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REPORT

When Hominins Conquered Highlands—an Acheulean Site at 3000 m a.s.l. on Mount Dendi/Ethiopia

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Introduction

High-altitude mountain habitats are regarded as unfavorable for human occupation (e.g., Aldenderfer 2014) and basic findings of high altitude human physiology research impressively illustrate this: e.g., prevalence of high-altitude hypoxia, increased UV radiation, increased loss of water, and higher basal metabolic rates (Beal 2001; Berghold and Schaffert 2009). Therefore, it seems reasonable that hominins would only be pushed into such conditions by decreasing land resources in the lowlands following rapid population increase or ecological changes (Basell 2008; Foerster et al. 2015). In fact, the scarce archeological evidence for a pre-Holocene occupation of high mountain ranges hypothesized a late colonization of these environments. Archeological investigations on Mount Dendi (3270 m a.s.l.) located on the Ethiopian Plateau question this assumption.

The Dendi caldera is situated about 110 km west from Addis Ababa in the Western Central Highland Plateaus of Ethiopia (Fig. 1a, b). It is among the central volcanoes along the Yerer-TulluWellel volcano tectonic lineament (YTVL) that begins at the western margin of the Main Ethiopian Rift (MER) and extends to the west as far as the Sudan border (Abebe 2014). The volcano is part of the upper volcanic sequence of the Ethiopian Plateau, where the volcanic activity started during the Late Miocene with formation of the YTVL, with volcanic activity ceasing less than 1 myr ago (Abebe et al. 1998; Abbate et al. 2015).

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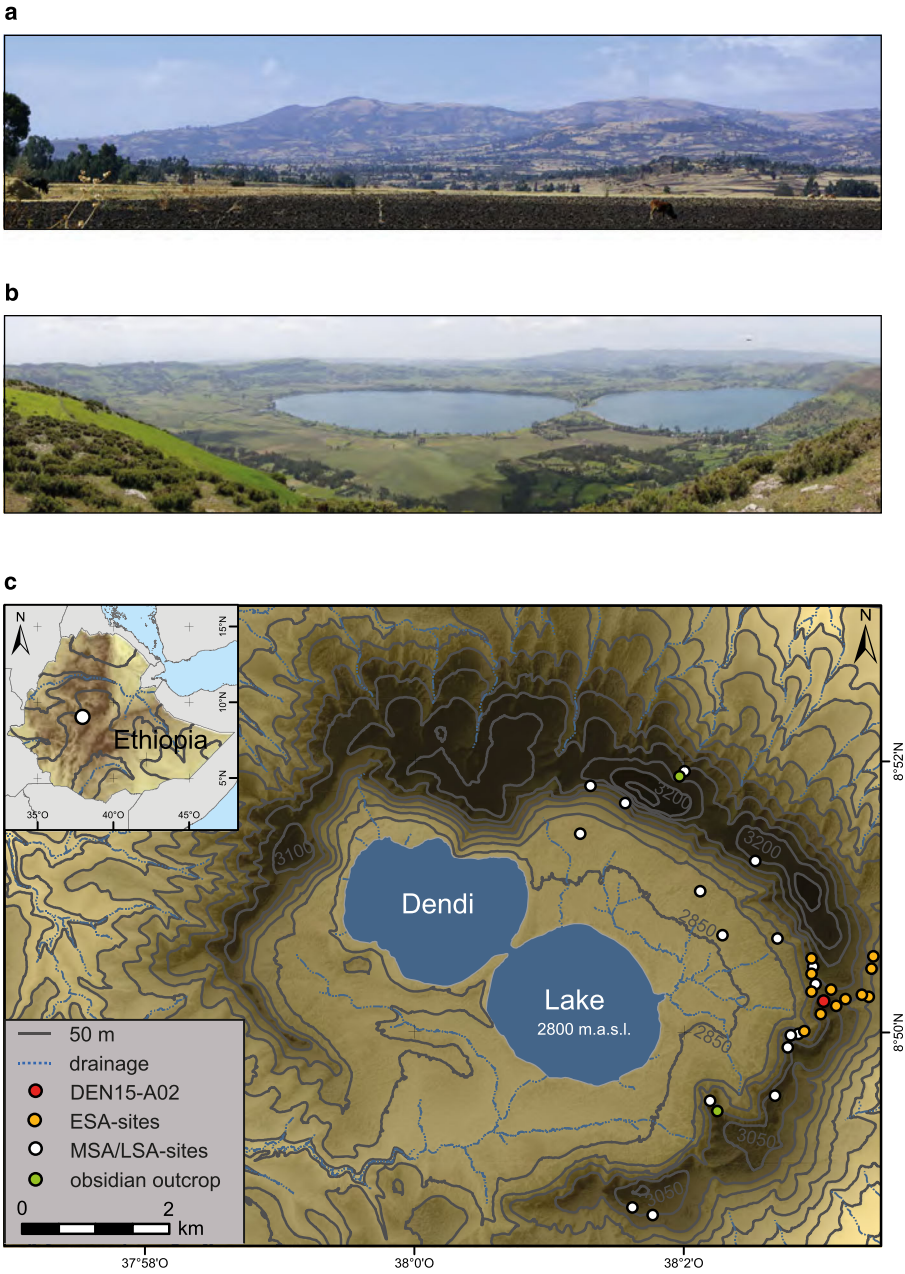


