Ichnological and archaeological evidence from Gombore II OAM, Melka Kunture, Ethiopia: an integrated approach to reconstruct local environments and biological presences between 1.2-0.85 Ma

Authors: Flavio Altamura[1], Matthew R. Bennett[2], Lorenzo Marchetti[3], Rita T. Melis[4], Sally C. Reynolds[2], Margherita Mussi[1]

[1]Dipartimento di Scienze dell'Antichità, Università di Roma Sapienza, Piazzale Aldo Moro 5, 00185 Rome, Italy,

[2]Institute for Studies in Landscapes and Human Evolution, Bournemouth University, Poole, BH12 5BB, UK.

[3]Urweltmuseum GEOSKOP/Burg Lichtenberg (Pfalz), Burgstrasse 19, 66871 Thallichtenberg, Germany

[4] Dipartimento di Scienze Chimiche e Geologiche, Università di Cagliari, Via Trentino 51, 009127 Cagliari, Italy

Corresponding author: Flavio Altamura, email: flavio.altamura@uniroma1.it

Abstract

New ichnological data are available at the prehistoric site of Melka Kunture, Upper Awash Valley in Ethiopia. Excavation of new test pits enabled us to explore the volcanic and fluvio-lacustrine sequence at the Gombore II Open Air Museum archaeological site (ca. 0.85 Ma). This has allowed a detailed reconstruction of the palaeoenvironment and of the fauna present in the time interval between 1.2 and 0.85 Ma. Various-sized mammals, birds, molluscs as well as hominins left tracks throughout the sequence, and document a varied fauna and associated behaviours. Most of the hominin tracks were made by young individuals on the basis of size and are some of the earlier child tracks to be reported. The mollusc traces document the presence and orientation of water streams which, according to the associated vertebrate traces, were visited by hominins, mammals and birds. Most of these traces were found within levels traditionally considered barren for archaeology, yet they all document life activity and are always *in situ*. This confirms the potential of the ichnological research as an important complementary tool for archaeological investigations.

Keywords: Melka Kunture, Pleistocene, Gombore, Archaeology, Fossil footprints, Ichnology, Palaeoenvironment

1 Introduction

In the last decade, ichnology has emerged as a powerful tool for reconstructing past landscapes and the ecology of sites relevant to our understanding of human evolution. While the record of fossil Plio-Pleistocene hominin footprints is constantly increasing (e.g., Bennett and Morse, 2014; Masao et al., 2016; Hatala et al., 2017, 2020; Bustos et al., 2018; Helm et al., 2018; McLaren et al., 2018; Duveau et al., 2019; Muñiz et al., 2019; Avanzini et al. 2020), the integrated analysis of footprints, lithostratigraphy, palaeontology and archaeology is less common although there are exceptions and the picture is slowly changing (but cfr. Fabiano and Zucchelli, 2003; Mastrolorenzo et al., 2006; Silva et al., 2013; Pastoors et al., 2015; Mussi et al., 2016; Ledoux et al., 2017; Panarello et al., 2017, 2020; Altamura et al., 2018; Moreno et al., 2019; Romano et al., 2019; Serangeli et al. 2020).

Melka Kunture consists of a cluster of Pleistocene sites, that spread over 100 sq. km on the Ethiopian Highland at about 2,000-2,200 m a.s.l. It is located along the Upper Awash River, some 60 km south of Addis Ababa (Fig. 1). French researchers started their investigations in 1960s (Bailloud, 1965; Chavaillon and Piperno, 2004), and in 1999 the activity was taken over by an Italian Archaeological Mission, currently under the direction of one of the authors of this study (MM). Melka Kunture is a complex accumulation of Pleistocene fluvial and lacustrine deposits, interbedded with volcanic units from eruptive centres a few dozens of kilometres away. Absolute radiometric dating (K-Ar and $^{40}Ar/^{39}Ar$), and magnetostratigraphic analyses give dates that start at 1.8 Ma (Chavaillon and Piperno, 2004; Morgan et al., 2012; Tamrat et al., 2014). A range of archaeological artifacts have been recovered over the years (Chavaillon and Piperno, 2004). On this plateau, hominins would have faced a challenging environment, with a cold and high-mountain ecosystem characterized by vegetation of the dry evergreen Afromontane forest and grassland complex, with variable high-altitude forests and grasslands (Mussi et al., 2016; Bonnefille et al., 2018). Accordingly, Melka Kunture could be viewed as a testing ground for the hominin survival and adaptive capabilities during the earliest Out of Africa episodes.

Recently, this Pleistocene record has been enriched by the discovery of ichnological surfaces. The fossil footprints were not reported, nor described, during the previous 50 years of research. Since 2013, bioturbated surfaces have been identified during fieldwork, and more were spotted during a review of the archival documentation of past excavations. They occur in the localities Kella Gully (1.8-1.7 Ma), Garba IVD (1.6 Ma), Garba XII (1.3-1.1 Ma) and elsewhere in the Garba Gully (1.3-1 Ma), Simbiro III (1.2 Ma) and Garba I (0.6 Ma) (Altamura, 2017, 2019, forthcoming). In the Gombore Gully, trampled layers were documented both by surveys of natural sections or in standing archaeological walls (Gombore I and above Gombore Iγ, ca. 1.5-1.3 Ma; Gombore X, ca. 0.7 Ma; Gombore III, ca. 0.6-0.4 Ma), and by extensive excavations and test pits. A well-preserved trackway and some isolated footprints made by a hippopotamus community were discovered at Gombore II-2 just above a tuff dated to 0.7 Ma (Altamura et al., 2017). Just below the same tuff, an ichnosurface exposed over ca. 35 m^2 hundreds of hippopotamus, bovid, equid, bird, and other small mammal footprints. Eleven hominin footprints were identified on this surface, some of them belonging to potentially young individuals (1-3 years old) on the basis of their size. They were associated with rich archaeological and faunal evidence, including fossil bones of hippopotamus butchered by the multi-age hominin group, suggesting activities conducted directly on the spot (Altamura et al., 2018).

Five metres below this ichnosurface, in the final units of the Lower Pleistocene sequence, lies Gombore II, a large middle Acheulean site with several sub-sites, dated at ca. 0.85 Ma. Surface bioturbations at the interface between fluvial and lacustrine deposits were identified at one of these sites (Gombore II OAM). The excavation of fossil footprints started there in 2015 and continued in the following years focused on deposits which date from between 1.2 and 0.85 Ma. Most of the recorded ichnosurfaces show signs of bioturbation. Footprints are associated with lithic and faunal remains, but in many cases, they provide the only hint of any biological activity. New hominin footprints were also recorded from these units. We present this new ichnological evidence in association with a compendium of lithostratigraphical, archaeological and palaeontological data. By combining these different lines of evidence, we can build a detailed reconstruction of the local palaeoenvironment. Moreover this work points to the potential promise for further ichnological research in this area.

1.1 The Gombore Gully

Gombore is one of several small gullies on the right side of the Upper Awash River. During the Holocene, and up to present times, a seasonal stream has eroded the Lower and Middle Pleistocene beds exposing archaeological horizons within them. The Pleistocene deposit (ca. 20 m thick) are formed of fluvial and lacustrine sediments (sand, clay, gravel) interbedded with either primary, or reworked, volcanic tephras (Taieb, 1974; Kieffer et al., 2004; Raynal et al., 2004; Morgan et al., 2012; Mussi et al., 2016).

The area was first surveyed by L. Bailloud, a French prehistorian, in the early 1960s (Bailloud, 1965) and became the focus of research led first by the French, and later by the Italian archaeological mission (e.g., Chavaillon and Berthelet, 2004; Gallotti et al., 2010; Gallotti and Mussi, 2016, 2018; Mendez-Quintas et al., 2019). The stratigraphic sequence starts with Gombore I, a multilayered site with Oldowan and early Acheulean evidence dated between 1.8 and 1.5 Ma (Chavaillon and Piperno, 2004; Morgan et al., 2012; Gallotti and Mussi, 2018). Higher up in the gully, an impressive middle Acheulean layer, the so-called "main level", directly overlies a tuff dated to 0.87 Ma that extends over at least 1,000 m^2 (Morgan et al., 2012; Mussi et al., 2016). The Acheulean layer has been explored in several areas, including: Gombore II-1 (70 m^2), Gombore II-3 (8 m^2), Gombore II-4 (13 m^2), and Gombore II-5 (9 m^2). In 2001, a further 35 m^2 was exposed, fenced, protected with a thatched roof and left in full view for visitors. This eventually became known as the Gombore II Open Air Museum, or Gombore II OAM for short (SI Fig. 1). Overall, the main archaeological layer is a dense accumulation of cobbles mixed with thousands of lithic and faunal remains. The layer is approximately 0.15 m thick and locally split into two superimposed lenses (Chavaillon and Piperno, 2004; Gallotti et al., 2010). Mendez-Quintas et al. (2019) interpreted the mixed cobbles at Gombore II OAM as a lag deposit, with a direct anthropogenic component on and within its upper surface.

As elsewhere all over the Pleistocene sequence of Melka Kunture (Chavaillon and Piperno, 2004), the taxon *Hippopotamus* cfr. *amphibius* is abundant, and represents a third of the whole faunal assemblage. The palaeoenvironment was clearly suitable for hippopotamus consisting of marshes and ponds along a meandering palaeo-Awash which provided both appropriate residential areas, and grazing surfaces nearby (Altamura et al., 2017). *Bovidae* are attested by several subfamilies such as Bovinae, Alcelaphinae, Reduncinae, and Antilopinae. This suggests the co-existence of both open and aquatic spaces. Suidae, Giraffidae, Rhinocerontidae and Equidae are also documented, while carnivores (Hyaenidae and Canidae) are extremely rare. Only two bird remains are recorded (Pichon, 1979; Chavaillon and Berthelet, 2004; Gallotti et al., 2010). At Gombore II sub-sites hominins are well documented by thousands of lithic implements, obtained both from debitage and from shaping methods. Typical middle Acheulean implements, as handaxes and cleavers, are common. Furthermore, two hominin cranial fragments were discovered at Gombore II-1 (Chavaillon et al., 1974; Chavaillon and Coppens, 1986) and recently attributed to an early form of *Homo heidelbergensis* (Profico et al., 2016).

Above the main archaeological layer, a sandy and sandy-silty fluvio-lacustrine unit accumulated and is followed by a ca. 2 m-thick lacustrine deposit of clays and silty-clays. On the top of this unit, another sandy and sandy-silty unit overlaps the Matuyama-Bruhnes magnetostratigraphic boundary (0.78 Ma). The fossil footprints and archaeological traces of the Gombore II-2 site, the so-called "hippo butchering site", post-date the palaeomagnetic reversal (Chavaillon and Berthelet, 2004; Tamrat et al., 2014; Mussi et al., 2016; Altamura et al., 2018, 2020). A 1 m thick distal volcanic tuff sealed the palaeo-landscape at 0.7 Ma (Morgan et al., 2010; Altamura et al., 2018). After this event, the fluvial environment and the fauna quickly recovered, allowing mammals and eventually hominins to repopulate the area (Altamura et al., 2017, 2020). In the uppermost Gombore Gully, late Acheulean evidence is found *in situ* at Gombore III, which is dated to between 0.6 and 0.4 Ma (Mussi et al., 2016). MSA and LSA implements were collected on the surface by L. Bailloud (1965) and M. Taieb (1974).

1.2 The ichnological record adjacent to Gombore II OAM

In the archival and published pictures and sketches of past excavations possible footprints are visible in the sedimentary sequence that pre-dates the Matuyama-Brunhes reversal (see e.g., Mussi et al., 2016; Altamura and Mussi, 2017; Altamura, 2019, forthcoming). These had previously gone unnoticed, or their significance was not recognized. Further potential tracks and bioturbations were spotted along the standing excavation walls of Gombore II-1 and Gombore II OAM by one of the authors of this study (FA). These structures consist of sharp downward undulations between silt and sand layers. They penetrated a few cm into the underlying layer and reveal a visible true track in cross-section. Beneath the true track further deformation is visible and is presumably the undertrack. The true tracks are infilled by the overlying sediment layer. Along the standing walls of Gombore II OAM, some of the potential tracks have rounded bases and are up to 23 cm wide. Due to their size these have been tentatively attributed to hippopotamus, or to large-sized bovids (Mussi et al., 2016).

In 2015 erosion revealed the surface of a Pleistocene silt layer, just north of Gombore II OAM. Several sandy spots were noticed on this silt surface. A 1 m^2 test pit was opened, called Gombore II OAM North Footprint test (henceforward Test Pit A, Fig. 2). In this test pit vertebrate footprints were recorded, including small hominin tracks (SI Fig. 1) and a preliminary report was published (Altamura and Mussi, 2017).

In 2017, a second test pit was opened (2 m^2) outside the southwestern corner of the open-air museum (Gombore II OAM South-West Footprint test, henceforward Test Pit B, Fig. 2). Here, the alternating silts and fine sands that cap the main archaeological layer were preserved and had a thickness of ca. 1.6 m. This part of the sequence was thought to be sterile since previous excavations had found no bones or lithics. However, along the excavation walls of Gombore II OAM, just 2.5 m away, a fluvial channel bank with bioturbated layers was visible. The test pit was stopped when at the depth of the main archaeological layer. Twelve bioturbated layers were documented throughout this sequence, but no archaeological remain above the rich Acheulean level at the bottom were identified.

In 2018 and 2019, a third test pit (6 m^2) was dug along the north-western corner of Gombore II OAM (Gombore II OAM North-West Footprint test, henceforward Test Pit C, Fig. 2). In this area the current seasonal stream had already eroded the Pleistocene deposits overlying the main archaeological layer, as well as the archaeological layer itself. We found the remains of the latter re-deposited within the modern clayey soil (Black Cotton Soil). Test Pit C started from the 0.87 Ma tuff layer (Morgan et al., 2012) at the base of the main archaeological horizon. The sequence (i.e. below the archaeological layer) was explored through a depth of 1.8 m. Lithic and faunal remains were unearthed in association with five trampled horizons. Another tuff, in the lower part of the test pit, corresponds to the "former B tuff" of the Gombore I Gully, described by Raynal et al. (2004) and dated by Morgan et al. (2012) to 1.2 ± 0.07 Ma. At the base of the test, two sandy layers and a sandy/gravel layer below the deepest trampled silt were brought to light over 1 m^2 and excavated over a sample area of 0.5 x 0.5 m.

