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The clever hominins: a surge in obsidian exploitation more than 1.2 million years ago at Simbiro III (Melka Kunture, Upper Awash, Ethiopia)

Abstract

Pleistocene archaeology records the changing behavior and capacities of early hominins. Changes in lithic tools are commonly linked to environmental constraints, and it is held that at first the multiple activities of everyday life were all indistinctly conducted at the same spot. Focused activities at selected localities, which imply a degree of planning, would characterize later hominins 500,000 years ago. Simbiro III level C, in the upper Awash valley of Ethiopia, allows us to test this model. It is a remarkable accumulation of only obsidian tools, more than 1.2 million years old. Here, we first assemble multiple pieces of evidence on the environment, showing that it was quite unstable. At some point, along a seasonally flooding and meandering river, an

accumulation of obsidian cobbles were deposited. Hominins soon exploited them in an innovative way, producing large tools with sharp cutting edges. Then, we show through statistical analysis that this was a focused activity and that very standardized handaxes were produced, i.e., this was a stone-tool workshop, by far the earliest discovered so far. Early hominins were doing much more than simply reacting to environmental changes; they were actively seeking new opportunities, cleverly developing new techniques, and methodically focusing on newly acquired skills.

Introduction

The interaction between environmental changes and human evolution, including the emergence of new lithic technocomplexes, has long been central in anthropological research (e.g., Potts[1] for a discussion). General scenarios correlate changes in hominin species and tool production with major shifts in aridity, temperature, and climate variability. However, rarely, if ever, the archaeological record is fine-grained enough for evaluating if and how the hominins, instead of just reacting, were able to grasp the opportunities offered by a sudden change. Level C of the Simbiro III-Monumental Section site (MS-level C), which is part of the Melka Kunture cluster of sites (MK) along the upper Awash River of Ethiopia (**Supplementary Information A**), has an extraordinary accumulation of obsidian tools that allows us to address how past hominins developed new capacities in a novel way.

The stratigraphic sequence and age of the MS site

The stratigraphic sequence of the MS is a ~5-m-high cliff along a seasonal affluent of the Awash River (**Extended Data 1 and Supplementary Information B**). It consists of a series of volcaniclastic layers sedimented in a fluvial environment. Five archaeological levels, cut by erosion, are in full view, i.e., from top to bottom levels A, B, C, D, and E. Elsewhere along the riverbank, levels C and D have been completely eroded (**Fig. 1, Extended Data 1-2**). Outside the MS, levels A and B accumulated directly on top of level E. They were capped by ~2-m-thick tuff and fluvial volcaniclastic sediments (**Supplementary Information C**). The overall sequence suggests a floodplain with lateral migration of a meandering river, point bars, and associated deposits. Seasonal flooding occurred. Fluvial sedimentation was also heavily impacted by volcanic activity and ash deposition. The minimum age of the compounded MS sequence is defined by sample 2005-10 dated 0.878 ± 0.014 Ma [2]. It was extracted from a tuff at the top of the sequence along the riverbank and accordingly postdates all the archaeological levels of the MS. Its age fits with the geology, which defines the stratigraphic sequence of the MS as part of the Melka Kunture Formation [3], predating a volcanic event dated ~1.2 Ma (**Supplementary Information D**). The biochronology further supports this age determination, as no animal species, including *Connochaetes* cf. *gentryi*, *Pelorovis oldowayensis,* (**Extended Data 3**) *P. turkanensis*, and *Theropithecus oswaldi*, point to an age younger than 1 Ma (**Supplementary Information E**).