Fig. 1 Mount Dendi. (**a**) View of Mount Dendi (looking west). (**b**) View of the two crater lakes within the caldera. (**c**) Map showing the location of archeological sites (The basic digital elevation model (DEM) was extracted using ENVI software and panchromatic images of Pléiades (1A) stereo pair satellite imagery (date: 2014-12-28: cloud cover: 0%; cell sizes: 0.5 m × 0.5 m; coordinate system: WGS 84)

Dendi is a large silicic volcanic complex constituted by both trachytic and rhyolitic lava flows and domes. The rhyolites and trachytes are pale gray and have an aphanitic

or microporphyritic texture with Sanidine phenocryst. Obsidian lava flows on top of these deposits have been an important raw material source for the production of stone artifacts. The lava flows are overlain by younger pyroclastic deposits dominated by pyroclastic surge lapilli tuffs and minor ignimbrite and volcanic ashes. These products mainly constitute the floor of the caldera except the volcanic ash which is found everywhere in the caldera (Zinaye 2014).

A notable feature is the presence of two connected lakes formed within the central depression (Fig. 1) surrounded by the caldera rim rising up to 440 m above lake surface. A large number of springs in the steep slopes of the caldera drain into the lakes, with the exception of some tributaries of the Huluka River, which joins the Blue Nile (Abay) Basin. During high water levels, the lakes flow out to this basin. The current abundance of water is recharged primarily during the main rainy season from June to September (annual mean precipitation: ~1400 mm) (Degefu et al. 2014; Adimassu et al. 2014).

Research Background

Archeological prospections concomitant to coring activities on the crater lakes by a CRC 806 research group in 2012 (Wagner et al. 2018), led to the first discovery of Stone Age sites. Further archeological surveys in 2013 and 2015 resulted in the recording of a total of 71 archeological sites from all Stone Age periods. A test-excavation in a small rockshelter (DEN12-A01) yielded four Holocene Later Stone Age layers with a tool spectrum dominated by backed microliths (Schepers et al. in prep.). The Middle Stone Age is mainly represented by single finds of obsidian points that might have been lost during hunting trips. Of outstanding importance are ten Early Stone Age (ESA) sites with large obsidian bifaces that demonstrate the presence of hominins at high altitudes already during the Middle Pleistocene. This short report will focus on one of these sites, DEN-12-A02 that is located at an altitude of 3000 m a.s.l. and yielded finds in stratigraphic context. The altitude has been the same at time of the deposition, given that the impact of tectonic uplift was insignificant during the last 500 ka in the southeastern Ethiopian Plateau (Pik et al. 2003; Xue et al. 2018).