2 Materials and methods

The excavations were led by the first author of this contribution (FA) under the direction of the Head of the Mission (MM), removing the layers through décapage horizontal, that is excavating progressively one thin layer at a time and following any change on the surface of each layer. This method allowed us to follow, expose and examine each layer for tracks in turn. Eighteen different bioturbated surfaces were identified within the Test Pits A, B and C and are numbered progressively from the top to the bottom, while the other layers are left unnumbered but described in detail in Section 3.1 (Table 1). Different colour, consistence and composition allowed these bioturbations to be identified and allowed discrimination between substrate and track infill possible. Sand or silty sand usually filled the bioturbations in the silty or silty-sandy substrate. Each track was emptied using lancettes and small brushes. In some cases, however, the track infill and the substrate were so similar that it was impossible to distinguish between them properly. In this case (e.g., Layer 8), rather than trying to explore the 3D shape(s) we simply noted the presence of any bioturbation(s), or we excavated small sample areas.

The lithostratigraphic sequence was documented between 2015 and 2019. Fieldwork included the systematic description of the exposed sections both from new and previous excavations. Sedimentary features at the meso and micro scale (grain size, structure, unconformities) were studied to document the fluvial sedimentation and volcanic facies. Finally results were correlated with datasets provided by Raynal and al. (2004) and Raynal and Kieffer (2004).

Each palaeosurface was recorded graphically and photographically, and by photogrammetry to produce 3D models using the software Agisoft Photoscan Professional. Once emptied of their infill seven large hippopotamus tracks in Level-14 and the hominin footprint of Level-17 (Test Pit C) were cast in plaster. The hominin footprints in Level-5 (Test Pit B) and in Test Pit A were removed as a consolidated block of sediment (SI Fig. 2, 3). All the archaeological materials, consolidated blocks and casts are kept in the Authority for Research and Conservation of Cultural Heritage storehouse at Addis Ababa, Ethiopia. The 3D models where scaled and auto-rectified so that the plane of the surface was perpendicular to the viewer using DigTrace (www.digtrace.co.uk). Contour maps were produced in DigTrace and colour images rendered using CloudCompare (https://www.danielgm.net/cc/). Ages of human track-makers were calculated with reference to a standard growth curve for modern humans (de Onis, 2006), accepting that this has clear limitations when making inferences above extinct hominins.

For the study of the archaeological material we follow the procedures and terminology used in similar studies on Melka Kunture (e.g., Altamura et al. 2020). Stone tool analysis identified the *chaînes opératoires*, following the terminology and technological concepts by Inizan et al. (1999). For the determination of raw materials we followed Kieffer et al. (2002). The diagnostic faunal remains were determined preliminarily, with the aid of paleontologist Denis Geraads.

3 Results

3.1 Litho-stratigraphic sequence

The new excavations combined with that already available allows a 3.2 m long litho-stratigraphic sequence to be drawn up that extends below and above the main archaeological horizon (Figs 3, 4). While the upper part of the stratigraphy is well-known from previous studies (e.g., Kieffer et al., 2004; Raynal et al., 2004; Gallotti et al., 2010), the section underlying the middle Acheulean layer had not been documented before in detail. Overall, the deposits formed in a fluvial environment and are generally composed of fine-grained overbank deposits with distal ash fall events. Two coarse deposits interpreted as lag deposits indicate higher energy flows that accumulated cobbles and pebbles mixed with fine and coarse sands. The first one is the main archaeological layer which has been identified in all Gombore II subsectors. It consists of a channel-floor lag deposit, 0.1/0.2 m-thick, composed by coarse volcanic pebbles and archaeological and faunal remains included in a well-sorted sandy matrix (Raynal et al., 2004; Gallotti et al., 2010; Mendez-Quintas et al., 2019). The second lag horizon is partially exposed at the base of the sequence in Test Pit C. Although these deposits indicate fluvial dynamics Mendez-Quintas et al. (2019) argued for a direct anthropogenic contribution to the uppermost layer.

Two primary, although distal, ash falls are found below the main archaeological layer in Test Pit C, dated respectively to ca. 0.87 Ma and 1.2 Ma. One lies just underneath the main archaeological layer of Gombore II OAM, while the second occurs almost at the base of the excavation and seals the lower lag horizon. The sequence overlying the main archaeological layer was documented both at Gombore II OAM and within Test Pit B (2 m^2). In Test Pit B, the overbank deposits overlying the main archaeological layer is cross-cut obliquely (N-S) by a palaeo-channel. This channel is also visible in the Gombore II OAM standing walls, just 2.5 m away. Raynal et al. (2004: 161) interpreted this feature as the northern bank of the palaeo-channel (Fig. 4; SI Fig. 4). The stratigraphic sequence in Test Pit B is consistent with a fluvial setting influenced by volcanic ash fall material. The sedimentation took place mainly in an overbank environment affected by the migration of the paleo-Awash River and by crevasse splay/channel deposits.

The stratigraphy in Tests Pits A and C and the units from Test Pit B are reported below from bottom to top (Fig. 3; Table 1).

3.2 Ichnosurfaces

We recorded a sequence of 17 numbered bioturbated surfaces (Fig. 5-8; SI Detailed description of footprint layers; SI Fig. 5-18). The tracks were left by various animals including hominins (Table 2). Some of the palaeo-surfaces are rippled and desiccation cracks indicated occasional sediment exposure and drying.

3.2.1 Bivalves

Almond-like impressions are ubiquitous in Test Pit B Level-3 to -12, and common in Test Pit C Level-14 and -17 (Fig. 9). They are 5 to 40 mm long, 5 to 20 mm wide and up to 10 to 20 mm deep. They are often accompanied by 5 to 20 mm wide elongated, continuous furrows which are either straight, curvilinear, meandering, or irregular. Almond-like impressions and furrows are often superimposed on each other, as in Test Pit B Level-11. A clear transitions between these two morphotypes (single and compound traces) are also observed in Test Pit B Level-4. These traces have a preferential orientation in some layers.
We interpret the almond-like impressions and the furrows as resting and grazing traces of invertebrates, probably bivalves (e.g., Ekdale and Bromley, 2001; Lawfield and Pickerill, 2006; Monaco et al., 2016). In some instances, a complete U-turn is visible and was probably produced by grazing behaviour. The identification of natural shell casts, as in Test Pit B Level-4, provide weight to this interpretation (SI Fig. 19). They most probably belong to unionid clams. In Test Pit B Level-10 the impression of shell ornaments is preserved and further supports this interpretation.

3.2.2 Hippopotamus

On Level-14, hippopotamus footprints, belonging to at least 5 individuals, are preserved and show clear anatomical details such as the four digits and the plantar pad (Fig. 10; see: Bennett et al., 2014; Altamura et al., 2017, 2018). In a few tracks, the two central toes (digits II and III) seem fused in a single impression, but a closer view (e.g., Fig. 10; SI Fig. 2, 14) reveals that they are separated by thin, sub-vertical walls of sediment, thereby excluding an alternative attribution to rhinoceros. Rhinoceros leave tracks characterized by the imprints of the animal wide and short three front toes (e.g., Leakey 1987; Van den Heever et al. 2017). They are also extremely rare in the faunal record of Melka Kunture (Gallotti et al. 2010). On the palaeo-surface of Level-14 there are at least four discrete trackways, as well as isolated tracks (SI Figs. 2 and 14). The largest elliptical depressions are up to 40 cm long and probably belong to adult hippopotamuses, while the smaller prints (ca. 27 cm long) were likely made by infants or juveniles (see comparisons in Altamura et al., 2017). Alternatively, the smaller tracks could be attributed to the pygmy *Hippopotamus aethiopicus*. However, this is less likely, as this species has just a single tentative identification at Melka Kunture in some of the oldest deposits (ca. 1.7 Ma; Geraads et al., 2004), and it is absent from the paleontology sampled so far in Gombore II area (e.g. Gallotti et al. 2010; Altamura et al. 2020). Level-13, -15 and -17 also yielded large-sized elliptical imprints, which are likely hippopotamus but lack sufficient diagnostic features to be definitively attributed.

3.2.3 Herbivores

Herbivore traces consist of bipartite depressions, produced by split hooves, ranging from the size of large bovids (up to 20 x 20 cm), possibly *Connochaetes taurinus*, to smaller tracks probably made by suids and small antelopes (4-12 cm wide; Fig. 10; e.g., Leakey, 1987; Liebenberg, 1990; Roach et al., 2016; Altamura et al., 2018). Middle- and small-sized bovid tracks have been documented in Level-3, -5 to -7, - 14, 15 and -17 and are usually represented by isolated tracks although they can sometimes occur in larger numbers suggestive of trackways or game trails, as noted in Test Pit A. Large-sized bovids left traces, up to 20 cm long, in Level-6, and -15 to -17.

3.2.4 Varia

In Level-1 in Test Pit B there is a cluster of four sub-elliptical depressions (7 to 12 cm in diameter) made by a circular indenter with smaller impressions to the side. The best-preserved footprint of this type is potentially consistent with a carnivore (e.g., Leakey, 1987) and resembles modern-day hyena tracks (Liebenberg 1990; Van den Heever et al. 2017). The circular depression could represent the central foot pad, and the smaller impression on the side digit imprints (Fig. 10; SI Fig. 20).

On Level-3 a few tracks forming both isolated traces and a partial trackway were imprinted by a tridactyl animal (Fig. 10). There is an elongated digit III impression and two well-divergent, lateral, shorter digit II and IV impressions of similar length, consistent with the morphology of a small bird track (e.g., Falk et al., 2011; Aramayo et al., 2015). In Level-3 and -6, slightly oblique burrows (3-5 cm in diameter) were observed, showing meniscate structures typical of backfilled invertebrate burrows (e.g., Buatois and Mangano, 2011)

3.2.5 Hominins

Eight potential hominin footprints are documented in this paper. Recognizing hominin tracks requires care (Tuttle, 2008). Here shallow, oval depressions with width/length ratio of ca. 0.4 were identified as potential hominin tracks (Domjanic et al., 2015). Criteria developed by Morse et al. (2010) and Helm et al. (2019) were then used to verify these identifications. Morse et al. (2010) set out a number of criteria for identifying human tracks one of which is the presence of low areas either side of the midline effectively corresponding to heel and ball. The presence of a well-defined rounded heel impression and a distal rake formed by the hallux and less toes being another important indicator. The interpretation of these traces as being hominin in origin is strengthened by the presence of an excellent adult track described in Altamura et al. (2018) from the 0.7 Ma Gombore II-2 horizon (Fig. 11, a). This allowed to work from a definitive example when interpreting some of the more questionable traces. Several partial or indistinct traces were excluded. The stratigraphically earliest example of possible hominin tracks (F1-2, Fig. 11) occur on Level-17 in Test Pit C and are directly overlain by the ca. 1.2 Ma tuff. Two more possible footprints (F3-4, Fig. 11), in Test Pit A, were imprinted on a silty layer that we correlate with Level-15, and are accordingly 1.2 to 0.87 million-years old. The most recent potential hominin traces (F5-8, Fig. 11) occur on Level-5 of Test Pit B, overlying the 0.87 Ma tuff and well below the Matuyama-Brunhes magnetostratigraphic boundary at 0.78 Ma. This boundary occurs ca. 2.5 m higher up in the Gombore Gully sequence (Gallotti et al., 2010; Morgan et al., 2012; Mussi et al., 2016; Mendez-Quintas et al., 2019). The suggested age of the youngest hominin traces is therefore approximately 0.85 Ma.

On the three surfaces identified with possible hominin footprints the following observations can be made (Fig. 11 and Table 3). The first track on Level-17 (F1, Fig. 11, b-c) has clear heel, elevated mid-foot and a series of impressions that are consistent with widely spaced toes where mud has been forced between them (see: Morse et al., 2013; Bennet and Morse, 2014; Hatala et al., 2016). The potential hallux is strongly divergent which may reflect slippage during foot placement. While the morphological definition is less than perfect, it is consistent with a hominin track made in soft mud (Bennett and Morse, 2014). The dimensions are typical of either a male or female adult (Table 3). The second track on Level 17 (F2, Fig. 11, d-e) is less well defined and is not definitively identified here as being of hominin origin. There are also a number of heel-like impressions on this surface, but a lack of associated toe impressions and potential alternative interpretations preclude definitive statements. In Test Pit A there is one clear hominin footprint (F3, Fig. 11, f-g) with a clear hallux impression and distal rake. This track like many on the site has potentially been modified by over-printing, none the less it is not dissimilar to tracks identified at Ileret (Hatala et al., 2016). There is also a smaller potential hominin track (F4, Fig. 11, f) which has some hominin-like characteristics, however with a maximum length of only 87 mm this would give the track-maker of around 6 months old based on the modern human growth curve. Level-5 contains a range of partially superimposed potential hominin traces. At least four tracks are visible, labeled F5-F8 in Figure 11. Perhaps the best developed anatomically of these is F7 which is also the largest in terms of length at 174 mm. The smallest is F8 which is just 133 mm long and quite narrow for a hominin track. A feature of mud-rich track sites (e.g., Ileret) however is narrowing of tracks due to side-wall suction as the foot is withdrawn in a similar fashion as the reader may have experienced in removing a foot from a rubber boot. Using a modern growth curve (Synder et al., 1977; Hatala et al., 2020) as a first approximation this would place the track-makers age somewhere between 4 and 6 years old. Tracks F5 and F6 are superimposed toe to heel, offset slightly in terms of long-axis orientation. The label in Figure 11h demarcates the distal edge of one-track with an abducted hallux to one side. The taping heel of F5, which is the later print, impacts on the lesser toes and lateral side of the lower F6 print. The F5 print has a clearly defined hallux. A minimum of two individuals is suggested with a maximum of four. It is important to recognize that none of the hominin tracks identified here have unambiguous anatomical definition, but at least some of the tracks have features consistent with those interpreted at other mud-rich tracks sites (e.g., Ileret, Hatala et al., 2016) as being hominin tracks.