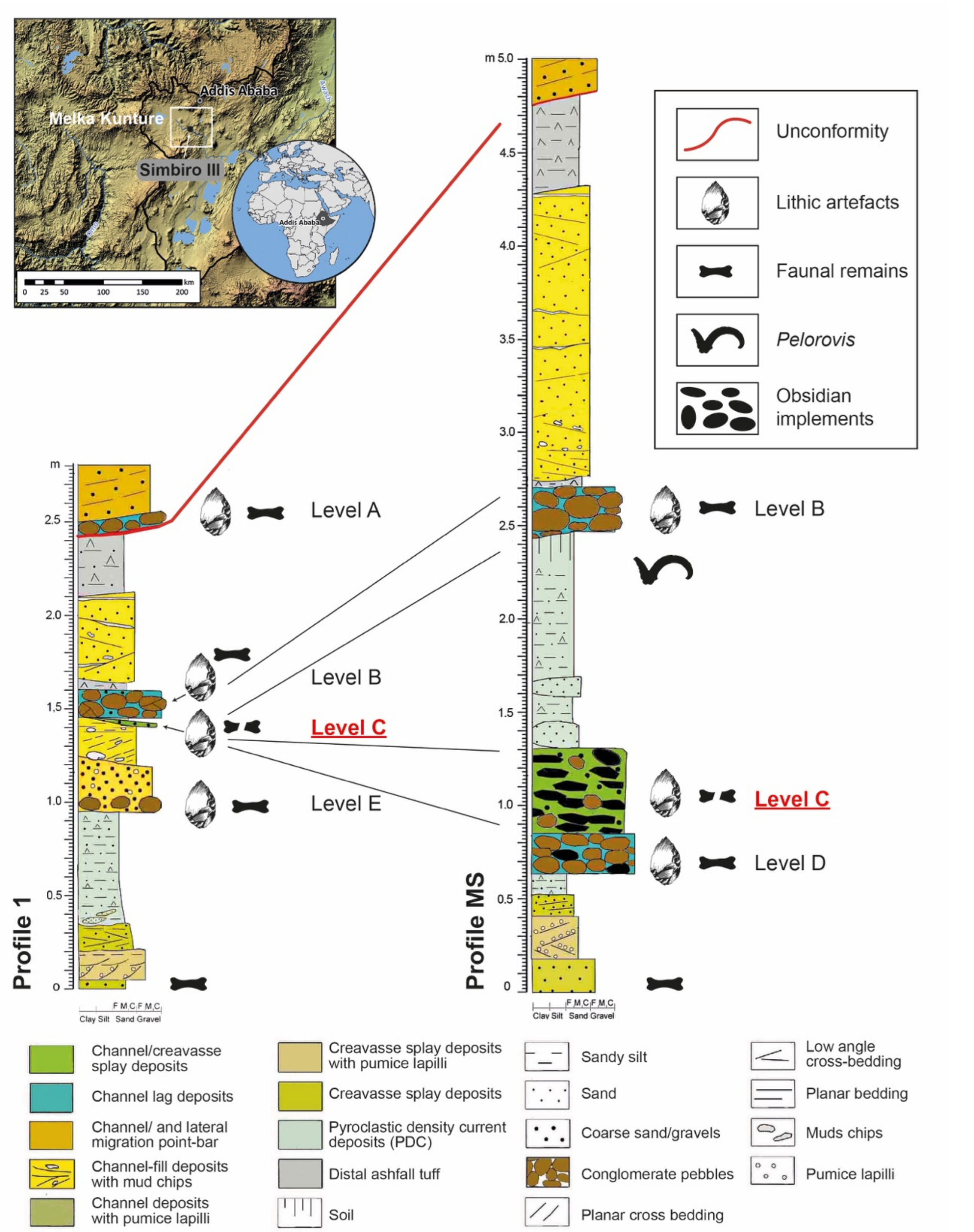

Fig. 1| Location map of Simbiro III site at Melka Kunture area and stratigraphic logs of the Monumental Section, with indication of the main level analyzed here (in red).

Paleoenvironmental data

Throughout the Pleistocene, palynological analysis documents varied vegetation at MK, 2000–2200 m above sea level, with mountain forests and high-elevation woodlands, wooded grasslands, and grasslands. These are all typical of the Dry Evergreen Afromontane Forest and Grassland Complex that currently develops in Ethiopia between

1800 and 3000 m above sea level [4]. Faunal analysis, isotopic and phytolith data, and geomorphological investigation at the MS all provide further details on the environment (**Supplementary Information E**). The isotopic results point to the sampled animal taxa having a diet based on C_4 plants, which develop in grasslands. Nearby, however, C_3 plants, typically related to wooded vegetation, also grew, as shown by the $\delta^{13}C$ values of hippopotamids. This fits with phytolith analysis, suggesting that the area of the MS was likely humid and dominated by grasses in the sampled time interval. Geomorphology shows that the river seasonally inundated the floodplain, which was flooded for a while. However, forests or woodlands, including broadleaved trees, conifers, and shrubs, also grew in the general area. MS-level C, discussed here, is notably characterized by a greater relative abundance of forest indicator phytoliths than the other levels. Open spaces granted grazing opportunities to the hippopotamids (*Hippopotamus* cf. *amphibius*), bovids (*Alcelaphini*, *Hippotragini*, and other *Bovidae*), and equids (*Equidae*), as recorded in the fossil fauna (**Supplementary Information E**).

The archaeological assemblage from level C

The excavated assemblage was found at a high density, with 578 stone tools over just ~4.8 m^2 (>120.5 pieces/m^2) (**Extended Data 4**). The same artifact density is in full view along the ~15-m-long and ~0.5-m-thick cliff over level C (**Fig. 2**).

The tools were almost exclusively obsidian tools (n = 575, 99.5%). The selection and management of this high-quality raw material is quite different from what is observed in both earlier and later levels of the MS (**Supplementary Information F**). Although much of the deposit has been washed away and the extant stone tools cannot be accurately counted, we estimate that the compounded original weight was more than a metric ton.

The flakes and waste happen to be thickly grouped like “clouds,” while larger implements are sometimes in heaps, often in a vertical or subvertical position. However, in part of the excavated surfaces, there are many tools with a planar arrangement (**Fig. 2c-d**). The preservation varies, ranging from fresh to heavily weathered, but even though obsidian is a fragile rock, the artifacts usually display sharp and nonabraded edges and knapped surfaces. The sizes are small (average length 42.9 mm) with many implements <40 mm (**Supplementary Information F**). All the available information points to slightly displaced elements and to an autochthonous position. Slide processes in a low-energy environment were active from a very close spot and accumulated obsidian tools without any prolonged transport.

The overall techno-typological pattern of the assemblage points to a behavior focused on the knapping of handaxes, i.e., shaped tools, those "made for the purpose of a single artifact by sculpting the raw material in accordance with the desired form [5].” Core management to produce middle-sized flakes is a minor activity (**Supplementary Information F**). The technological pattern of handaxes as a group is quite significant (**Fig. 3**). They are mainly shaped on large obsidian flakes with a variable amount of residual cortex and only occasionally on pebbles, but intensive shaping sometimes blurs the type of blank. They are not very large (average length 95.7 mm). Some are shaped with a low number of negatives, with the knapper cleverly taking advantage of the initial shape of the blank (**Supplementary Information F**). They display a marked uniformity in shape, with largely prevailing pointed morphologies, either amygdaloid or ovate

(**Supplementary Information F**). The analysis shows a higher degree of morphological standardization than in other MS levels or in other Lower and Middle Pleistocene Acheulean assemblages from close localities (**Fig. 3, Extended Data 5, Supplementary Information F**). In other words, the standardization is remarkable and even unique, underlining the shape specificity of the MS-level C handaxes.