Site DEN-12-A02

Road construction work, creating artificial terraces in three successive levels at the shoulder of the crater rim, exposed the site of DEN-12-02 (Fig. 2a). Obsidian is the exclusive raw-material used for the production of the 65 artifacts (33 flakes, 8 cores, 5 blades, 8 large bifacial tools, 7 small facially retouched points). On the upper artificial terrace, characteristic stone tools are typologically attributed to the Middle Stone Age (MSA), while on the surface of the middle artificial terrace artifacts appear to be from the Early Stone Age (ESA) with only a number of probably displaced MSA artifacts. A thin scatter of artifacts from both periods on the lower terrace is interpreted as having been redeposited. The assumed origin of the ESA artifacts from the wall above the middle artificial terrace was verified in 2015 by the excavation of an archeological horizon in this part of the sequence that included one handaxe and two flakes in situ (Fig. 2c).

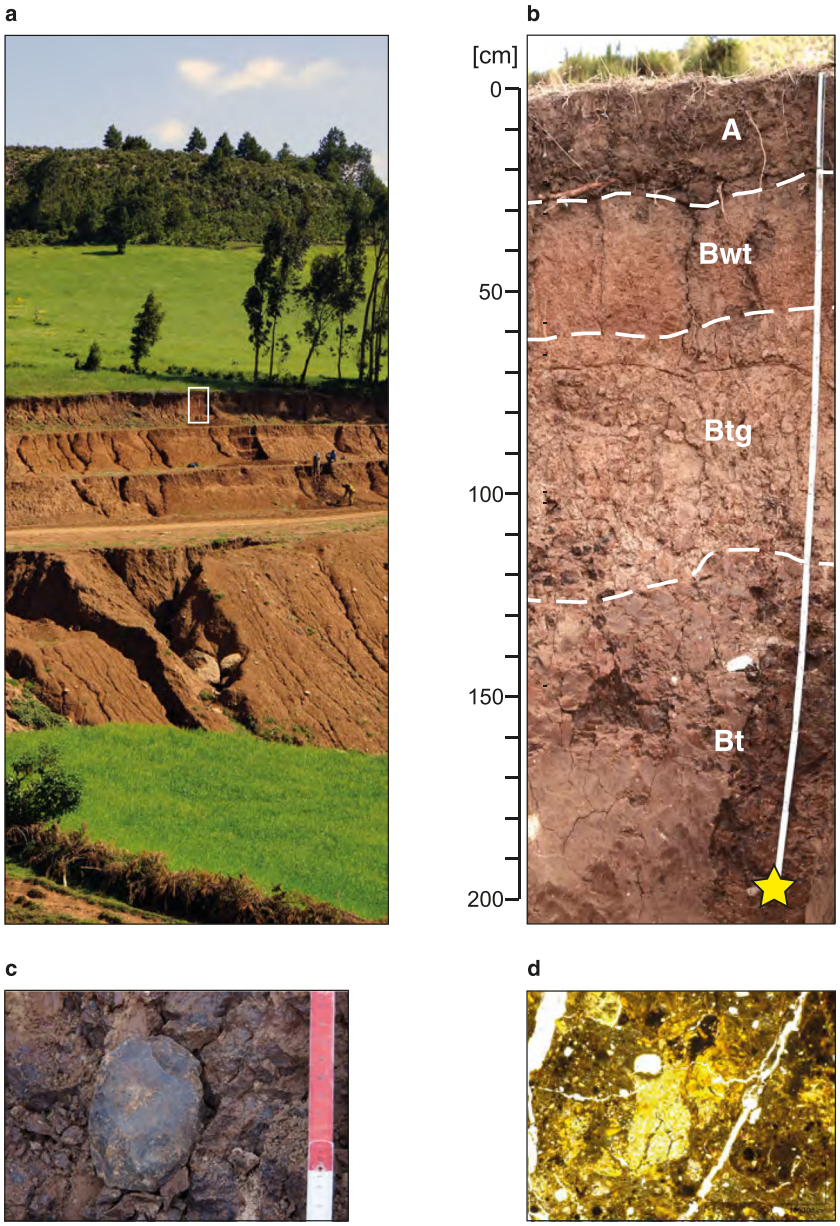


Fig. 2 The Acheulean site DEN12-A02. (**a**) View of the three artificial terraces and location of profile B (white rectangle, humans as scale). (**b**) Profile DEN15-A02 with four different soil horizons. The in situ handaxe was found in the Bt horizon (★). The surface horizon A is a silty clay loam containing roots and showing a high total organic content (TOC; 4%). TOC and grain size decrease with depth. The lower horizons Bwt, Btg, and Bt all classify as clays and have TOC-values < 1%. These horizons show blocky soil structure and firm soil consistence. Furthermore, strong accumulation of siliceous clay with voids of manganese-oxides and iron hydroxides in the matrix are evident, also in characteristic micromorphological features such as intact coatings and nodules (**d**). (**c**) Handaxe in situ

Stratigraphy and Micromorphology

The hand axe was found 2 m below the actual surface in the uppermost level of the terrace embankments that was further excavated. The profile DEN15-A02 prepared at this location exposed dark reddish colored clayey slope deposits, more than 2 m thick (Fig. 2b) interspersed with heavily weathered pyroclastic rock fragments. Features of sediment redeposition such as sharp boundaries between soil horizons, bedding, laminations, or rotational features were not apparent. Pronounced pedogenesis resulted in a sequence of A/Bwt/Btg/Bt horizons, with all horizons containing at least 37% clay. The lowermost