3.3 Lithic industry and faunal remains

No archaeological material was discovered in Test Pit B in the 1.6 m thick sequence overlaying the main archaeological layer. This Acheulean layer was exposed over just 0.6 x 0.4 m at the base of the eastern wall of the pit (SI Fig. 4).

A total of 159 finds were recovered from Test Pits C and A (Table 4). The three gravel and sand layers at the base of Test Pit C (below ichnological Level-17) were the richest in archaeological material (88 finds, i.e. the 55.3% of the total), especially considering that only surface cleaning and a 0.5 x 0.5 m excavation were performed over the lower part of this sequence. These finds show abraded and rounded surfaces, suggesting water transport may have been involved in their deposition and accumulation. The artefacts collected higher up in the sequence, above the 1.2 Ma tuff, were better preserved with lithics often retaining sharp and ‘fresh’ cutting edges. Overall, 124 modified and unmodified stone artefacts and 35 bone fragments were recovered (Fig. 12). Obsidian pebbles (max. 50 mm in length) were abundant in the lowermost layers but were not collected since they appear to be naturally transported and are unworked. A single natural basalt pebble (80 mm in length) was however recovered and could be a manuport.

The lithic industry includes 123 pieces. The hominins appear to have principally selected obsidian (N=75), while basalt and other volcanic rocks make up the remaining of the sample (N=48). Most obsidian implements are either flakes or flake fragments (N=46), which frequently are debitage debris. The knapping method indicated by the dorsal scars on the flakes and technological features point to simple debitage methods as the unipolar, centripetal, or multidirectional exploitation of striking platforms. Seven small obsidian cores (max. 49 mm in length) were retrieved from the lowermost archaeological levels. They mostly confirm debitage by centripetal exploitation, both unifacial and bifacial (Fig. 12, no. 6). Three sidescrapers and 16 flakes with some marginal retouched edges were also discovered (Fig. 12, no.1-5). Overall, the flakes are relatively small and just 21.8 mm in length on average. An elongated flake (63 mm) was produced probably by the shaping of a handaxe (Fig. 12, no.7). Among shaping products, obsidian was exploited to produce a small bifacial tool (64x42x20 mm) and a tiny chopping tool (36x28x18 mm) (Fig. 12, no.8-9).The 33 unretouched and 6 retouched basalt flakes and flake fragments (Fig. 12, no.10-11) are larger than the obsidian ones (length average = 36.1 mm). They are the outcome of simple or centripetal flaking methods, as a single basalt core also suggests. Basalt and tuffaceous pebbles were also used as percussors and heavy-duty tools (N=8).

The faunal assemblage is quite limited (N=35). The bone fragments are mostly small and undiagnostic pieces (50 mm-long in average). Few specimens are long bone fragments or trabecular ones. There are three hippopotamus tooth fragments, a small-sized herbivore and an equid tooth (Fig. 12, no.12-13). A small rodent lower jaw is the only find from Test Pit A (Fig. 12, no.14). In Level-14, two obsidian flakes were almost in contact with two hippopotamus footprints (SI Fig. 21). They were lying obliquely as pushed downward by a heavy load and probably by the hippopotamus feet pressure. In Level-16 and -17, and mostly so in Level-15, the finds were either lying on the surface or stuck either in the footprint sandy infill or in the covering sands, providing more direct association with the trampled palaeo-surfaces.

4 Discussion

The ichnological tests pits adjacent to Gombore II OAM provide additional detailed information that allows us to reconstruct the general environment as well as the archaeology and fauna in this part of the landscape. The 3.2 m thick sequence formed between 1.2 and 0.85 Ma, recording events over a relatively long time span. Sands, silts, and clays are the main depositional products during this time. As described in previous research (Raynal et al., 2004; Mussi et al., 2016; Mendez-Quintas et al., 2019), these were deposited in a low-energy environment, perhaps as part of a meandering river system characterized by ponds, marshes and floodplains, interrupted periodically by volcanic activity. Nevertheless, there were occasional episodes of faster flow as indicated by the lag deposits. The animal tracks had to be relatively quickly buried by fine-grained sediments to allow their preservation which also suggest flood prone waters. The track infilling was not an erosive process, so while occurring rapidly it is still consistent with a low energy environment. The only coarse-grained laterally-extensive level is the main middle Acheulean surface post-dating the deposition of the 0.87 Ma ignimbrite, visible at Gombore II OAM (SI Fig. 21) and also at the bottom of Test Pit B, and found eroded at the top of Test Pit C. It is a thick accumulation deposited by fluvial transport at the bottom of a channel with iso-oriented pebbles and associated later with hominins producing lithic and bone remains (Mendez-Quintas et al., 2019).

Below the 0.87 Ma ignimbrite, earlier lithic artifacts and faunal remains were mostly recovered from the basal layers (below Level-17) where a relatively high-energy stream accumulated gravels and coarse sands as well as redepositing archaeological material. The other layers formed in a low energy environment (Level-14/17), preserving animal footprints. In these layers the lithics have sharp edges, excluding long-distance transport. These sporadic archaeological remains likely reflect an autochthonous or para-autochthonous assemblage. Centripetal debitage and a small bifacial tool quite similar to a small handaxe occur at the base of the sequence that pre-dates 1.2 million years. Later on, a shaping flake from level 15 provides further evidence that this is also part of an Acheulean technocomplex.

A notable feature is the recurring presence of bivalve resting and/or grazing traces, on many of the bioturbated layers. Some palaeosurfaces (Level-9, -10, -11, -12) show only bivalve traces, while in other levels (Level-3, -4, -5, -6, -7, -8, -14, -17) the latter are associated with hominin and other animal footprints. The bivalve traces discovered are consistent with the morphology and behavioural features of unionoids (e.g., Ekdale and Bromley, 2001; Lawfield and Pickerill, 2006; Monaco et al., 2016; Knoll et al., 2017; Carmona et al., 2018) and are assigned as unionoid clams. Unionoid shell fossils, or endocasts, have been recovered elsewhere at Melka Kunture, as in the Middle Pleistocene deposit of Garba III (Chavaillon and Berthelet, 2004; Mussi et al., 2014). They are also known from other locations in the Gombore Gully before 0.875 Ma in the sequence between Gombore Iδ and Gombore II (Mendez-Quintas et al., 2019) and at Gombore III, 0.6-0.4 Ma (SI Fig. 19;Altamura, 2017). At these sites, the shell valves are mainly paired and still joined in life position. The molluscs died *in situ* after having been buried by sediment without managing to escape, or alternatively may have experienced a severe ecological stress (e.g., Knoll et al., 2017). In contrast, the ichnological traces in the test pits at Gombore II-OAM appear to belong to a living community that was able to migrate/move. As a result, there are no fossil shells, which prevents us from directly inferring a species. Acidic waters and other local factors could also have hampered shell preservation.

Freshwater mussels and other molluscs are useful indicators in bio-geographic and archaeological reconstruction (e.g., Girod, 2005; Ashkenazi et al., 2010; Wolverton et al., 2010; Mienis and Ashkenazi, 2011; Urban and Bigga, 2015; Shchelinsky et al., 2016; Van Bocxlaer, 2017; Lundquist et al., 2019; Lyubas et al., 2019). Widespread worldwide and in Africa (Bacci,1948; Daget, 1998; Van Damme and Van Bocxlaer, 2009; Graf and Cummings, 2011; Lopes-Lima et al., 2017), they provide detailed information, since they have developed specific living, reproductive and feeding habits (Vaughn et al., 2008; Zając et al., 2016). Unionoids are sessile and filter-feeding bivalves that need clear, well-oxygenated running water (Vaughn et al., 2008). Usually these molluscs live in permanent rivers rather than in ephemeral ones; for instance, a species tentatively assigned to *Unio dembeae* (A. Girod pers. comm. to MM in 2019) still populates the upper Awash River at Melka Kunture (SI Fig. 19). This suggests that the bivalve-rich trace layers probably experienced clean, running water. Since on Levels -3, -4, -5, -6, -7, -8, -14 and -17 unionids were associated with bird and mammal footprints and desiccation cracks, we surmise that at the time the water was either relatively shallow, or that seasonal fluctuations in water level and sediment exposure occurred before new deposits sealed the palaeo-surfaces.

The occurrence of invertebrate meniscate burrows (Layer-3 and -6) is consistent with a stable substrate. However Levels -9, -10, -11, and -12 show only mollusc traces consistent with the observed evidence of channel deposit, later eroded by the river migration. Freshwater mussels usually do not colonize the bottom of channels deeper than 2 m. However they appear to have occupied a slightly deeper water, where mammals and birds had no access and where seasonal water fluctuations did not expose the sediment to the air, except for short time intervals as appears to have occurred on Layer-9 which shows evidence of incipient mud cracks. In Levels -9 to -12 many traces are iso-oriented NW-SE. This probably was the direction of the water flow for a consistent amount of time, as the same orientation is also suggested by ripple marks in the underlying Level-14 and -16. Alternatively, the iso-orientation of the molluscs could have been the outcome of palaeoenvironmental changes that led to population movements in a specific direction (e.g. Knoll et al., 2017).

The reproductive cycle of unionoids provides further information. Unionoid clams pass through a larval stage during their reproductive cycle. The larvae are obligate parasites of fish, using them as a mean of transport to spread through a drainage system. Accordingly, unionoid and fish abundance are correlated and co-occur (Graf and Cummings, 2011). Fish are not unexpected at Melka Kunture, but they are not so far recorded as part of the fossil record and this is the first positive indicator of fish in the upper palaeo-Awash. Furthermore, the association between unionoids and mammals (Level-3, -4, -5, -6, -7, -8, -14, -17) provides evidence that animals and occasionally hominins were walking through shallow, clear, and running water.

A close association between hominins and lake or river shores was already evidenced by the 1.5 Ma hominin footprints of Ileret, in Kenya (Roach et al., 2016), and by the 1.4 Ma hominin trail associated to bird and hippopotamus footprints at Koobi Fora (Behrensemeyer and Laporte, 1981; Bennett et al., 2009). Shallow freshwater could also have been important in the search for food and perhaps to capture fish or molluscs. The earliest recorded exploitation of aquatic animals by hominins dates to almost 2 Ma (Braun et al., 2010), and the evidence increases throughout the Middle and Upper Pleistocene (Joordens et al 2015; Bosch et al., 2018). In later prehistoric times, unionoids are well recorded as part of hominin diet (e.g. Girod, 2005; Rabett et al., 2011; Szabó and Amesbury, 2011; Peres et al., 2016; Merzoug, 2017). Consequently it is not beyond the realm of possibility that they were a small but valuable resource for the Pleistocene hominins of Melka Kunture.

The preserved possible hominin footprints are dated respectively to just before 1.2 million-years (Level-17 of Test Pit C); between 1.2 and 0.87 million-years (Level-15 of Test Pit A); and between 0.87 and 0.78 million-years (Level-5 of Test Pit B). Assuming the traces are correctly interpreted as hominin tracks, they appear to mostly belong to young individuals. These traces combine with a definitive adult track at the 0.7 Ma site of Gombore II-2 and several possible child tracks (Altamura et al., 2018). Collectively these traces are one of a relatively few early ichnological sites currently known, with older sites at Laetoli in Tanzania (3.6 Ma; Leakey and Hay, 1979; Leakey and Harris, 1987; Masao et al., 2016); Koobi Fora and Ileret in Kenya (1.5-1.4 Ma; Behrensmeyer and Laporte, 1981; Bennett et al., 2009; Hatala et al., 2017); and Happisburgh in the UK at 1-0.78 Ma (Ashton et al., 2014; Wiseman et al. 2020). The new data from the Gombore II OAM, confirms that juveniles are the most common trace in the Melka Kunture ichnological record. Children were free to move around, sometimes entering into shallow waters, while the rest of the group, including adults, was presumably not far away.

Carnivores and birds are extremely rare in the Pleistocene palaeontological record of Melka Kunture. The possible carnivore (hyena?) track in Test Pit B Level-1 (Fig. 10; SI Fig. 20), is consistent with the discovery at Gombore II of remains of either *Hyaena* or *Crocuta* (Geraads et al., in press). Overall, the fauna in the ichnological record mirrors the fauna found from coeval archaeological layers of Melka Kunture. However, the fossil tracks reveal a substantial component of small- and middle-sized animals while hominins and hippopotamuses were scarcely present. Accordingly, ichnology is complementary to the archaeological and palaeontological record but also overturns it at Gombore II. As it is easier for big bones rather than for those small animals to preserve and enter the archaeological record, and the same holds true for lithics, due to taphonomic and formation processes both the hominin and hippopotamus population are overestimated.

5 Conclusions

The combined lithostratigraphical, ichnological and archaeological records allow a detailed reconstruction of the paleoenvironment and biological presence in the research area. The sediments and the ubiquitous unionid traces show that it was part of a hydrographical system that we tentatively call palaeo-Awash. The sequence above and below the 1.2 Ma tuff documents wet environments with muddy walking surfaces, as in Level-15 and -16. Hominins appear to have occasionally walked through and knapped stone nearby, leaving Acheulean lithic implements. Variously sized mammals, mostly bovids, roamed the landscape and the footprints on Level-14 show that hippopotamuses were ubiquitous. The residential areas, hippo pools, had to be relatively close by as the tracks were made on a wet, unconsolidated silt. These dangerous animals over-trampled small obsidian implements which sunk under their feet (SI Fig. 21). This suggest hominin-hippopotamus coexistence and possibly interaction, as evidenced again at 0.7 Ma Gombore II-2 (Altamura et al., 2018, 2020).