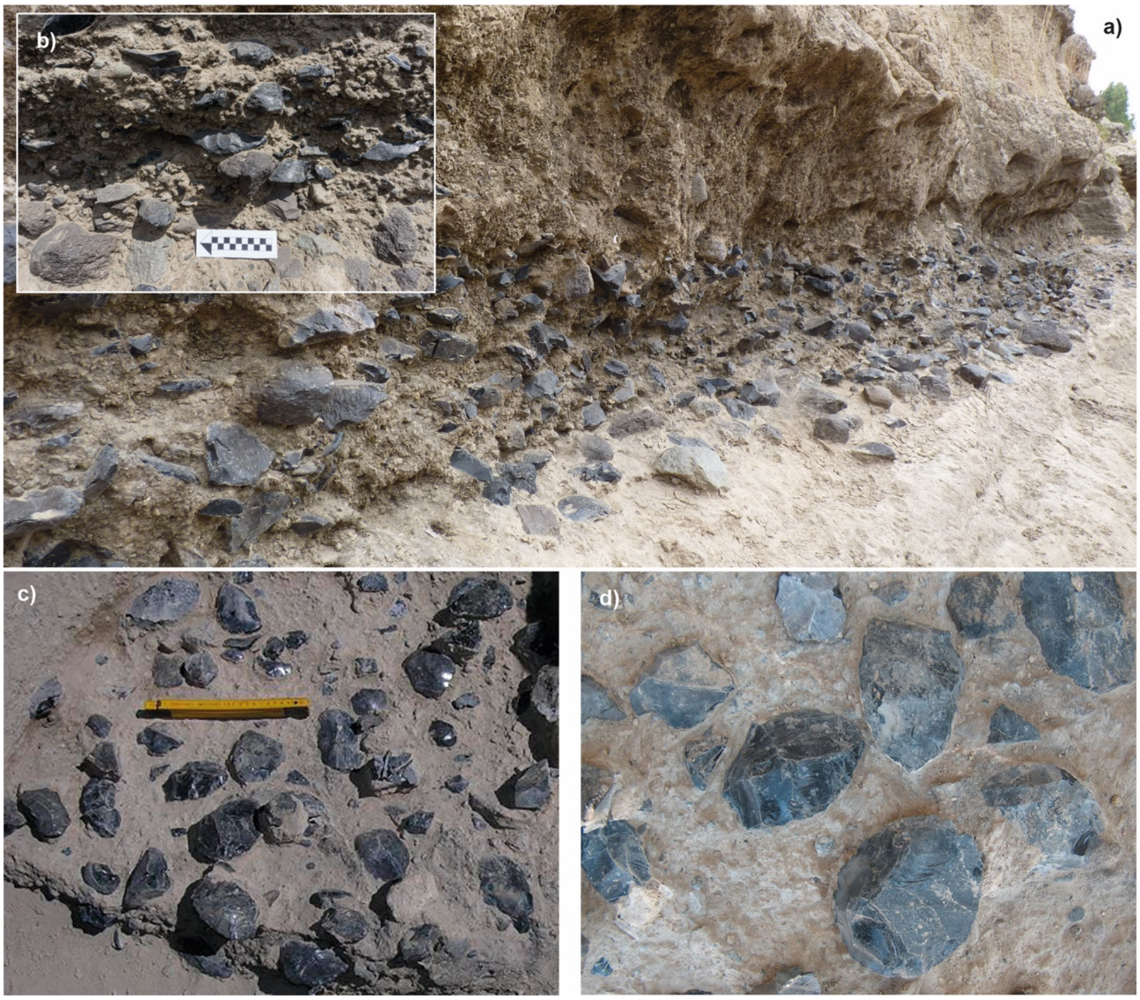

Fig. 2| Examples of the extensive accumulations of obsidian artifacts in level C: a-b: main view of the level and detail of artifact density. General view (c) and detail (d) of the concentration of artifacts (mainly handaxes) in a trench dug in 2004 at the top of level C.