Bt with 54% clay shows a particularly strong pedogenic alteration. This is reflected by several generations of illuvial clay coatings, frequent manganese oxide and iron hydroxide nodules and coatings as well as by a strongly developed soil structure. Stagnic color pattern in the Btg horizon (46% clay) indicates reduction/oxidation processes caused by seasonal water saturation. Micromorphological evidence and granulometric composition suggest that an eluvial horizon is lacking, probably due to erosion of the upper part of the profile. The lower part of the sequence, however, does not show any characteristic feature of reworking along the slope, hence, an in situ preservation of the lower part of the sediment sequence is suspected. Considering the different generations of illuvial clay coatings and intercalation by manganese coatings (Fig. 2d), it is highly likely that formation of the lower Bt horizon started a long time ago and was polygenetic, i.e., it continued during several glacial/interglacial cycles. Radiocarbon dating of organic samples has a maximum age limit of around 50,000 years, while a much higher age of several 100,000 years is expected for the find horizon. As luminescence dating of vulcanogenic minerals has proven unreliable (e.g., Tsukamoto et al. 2007), we did not carry out these radiometric methods. In addition, palaeomagnetic measurements yielded no results.

Lithic Assemblage

The analysis of all archeological finds from Mount Dendi is ongoing and a large contextual study, which will present detailed data from all sites, is planned for a comprehensive research article. Despite the preliminary stage of this work, we wanted to share a few observations about the DEN-12-A02 assemblage.

The DEN-12-A02 ESA assemblage is characterized by varied tool type forms, including elongated hand axes ($n = 2$), ovate hand axes ($n = 3$), one cordate hand axe, leaf-shaped scrapers ($n = 2$), one backed biface ("Keilmesser"), and one cleaver (Fig. 3). In contrast to the diverse tool-types, the operational sequences (*chaines opératoires*) are similar (standardized analysis after Richter 2004; 2018 p.78–95). In the majority of cases, the platy natural surface of the obsidian slabs is partly preserved and sometimes used as a naturally backed edge. Facial shaping was first completely finished on one face and then on the other. In a last step, lateral thinning and edge retouch were performed for the preparation of the working edge (Fig. 4).

