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Halibee member archaeology: Middle Stone Age environment, technology, and postmortem modifications

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The Middle Awash study area of Ethiopia's Afar Rift features a composite stratigraphic thickness of >1 km. Near the top of this succession lie sediments of the lower Halibee member, comprising the Faro Daba and Chai Baro beds. The former are radioisotopically dated to ~100,000 y in age and contain abundant fossils and associated lithic artifacts representing the Middle Stone Age (MSA). Geological, paleontological, and archaeological datasets recovered from these sediments enlarge a sparse later Pleistocene record of African human evolution, a time before anatomically modern populations of our species expanded into Eurasia. The Faro Daba occurrences comprise the richest, least disturbed, and most spatially extensive of many open-air MSA-bearing localities in the study area and beyond. Protected atop a resistant underlying conglomerate, the largely horizontal outcrops of the soft, eroding fossiliferous Faro Daba sediments provide spatially extensive access to in situ assemblages of artifacts and fossils. Sedimentology, faunal composition, and combustion features are consistent with a wooded depositional environment with seasonal flooding distant from the main river channel. Archaeological and paleontological assemblages indicate minimal postdepositional disturbance of primary lithic tool manufacture and discard during ephemeral human occupations on this floodplain. Among the recovered fossils are three partial human skeletons with taphonomic evidence of different postmortem pathways.

paleoanthropology | Ethiopia | Afar Rift | archaeology | Middle Stone Age

Significance

Homo sapiens emerged in an African late Middle Pleistocene cultural context featuring an industry known as the Middle Stone Age (MSA). Understanding the ecological and behavioral dimensions of this emergence has proven difficult due to the continent's vast geography, the limited number of human and nonhuman fossils, and the rarity of archaeological occurrences in open-air settings. The results of sustained field and laboratory studies on the Halibee member of the Dawaitoli Formation in the Afar Rift of Ethiopia are reported here. Thousands of lithic artifacts—many in undisturbed contexts—were recovered. Partial skeletons of three fossil *H. sapiens* individuals are included among the abundant associated fossils from sediments deposited ~100,000 y ago by the paleo-Awash River.

Sustained paleoanthropological research in Ethiopia has proven central to understanding the African emergence, biogeography, ecologies, and behaviors of African Middle Stone Age populations. Here, we report results of exploratory archaeological investigations of the Late Pleistocene Faro Daba beds (Halibee member) of the Dawaitoli Formation. These sediments encapsulate physical and biological evidence bearing on our species' origins. Building on geological and chronological foundations (1), we present here the environmental, technological, and taphonomic contexts of early *Homo sapiens* populations active ~100,000 y ago in the Afar Rift valley.

The Middle Awash research project has been an Ethiopian-based, multidisciplinary, international effort since 1981 (*SI Appendix*, section 1.1.1). Extending research at Herto (2) and Aduma (3, 4), our Halibee investigations began with foot and vehicle transects in 1994. Work in this northwestern part of the study area established chronostratigraphic and geomorphological frameworks (1). The Dawaitoli Formation's Halibee member comprises four beds. The upper two contain Late Stone Age evidence (~20 ka Oulen Dora and ~31 ka Wallia beds). Underlying these sediments are the ~100 ka Faro Daba beds ("FD", Afar words for "sloped tunnel") unconformably overlying the member's basal Chai Baro beds ("CB", Afar words for "tea place") (Fig. 1).

Both FD and CB sediments are fining-upward packages containing Middle Stone Age (MSA) artifacts. The older MSA assemblages of the underlying Chai Baro beds in turn overlie a succession of even earlier Acheulean artifacts and fossils. The Didale Glass Shard tuff (DGST) atop ~10 m of sterile fine-grained sediments sets the minimum age of the fossiliferous CB MSA at 158.1 ± 11.0 ka (1). The CB beds have yielded an ecologically distinct vertebrate fauna that also includes *Homo sapiens*. They have not yet been subjected to intensive archaeological research. We focused on the FD beds because of their wider exposure, tighter chronological placement, and richer paleoanthropological content.

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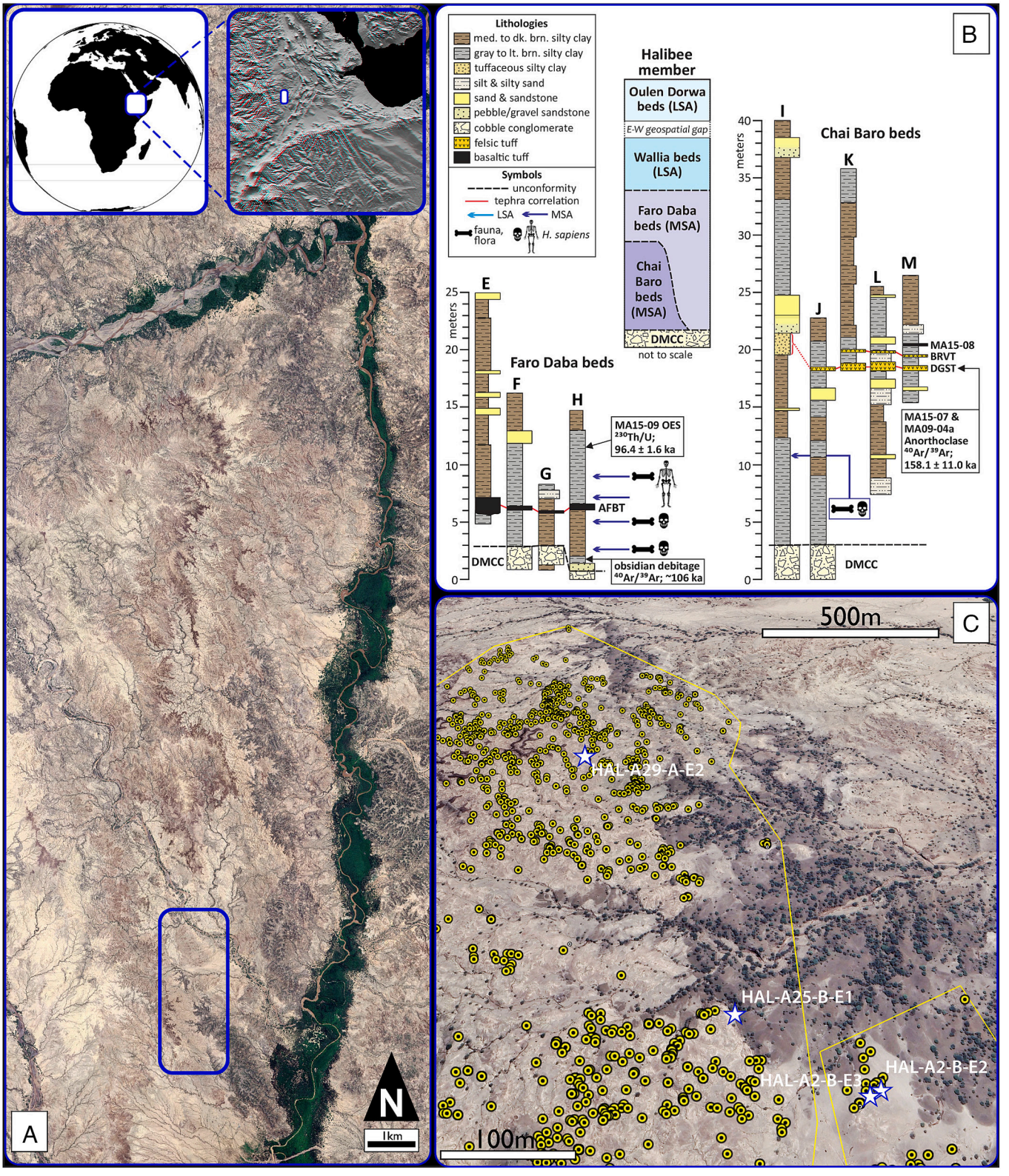

Fig. 1. Satellite imagery, Middle Awash study area, Afar Rift, Ethiopia. (*A*) The northwest quadrant of the study area. Blue rectangle at lower center bounds the adjacent expanded oblique view on the right. (*B*) Chronostratigraphy of the Halibee member (1). (*C*) Vertically tilted view of the blue rectangle in (*A*), across the HAL-VP-3 and -9 paleontological localities (yellow borders, *Left* and *Right*), showing density of collected vertebrate specimens. White stars indicate MSA excavations. The dark surface to the right is the exposed top of the DMCC, an underlying cobble conglomerate. Fauna and archaeology are dated to ~100,000 y ago.