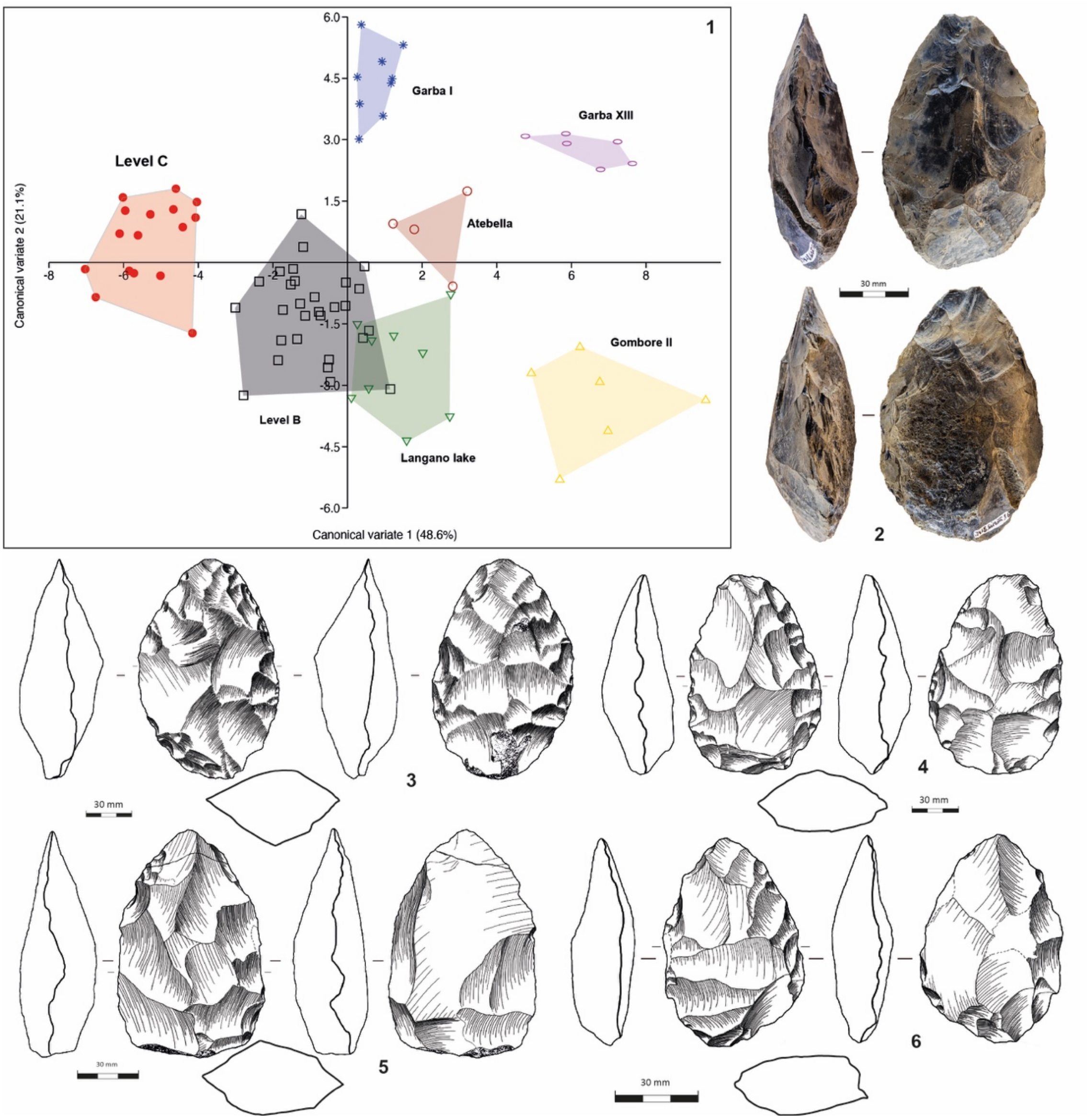

Fig. 3| Scatter plot of geometric morphometry analysis (CVA results) in the analyzed assemblages (1) and some examples of handaxes of level C (2-6).

Discussion

This archaeological record is striking because of the almost exclusive use of obsidian (>99%), which is truly exceptional during the Early Stone Age. Elsewhere at MK, tiny locally available obsidian pebbles were selected and flaked in substantial numbers in the Oldowan [6,7], but these were only used to produce small tools for immediate use. In Africa at large, obsidian artifacts have been reported only in low percentages in the Oldowan and Acheulean [6,8-10]. Intensive use only emerged much later on, from the Middle Stone Age onward [6,11].

An obsidian outcrop, called Balchit, is 7 km from Simbiro but at a substantially higher elevation on the other side of the Awash River. The small pebbles (<5 cm) used elsewhere at MK are from the alluvia of streams draining from Balchit. Given the size of the pebbles needed for the handaxes of MS-level C, calculated as >20 cm, and the impressive amount of accumulated implements, the best explanation is the exploitation of a nearby obsidian source, such as a local cobble accumulation, accessible to hominins for a while and later eroded or buried by sediments. Some tools display the remnants of irregular and nonabraded cortex typically found on pebbles (**Extended Data 6**). This conclusion fits with our reconstruction of the environment, with changes and even sudden changes in the landscape occurring when the meandering river modified its course or seasonally inundated the floodplain.

MS-level C so far is unique for more than just the almost exclusive use of obsidian, which allowed the production of large flakes and transformation of them into regular shapes with sharp cutting edges. That is, in the entire Lower Pleistocene record, no other site is specifically focused on shaping LCTs. The technological composition of the record, with a substantial percentage of waste and shaping flakes, allows us to hypothesize only one main activity, i.e., knapping, focused on handaxe production. In the scientific literature, this is defined as a "workshop" (**Supplementary Information G**). At MS-level C, this workshop is further characterized by the skills needed for high shape standardization. This was a routine activity, and over time, lenses of debris slipped into the nearby channel, accumulating downslope.

Abundant literature discusses the existence of evolutionary trends throughout the development of the Acheulean techno-complex and the iconic handaxes that make most LCTs [12-15]. However, during the early stages of the African Acheulean, no such trend was observed in the refinement of LCT shaping abilities. Some of the main conceptual elements (i.e., mental template imposition on blanks, bifacial reduction, and extensive large flake production) were already well developed in the earliest stages [16]. A trend only appears later, approximately one million years ago, and continues until the second half of the Middle Pleistocene, when in Africa this technocomplex disappears [17,18]. Currently, the variability of Acheulean assemblages, including LCT variability, is explained by exogenous factors such as site function and raw material availability or by ecological constraints [19].

In the artifacts of level B, we did not find the same standardization and shaping intensity as displayed by the handaxes of MS-layer C. As layer B is later than layer C, this is contrary to a straightforward evolutionary process. Instead, we interpret the pattern of the MS-layer C assemblage as the innovative response to the sudden, easy, and extensive availability of obsidian, i.e., of an excellent material in an adequate flaking size. These were the supports needed to shape or retouch large tools with sharp cutting edges, providing some advantage to hominin groups. The obsidian source was exploited until it was eventually buried or washed away in the seasonally variable landscape.

Approximately 1.2 million years ago, MS-level C was on a riverbank, where more activities than just knapping were most likely going on. However, those apparently did not include the manipulation of animal food, as the faunal remains are almost nonexistent, contrarily to other levels the MS. Instead, we observe a scheduled, repeated, and well-organized on-site exploitation of obsidian, detaching blanks nearby where the raw material was available and shaping LCTs for future use. The tools were needed at a nearby spot or elsewhere at MK where obsidian handaxes are recorded at penecontemporaneous and later sites. This provides early evidence of specialized behavior in the context of human evolution.