The technological similarity of the production processes indicates a consistent association of the assemblage, which would most probably represent one temporary occupational event. Tool types, their heterogeneous spectrum and the shaping method, indicating a high level of knapping skill, i.e., bifacial retouch extending over whole

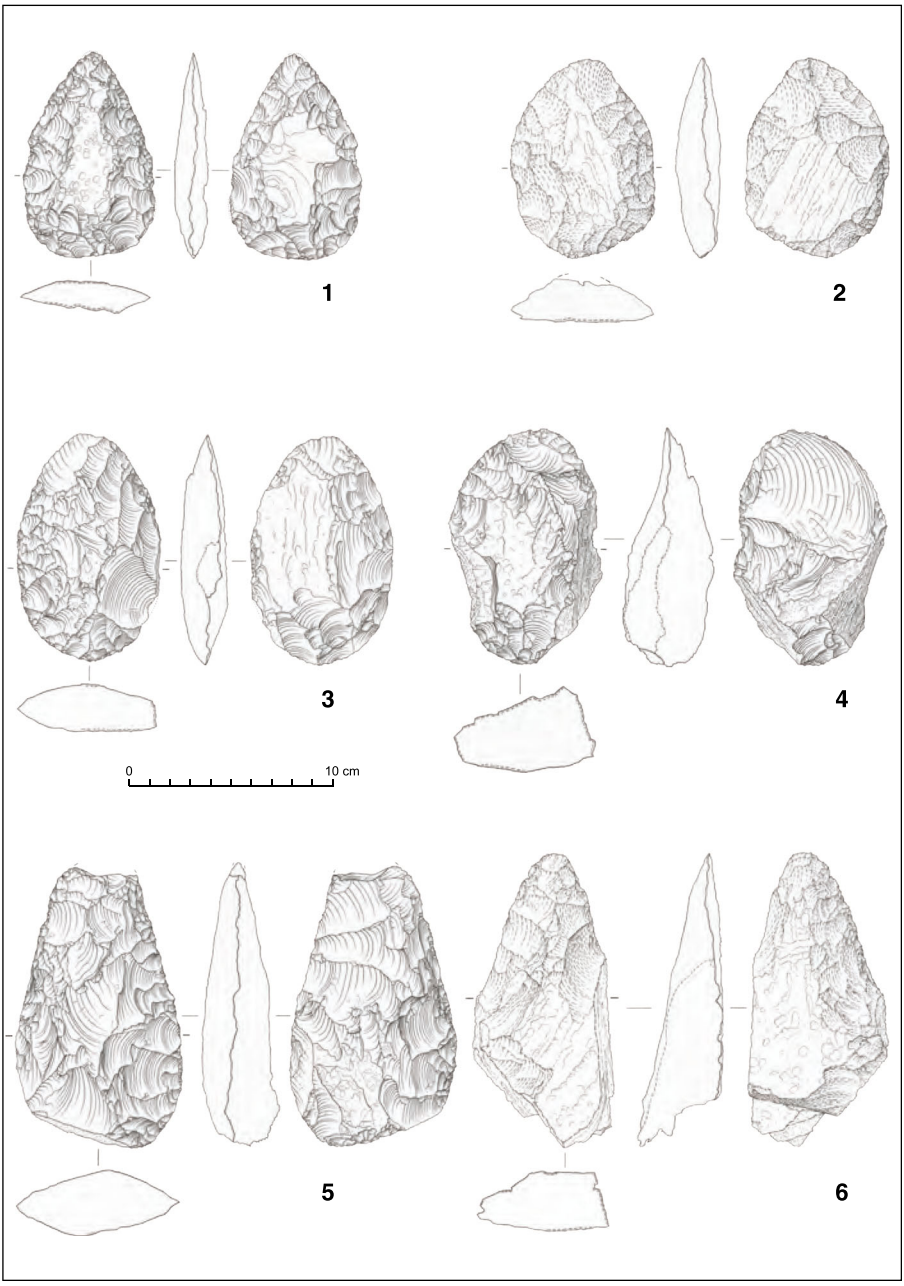
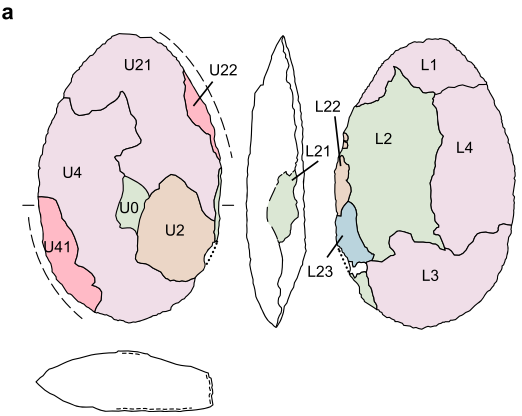
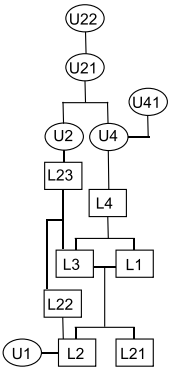