Continental Context: The African Middle Stone Age. Chronological dimensions, modes, and tempos of change during the African later Middle Pleistocene are current subjects of intense research. However, the evidentiary basis for human origins on the continent remains frustratingly incomplete due to Africa's large size and ecological diversity, historical constraints, and vagaries of preservation. Recent advances in paleogenetics, geology, and geography have all pointed to the importance of the Horn of Africa where key early fossils and artifacts have been discovered.

The 20th century's terminologies and interpretations of Pleistocene African paleogeography, paleobiology, and archaeology inadequately express the complexity now evident for each. The archaeological term "Middle Paleolithic" is still used to characterize largely post-Acheulean, flake-based lithic assemblages in Europe and the Levant. Contemporaneous African stone tool assemblages are traditionally assigned to the ill-defined "Middle Stone Age" (MSA). However, African lithic assemblages attributed to this technocomplex challenge the traditional notion of an abrupt "transition" or "threshold" between "Acheulean" handaxe and "Middle Stone Age" Levallois prepared core technologies (5–7). Indeed, the very notion of "transitions" between traditional lithic "industries" has been questioned (8) as the archaeological record has expanded. Examples of spatially asynchronous, and locally progressive technological change defy categorization in traditional classifications invoking saltational, pan-continental change.

Difficulties in characterizing this complexity also stem from the facts that most MSA occurrences between 300 ka and 50 ka exceed the reach of radiocarbon dating and often lack independent verification by alternative chronometric methods (9, 10). Lithic technology is best understood within its broader environmental, behavioral, and anatomical contexts. However, many of Africa's better-calibrated Middle Stone Age records are preserved in relatively small cave deposits whose archaeological contents are of variable "integrity" (how many agents accumulated and modified the assemblage) and/or "resolution" (how much time is averaged in assembly of the assemblage) (11). These constraints impose archaeological biases toward regions with caves and toward Pleistocene activities in residential shelters.

Despite their importance in elucidating microhabitat in geographically defined areas (12), Africa's relatively few large open-air MSA occurrences share similar problems of chronometry and preservation. Compared to reoccupied shelter situations, open-air counterparts are usually spatially diffuse, short-term occupations with ill-defined boundaries, their archaeological visibility usually resulting from modern erosion. Compared to shelter deposits, such MSA surface scatters or in situ open-air occurrences often lack faunal remains, spatial control, and/or chronostratigraphic context. We address these knowledge gaps by reporting here on initial investigations of the long-buried but little-disturbed Faro Daba sediments now being exposed across a kilometer-scale landscape, revealing evidence of anatomy, ecology, and behaviors of early *H. sapiens* occupants around 100,000 y ago.

Physical Contexts: Halibee Geoscience and Geography. Results of $^{40}Ar/^{39}Ar$ dating of primary silicic tephra and obsidian were combined with $^{230}Th/U$ burial dating of ostrich eggshells to bracket the age of the Late Pleistocene Faro Daba sediments at ~100 ka (1). Fossils and lithics eroding from FD sediments were deposited on a floodplain of the paleo-Awash River during Marine Isotope Stage 5 (MIS-5), a time of central importance in human evolutionary studies (13, 14) (Fig. 1).

A voluminous recent literature contains attempts to "squiggle match" (15) proxies of global climate change with paleobiological and/or archaeological "events," often via modeling and metadata (e.g., refs. 16–19). However, there is an increasing appreciation that chronological correlation (synchronicity) is insufficient to demonstrate causation (20, 21) in the face of the taphonomic and stratigraphic biases, gaps, incompatible datasets (22), biotic interactions (23), and complexity (24) involved. Better terrestrial records of local and regional biological and technological change are required to move forward. Lost in these debates has been the simple fact that water and elevation were—and today remain—the major conditioning variables that shaped Africa's prehistoric records and today's biogeography (25).

Halibee's Pleistocene water-lain deposits resulted from complex tectonics, fluvial sedimentation, and erosion near the western margin of the Afar Rift. Erosion here is still active, controlled by base level lowering farther northeast that promoted rapid and ongoing incision of the Awash River, and headward erosion of its tributaries. Halibee's modern topography and ecology contrast dramatically with those >25 km to the south where more stable Awash valley landscapes are dominated by wider modern floodplains, lakes, and swamps supporting diverse flora and fauna. Sediments there are now actively aggrading around the rift-bound uplifted fault block of the Bouri horst (26) and the Central Awash Complex structural dome (27). Modern Awash valley geography offers a directly relevant modern analog for Halibee's Pleistocene geomorphology and biota (*SI Appendix*, section 2.1).

Deposition of fossil-bearing FD sediments was dominated by the influence of the paleo-Awash River's floodwaters. These deposited horizontally bedded, massive, very fine grained, medium dark brown silts and clayey silts in shallow standing or slow-moving water derived from its repeatedly breached channel banks. Resultant riparian ecosystems are seen today along the modern river where vegetation is dependent on gradient and hydrology. A dense gallery forest centered on the main channel grades laterally, often without an abrupt ecotonal break, into groundwater-sustained and seasonally inundated, kilometers-wide woodlands more distal to the channel, then finally into even more distant, desertic open savanna (28).

Stinchcomb et al. contend that nearby Gona hominids "preferred proximal channel settings" characterized as "gallery forest edge" of 5 to 10 m width [(29), p. 11]. However, this characterization seems unduly influenced by the deep incision and steep gradient of the modern Awash River analogs within their Gona study area (e.g., their figures 4 and 9) and is therefore likely a serious dimensional and ecological underestimate, by orders of magnitude. Environmental reconstructions and assertions about hominid preferences spanning millions of years are therefore inconsistent with such upriver considerations and further evidence presented in *SI Appendix*, section 2.1).

Pleistocene and Holocene Awash tributary wadi paleochannels are evident as inverted sinuous channel beds of sands, gravels, and pebbles in Halibee and Gona deposits (1). Those tributaries provided fauna and humans solid footing and recurrent access to the seasonal ponds and marshes closer to the ancestral river. Abundant evidence now eroding from the FD Pleistocene overbank silts shows that MSA people accessed and episodically occupied this landscape (1). We infer below that they took advantage of standing water, shade, lithic raw material, and mesic biotic resources in an otherwise arid, tropical savanna rift valley setting. The occupied topography was eventually submerged by sedimentation, burying the paleontological and archaeological residues in seasonally deposited, relatively rapidly aggrading silts. Further aggradation of overlying finer, dark brown, clay-rich, sterile deposits suggests that the circumstances favorable to occupation and preservation were short-lived and that the lithic and faunal palimpsest assemblages are time-averaged only to a limited degree.

