack of an adequate hominid fossil record in eastern Africa between 2 and 3 million years ago (Ma) has hampered investigations of early hominid phylogeny. Discovery of 2.5 Ma hominid cranial and dental remains from the Hata beds of Ethiopia's Middle Awash allows recognition of a new species of *Australopithecus*. This species is descended from *Australopithecus afarensis* and is a candidate ancestor for early *Homo*. Contemporary postcranial remains feature a derived humanlike humeral/femoral ratio and an apelike upper arm-to-lower arm ratio.

The succession of early hominid genera and species indicates diversification into at least two distinct adaptive patterns by ~ 2.7 Ma. A meager east African hominid record between 2 and 3 Ma has caused the pattern and pro-

cess of this diversification to remain obscure. The *Australopithecus afarensis* (3.6 to 3.0 Ma) to *A. aethiopicus* (2.6 Ma) to *A. boisei* (2.3 to 1.2 Ma) species lineage is well corroborated by craniodental remains. In contrast, a suggested relationship between *A. afarensis* and early *Homo* has previously been evidenced only by relatively uninformative isolated teeth (1), a palate (2), and a temporal fragment (3).

The recovery of hominid remains from the Hata (abbreviation of Hatayae) Member of the Bouri Formation adds substantially to the inventory of fossils bearing on these phylogenetic issues. These remains comprise craniodental and postcranial elements from several areas in the Middle Awash. The first of these was discovered in 1990 at Matabietu and Gamedah.

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