Conclusion

The selective exploitation and methodical shaping of obsidian signals complex behaviors since the Lower Pleistocene and from an early stage of the Acheulean Technocomplex. The hominins had good capacities for anticipating and planning activities in a diverse and locally wooded environment. They also made provisions for the seasonal flooding of the area, returning many times to the same important spot. Overall, the evidence provided by MS-level C contradicts the usual assumption of early hominins simply "coping" with environmental change: more than ~1.2 Ma, they eagerly sought novelties and exploited new resources, brilliantly solving technological problems such as effectively detaching and shaping large flakes of unusually brittle and cutting volcanic glass. MS-level C signals the need, when discussing human evolution, to address the emergence of behaviors and capacities more complex than commonly assumed. Pleistocene hominins were clearly cleverer than often believed.

Methods

Pictures, maps, notes, and manuscripts are kept in the archives of the archaeological mission, which had been prepared by Jean Chavaillon and his team when investigating Simbiro. Notably, from 1974 to 1976, Ouardya Oussedik directed the field research and took daily notes on the ongoing operation. A report on the 1974 excavations was published [20], and another one, prepared in 1976, remained unpublished.

Stable isotope analysis

Isotopic analyses were performed following the internal protocol of the working group Biogeology (University of Tübingen) for chemical analyses of carbonates from fossil teeth (enamel). Fossil enamel was sampled using a drilling device equipped with a diamond-tipped bit to obtain 12-15 mg of powder. Powdered samples were soaked in 2–3% NaOCl for 24h at 20°C to oxidize organic residues and rinsed twice with distilled water. Then, the remaining samples were treated with 0.1 M buffer acetic acid-calcium acetate for 24h at 20°C to remove exogenous carbonate. Only 2.5-3 mg of carbonate proceeded into the IRMS-analysis [21].

Phytoliths analysis

Phytoliths were extracted from sediments using HCl to remove carbonates and H_2O_2 to oxidize organic matter. Clays were removed by decantation and heavy $ZnBr^2$ liquid set at d=2.3 cm^3/g was used to separate biogenic silica (including phytoliths, sponge, cysts, diatom remains and sometimes volcanic ashes) from minerals. Residues were mounted using Cargile mounting medium. Observations and identifications were carried out under the microscope at magnification x500.

Geometric Morphometric Analysis

2D Geometric Morphometric Analysis (GMA) in the handaxes assemblages was performed following Generalized Procrustes Analysis (GPA) and Elliptic Fourier Analysis (EFA) approaches. Initially, we performed ordination tests -Canonical Variates Analysis (CVA)- and pairwise comparisons -Discriminant Function Analysis (DFA)- to measure the diversity of shapes in the studied sample. In addition, we applied other statistical test (PerMANOVA and Euclidean hierarchical clustered classification) to explore the degree of shape diversity of the assemblages analyzed.

Author Contributions

M.M. coordinated the research, D.B. and R.B. did the phytolith analysis and researched the paleo vegetation, H.B. and G.B. did the stable isotopes analysis, D.G. determined the faunal remains, R.T.M. investigated the geology and geomorphology, E.M.Q., J.P. and S.R.J did the archaeological analysis, L.P. researched the volcanology, A.S.D. assembled and filed the collections. All authors wrote, discussed the paper and participated to the extension of the final manuscript.