Halibee's paleotopography and ecology at ~100 ka ago may be inferred from the fossil and lithic surface palimpsests now encountered on the eroding surfaces of the FD beds, concentrated both above and below a widespread basaltic tuff marker horizon, the Afcaro Basaltic Tuff (AFBT). This horizontally deposited unit of variable thickness lies between 1-4 m above the upper surface of a thick, resistant underlying conglomerate, the Didamela Cobble Conglomerate (DMCC) (1). Abundant undisturbed rhizoliths and burned tree root/trunk systems in silty overbank sediments indicate that water was sufficient to support wide tracts of dense vegetation in proximity to the

paleo-Awash and its tributaries. Seasonal inundation of the cobble conglomerate's undulating upper surface (and associated inverted channels (1)) would have initially created ephemeral ponds flanking the river, the drying ponds attracting a wide variety of fauna in a gallery forest-to-woodland gradient. As revealed by today's geomorphology, sedimentology, and ecology in the Middle Awash, the local hydrological effects of a dynamic Pleistocene Awash River system were far more important in influencing the paleoecology of the Afar than any conceivable effect of global climate change.

For example, the compositions and extent of riverine forests depend on interactions with the floodplain morphology, hydrological regime, and soil properties (30). These variables shift even at the millennial scale in this part of the Afar Rift. Forest-savanna dynamics are particularly affected in double-stress settings where seasonal (and longer) drought and waterlogging are key factors (31). Biotypes along the modern Awash River are subjected to both stresses, and the FD sediments contain evidence of this. As noted by Hoffman (32), flooded conditions predispose trees to be more vulnerable to fire, a phenomenon evident today along the Awash River.

Landscape dynamics during deposition of the FD beds are further elucidated by widespread evidence of combustion. This takes the form of uncontained primary combustion features, primarily baked sediment patches (*SI Appendix*, section 2.2). Textures and shapes of surface impressions of some large burned cemented fragments indicate that these represent stumps of burned trees. In one case, charcoal was recovered within baked clay (1). Some baked patches coincide with, or are close to, dense scatters of stone tools, influencing placement of our test excavations. Some surface manuports are also burned, with pot-lid fractures and apparent thermal cracking and degradation of their surfaces. Many of the baked patches today stand higher than the surrounding deflating unbaked silts, a function of carbonate cementation probably associated with fire ash (33).

Similar baked sediment occurrences were reported for Acheulean-bearing sediments at Bodo (34) and became part of longstanding debates regarding the control of fire in archaeological contexts (34–38). We lack temporal resolution required to establish whether the FD burned tree stumps predated, postdated, or were contemporary with the spatially associated MSA occupations. We also lack evidence to establish whether the burning was natural or anthropogenic in origin. Modern analogs are useful in understanding this equifinality (ambiguity-of-agency). Even today, lightning strikes can ignite dead emergent trees, as can occasional bushfires and deliberate anthropogenic burning.

Intensive paleontological and archaeological survey across the eroding Faro Daba sediments was constantly alert to the possible evidence of diagnostically anthropogenic structural or combustion-related features, or other features unambiguously attributable to humans. We have failed to detect any patterns unambiguously identifying the MSA occupants as responsible for the widespread evidence of Pleistocene combustion features across the broadly eroding FD paleolandscape, a surface with hundreds of thousands of stone artifacts and bones. Nor did we identify any unambiguously nonfunctional items such as engravings, carvings, body ornamentation via beads or ochre in any of the encountered or collected surface or subsurface assemblages.

Artifacts discarded in the shade of a tree (or in the roots of one sprouting decades afterward) would have a spatial association with its burned stump and roots. The same equifinality applies to burned faunal remains, a phenomenon documented in a similar open-air setting in Tanzania (39). Spatial and stratigraphic co-occurrence is not the same thing as temporal co-occurrence and/or anthropogenic intent in the FD context. Even for burned patches centered in dense lithic concentrations such as in the HAL-A2B-E2 excavation (below), such correlation does not provide evidence necessary to establish causation.

Ecological Contexts: Halibee Paleobiology. Most MSA occupations with vertebrate fauna in spatial and stratigraphic proximity to lithic assemblages come from relatively small, sheltered contexts, accumulated by recurrent occupations of humans and others. Anthropogenic and carnivore processing usually creates high levels of fragmentation, with low integrity and resolution for the resulting palimpsest assemblages. The ecological circumstances surrounding these archaeological faunas are therefore difficult to infer.

Halibee member faunas are exceptions to these tendencies. Here, we report 3,365 individually identified vertebrate specimens (number of identified specimens; NISP) from surface, sieved, and in situ contexts within CB (NISP = 994) and FD localities (NISP = 2,371). Faunal lists are in *SI Appendix*, Table S1; counts and relative abundance values in Fig. 2; specialist narratives in *SI Appendix*, section 2.2; and cercopithecid primates described in refs. 40–42.

Abundant rhizoliths and preserved tree stumps are evidence that FD paleolandscape was extensively vegetated. The FD vertebrate assemblages agree with this evidence. They provide additional ecological, biogeographic, and evolutionary evidence for Pleistocene Africa where there are few paleontological assemblages collected at landscape scale at ~100 ka. For example, the most relevant contemporaneous faunas are from the Omo Kibish, yielding only 118 identified specimens (NISP) from its hominid-bearing member (43), and only 22 bovid specimens available for ecological comparisons (44). In contrast, the FD bovids alone comprise an NISP of 339 in an overall fauna 20 times larger.

As with FD's evidence of combustion, the random co-occurrence of fauna with lithic remains is not necessarily functional. Lithics and bones were accumulating on, and buried in, seasonally deposited FD sediments. Proximity of MSA archaeological lithics and surface-collected vertebrate fauna is probably largely nonanthropogenic. Taphonomic analyses have so far failed to reveal unambiguous evidence of anthropogenic acquisition or processing among the abundant bovids, birds, or primates from excavations or surface collections. Without evidence of human involvement (below), the presence and numbers of paleontological vertebrates in the Halibee member cannot yet be linked to archaeological procurement or processing, even when recovered in close, in situ proximity.

The archaeological faunal assemblages in upper Aduma (3) are dominated by hippos and fish, whereas the Faro Daba archaeology-associated surface-collected assemblages are dominated by more terrestrial mammals. The dominant mammal remains in our archaeological excavations were the background of small rodents probably derived from owl pellets dropped on the accumulating silts throughout FD. Rare limb bone shaft fragments of medium-sized ungulates are present, most in the ~1 to 2 cm length category. A few were fossilized soon after fracture, held together by periosteum; several have inner conchoidal scars, but the veneer of carbonate/rootcasts obscures bone surface modifications by hominids or carnivores.

The CB and FD faunas offer opportunities for ecological assessment via relative abundance and presence/absence. Both approaches have obvious merits and both are subject to a variety of biases potentially affecting ecological inferences (summarized by ref. 45 for fossils in general and by refs. 46 and 47 for smaller vertebrates). Sokolowsky et al. (48) discuss issues of facile ecotype assignments and agree with (49) that applying the term "mosaic" to Plio-Pleistocene African environments has lost any biological meaning because of the spatiotemporal dimensions involved.