Fig. 3 DEN12-A02 bifacial tools. (1) Flat cordate hand axe, (2) bifacial scraper, (3) ovate hand axe, (4) cleaver-like biface, (5) elongated hand axe, and (6) bifacial knife ("Keilmesser")

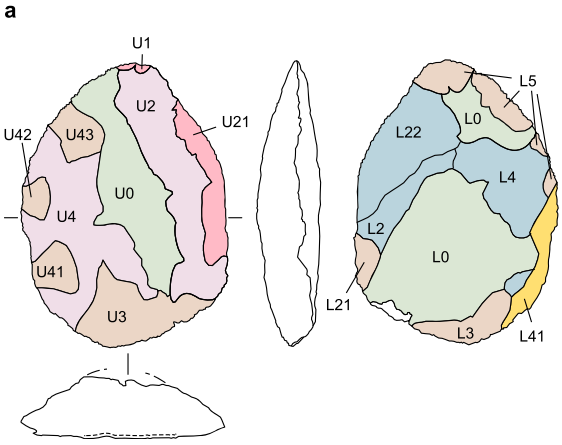
surfaces, lateral thinning, and edge retouch point to a Middle to Late Acheulean age classification of the site (Chazan 2015, Gallotti & Mussi 2017, Schick and Toth 2017, Shipton 2018). Working on one face and then on the other has also been documented in

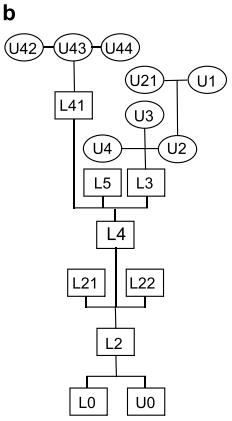




c

Upper face		Lower face	
Step	**Modification**	**Step**	**Modification**
U0	cortical surface	L2	cortical surface
U4	convex shaping	L21	cortical surface
U41	flat retouch	L22	lateral thinning
U2	lateral thinning	L3	convex shaping
U21	convex shaping	L1	convex shaping
U22	semi-steep retouch	L4	convex shaping
		L23	platform preparation (for U2)





c

Upper face		Lower face	
Step	**Modification**	**Step**	**Modification**
U0	cortical surface	L0	cortical surface
U1	traces of utilization	L2	flat shaping
U2	convex shaping	L21	lateral thinning
U3	distal thinning	L22	flat shaping
U21	semi-steep retouch	L3	lateral thinning
U4	convex shaping	L4	flat shaping
U41	lateral thinning	L41	La Quina retouch
U42	lateral thinning	L5	lateral thinning
U43	lateral thinning		

Fig. 4 Two examples for the operational sequence analysis after Richter (2004); 2018 p.78–95; Online resource 1) of bifaces from the site DEN12-A02. **c** Classification of the steps of procedure