Acknowledgments

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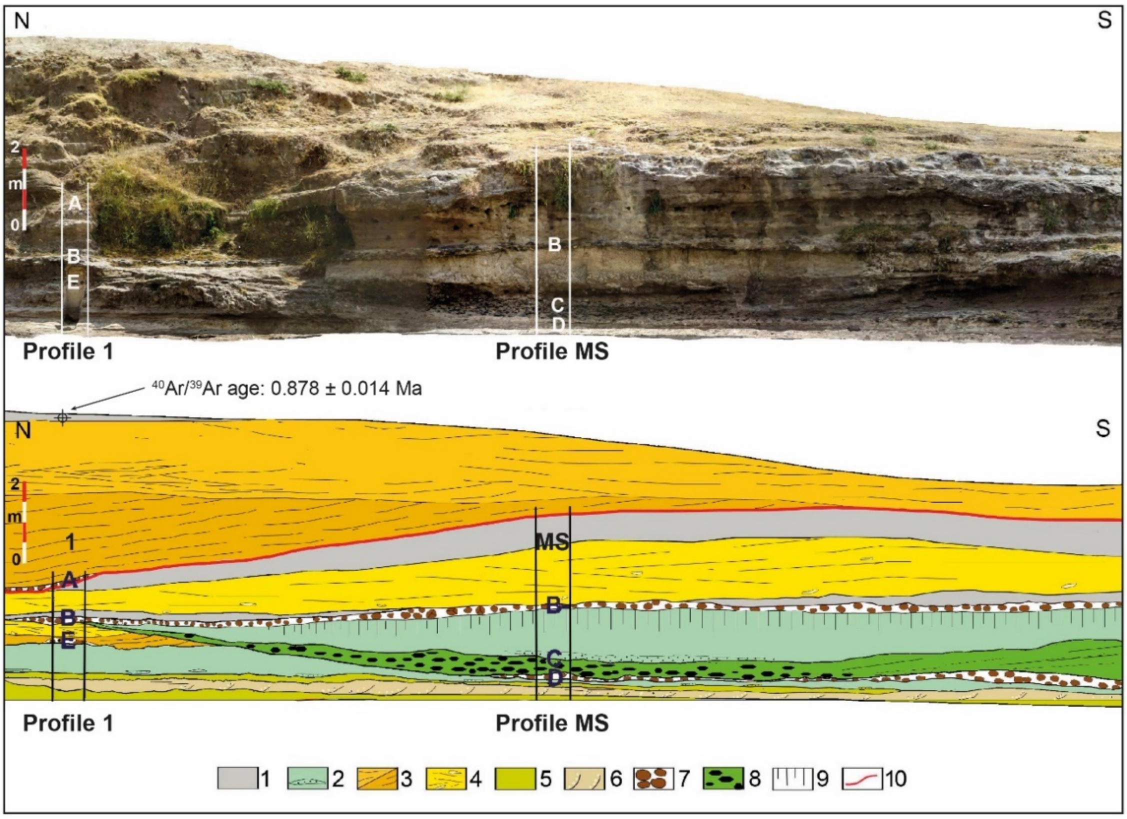
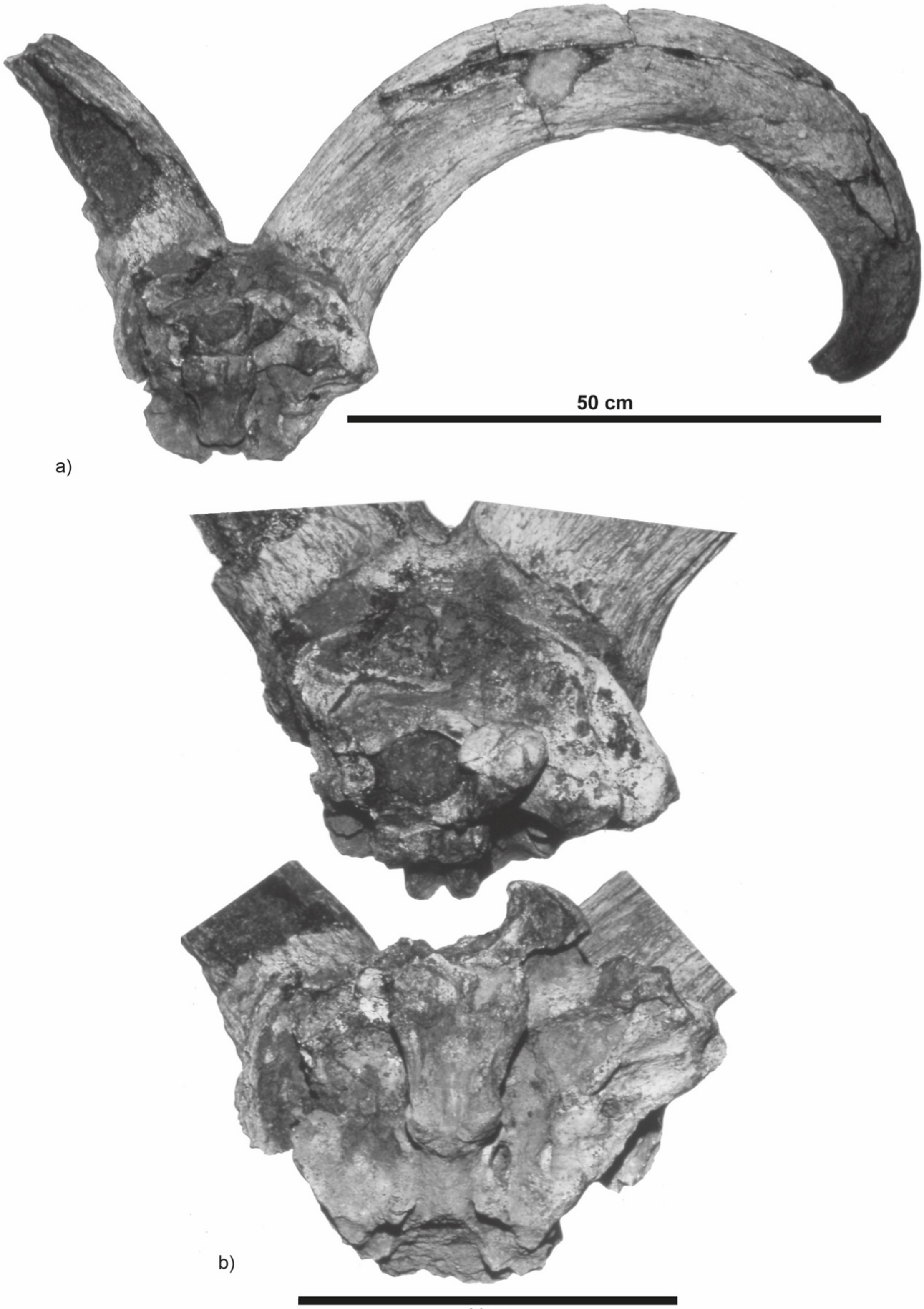
Extended data