All genera represented as fossils at FD and CB have living counterparts. Equids (n = 1 at CB), elephants, and *Giraffa* (n = 1 each) are rare, as are fish, hippos, and crocodiles. This is consistent with sedimentological evidence of deposition in still, evaporating water distal to the main paleoriver channel. A high relative abundance

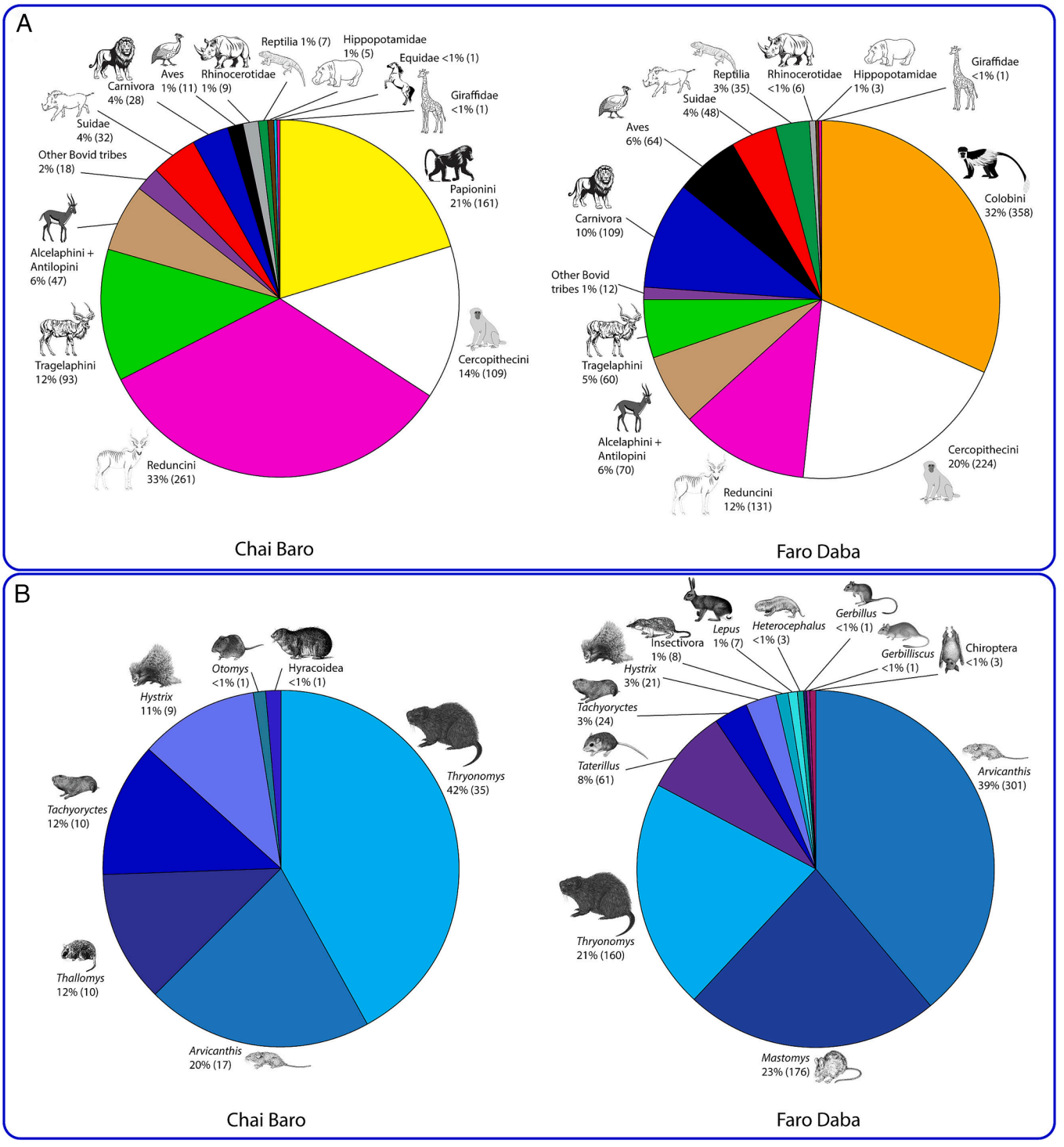

Fig. 2. Halibee member faunal representation based on raw NISP counts. (*A*) Both assemblages show relatively very high primate numbers, but the abundant *Colobus* monkeys and absence of baboons at Faro Daba indicate a more closed environment, and the small relative abundances of alcelaphins plus antilopins is notable. (*B*) Smaller rodents are largely derived from decomposed owl pellets in both beds; the FD abundance reflects more recovery via surface sieving of hominid and cercopithecid parts than at Chai Baro.

of primates and cane rats in the FD beds is consistent with the evidence for large trees and regular inundation, respectively. Primates were a major component of the faunas at both CB and FD, but relative abundances indicate different ecologies and/or depositional circumstances. Of the 272 NISP papionins plus cercopithecins from CB, *Colobus* is absent. It was the dominant monkey at FD (360 of 584 NISP) (40–42).

Likewise, Bovids comprise 53% of NISP at CB, but only 24% at FB. In both units, Reduncini, Tragelaphini, and Antilopini are dominant, represented mainly by *Redunca* and *Tragelaphus scriptus*, taxa often associated with flooded grasslands and woody cover, respectively. Alcelaphini and Antilopini, residents of open habitats, are far less abundant at Chai Baro. They are second to Reduncini at FD, but represented there mainly by *Nanger soemmerringi*, an inhabitant of semiarid grasslands and shrublands. Bovid relative abundances support the dominance of wooded and inundated habitats at both CB and FD, with a greater sampling of open habitat taxa at FD. The relatively high number of subadult

individuals in FD could be the result of interactions with predators in a relatively sheltered woodland setting, with or without anthropogenic involvement.

Carnivore taxa in both beds ranged from a small *Felis* to a "gigantic" CB lion similar in size to contemporaneous taxa described elsewhere (50, 51). The FD carnivore assemblage features a relatively large and diverse sample of small and medium-sized taxa. Suid abundance shifted dramatically between a near-absence of warthogs in CB to a higher presence in FD. Birds at FD include an extensive spectrum of taxa and sizes and were dominated by galliforms (guineafowl, francolins). Waterbirds (ducks, herons) were rare at FD, sharing the area with, among others, diurnal and nocturnal raptors. The latter included barn owls that would have roosted in riparian trees and hunted in more open settings farther from the river. Squamates are well represented in both faunas, consisting primarily of large-bodied pythonid snakes (*Python*) and monitor lizards (*Varanus*). Faro Daba squamates are more diverse than CB, including cobras (*Naja*) and lizards such as scincids, lacertids, and chamaeleonids, the latter being consistent with the presence of local woody cover.

Two large rodent genera were present at both CB and FD. The water-dependent, semiaquatic, mainly nocturnal cane rat, *Thryonomys*, prefers marshy wetland areas. The terrestrial burrowing giant mole rat *Tachyoryctes* prefers moist soil with grassland habitats. Porcupines were less abundant. The higher abundance of the semiaquatic *Thryonomys swinderianus* in the FD beds is consistent with geological evidence of seasonal flooding. Most of the smaller rodents in both beds were derived from decomposed owl pellets, their abundances reflecting predator preference across a variety of terrestrial habitats. The murine *Arvicanthis* was present at both FD and CB, but more abundant at FD. This genus prefers dry bushy and grassy savanna habitats often close to water, with population densities quickly increasing after seasonal vegetation growth. The CB small mammal fauna is ecologically differentiated from that of FD, with higher proportions of *Otomys*, *Hystrix*, *Tachyoryctes*, *Thryonomys gregorianus*, and gerbils.