Volcanic products periodically fell in the area, primarily in the form of distal ash falls (Kieffer et al., 2004) and would have presumably disrupted hominin and other animal life. The 1.2 Ma eruptive event is documented by a significant ash deposit which would have covered the landscape interrupting the record of biological presence. However, hominins and other mammal species soon recovered and repopulated the area as indicated by traces on Level-16 and -15. Around 0.87 Ma, another major volcanic event impacted the upper Awash valley. The ashes filled meanders, ponds and other depressed areas as well, changing the local hydrography and leading in time to a new palaeochannel. The stream accumulated cobbles in this channel, forming the stone-rich surface on which hominins settled, producing the main middle Acheulean layer (Gallotti et al., 2010; Mendez-Quintas et al., 2019). Later, these waters started to flow at lower discharge and low-energy, silt-rich environments returned to the area. The biological traces at this time are exclusively left by freshwater bivalves and this points to subaquatic sedimentation. The palaeochannel then migrated laterally and the infilling channel deposits were eroded obliquely along the new channel banks (Raynal et al., 2004; Gallotti et al., 2010). Bovids, birds, young hominins and possibly a carnivore produced sets of tracks which in several levels were associated with freshwater bivalves and mud cracks. This suggest intermittent or shallow water.

This rich and complex ichnological record contrasts with the absence of artifacts and palaeontological remains above the main Acheulean level which dates to ca. 0.85 Ma. This is seen in Test Pit B and similarly recorded at Gombore OAM by Gallotti et al. (2010). The sequence had been deemed "sterile" by previous workers who did not see or document the fragile ichnological evidence and consequently overlooked this valuable 'ghost evidence'. The integration of archaeology, lithostratigraphy and ichnology, allows us to reconstruct in much greater detail what happened between 1.2 and 0.78 Ma at Gombore. The area was characterized by a fluvio-lacustrine environment which was sub-aerial or at times covered by deep and shallow waters. It was cyclically invested by eruptions that impacted in different ways on the local hydrography, landscape evolution, and animal peopling. Young hominins were attracted by watery environments along river or pond shores, entering shallow waters just as other mammals and birds did. The recurrent association with water clams suggests that fish and freshwater molluscs possibly were a welcome supplement to the diet of these final Lower Pleistocene hominins.

Acknowledgements

The research at Melka Kunture is supported by grants from Sapienza University of Rome ("Grandi Scavi Archeologici") and from the Italian Foreign Ministry. The Authority for Research and Conservation of the Cultural Heritage of Ethiopia's Ministry of Culture & Tourism provided research permits while the Oromia Culture and Tourism Bureau and helped in many ways. We are also grateful to the colleagues involved in the fieldwork: Giuseppe Briatico, Giuseppe Lembo, Ilenia Lungo, Eduardo Mendez-Quintas, Joaquín Panera, Flavia Piarulli and Laura Pioli. We thank Alberto Girod who provided us with useful suggestions on East Africa malacology, and Denis Geraads for his observations on faunal remains. Last but not least, we wish to thank the Editor Danielle Schreve and the two unknown reviewers for their constructive comments.

Author contributions

FA: conceptualization, excavations, archaeological and ichnological (vertebrate) analysis; MM: funding acquisition, project administration, scientific supervision of the investigations; MRB and SCR analysis of hominin ichnology; LM ichnological analysis (vertebrates and invertebrates); RTM lithostratigraphy and sedimentology. FA wrote the paper with MM, LM, RTM, MRB; all the authors reviewed and edited the manuscript.

References

Altamura, F., 2017. Il sito acheuleano di Gombore II-2: revisione dei dati e nuove ricerche. Ph.D. Dissertation, University of Roma Sapienza.

Altamura, F., 2019. 12. Ichnology and archaeology in the African record: a complementary approach, in: Di Lernia, S., Gallinaro, M. (Eds.), Papers from the 1st Workshop Archaeology in Africa. Potential and perspectives on laboratory & fieldwork research, Arid Zone Archaeology, Monographs 8, All'Insegna del Giglio, Sesto fiorentino, pp. 127-140.

Altamura, F., forthcoming. Finding Fossil Footprints in the Archival Record: Case Studies from the Archaeological Site of Melka Kunture (Upper Awash, Ethiopia). J. Afr. Archaeol.

Altamura, F., Mussi, M., 2017. Archeologia e impronte fossili nel sito acheuleano di Gombore II (0,85 Ma), Melka Kunture, Etiopia. Scienze dell'Antichità 23.1, 21-35.

Altamura, F., Mussi, M., Melis, R.T., 2017. A Middle Pleistocene hippo tracksite at Gombore II-2 (Melka Kunture, Upper Awash, Ethiopia). Palaeogeogr. Palaeoclimatol. Palaeoecol. 470, 122-131.

Altamura, F., Bennett, M.R., D'Août, K., Gaudzinski-Windheuser, S., Melis, R.T., Reynolds, S.C., Mussi, M., 2018. Archaeology and Ichnology at Gombore II-2, Melka Kunture, Ethiopia: Everyday life of a mixed-age hominin group 700,000 years ago. Scientific reports 8, 2815.

Altamura, F., Gaudzinski-Windheuser, S., Melis, R.T., Mussi, M., 2020. Reassessing an early Middle Pleistocene Hippo Butchery Site: Gombore II-2 (Melka Kunture, Upper Awash valley, Ethiopia). J. Paleolit. Archaeol. 3 (1), 1-32.

Aramayo, S.A., de Bianco, T.M., Bastianelli, N.V., Melchor, R.N., 2015. Pehuen Co: Updated taxonomic review of a late Pleistocene ichnological site in Argentina. Palaeogeogr. Palaeoclimatol. Palaeoecol. 439, 144-165.

Ashkenazi, S., Klass, K., Mienis, H.K., Spiro, B., Abel, R., 2010. Fossil embryos and adult Viviparidae from the Early–Middle Pleistocene of Gesher Benot Ya'aqov, Israel: ecology, longevity and fecundity. Lethaia 43, 116-127.

Ashton, N., Lewis, S.G., De Groote, I., Duffy, S.M., Bates, M., Hoare, P., Lewis, M., Parfitt, S.A., Peglar, S., Williams, C., Stringer, C., 2014. Hominin Footprints from Early Pleistocene Deposits at Happisburgh, UK. PLoS ONE 9 (2), e88329.

Avanzini, M., Citton, P., Mietto, P., Panarello, A., Raia, P., Romano, M., Salvador, I., 2020. Human footprints from Italy: the state of the art. J. Mediterr. Earth Sci.12, in press.

Bacci, G., 1948. Le malacofaune dell'Abissinia e della Somalia e i loro elementi di origine Indiana e Paleartica. Bollettino di zoologia 15(1-3), 1-9.

Bailloud, G., 1965. Le gisement paléolithique de Melka-Kontouré. Cahier n°1, Institut Èthiopien d'Archéologie.

Behrensmeyer, A.K., Laporte, L.F., 1981. Footprints of a Pleistocene hominid in northern Kenya. Nature 289, 167-169.

Bennett, M.R., Morse, S.A., 2014. Human Footprints: Fossilised Locomotion?. Springer.

Bennett, M.R., Harris, J.W.K., Richmond, B.G., Braun, D.R., Mbua, E., Kiura, P., Olago, D., Kibunjia, M., Omuombo, C., Behrensmeyer, A.K., Huddart, D., Gonzalez, S., 2009. Early Hominin

Foot Morphology Based on 1.5-Million-Year-Old Footprints from Ileret, Kenya. Science 323, 1197-1201.

Bennett, M.R., Morse, S.A., Falkingham, P.L., 2014. Tracks made by swimming Hippopotami: an example from Koobi Fora (Turkana Basin, Kenya). Palaeogeogr. Palaeoclimatol. Palaeoecol. 409, 9-23.

Bonnefille, R., Melis, R.T., Mussi, M., 2018. Variability in the Mountain Environment at Melka Kunture Archaeological Site, Ethiopia, during the Early Pleistocene (~1.7 Ma) and the Mid-Pleistocene Transition (0.9-0.6 Ma), in: Gallotti, R., Mussi, M. (Eds.) The Emergence of the Acheulean in East Africa and Beyond, Contributions in Honor of Jean Chavaillon, Springer, pp. 93-114.

Bosch, M.D., Mannino, M.A., Prendergast, A.L., Wesselingh, F.P., O'Connell, T.C., Hublin, J.-J., 2018. Year-round shellfish exploitation in the Levant and implications for Upper Palaeolithic hunter-gatherer subsistence. J. Archaeol. Sci. Rep. 21, 1198-1214.

Braun, D.R., Harris, J.W.K., Levin, N.E., McCoy, J.T., Herries, A.I.R., Bamford, M.K., Bishop, L.C., Richmond, B.G., Kibunjia, M., 2010. Early hominin diet included diverse terrestrial and aquatic animals 1.95 Ma in East Turkana, Kenya. Pnas 107(22), 10002-10007.

Buatois, L.A., Mangano, M.G., 2011. Ichnology: Organism-substrate interactions in space and time. Cambridge University Press.

Bustos, D., Jakeway, J., Urban, T.M., Holliday, V.T., Fenerty, B., Raichlen, D.A., Budka, M., Reynolds, S.C., Allen, B.D., Love, D.W., Santucci, V.L., Odess, D., Willey, P., McDonald, H.G.,

Bennett, M.R., 2018. Footprints preserve terminal Pleistocene hunt? Human-sloth interactions in North America. Science Advances 4 (4), eaar7621.

Carmona, N.B., Ponce, J.J., Wetzel, A., 2018. Biogenic structures of unioniform bivalves in wet-interdune deposits (late Miocene–early Pliocene, Argentina). Palaios 33, 431-440.

Chavaillon, J., Coppens, Y., 1986. Nouvelle découverte d'Homo erectus à Melka-Kunturé. Comptes Rendus de l'Académie des Sciences Paris 303 (II, 1), 99-104.

Chavaillon, J., Piperno, M. (Eds.) 2004. Studies on the Early Paleolithic Site of Melka Kunture, Ethiopia, Origines, Istituto Italiano di Preistoria e Protostoria, Florence.

Chavaillon, J., Brahimi, C., Coppens, Y., 1974. Première découverte d'Hominidé dans l'un des sites acheuléens de Melka-Kunturé (Ethiopie). Comptes Rendus de l'Académie des Sciences Paris 278, 3299-3302.

Daget, J., 1998. Catalogue raisonné des Mollusques bivalves d'eau douce africains, V.Backhuys Publishers/Orstom, Leiden/Paris.

de Onis, M., 2006. Assessment of differences in linear growth among populations in the WHO Multicentre Growth Reference Study. Acta Paediatr. 95, 56-65.

Di Vincenzo, F., Rodriguez, L., Carretero, J.M., Collina, C., Geraads, D., Piperno, M., Manzi, G., 2015. The massive fossil humerus from the Oldowan horizon of Gombore I, Melka Kunture (Ethiopia, >1.39 Ma). Quat. Sci. Rev. 122, 207-221.

Domjanic, J., Seidler, H., Mitteroecker, P., 2015. A Combined Morphometric Analysis of Foot Form and Its Association with Sex, Stature, and Body Mass. Am. J. Phys. Anthropol. 157, 582-591.

Duveau, J., Berillon, G., Verna, C., Laisné, G., Cliquet, D., 2019. The composition of a Neandertal social group revealed by the hominin footprints at Le Rozel (Normandy, France). Pnas 116(39), 19409-19414.

Ekdale, A.A., Bromley, R.G., 2001. A day and a night in the life of a cleft- foot clam: Protovirgularia- Lockeia- Lophoctenium. Lethaia 34(2), 119-124.

Fabiano, M., Zucchelli, M., 2003. Impronte di elefante sulle rive del lago pleistocenico di Atella (PZ). Studi per l'Ecologia del Quaternario 25, 9-22.

Falk, A.R., Martin, L.D., Hasiotis, S.T., 2011. A morphologic criterion to distinguish bird tracks. J. Ornithol. 152(3), 701-716.

Gallotti, R., 2013. An older origin for the Acheulean at Melka Kunture (Upper Awash, Ethiopia): Techno-economic behaviours at Garba IVD. J. Hum. Evol. 65, pp. 594-620.

Gallotti, R., Mussi, M., 2015. The Unknown Oldowan: ~1.7-Million-Year-Old Standardized Obsidian Small Tools from Garba IV, Melka Kunture, Ethiopia. PLoS ONE 10(12), e0145101.

Gallotti, R., Mussi, M., 2016. Two Acheuleans, two humankinds: From 1.5 to 0.85 Ma at Melka Kunture (Upper Awash, Ethiopian highlands). J. Anthropol. Sci. 95, 1-46.

Gallotti, R., Mussi, M., 2018. Before, during, and after the Early Acheulean at Melka Kunture (Upper Awash, Ethiopia): A techno-economic comparative analysis, in: Gallotti, R., Mussi, M. (Eds.), The Emergence of the Acheulean in East Africa and Beyond, Contributions in Honor of Jean Chavaillon, Springer, pp. 53-92.

Gallotti, R., Collina, C., Raynal, J.-P., Kieffer, G., Geraads, D., Piperno, M., 2010. The Early Middle Pleistocene site of Gombore II (Melka Kunture, Upper Awash, Ethiopia) and the issue of Acheulean bifacial shaping strategies. Afr. Archaeol. Rev. 27, 291-322.

Geraads, D., Eisenmann, V., Petter, G., 2004. Paleontology. The large mammal fauna of the Oldowan sites of Melka Kunture, in: Chavaillon, J., Piperno, M. (Eds.), Studies on the Early Paleolithic Site of Melka Kunture, Ethiopia, Origines, Istituto Italiano di Preistoria e Protostoria, Florence, pp.169-192.

Geraads, D., Gallotti, R., Raynal, J-P., Bonnefille, R., Mussi, M., in press. Melka Kunture, Ethiopia: early Pleistocene faunas of the Ethiopian highlands, in: Reynolds, S.C., Bobe, R. (Eds.), African Paleoecology and Human Evolution, Chapter 13, Cambridge University Press.