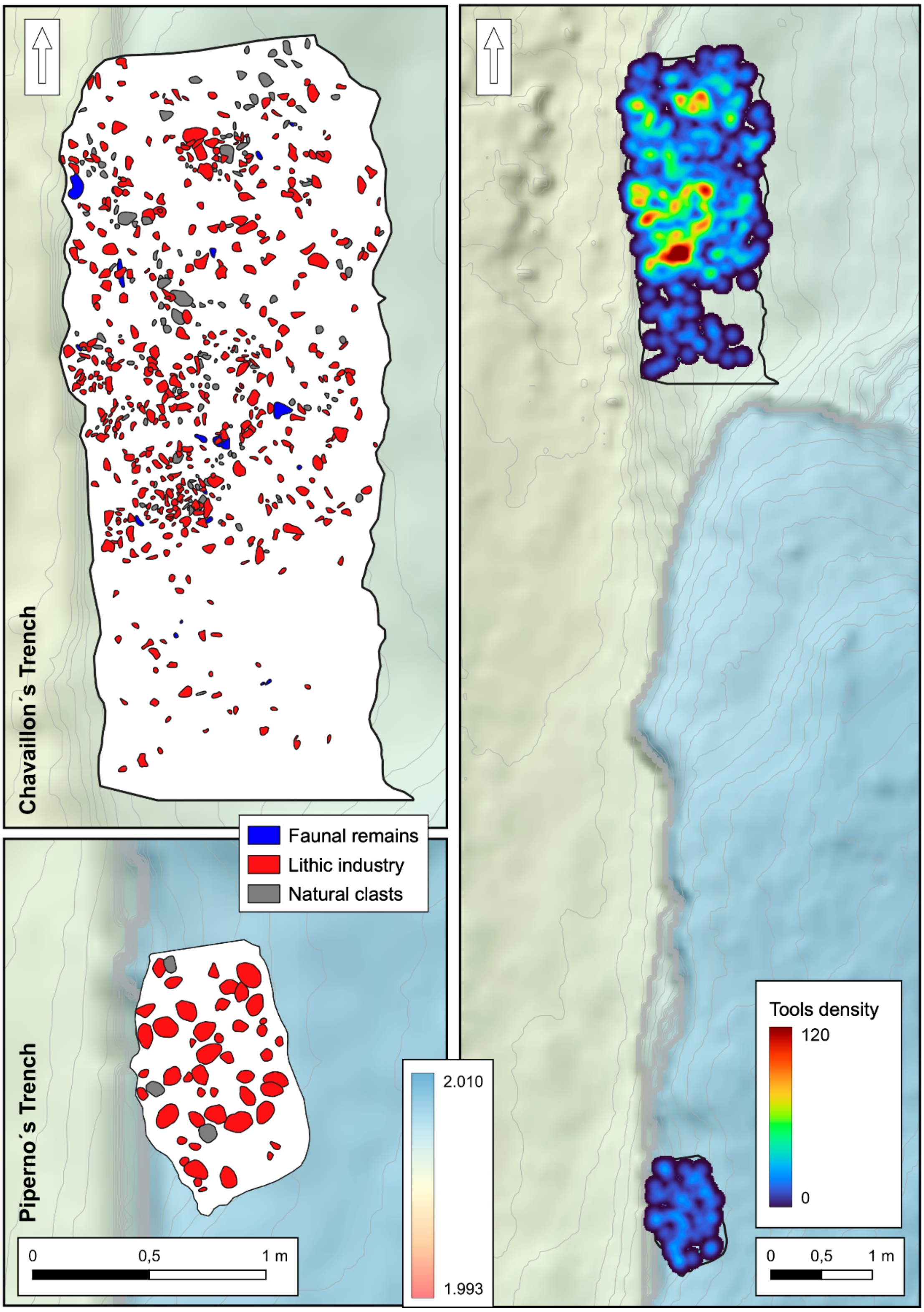
Extended Data Fig. 1| General views of the Monumental Section at Simbiro III.



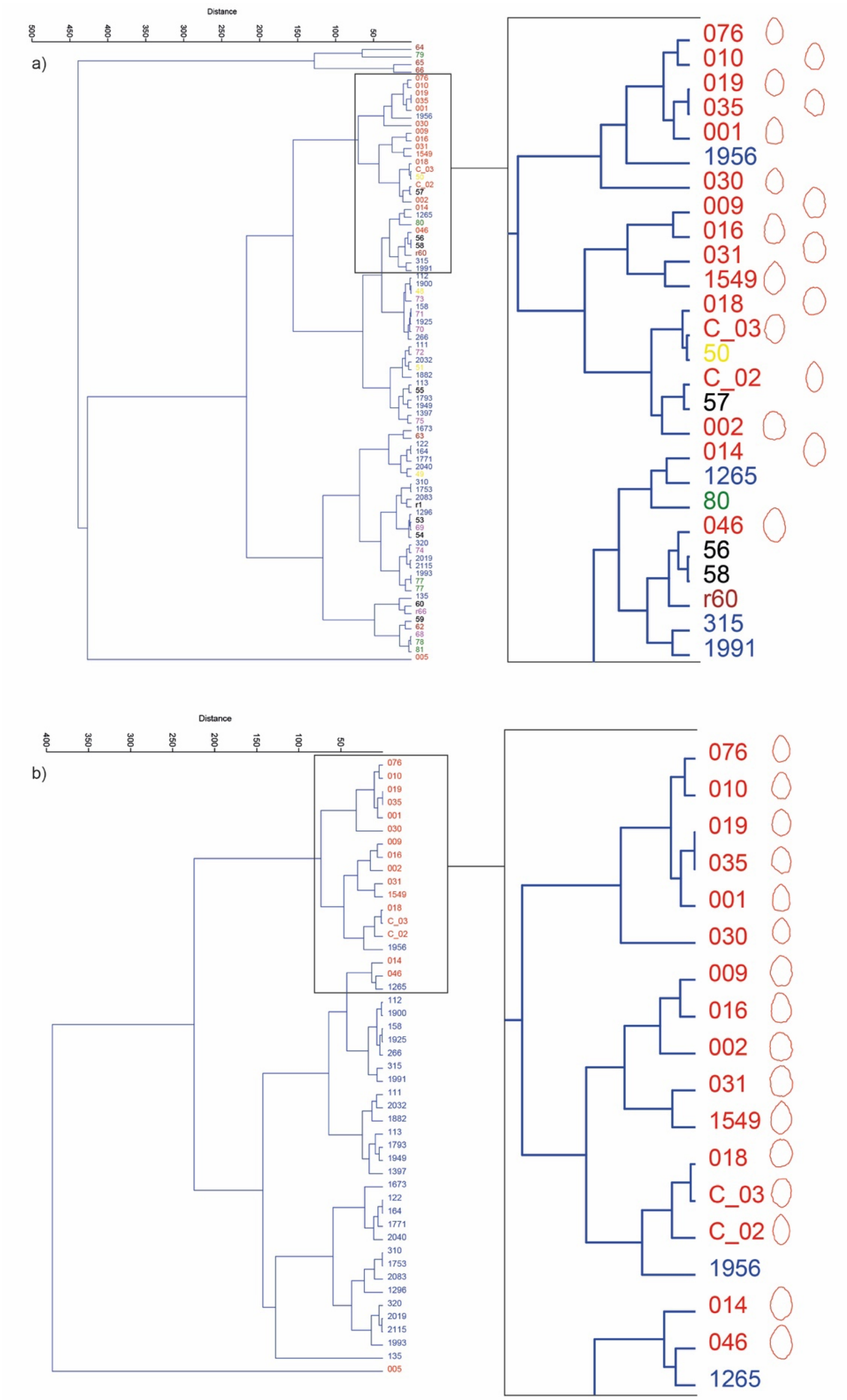
Extended Data Fig. 2| Orthophoto and schematic cross-section of the MS showing the stratigraphic sequence, $^{40}Ar/^{39}Ar$ sample position, and archeological levels. 1: tuff; 2: pyroclastic density current deposits (PDC) in the floodplain; 3: channel and point bar deposits; 4: channel-fill deposits with mud chips; 5: crevasse splay deposits; 6: crevasse splay deposits with lapilli; 8: conglomeratic lag deposits with lithic artefacts; 8: channel/crevasse splay deposits with obsidian artefacts; 9: paleosol; 10: unconformity; A, B, C, D, E archaeological levels.