Cane rats were dominant in both Halibee assemblages and today constitute a protein-rich, fast-breeding 'mini livestock' animal for some human populations. Mole rats are present in other MSA faunal assemblages across Africa—from South Africa (52, 53) to Morocco (54)—and at Fincha Habera in the Ethiopian highlands (55). However, the relatively abundant large rodents in the FD beds lack evidence of processing or co-occurrence with artifacts in any nonrandom pattern. The abundance of craniodental remains of these larger rodents is a likely product of several potentially interacting and impossible to untangle factors resulting in equifinality. Among these are carnivore activity, possible human acquisition and processing, and paleontological collection biases.

Behavioral Contexts: Technology. Rift-bound African Paleolithic archaeology-bearing strata are often found in steep and gullied modern erosional terrain, their Pleistocene landscapes only visible through thin, ribbon-like exposures that release embedded artifacts that gravitate and mix downslope. Further surface collection biases may be introduced by taphonomic factors, and/or by selectivity favoring larger artifacts. Archaeologists therefore often dismiss surface-collected lithic and zooarchaeological assemblages and restrict their analyses to excavated artifacts. However, spatially extensive excavations in remote open-air contexts are logistically expensive and often yield low return rates resulting in small samples from tiny windows likened to "telephone booths" (56). Even landscape studies and sampling are constrained by steep topographies where thick overburden restricts excavation size (57).

In contrast, active deflationary erosion has exposed FD lithics and fauna close to their original embedded positions, and at landscape scale. These artifacts and fossils are overwhelmingly fresh, unabraded, and unpatinated, usually retaining un-shed carbonate skins and rhizoliths even after exposure. Many little-disturbed lithic refitting sets are surfacing in tight concentrations. These circumstances allowed foot survey to assess the spatial patterning of emergent MSA lithics and fauna at a square kilometer scale rarely possible in paleoanthropology. Surface survey established that the MSA technology was similar across the large FD bed exposures where artifact density varies from sparse to concentrated. These results emphasize the ambiguity and inapplicability of the term "site" to the archaeological reality of such landscape-scale artifact distributions. This habitually used term has lost its meaning after decades of uncritical application by anthropologists and the public. The Middle Awash project uses the term "locality" instead (*SI Appendix*, section 1.1.3).

Traditional archaeological approaches to open-air study areas with outcrops of eroding fossiliferous sediments are often compartmentalized into walking surveys, surface collections, and excavations (58). We value application of a "CPT" (coring, profiling, trenching) (59) approach in many cases but note that an overfocus on excavation at the expense of surface survey and sampling in settings like Faro Daba's can squander available information about large-scale activity patterning and miss rare features that owe their archaeological visibility to surface erosion. The deflating FD surfaces are unusual in combining a stratigraphically constrained depositional interval that is now widely exposed, providing an ideal setting for recovering spatial and stratigraphic information via surface observations.

A "survey-first" approach allowed us to generate hypotheses about the relationships between surface evidence of combustion and in situ artifacts and fauna that we subsequently tested by excavations. Locations of these probes ("sondages" Fr.) were chosen based on the surface abundance of freshly eroded finds, minimal sedimentary overburden, and positions that span the large HAL-VP-3 and -9 paleontological localities. This staged, combinatorial approach took advantage of the fact that the largely subhorizontal modern erosional surfaces of the FD beds largely correspond to original depositional planes (evidenced by the horizontal AFBT lower contact).

Our first archaeological collections were of lithics encountered during fossil recovery. We then made controlled surface collections of shaped surface artifacts to establish a broad techno-typological representation, sampling rare artifacts unlikely to be included in excavations, and obsidian samples constraining maximum age (60). A total of 2,228 individually numbered lithic items were derived from FD surface collections during five seasons of Halibee fieldwork. Formal excavations allowed us to assess the relationship between freshly eroded surface collections and the bone and stone assemblages residing in situ below. The excavations into a total area of 112 square meters yielded in situ components of the overall FD assemblages, a total of ~1,800 piece-plotted lithic artifacts >1 cm, alongside 132 faunal remains. Excavation methods are provided in *SI Appendix*, section 1.1.4; piece-by-piece catalogs of all lithics from the Faro Daba excavations are in Dataset S1.

Excavation profiles and plans are provided in Fig. 3 and *SI Appendix*, section 2.4. We found minimal evidence of stratification in the excavated silts, only increasing induration at depth and what may be two chronologically distinct knapping/occupation episodes at HAL-A29A-E1. The FD MSA surface lithic assemblages did not differ significantly from the excavated in situ assemblages. The in situ lithic and faunal assemblages had high spatial integrity and chronostratigraphic resolution.

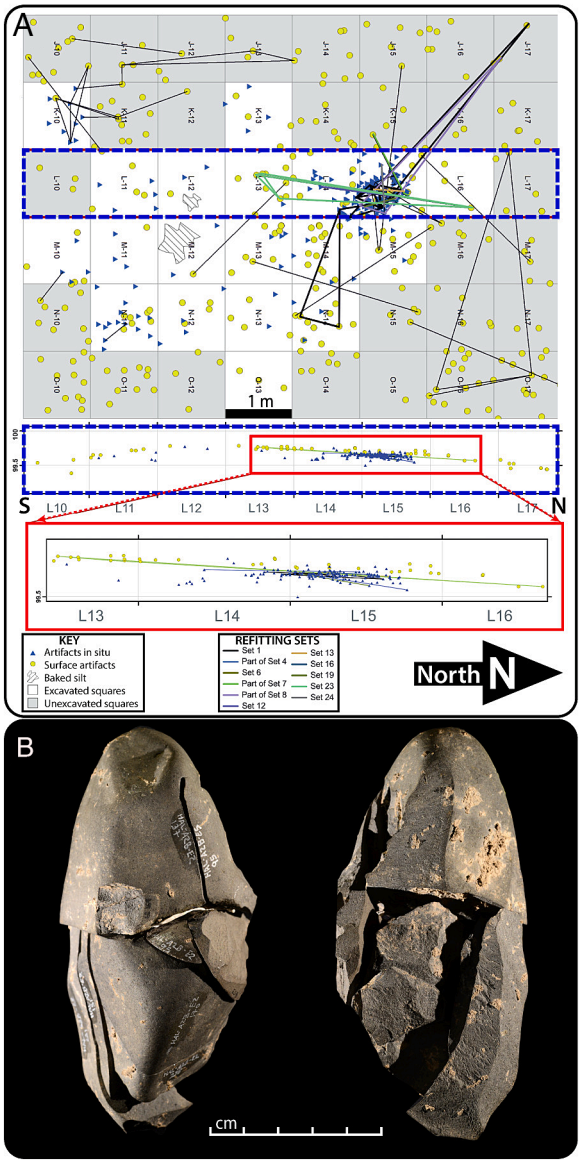

Fig. 3. Plan view, profiles and lithic refits (lines) in the HAL-A2B-E2 excavation. (*A*) The horizontal projection of the "L" excavation grid row content is bounded by blue dashed boxes to show the main concentration of remains and the refitting sets linking surface and subsurface (in situ) assemblages (produced using ArcGIS 20.8.1). (*B*) Views of the split and further reduced basalt cobble comprising Refitting Set #1.

Faro Daba's MSA knappers employed a wide range of volcanic rocks. For larger tools, they chose basalt and coarser-grained rhyolite and ignimbrite cobbles to which they had immediate access via exposures of the underlying DMCC. Up to 10% of the flakes in the pooled excavated assemblage retain cortex, confirming local raw material exploitation. Between 65% and 82% of all artifacts from each excavation were made on basalt. The paleo-Awash River and its tributaries/inverted channels lack obsidians and siliceous volcanic materials for fine tool manufacture. High-quality cryptocrystalline raw materials are relatively rare, with siliceous artifacts accounting for ~8% and obsidian only <2% of the total artifact count.