Girod, A., 2005. Importanza dei molluschi terrestri e d'acqua dolce in archeologia. Preistoria Alpina 40 (suppl. 1), 125-132.

Graf, D.L., Cummings, K.S., 2011. Freshwater mussel (Mollusca: Bivalvia: Unionoida) richness and endemism in the ecoregions of Africa and Madagascar based on comprehensive museum sampling. Hydrobiologia 678, 17-36.

Hatala, K.G., Roach, N.T., Ostrofsky, K.R., Wunderlich, R.E., Dingwall, H.L., Villmoare, B.A., Green, D.J., Harris, J.W.K, Braun, D.R., Richmond, B.G., 2016. Footprints reveal direct evidence of group behavior and locomotion in Homo erectus. Scientific Reports 6, 28766.

Hatala, K.G., Roach, N.T., Ostrofsky, K.R., Wunderlich, R.E., Dingwall, H.L., Villmoare, B.A., Green, D.J., Braun, D.R., Harris, J.W.K., Behrensmeyer, A.K., Richmond, B.G., 2017. Hominin track assemblages from Okote Member deposits near Ileret, Kenya, and their implications for understanding fossil hominin paleobiology at 1.5 Ma. J. Hum. Evol. 112, 93-104.

Hatala, K.G., Harcourt-Smith., W.E.H., Gordon, A.D., Zimmer, B.W., Richmond, B.G., Pobiner, B.L., Green, D.J., Metallo, A., Rossi, V., Liutkus-Pierce, C.M., 2020. Snapshots of human anatomy, locomotion, and behavior from Late Pleistocene footprints at Engare Sero, Tanzania. Scientific reports 10, 7740.

Helm, C.W., McCrea, R.T., Cawthra, H.C., Lockley, M.G., Cowling, R.M., Marean, C.W., Thesen, G.H.H., Pigeon, T.S., Hattingh, S., 2018. A New Pleistocene Hominin Tracksite from the Cape South Coast, South Africa. Scientific reports 8, 3772.

Helm, C.W., Lockley, M.G., Cole, K., Noakes, T.D., McCrea, R.T., 2019. Hominin tracks in southern Africa: a review and an approach to identification. Palaeontol. Africana 53, 81-96.

Inizan, M.-L., Reduron-Ballinger, M., Roche, H., Tixier, J., 1999. Technology and terminology of knapped stone, CREP, Nanterre.

Joordens, J.C.A., d'Errico, F., Wesselingh, F.P., Munro, S., de Vos, J., Wallinga, J., Ankjærgaard, C., Reimann, T., Wijbrans, J.R., Kuiper, K.F., Mücher, H.J., Coqueugniot, H., Prié, V., Joosten, I., van Os, B., Schulp, A.S., Panuel, M., van der Haas, V., Lustenhouwer, W., Reijmer, J.J.G., Roebroeks, W., 2015. Homo Erectus at Trinil on Java used shells for tool production and engraving. Nature 518, 228-231.

Kieffer, G., Raynal, J.-P., Bardin, G., 2002. Cadre structural et volcanologiques des sites du Paléolithique ancien de Melka Kunture (Awash, Ethiopie): premiers resultants, in: Raynal, J.-P., Albore-Livadie, C., Piperno, M. (Eds.), Hommes et Volcans. De l'éruption à l'objet. Les Dossiers de l'Archéologie 2, 77-92.

Kieffer, G., Raynal, J.-P., Bardin, G., 2004. Volcanic markers in coarse alluvium at Melka Kunture (Upper Awash, Ethiopia), in: Chavaillon, J., Piperno, M. (Eds.), Studies on the Early Paleolithic Site of Melka Kunture, Ethiopia. Origines, Istituto Italiano di Preistoria e Protostoria, Florence, pp. 93-101.

Knoll, K., Chamberlain, R.B., Chamberlain, J.A., 2017. Escape burrowing of modern freshwater bivalves as a paradigm for escape behavior in the Devonian bivalve *Archanodon catskillensis.* Geosciences 7, 102. DOI:10.3390/geosciences7040102

Lawfield, A.M., Pickerill, R.K., 2006. A novel contemporary fluvial ichnocoenose: unionid bivalves and the Scoyenia–Mermiaichnofacies transition. Palaios 21(4), 391-396.

Leakey, M.D., 1987. Animal prints and trail, in: Leakey, M.D., Harris, J.M. (Eds.), Laetoli a Pliocene site in northern Tanzania, Clarendon Press, Oxford, pp. 451-489.

Leakey, M.D., Harris, J.M. (Eds.) 1987. Laetoli: A Pliocene Site in Northern Tanzania, Clarendon Press, Oxford.

Leakey, M.D., Hay, R.L., 1979. Pliocene footprints in the Laetolil Beds at Laetoli, northern Tanzania. Nature 278, 317-323.

Ledoux, L., Fourment, N., Maksud, F., Delluc, M., Costamagno, S., Goutas, N., Klaric, L. Laroulandie, V., Salomon, H., Jaubert, J., 2017. Traces of human and animal activity (TrAcs) in Cussac Cave (Le Buisson-de-Cadouin, Dordogne, France): Preliminary results and perspectives. Quat. Int. 430, 141-154.

Liebenberg, L., 1990. A field Guide to the Animal Tracks of Southern Africa, David Philip Publishers, Cape Town & Johannesburg.

Lopes-Lima, M., Froufe, E., Tu Do, V., Ghamizi, M., Mock, K.E., Kebapçı, Ü., Klishko, O., Kovitvadhi, S., Kovitvadhi, U., Paulo, O.S., Pfeiffer, J.M., Raley, M., Riccardi, N., Şereflişan, H., Sousa, R., Teixeira, A., Varandas, S., Wu, X., Zanatta, D.T., Zieritz, A., Bogan, A.E., 2017. Phylogeny of the most species-rich freshwater bivalve family (Bivalvia: Unionida: Unionidae): Defining modern subfamilies and tribes. Mol. Phylogenetics Evol. 106, 174-191.

Lundquist, S.P., Worthington, T.A., Aldridge, D.C., 2019. Freshwater mussels as a tool for reconstructing climate history. Ecol. Indic. 101, 11-21.

Lyubas, A.A., Kabakov, M.B., Kriauciunas, V.V., Obada, T.F., Nicoara, I.N., Tomilova, A.A., 2019. Freshwater mollusks from Neogene-Quaternary Dniester and Prut riverine deposits as indicator paleoenvironments: chemical composition of shells and its palaeoecological interpretation. Arct. Environ. Res. 19(1), 35-42.

Masao, F.T., Ichumbaki, E.B., Cherin, M.B.A., Boschian, G., Iurino, D.A., Menconero, S., Moggi-Cecchi, G., 2016. New footprints from Laetoli (Tanzania) provide evidence for marked body size variation in early hominins. Elife 5, e19568.

Mastrolorenzo, G., Petrone, P., Pappalardo, L., Sheridan, M.F., 2006. The Avellino 3780-yr-B.P. catastrophe as a worst-case scenario for a future eruption at Vesuvius. Pnas 203(12), 4366-4370.

McLaren, D., Fedje, D., Dyck, A., Mackie, Q., Gauvreau, A., Cohen, J., 2018. Terminal Pleistocene epoch human footprints from the Pacific coast of Canada. PLoS ONE 13(3), e0193522.

Mendez-Quintas, E., Panera, J., Altamura, F., Di Bianco, L., Melis, R.T., Piarulli, F., Ruta, G., Mussi, M., 2019. Gombore II (Melka Kunture, Ethiopia): a new approach to the formation processes and spatial patterns of an Early Pleistocene Acheulean site. J. Archaeol. Sci. 108, 104975.

Merzoug, S., 2017. Les comportements de subsistance en Afrique du Nord-Ouest durant la transition Pléistocène supérieur/Holocène: entre homogénéité et variations stratégiques. L'anthropologie 121, 189-203.

Mienis, H.K., Ashkenazi, S., 2011. Lentic Basommatophora molluscs and hygrophilous land snails as indicators of habitat and climate in the Early-Middle Pleistocene (0.78 Ma) at the site of Gesher Benot Ya'aqov (GBY), Israel. J. Hum. Evol. 60, 328-340.

Monaco, P., Famiani, F., La Iacona, F., 2016. Bulldozing and resting traces of freshwater mussel *Anodonta woodiana* and substrate characteristics in lake-margin and river settings of Umbria, Italy. Riv. Ital. Paleontol. S. 122(1), 53-62.

Moreno, K., Bostelmann, J.E., Macías, C., Navarro-Harris, X., De Pol-Holz, R., Pino, M., 2019. A late Pleistocene human footprint from the Pilauco archaeological site, northern Patagonia, Chile. PLoS ONE 14(4), e0213572.

Morgan, L.E., Renne, P.R., Kieffer, G., Piperno, M., Gallotti, R., Raynal, J.-P., 2012. A chronological framework for a long and persistent archaeological record: Melka Kunture, Ethiopia. J. Hum. Evol. 62, 104-115.

Morse, S.A., Bennett, M.R., Gonzalez, S., Huddart, D., 2010. Techniques for verifying human footprints: reappraisal of pre-Clovis footprints in Central Mexico. Quat. Sci. Rev. 29(19), 2571-2578.

Morse, S.A., Bennett, M.R., Liutkus-Pierce, C., Thackeray, F., McClymont, J., Savage, R., Crompton, R.H., 2013. Holocene Footprints in Namibia: The Influence of Substrate on Footprint Variability. Am. J. Phys. Anthropol. 151(2), 265-79.

Muñiz, F., Cáceres, L.M., Rodríguez-Vidal, J., Neto de Carvalho, C., Belo, J., Finlayson, C., Finlayson, G., Finlayson, S., Izquierdo, T., Abad, M., Jiménez-Espejo, F.J., Sugisaki, S., Gómez, P., Ruiz, F., 2019. Following the last Neanderthals: Mammal tracks in Late Pleistocene coastal dunes of Gibraltar (S Iberian Peninsula). Quat. Sci. Rev. 217, 297-309.

Mussi, M., Altamura, F., Macchiarelli, R., Melis, R.T., Spinapolice, E.E., 2014. Garba III (Melka Kunture Ethiopia): a Middle Stone Age site with archaic Homo sapiens remains revisited. Quat. Int. 343, pp. 28-39.

Mussi, M., Altamura, F., Bonnefille, R., De Rita, D., Melis, R.T., 2016. The environment of the Ethiopian highlands at the Mid Pleistocene Transition: fauna, flora and hominins in the 850-700ka sequence of Gombore II (Melka Kunture). Quat. Sci. Rev. 149, 259-268.

Panarello A., Palombo M.R., Biddittu I., Mietto P. 2017. Fifteen years along the "Devil's trails": new data and perspectives. Alp. Mediterr. Quat. 30(2), 137-154.

Panarello, A., Palombo, M.R., Biddittu, I., Di Vito, M.A., Farinaro, G., Mietto, P., 2020. On the devil's tracks: unexpected news from the Foresta ichnosite (Roccamonfina volcano, central Italy). J. Quat. Sci. DOI: 10.1002/jqs.3186

Pastoors, A., Lenssen-Erz, T., Ciqae, T., Kxunta, U., Thao, T., Bégouën, R., Biesele, M., Clottes, J., 2015. Tracking in caves. Experience based reading of Pleistocene human footprints in French caves. Camb. Archaeol. J. 25(3), 551-564.

Peres, T.M., Deter-Wolf, A., Keasler, J., Chappell Hodge, S., 2016. Faunal remains from an archaic period cave in the Southeastern United States. J. Archaeol. Sci. Rep. 8, 187-199.

Pichon, J., 1979. Oiseaux fossiles de Melka-Kunturé. Abbay X, 51-56.

Profico, A., Di Vincenzo, F., Gagliardi, L., Piperno, M., Manzi, G., 2016. Filling the gap. Human cranial remains from Gombore II (Melka Kunture, Ethiopia; ca. 850 ka) and the origin of *Homo heidelbergensis*. J. Anthropol. Sci. 94, 41-63.

Rabett, R., Appleby, J., Blyth, A., Farr, L., Gallou, A., Griffiths, T., Hawkes, J., Marcus, D., Marlow, L., Morley, M., Cao Tan, N., Son Van., N., Penkman, K., Reynolds, T., Stimpson, C., Szabo, K., 2011. Inland shell midden site-formation: Investigation into a late Pleistocene to early Holocene midden from Tràng An, Northern Vietnam. Quat. Int. 239, 153-169.

Raynal, J.-P., Kieffer, G., 2004. Lithology, dynamism and volcanic successions at Melka Kunture (Upper Awash, Ethiopia). in: Chavaillon, J., Piperno, M. (Eds.), Studies on the Early Paleolithic Site of Melka Kunture, Ethiopia, Origines, Istituto Italiano di Preistoria e Protostoria, Florence, pp. 115-135.

Raynal, J.-P., Kieffer, G., Bardin, G., 2004. Garba IV and the Melka Kunture Formation. A preliminary lithostratigraphic approach, in: Chavaillon, J., Piperno, M. (Eds.), Studies on the Early Paleolithic Site of Melka Kunture, Ethiopia, Origines, Istituto Italiano di Preistoria e Protostoria, Florence, pp. 137-166.

Roach, N.T., Hatala, K.G., Ostrofsky, K.R., Villmoare, B., Reeves, J.S., Du, A., Braun, D.R., Harris, J.W.K., Behrensmeyer, A.K., Richmond, B.G., 2016. Pleistocene footprints show intensive use of lake margin habitats by *Homo erectus* groups. Scientific reports 6, 26374.

Romano, M., Citton, P., Salvador, I., Arobba, D., Rellini, I., Firpo, M., Negrino, F., Zunino, M., Starnini, E., 2019. A multidisciplinary approach to a unique palaeolithic human ichnological record from Italy (Bàsura Cave). eLife 8, e45204.