India, where it was argued to relate to increased hierarchical complexity at the transition from the Acheulean to the Middle Paleolithic (Shipton et al. 2013, 101). Inter assemblage variability of tool size might be explained by functional variability, geographic distinctions, different raw-material usage, or chronological differences. Therefore, a comparison of mean length/breadth measurements from DEN12-A01 with other Ethiopian ESA sites as a chronological indicator has to be considered with care. However, there seems to be a general trend of miniaturization that supports the Late Acheulean chronological classification (Fig. 5). The most resembling assemblage, not only in the

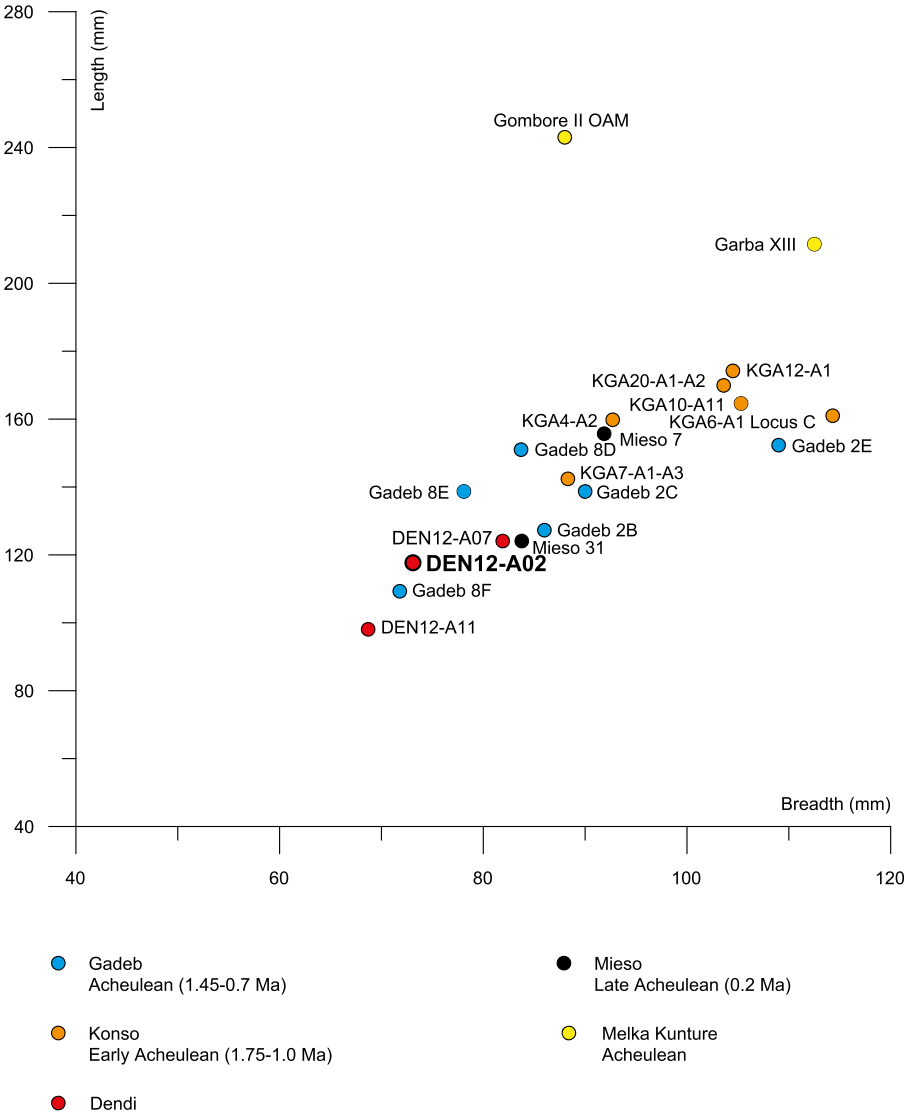


Fig. 5 Mean length-breadth ratio of Ethiopian hand axe assemblages (Gadeb: de la Torre 2011; Clark and Kurashina 1979. Konso: Beyene et al. 2013. Melka Kunture: Gallotti et al. 2010, 2014; Piperno et al. 2004. Mieso: de la Torre et al. 2014)

relatively small size of the artifacts, but also in the typological diversity and technological aspects, such as marginal trimming, is Mieso 31. The Mieso Acheulean is dated around 212 ka ago and is one of the latest evidences of this period in Eastern Africa (de la Torre et al. 2014). A similar Late Acheulean chronological classification can be assumed for DEN-12-A02, indicating an age between 500 and 200 ka ago.