The lack of obsidian cores at FD indicates that volcanic glass was highly valued and difficult to procure; earlier sourcing work posited sources up to 240 km away (61). A variety of archaeological assessments have argued about MSA mobility, trade, and social relations based on raw material sourcing information (62–64). Extending such arguments is a recent claim of 13 km transport of "nonlocal" cobbles by the Oldowan toolmakers at 2.6 Ma (65). However, such claims often downplay the fact that geologically rapid erosional erasure and/or depositional obscuration of more proximal outcrops of the same raw material with the passage of time can bias the results of "sourcing" studies toward the more distant. Even a recent critical review (66) continues to understate the fundamental issue that many sourcing claims are based on inadequate geological survey and appreciation of deep time geomorphology.

Persistent typological inconsistencies debilitate cross-assemblage comparisons in Paleolithic archaeology (67–69). Classifying larger stone artifacts has proven particularly difficult. Idiosyncrasy and inconsistency persist despite the best efforts of many (70, 71). We chose a conservative and minimalist approach to techno-typology (*SI Appendix*, section 1.2.1) and illustrate the overall FD assemblage in *SI Appendix*, Figs. S1–S11. Comparisons of FD lithics with those of other study areas are presented in *SI Appendix*, section 2.5.

Surface and excavated FD artifacts include relatively abundant manuports; small to large unmodified cobbles are recognizable as imported by their anomalous presence in fine silt. The immediately underlying DMCC is the obvious source, and their functions were probably multiple. The heavy-duty tools are mostly classifiable as picks and core axes made on elongate cobbles (Fig. 4). These crudely shaped artifacts probably represent expedient heavy-duty tools. Prominent among them are elongate cobbles end-sharpened by large, invasive flake scars from hard hammer percussion. The function(s) of these heavy, pointed pieces is/are unknown, but manufacture persisted across deep time, spanning the entire underlying Middle Awash Acheulean technocomplex (72).

Cores and core-trimming elements are relatively rare at FD, amounting to between 0 and 3.4% of the pooled excavated assemblage. Nearly half of the Levallois cores were exploited using the preferential Levallois technique. Other core types include a few bifacial choppers, attempt cores, a single platform core, and one possible "Aduma" core (3). On average, Faro Daba cores are larger than the Upper Aduma cores, possibly reflecting raw material proximity. Defined narrowly, the "Nubian" technocomplex may be represented at Faro Daba by "Nubian Type-1" cores (double distal divergent removals on a preferential Levallois core facilitating the exploitation of a major convergent piece). What "Nubian" includes and signifies is under a current debate (e.g., refs. 73–76) to which the FD MSA assemblages may contribute given their temporal and spatial placements.

Flakes account for more than half of the FD excavated artifacts. Blades are less frequent. Both are frequently broken near mid-length, making blade/flake assignations difficult, thereby reducing relative blade frequency. Horizontally broken flake and blade fragments are well represented; some of them refit. Attributing such fracture to intentionality, raw material physics, or postdiscard breakage (trampling, sediment expansion/contraction) may be resolved with actualistic studies. Some flakes exhibit traces of possible utilization in the form of edge attrition (e.g., shallow notches). Specialized, non-Levallois flake types are rare. Formal categories of small, retouched tools (notched and denticulated pieces, scrapers, burins, points, and perforators) are ~<1% of the unmodified flakes and knapping debris in both the surface and excavated FD assemblages.

Disproportional attention is bestowed upon points in MSA lithic analyses (e.g., refs. 18 and 77). Our initial FD surface surveys encountered and photographically documented a wide variety in sizes, shapes, and raw materials of points (1). Excavations confirmed this variation, albeit with smaller ranges in smaller samples. Point forms range from long narrow blades to blunt Levallois flakes, across a very large size range of fine-grained rocks. Flaking ranges from virtually no retouching to intensive bifacial thinning

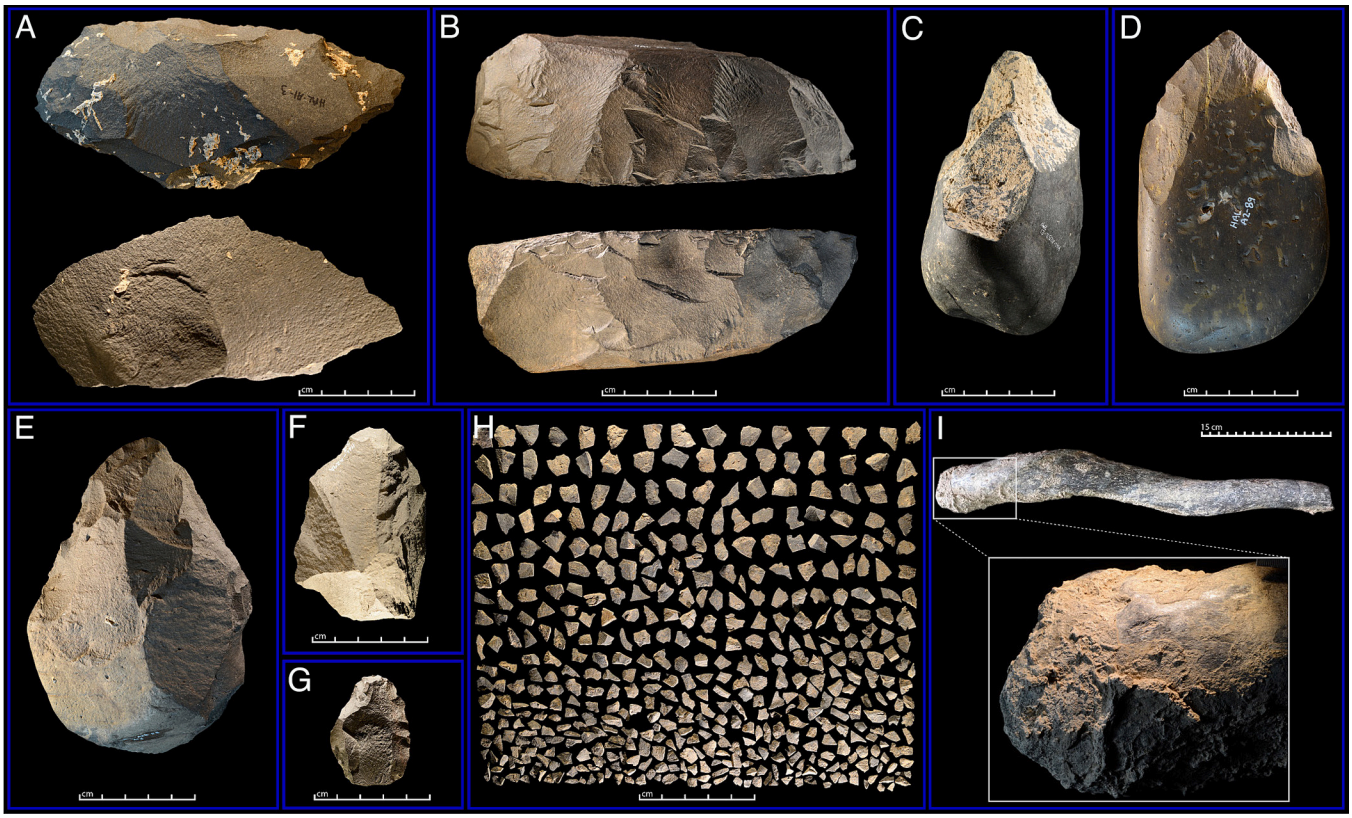

Fig. 4. Large MSA tools and small debitage from Faro Daba. (*A* and *B*) Elongate cores; (*C*–*E*) Cobble-butt picks/bifaces; (*F* and *G*) Levallois cores; (*H*) Sieved and unplotted small flakes and debitage from a single 1 m x 1 m grid square of the HAL-A29A-E1 excavation (spit 2 only, n = 444 pieces); (*I*) Full-length and close-up of matrix-covered polish on the working end of a fossilized eland horn core broken from its vault when fresh to form a chisel-like end, inferred to be an MSA digging implement. See *SI Appendix*, artifact figures, for additional selected large tools.