Shchelinsky, V.E., Gurova, M., Tesakov, A.S., Titov, V.V., Frolov, P.D., Simakova, A.N., 2016. The Early Pleistocene site of Kermek in western Ciscaucasia (southern Russia): Stratigraphy, biotic record and lithic industry (preliminary results). Quat. Int., 393, 51-69.

Serangeli, J., Verheijen, I., Rodríguez Álvarez, B., Altamura, F., Lehmann, J., Conard, N.J., 2020. Elefanten in Schöningen. Archäologie in Deutschland 3, 8-13.

Silva, P.G., López-Recio, M., Tapias, F., Roquero, E., Morín, J., Rus, I., Carrasco-García, P., Giner-Robles, J.L., Rodríguez-Pascua, M.A., Pérez-López, R., 2013. Stratigraphy of the Arriaga Palaeolithic sites. Implications for the geomorphological evolution recorded by thickened fluvial sequences within the Manzanares River valley (Madrid Neogene Basin, Central Spain). Geomorphology 196, 138-161

Snyder, R.G., Schneider, L.W., Owings, C.L., Reynolds, H.M., 1977. Anthropometry of infants, children, and youths to age 18 for product safety design. Report UM-HSRI-77-17. Univ. Michigan Transportation Research Institute.

Szabó, K., Amesbury, J.R., 2011. Molluscs in a world of islands: The use of shellfish as a food resource in the tropical island Asia-Pacific region. Quat. Int. 239, 8-18.

Taieb, M., 1974. Evolution quaternaire du bassin de l'Awash. Thèse Doctorat ès Sciences, Paris.

Tamrat, E., Thouveny, N., Taieb, M., Brugal, J.P., 2014. Magnetostratigraphic study of the Melka Kunture archaeological site (Ethiopia) and its chronological implications. Quat. Int. 343, 5-16.

Tuttle, R.H., 2008. Footprint clues in hominid evolution and forensics: lessons and limitations. Ichnos 15, 158-165.

Urban, B., Bigga, G., 2015. Environmental reconstruction and biostratigraphy of late Middle Pleistocene lakeshore deposits at Schöningen. J. Hum. Evol. 89, 57-70.

Van Bocxlaer, B., 2017. Paleoecological insights from fossil freshwater mollusks of the Kanapoi Formation (Omo-Turkana Basin, Kenya). J. Hum. Evol. DOI: 10.1016/j.jhevol.2017.05.008.

Van Damme, D., Van Bocxlaer, B., 2009. Freshwater molluscs of the Nile Basin, past and present, in Dumont H.J. (Ed.), The Nile: Origin, Environments, Limnology and Human Use, Springer Science + Business Media B.V. , pp. 585-629

Van den Heever, A., Mhlongo, R., Benadie, K., 2017. Tracker manual: a practical Guide to Animal Tracking in Southern Africa. Struik Nature, Cape Town.

Vaughn, C.C., Nichols, S.J., Spooner, D.E., 2008. Community and foodweb ecology of freshwater mussels. J. N. Am. Benthol. Soc. 27(2), 409-423.

Wiseman, A.L.A., Stringer, C.B., Ashton, N., Bennett, M.R., Hatala, K.G., Duffy, S., O'Brien, T., De Groote, I., 2020. The morphological affinity of the Early Pleistocene footprints from Happisburgh, England, with other footprints of Pliocene, Pleistocene, and Holocene age. J. Hum. Evol. 144, 102776.

Wolverton, S., Randklev, C.R., Kennedy, J.H., 2010. A conceptual model for freshwater mussel (family: Unionidae) remain preservation in zooarchaeological assemblages. J. Archaeol. Sci. 37, 164-173.

Zając, K., Zając, T., Ćmiel, A., 2016. Spatial distribution and abundance of Unionidae mussels in aeutrophic floodplain lake. Limnologica 58, 41-48.

Captions

Fig. 1 Location map of Melka Kunture

Fig. 2 Location of Gombore II OAM and of Test Pits A, B and C.

Fig. 3 Stratigraphic log of the Gombore gully with details of the sequence of the ichnological Test Pits at Gombore II OAM

Fig. 4 Stratigraphic and altimetric correlation of the standing walls of Gombore II OAM and of Test Pits A, B and C.

Fig. 5 Planimetries of Test Pit B: Levels -1/-6

Fig. 6 Planimetry of Test Pit B: Levels -7/-12

Fig. 7 Planimetry of Test Pit A (top left), and of Test Pit C: Levels -13/-14

Fig. 8 Planimetry of Test Pit C: Levels -15/-17

Fig. 9 Unionoids traces at Test Pit B: Level-10 before and after the excavations (a-b); Level-11 (c); excavated portion of Level-11 at the NE corner of the test pit (d); Level-12 (e).

Fig. 10 Footprints found in the ichnological Test Pits B and C: hippopotamus footprints of Level-14 before (a) and after the excavation (b-e), including an hippopotamus track overtrampled by a small-sized bovid (e); big-sized bovid footprints of Level-17 (f) and of Level-5 (g), the last one associated with mollusc and small-sized bovid tracks; small-sized bovid, mollusc and bird tracks (white arrow) of Level-3 (h); possible carnivore footprint of Level-1 (i).

Fig. 11 Pictures and elaboration of hominin footprints: picture of an adult hominin track found at Gombore II-2 (a); contour map (b) and picture (c) of the track cast from Level-17, Test Pit C; picture before (d) and after (e) the excavation of the second footprint from Level-17, Test Pit C; contour map (f) and picture (g) of the tracks found at Test Pit A; contour map (h) and picture (i) of the tracks from Level-5, Test Pit B.

Fig. 12 Archaeological materials from the excavations. Obsidian implements: retouched flakes (1-4), side-scraper (5), centripetal core (6), flake from handaxe shaping (7), bifacial tool (8) and chopper (9). Basalt implements: retouched flakes (10-11). Faunal remains: hippopotamus (12) and equid (13) tooth, rodent jaw (14).

Tab. 1: Summary table of the main lithostratigraphic units in Test Pits A and C, and in Test Pit B.

Tab. 2 Attribution to species of the ichnological evidence divided per level, with association of lithic and faunal remains.

Tab. 3 Measures and age attribution of the potential hominin footprints F1-8.

Tab. 4 Typological characterization of the lithic industry and attribution of the faunal remains found in Test Pits A and C, with reference to the numbered ichnological levels.

Figure 1

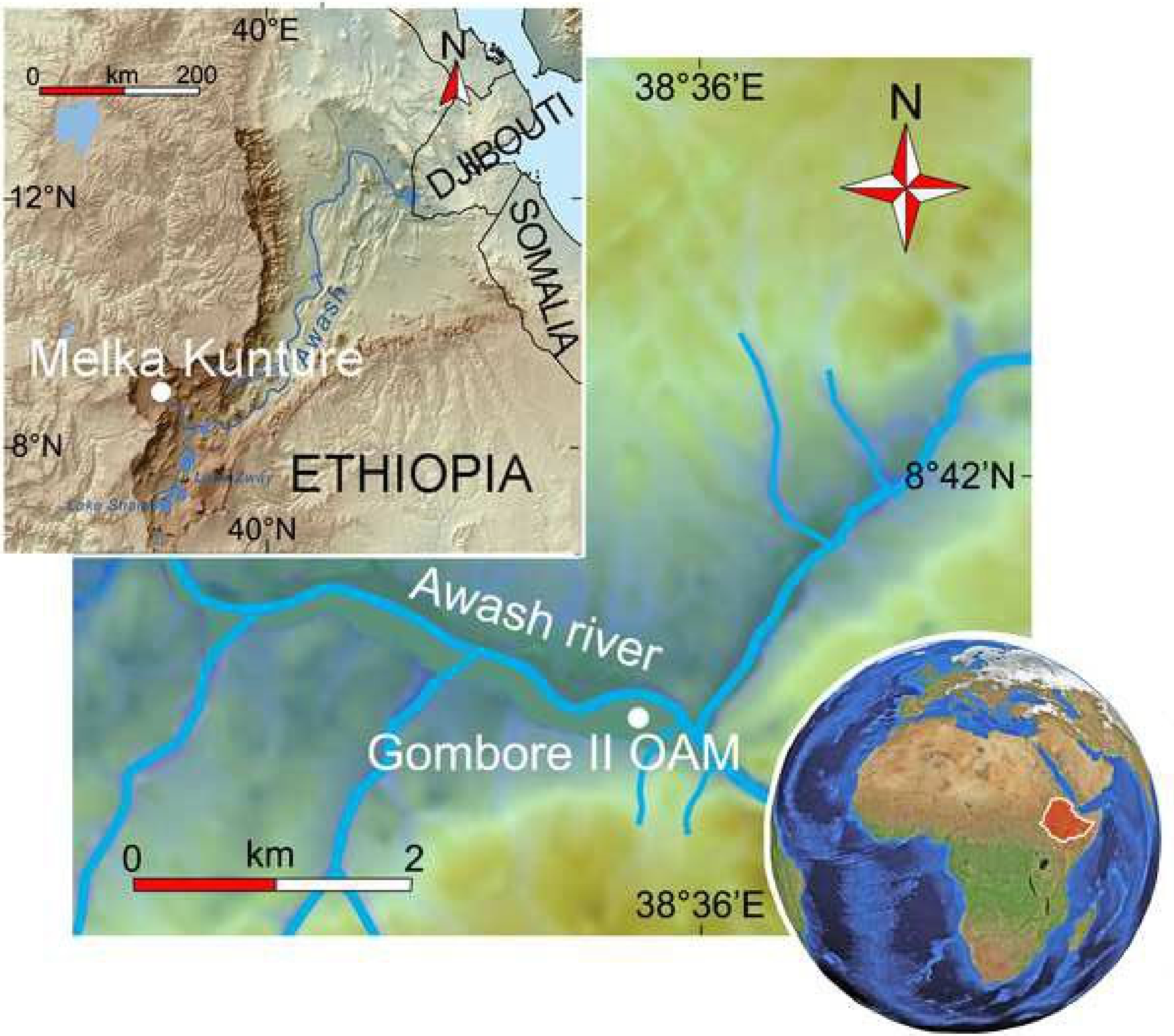
40°E
N
0 km 200
DJIBOUTI
12°N
SOMALIA
Awash
Melka Kunture
8°N
ETHIOPIA
40°N
38°36'E
N
8°42'N
Awash river
Gombore II OAM
0 km 2
38°36'E