To our knowledge, the site DEN12-A02 is the highest-located Acheulean site (Table 1). Such sites are extremely rare and "modern behavior" connected to the advance of early *Homo sapiens sapiens* seemed to be the precondition for the successful colonization of such harsh environments. Indeed, the systematic occupation of Europe's high-relief upland regions began as late as the Mesolithic (Biagi and Starnini 2015). Only few earlier exceptions came to our knowledge such as Neanderthal presence at 1477 m (Wildkirchli) and at Salzofen (2007 m) in the Central Alps (Richter 2006). But there are also only rare examples of modern *Homo sapiens* presence exceeding 1000 m.a.s.l. from the Upper Paleolithic period in Europe, e.g., in the southeastern Alps (Verpoorte 2012). Indeed, it is striking that with a single exception all Acheulean sites in high-altitude environments are located in Ethiopia (Chavaillon and Piperno 2004; de la Torre 2011).

Conclusions

The site DEN12-A02 shows that hominins might have settled in high-altitude regions already before the advance of *Homo sapiens sapiens*. This would question the concept of modern humans' superiority in a wide range of domains, such as subsistence strategies and hunting equipment in comparison to extinct hominins (for a critical discussion of this concept see: Villa and Roebroeks 2014). In any case, for millennia modern *Homo sapiens* seemed to have no reasons to colonize high mountains in Europe.

Table 1 Finds of bifaces in high-altitudes. Single finds from northwest Iran (Biglari and Shidrang 2006) and Namibia (Breunig 2003) are not included

Name	Location	~Altitude m a.s.l.	Finds	References
Tsona	Caucasus	2150	134 Lithics including at least 18 Acheulean bifaces, dating to the end of OIS 7 92% bones *Ursus spelaeus*	Doronichev 2008
Melka Kunture	Ethiopia	2020	More than 70 sites ranging from the Oldowan to the Late Stone Age. Besides few Early Acheulean sites, especially a later phase of the African Acheulean is well-represented (Gombore II, dated to ~0.8 myr ago, Garba I, dated to ~0.5 myr ago)	Chavaillon and Piperno 2004
Gadeb	Ethiopia	2300	Eight localities dated between 1.45 and 0.7 myr ago with more than 50 hand axes/large cutting tools (LCT)	de la Torre 2011

Why hominins conquered the tropical high-altitude habitat already at this early time is still an open question. Was the area a common habitat or was it only used as a refugium during times of environmental stress? Is the case of Dendi, an exception from the general settlement scheme or is the absence of sites the result of a research deficit in high-altitude regions? It is striking that with only one exception, all Acheulean sites in high-altitude environments are located in Ethiopia. Under certain environmental conditions, high mountains in tropical zones might have been favorable ecological niches despite the general stress factor for hominins in high altitudes. Fresh water availability may have played a key role. Modern circulation patterns suggest the Ethiopian Highlands are likely to have received more rainfall than surrounding regions of northern Africa and the Horn during prehistoric times. The region receives moisture from both the Atlantic and Indian Ocean system (Umer et al. 2004) and as a major topographic feature, the highlands capture high orographic rainfall. In the case of Mount Dendi, the crater lakes, if they already existed, might have been important water reservoirs during arid periods.

The ongoing analysis of lacustrine and terrestrial sediment cores from the crater lakes and the caldera deposits hopefully will elucidate the climate history and environmental conditions of the area and might help to answer these questions.

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Compliance with Ethical Standards

Conflict of Interest On behalf of all authors, the corresponding author states that there are no conflicts of interest.

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