(Fig. 5). Very few points exhibit fracture patterns that might be unequivocally related to projectile impact.

Analysis comparing the HAL and ADU point assemblages with Goda Buticha, Omo Kibish, Porc Epic, and Shinfa was undertaken to test the hypothesis that MSA points became smaller through time across the Ethiopian region (*SI Appendix*, section 2.5.2). We cannot falsify the "minaturization" hypothesis (78) based on the available evidence, whether evaluated by point weight or size. None of the other comparative assemblages match the variation in raw material, point dimensions, or shapes among the Aduma A1 and FD point assemblages.

The FD excavations confirmed surface indications that much knapping debris remained in close proximity based on fresh preservational status and density of small flaking debris recovered by dry sieving. Thousands of subcentimeter flakes and fragments were found in situ, confirming that the flaking debris scatters were relatively undisturbed. Two fossilized eland horn core fragments recovered by surface collection exhibited fracture patterns and use wear signatures consistent with use in digging (Fig. 4).

Refits among all four excavated FD lithic assemblages further tested integrity and resolution. Methods and results are presented in *SI Appendix*, section 2.5. The larger conjoining networks (Fig. 3) indicate resolution concordant with the small debitage. Lack of sedimentological differentiation in the excavations combines with the refitting evidence to suggest that occupations were of relatively short duration (79–82).

Behavioral Contexts: Subsistence and Postmortem Patterns. Foot surveys and excavations revealed no apparent spatial correspondence of FD artifacts and fossils. Two most commonly found larger taxa in the FD paleontological surface collections broadly juxtaposed with lithic assemblages were *Colobus* and vervet monkeys. Also relatively abundant are large rodents and medium-sized bovids. Fossils of those taxa were closely examined by their specialist analysts (L.J.H. and F.K.). No butchery-related, or unambiguously humanly induced bone modifications were found, only the expected rodent gnawing, insect, and carnivore damage that are normal in such depositional settings. Additional taphonomic work may yet reveal anthropogenic associations, element damage patterns, and surface modifications.

Each FD excavation yielded in situ faunal skeletal and dental remains spatially coincident with lithic artifacts. The most abundant excavated taxa were small rodents constituting "background" across the entirety of the Faro Daba exposures. Zooarchaeological fragments of larger mammals were few compared to the lithic counts from excavations. Most are enveloped with adherent matrix obscuring possible underlying bone modifications attributable to human agency. Neither artifact density nor medium-to-large mammal bone elements reached concentrations indicative of intensive "home base" or residential MSA occupations. Thus, the FD surface and excavated assemblages are palimpsests from which short term or ephemeral MSA presence may be inferred.

Surface collections of the FD beds include the remains of 13 *H. sapiens* individuals preliminarily described elsewhere (83) and summarized in *SI Appendix*, section 2.6. Most are represented by isolated elements, including cranial portions, mandibles, and postcranial parts. Three of these bear taphonomic evidence potentially related to MSA mortuary or abandonment behaviors.

The first set of remains is HAL-VP-9/1. It constitutes the most complete adult human skeleton from the African MSA (Fig. 6)

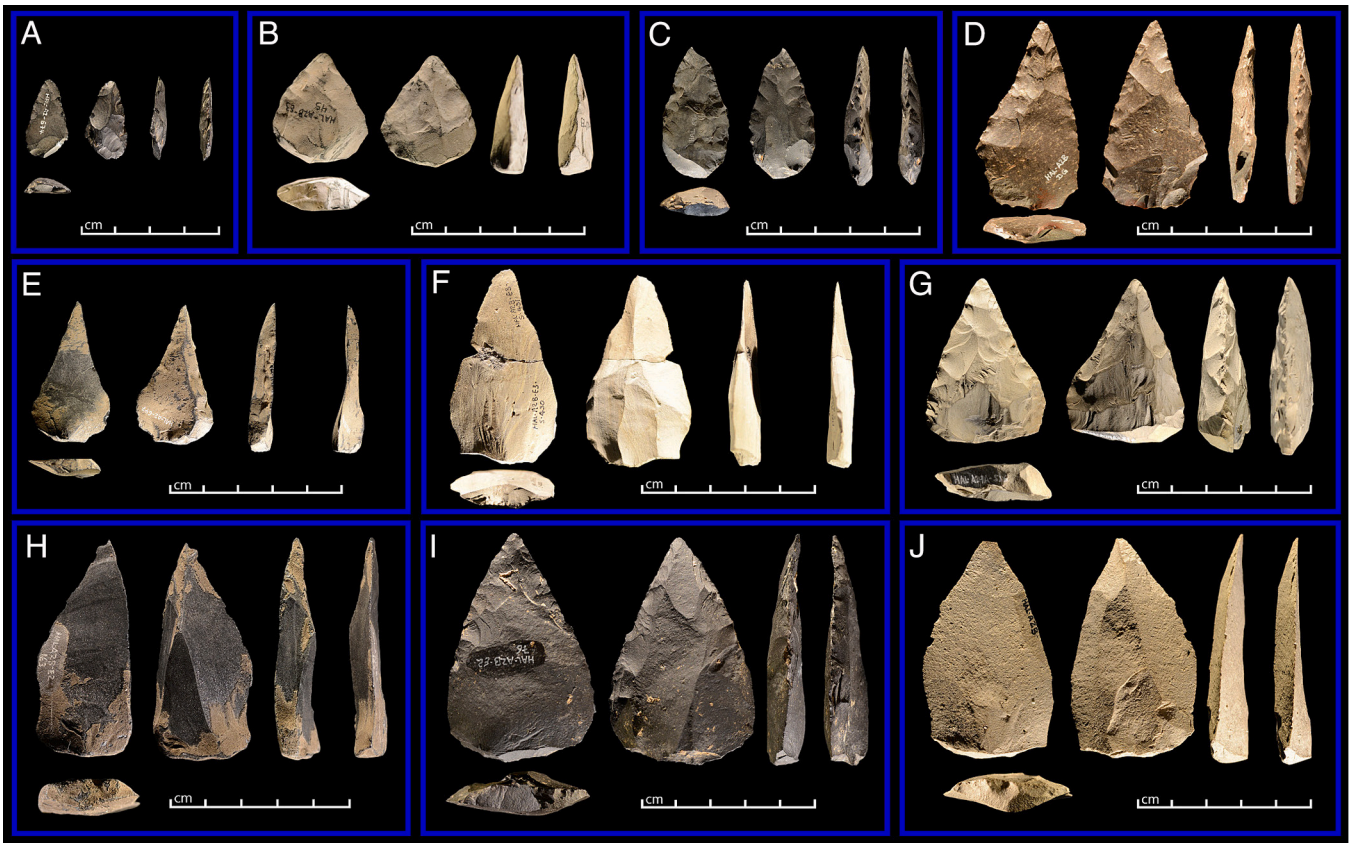

Fig. 5. MSA points from the Faro Daba beds. (*A–J*) Selected points from the surface and excavations of the Faro Daba beds MSA to illustrate workmanship, raw materials, size, and shape variation in the overall assemblage. See *SI Appendix*, artifact figures, for additional points.