Figure 2 Click here to access/download;Figure;Fig. 2.jpg

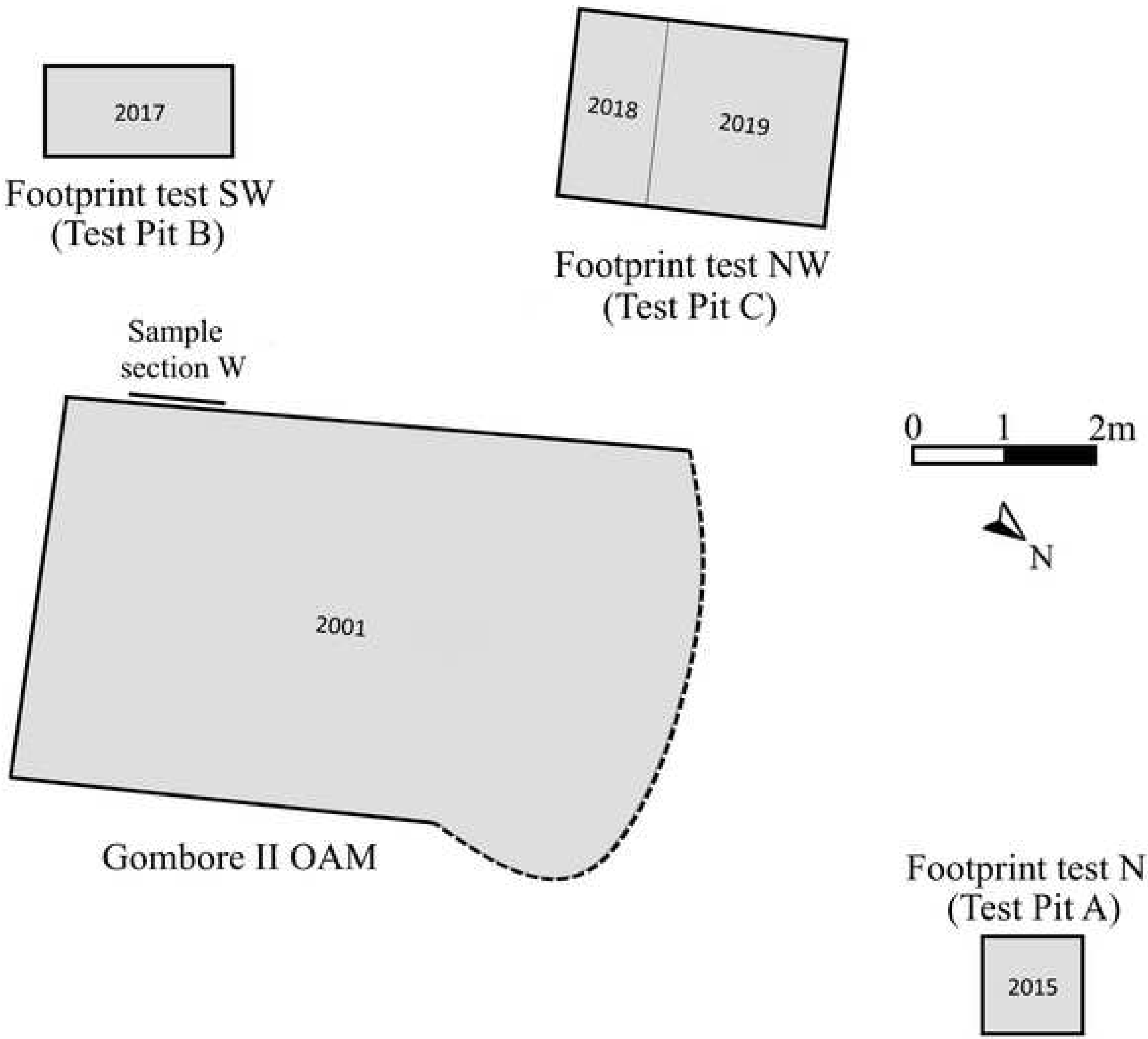

Figure 3

Click here to access/download;Figure;Fig. 3.tif

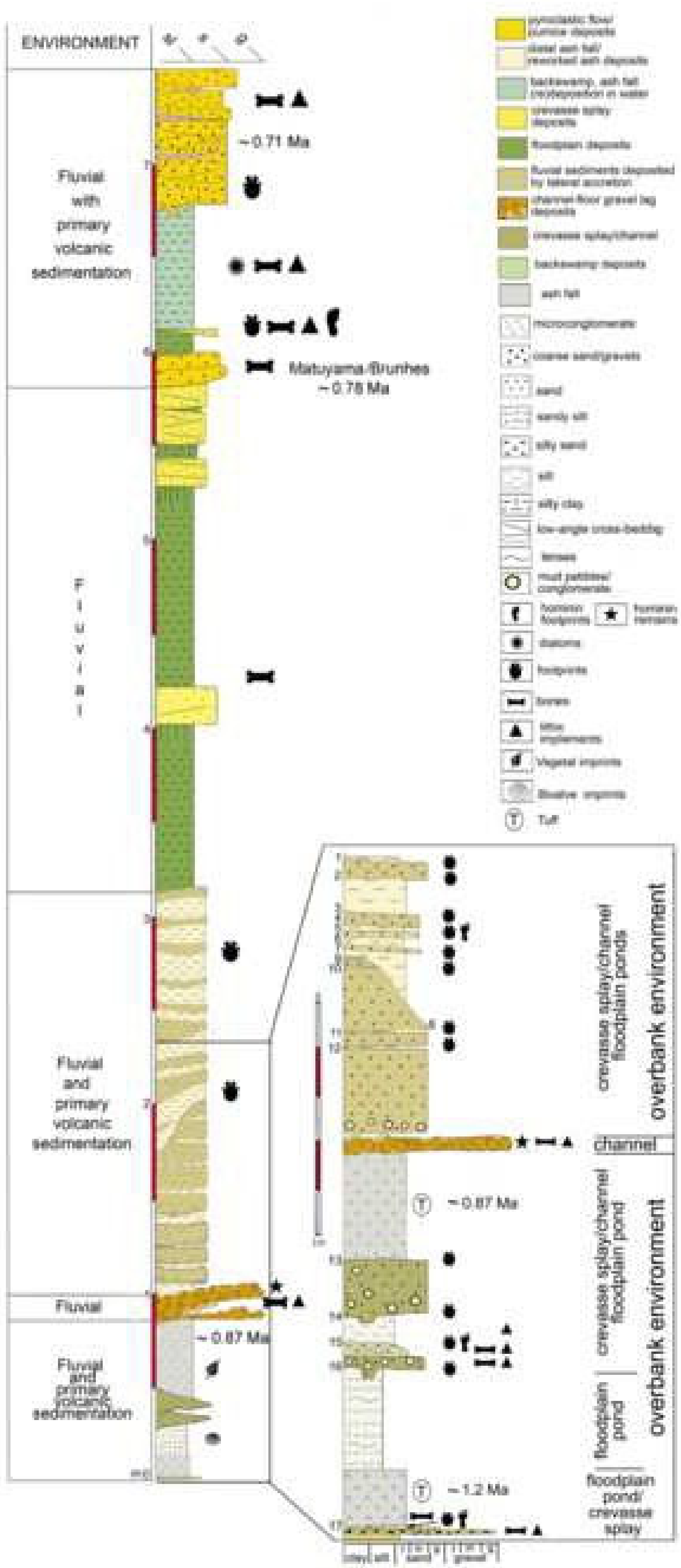

Figure 4

Click here to access/download;Figure;fig. 4..jpg

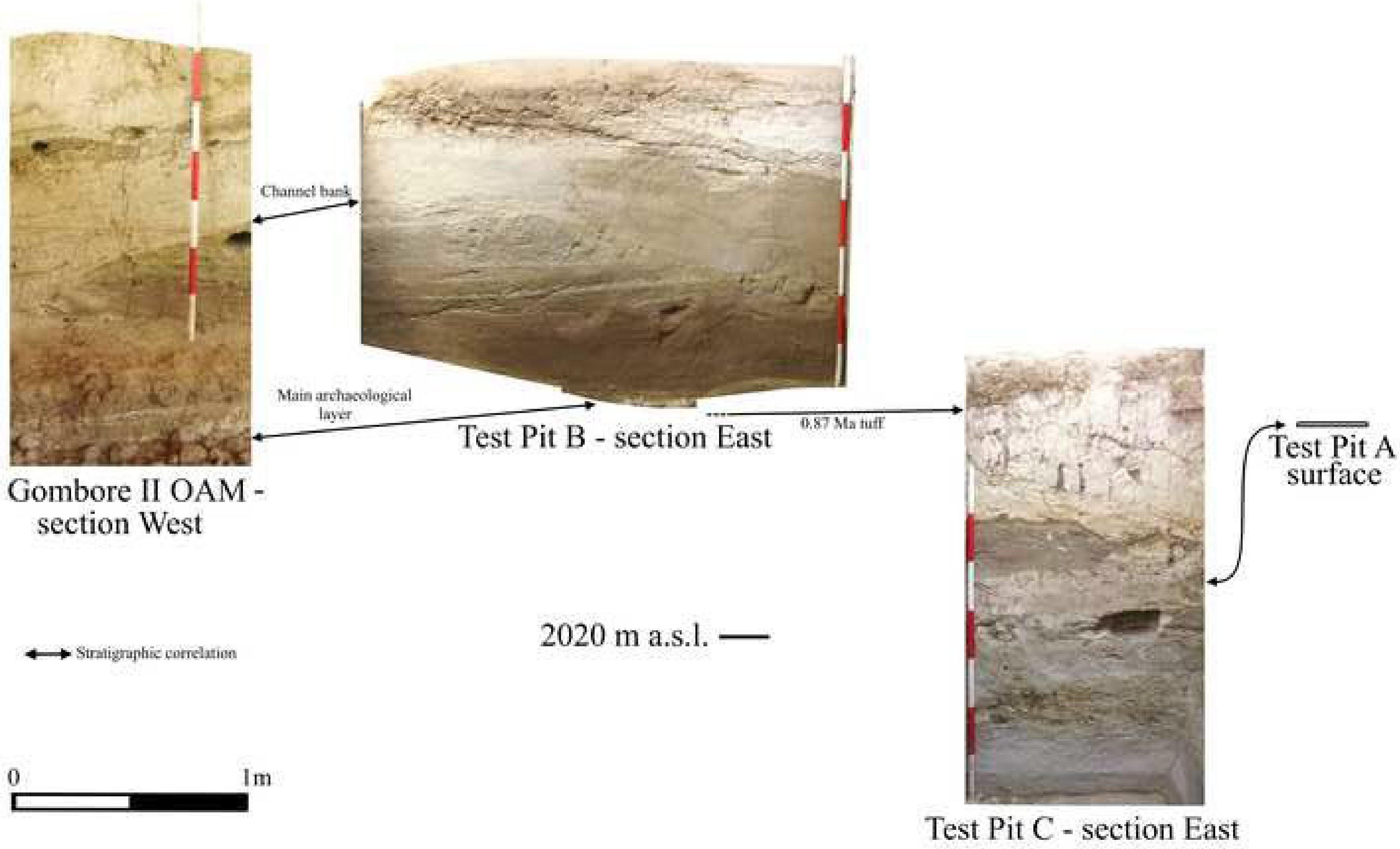

Figure 5

Click here to access/download;Figure;fig. 5.tif

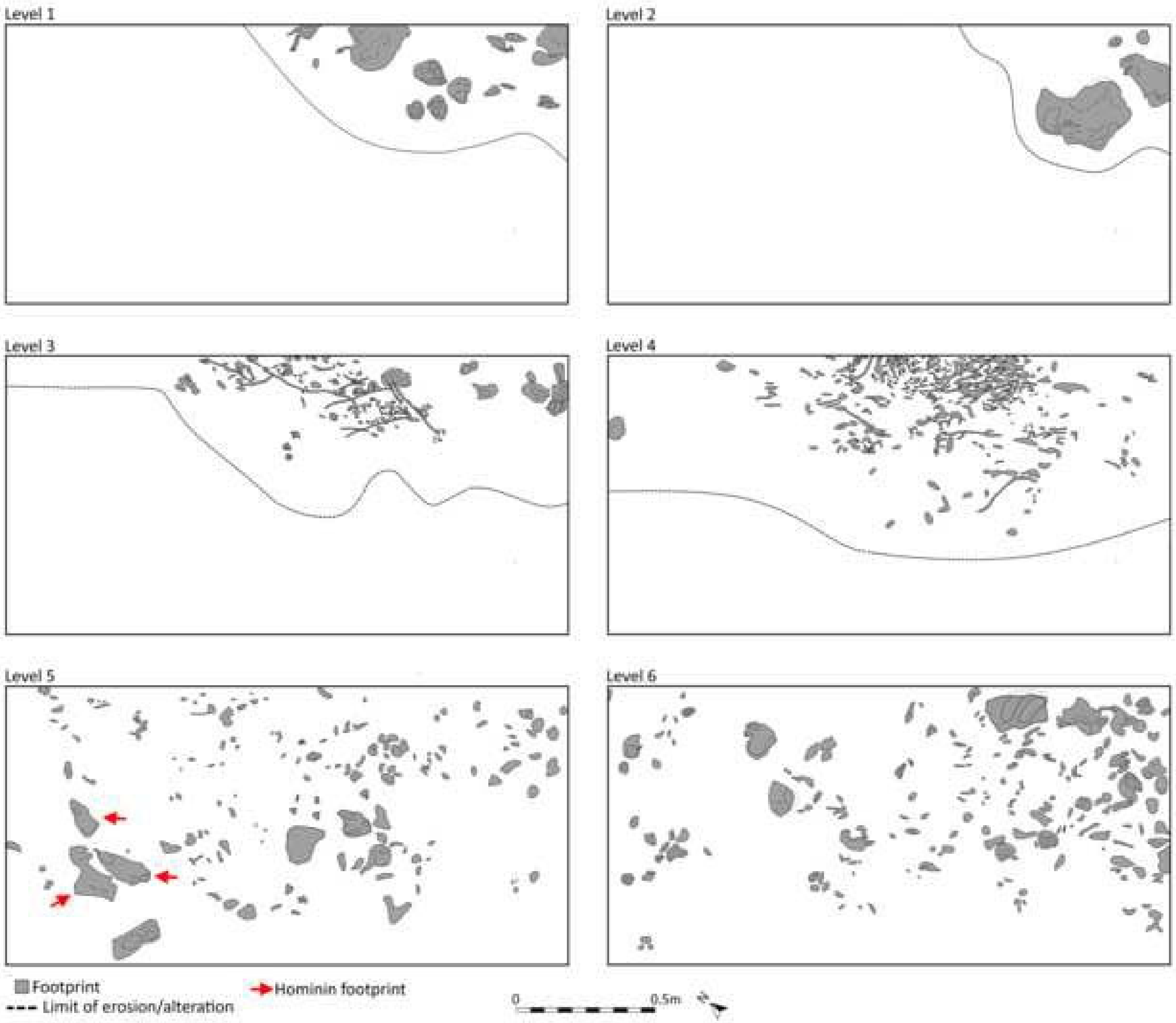

Figure 6

Click here to access/download;Figure;fig. 6.tif

Figure 7

Click here to access/download;Figure;fig. 7.tif

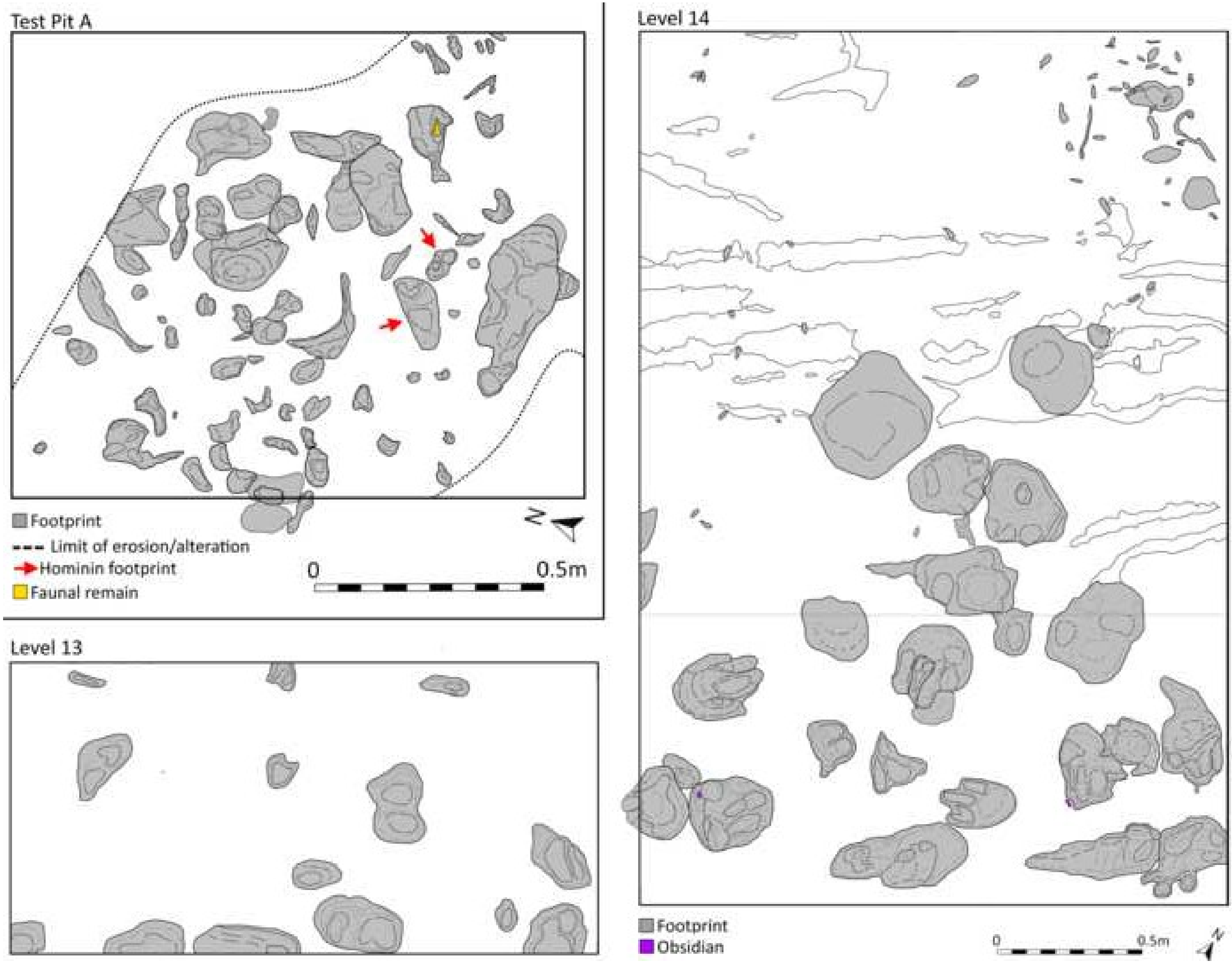

Figure 8

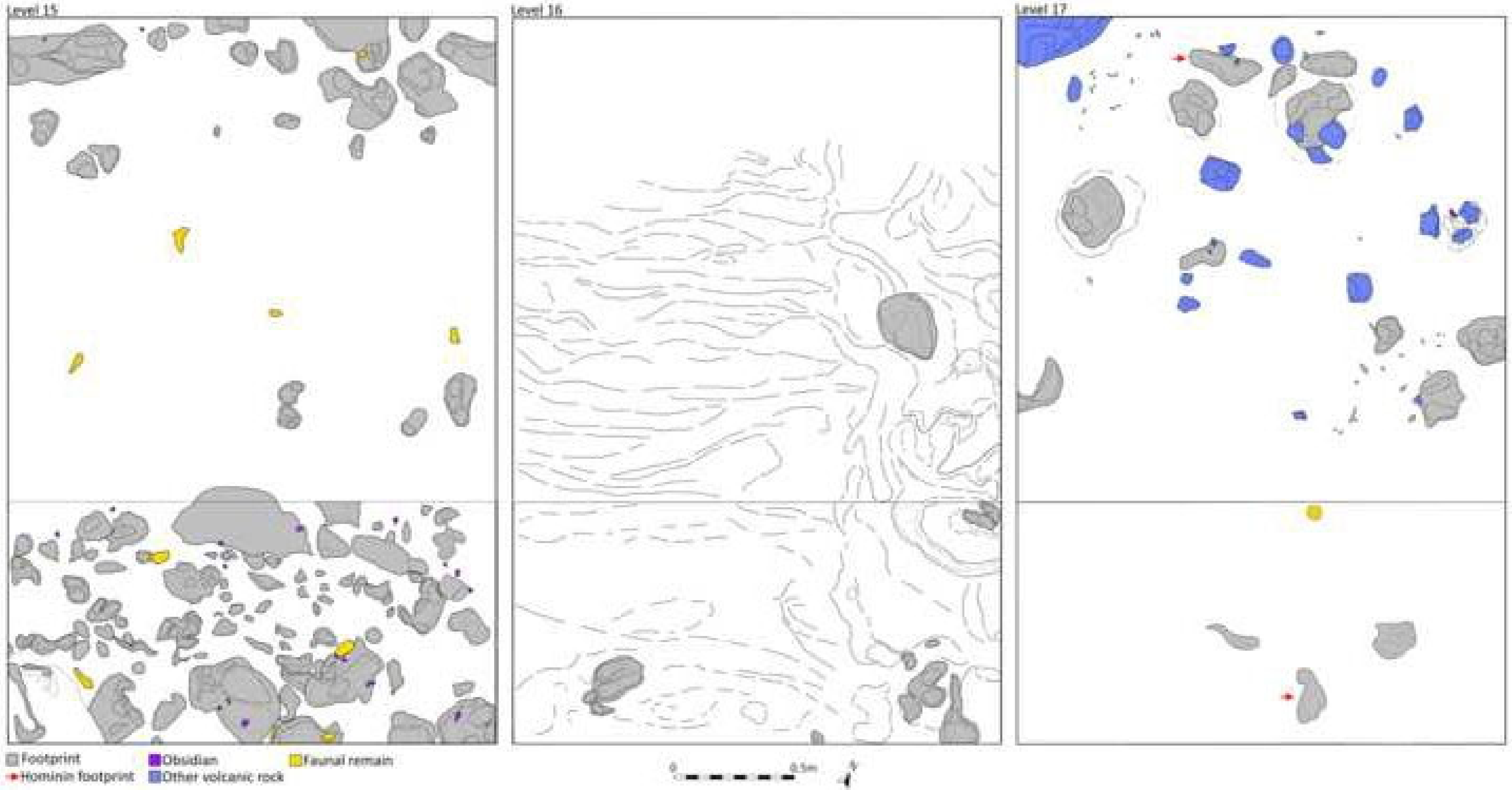
Level 15
Level 16
Level 17
Footprint
Hominin footprint
Obsidian
Other volcanic rock
Faunal remain
0
0.5m
N

Figure 9

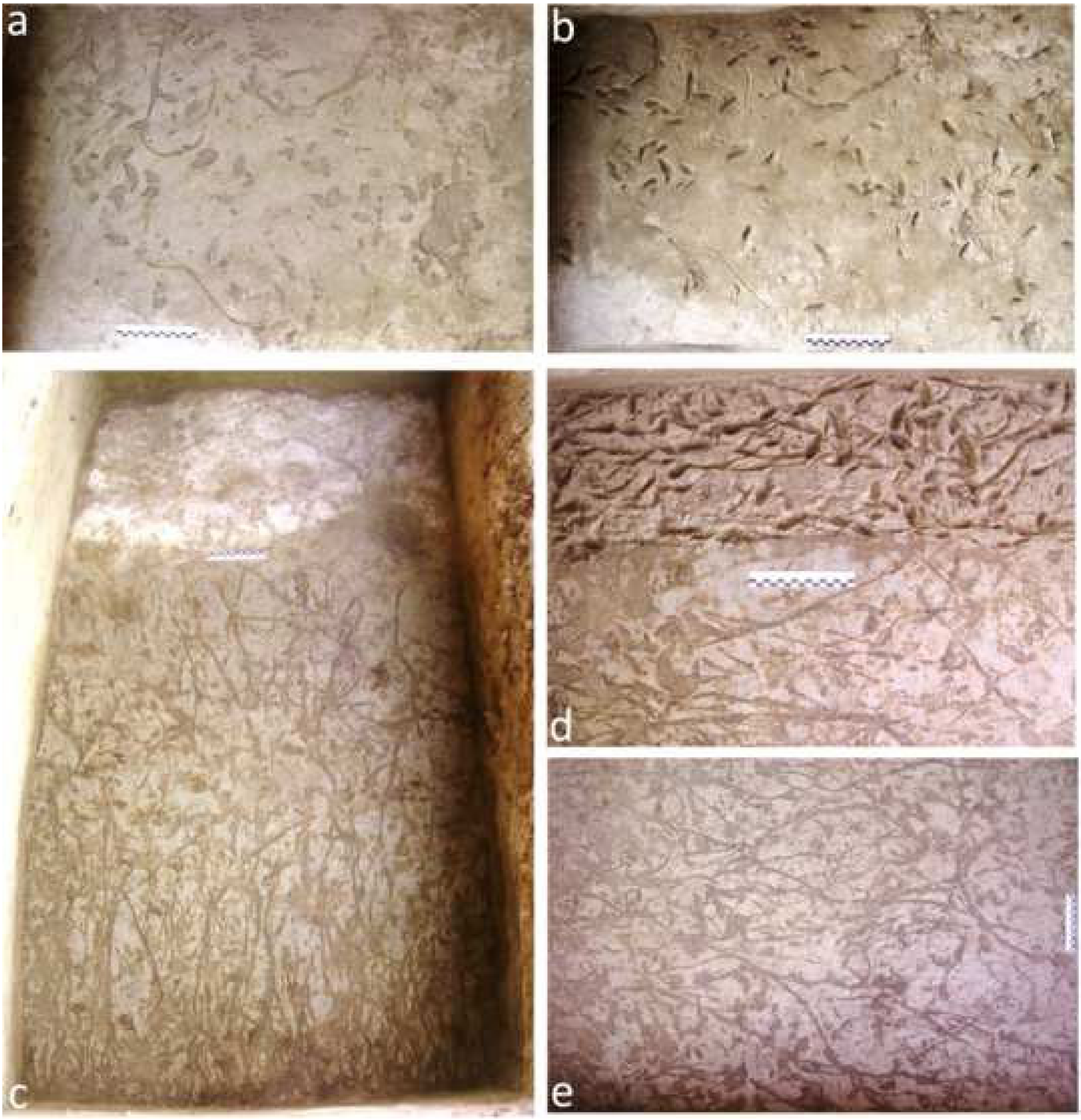

Figure 10

Click here to access/download;Figure;fig. 10.tif

Figure 11

Click here to access/download;Figure;fig. 11.tif

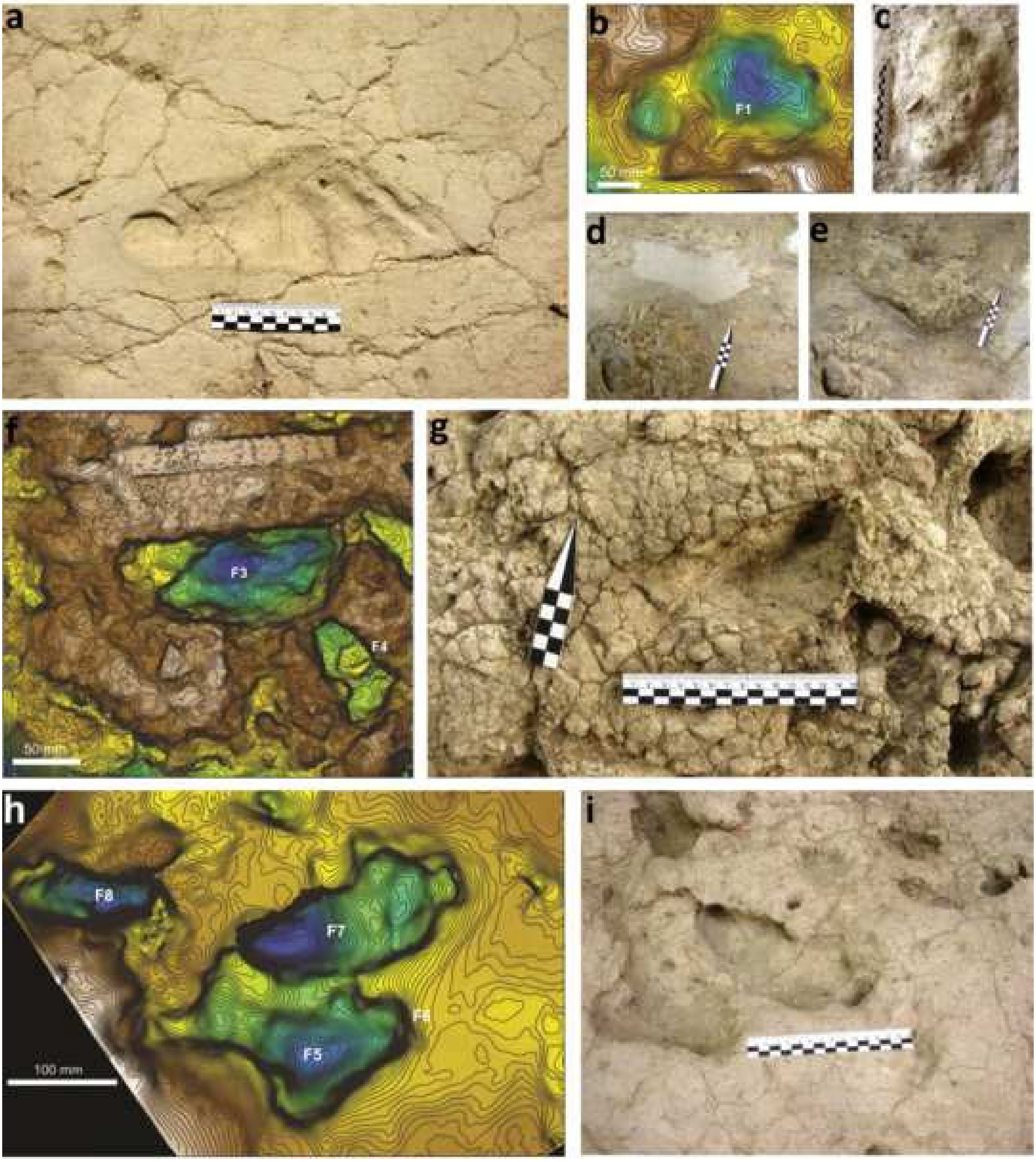

Figure 12

Table 1

Click here to access/download
Table
Tab 1.xls

Table 2

Click here to access/download

Table

Tab 2.xls

Table 3

Click here to access/download
Table
Tab 3.xlsx

Table 4

Click here to access/download
Table
Tab 4.xls

Conflict of Interest

Declaration of interests

X The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

☐The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

Author statement

FA: conceptualization, excavations, archaeological and ichnological (vertebrate) analysis; MM: funding acquisition, project administration, scientific supervision of the investigations; MRB and SCR analysis of hominin ichnology; LM ichnological analysis (vertebrates and invertebrates); RTM lithostratigraphy and sedimentology. FA wrote the paper with MM, LM, RTM, MRB; all the authors reviewed and edited the manuscript.

Click here to access/download

e-Component (supplementary data)

Altamura et al. SI.pdf