(*SI Appendix*, section 2.6). Reassembled from hundreds of fossil fragments with no element part duplications, this is a male based on large body size. All fragments were surface finds or sieve recovered. Excavation failed to recover any in situ parts. No spatially associated lithics were found in situ during the surface scrape. Completeness and preservation suggest that a full skeleton was present prior to exposure. Element representation is head-to-foot, with virtually all element categories represented. The deceased was at least partially articulated when embedded and fossilized based on refitting of matching postfossilization molds and bone fracture surfaces embedded in carbonate matrix between articulating joint surfaces. These articulating elements are inferred to have been bound together by soft tissue when embedded. There is no evidence of perimortem damage, no carnivore or rodent gnawing, only extensive prefossilization termite damage. There are no humanly induced bone modifications on preserved surfaces. Available information suggests rapid burial without prolonged surface exposure, but comparisons with multiple surface-collected cercopithecid skeletons elsewhere at FD (41) caution against concluding that this individual was intentionally buried (84). Future discoveries may reveal whether FD mortuary practices included burial as for a Kenyan MSA child (85).

The second FD partial human skeleton (HAL-VP-9/1520) is represented by fragments of a smaller adult (*SI Appendix*, section 2.6). Again, the fossils represent a single individual without duplicated elements found eroded atop FD sediments. No in situ pieces or artifacts were recovered by subsequent excavation into the underlying original deposit. In contrast to the skeleton described above, there is extensive evidence of perimortem carnivore-induced damage, with ancient pitting, tooth scores, and fractures. Joints are missing. There is no termite damage. The element representation and ancient surface modifications are consistent with perimortem ravaging and scattering by large carnivore(s).

The third Faro Daba partial human skeleton is HAL-VP-3/15. Its elements display a third suite of distributional and preservational characters less expected in an open-air MSA context. A partially burned, fossilized upper third molar (Fig. 6) was first found on a lightly armored slope of the FD beds directly adjacent and stratigraphically equivalent to in situ artifacts of the HAL-A2B-E2 excavation >32.7 m to the NNE. Surface collection recovered a variety of MSA artifacts and fragmentary vertebrate remains deflated from the same strata, including assorted small bone fragments identified as human. Both the molar and the additional surface pieces show evidence of burning at high temperature in the form of extensive cracking, charring, discoloration, and fragmentation. Surface scraping and sieving of the sublocality revealed an additional set of in situ hominid fragments and two lithic flakes coincident with the apex of the surface scatter, demonstrating that the burned remains were in the same elevational plane and below the AFBT as the archaeological occupation excavations at HAL-A2B-E2 and -E3 (Fig. 6 and Movie S1).

In modern forensic settings, alterations of bone and teeth matching those seen on the HAL-VP-3/15 partial human skeleton would probably be classified as an intentional cremation involving fire intensities exceeding what is observed in most bushfires (discussion and references in *SI Appendix*, section 2.6). If this were the case here, it would be the world's earliest cremation and a mortuary practice not previously recognized in the Middle Paleolithic (86). However, given the extensive evidence of intensive burning documented at this very archaeological locality—and more generally across the FD paleolandscape—we favor a cautious interpretation, awaiting additional confirmatory evidence to resolve this equifinality.

Fig. 6. Taphonomy of human fossils from the Faro Daba beds. (*A*) Overview of the HAL-VP-9/1 skeleton recovery. Yellow flags mark fragments. The white arrow marks the AFBT horizon. (*B*) Fragments recovered by surface scrape and sieve; no in situ pieces were found. (*C*) Recovered element portions shown in gray. (*D*) Termite damage to the superior surface of the cranial vault. (*E*) Arrows indicate calcium carbonate molds of the proximal navicular surface (*Top*, for the talar head) and proximal ulnar surface (for the radial head). This is evidence of prefossilization articulation. (*F*) Blue arrows indicate prefossilization, ancient fractures of the conjoined HAL-VP-9/1520 limb bone shafts. (*G*) The recovered, preconjoined assemblage includes a frontal fragment and various limb bones with both pre- and postmortem fractures. (*H*) Positions of the HAL-VP-3/15 lag surface fragments indicated by yellow flags; blue flags are surface lithic artifact positions. (*I*) Excavation grids of the closest archaeological excavations are located nearby in the same stratigraphic package below the AFBT. (*J*) The upper third molar, showing mosaic enamel cracking from thermal alteration. (*K*) Long bone fragment with longitudinal and transverse cracking typical of combustion. (*L*) Burned cranial fragment found on end, in situ, in undisturbed silt sediment. (*M*) Fragments recovered on the surface and in situ with evidence of intense combustion, representing nonduplicating ribs, limb bones, teeth, cranial vault, basicranium, hand and foot, and maxillary/mandibular body parts. *SI Appendix*, section 2.6 gives additional descriptions and illustrations of all three partial skeletons.

Summary and Scenario

Our data and observations suggest an evidence-based Middle Stone Age occupational scenario that integrates available geological, paleontological, and archaeological results. The Faro Daba beds offer landscape-to-locus evidence in a Late Pleistocene African setting. The paleo-Awash river seasonally flooded an undulating paleotopography, its channel water perennially supporting flora and fauna in a semiarid environment, and its seasonal flooding deposited sediment across the river's wider floodplain. Inverted tributary channels provided Faro Daba's MSA humans intermittent access to shade, food, and lithic raw materials in this otherwise swampy, seasonally flooded landscape dominated by woodland-to-riverine forest vegetation.

During recurrent ephemeral occupations of this rich landscape, humans shared this catchment with an array of animals including abundant large rodents, small to medium bovids, arboreal monkeys, and a variety of birds, lizards, and snakes. Procurement of locally exposed raw material enabled fine and heavy-duty tool manufacture during occupations of unknown frequency and duration. The results of this manufacture—and sometimes the remains of the human visitors—were embedded in overbank silts on an aggrading floodplain distal to the main river channel. They are now being revealed by slow wind and water erosion at Faro Daba.

Recent reviews show that earlier continentally inclusive concepts of the African Middle Stone Age are being abandoned by contemporary paleoanthropologists as evidence for temporal and geographic ranges has expanded (e.g., refs. 87 and 88), following pioneering assessments of the late J.D. Clark (89). There is broad consensus that humans occupied a wide range of habitats across the continent by 100,000 y ago when the Halibee MSA populations lived. Some now argue that late MSA *H. sapiens* evolved to occupy a "new generalist specialist niche" (90), whereas others postulate linkage between a hypothesized "broader niche" and global climatic instability (19). But as Clark appreciated decades ago based on a far more restricted pan-African record, our African ancestors had already spread across the continent with technological skills and cognitive capabilities that had allowed niche and geographic expansion at least a million years earlier.

The surface and subsurface resources embedded in Ethiopia's Halibee member will last for generations. The initial scenario for Faro Daba offered above will be subject to further testing and validation via field and laboratory studies. We predict that the continued integration of ongoing actualistic investigations of the modern Middle Awash geology and biology will continue to contextualize the geological, paleobiological, and archaeological traces at Halibee, just as the Middle Pleistocene evidence lying directly below the Halibee member will contribute to understanding how behaviors, anatomies, and environments of the Middle Awash inhabitants changed across deep time.

Data, Materials, and Software Availability. Access to original fossils and artifacts require Ethiopian Government permission. All other data are included in the article and/or supporting information.

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