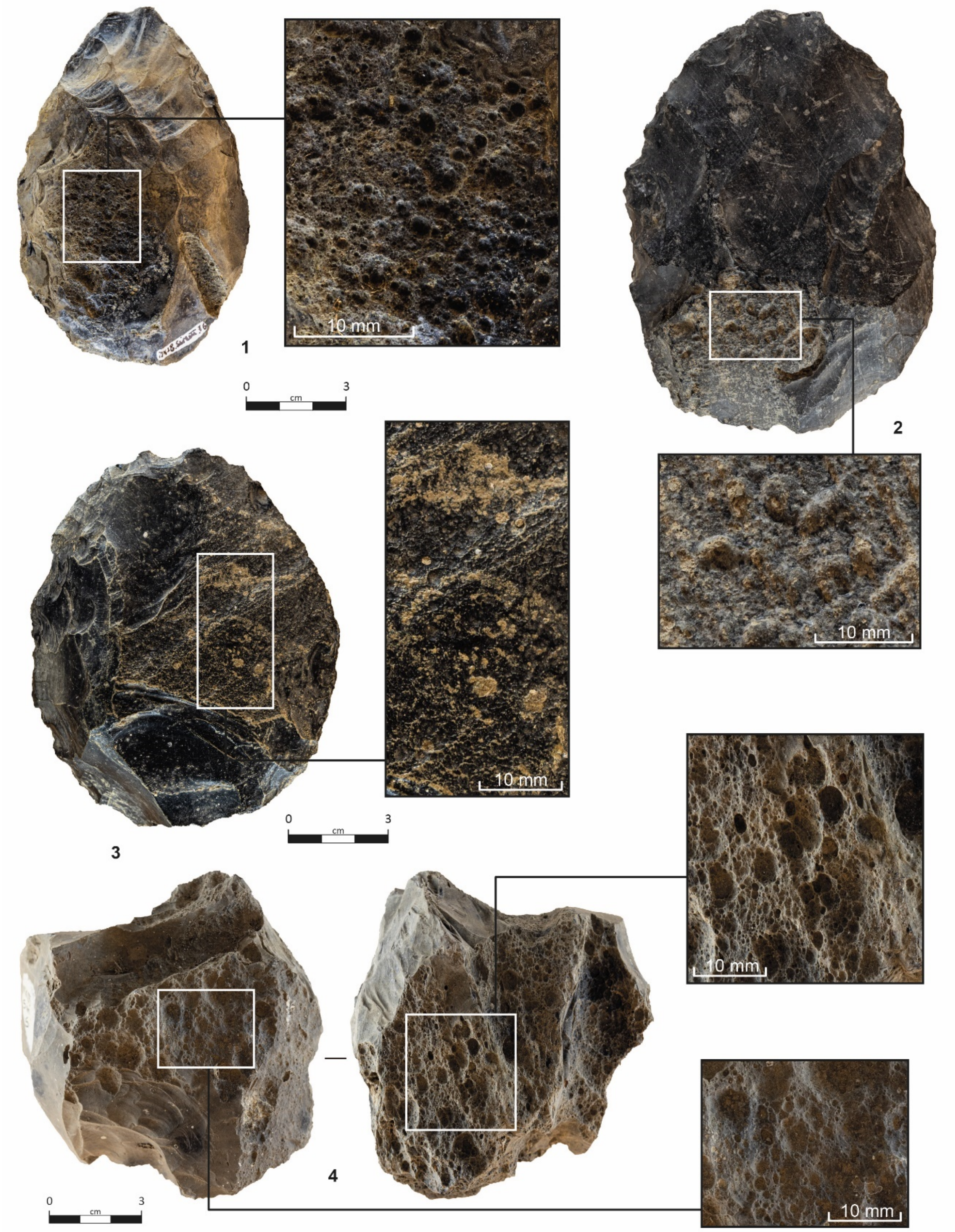
Extended Data Fig. 3| The *Pelorovis oldowayensis* discovered in 1973: a) braincase with complete right horncore; b) posterior view, and details of the occiput and cranial basis.



Extended Data Fig. 4| Level C: maps of the excavations and density of remains per square meter.



Extended Data Fig. 5| Plot of Euclidean hierarchical clustered classification (paired group UPGMA): (a) the handaxes of levels B (in blue) and of level C (in red); (b) handaxes of various sites of MK (in blue) and of level C (in red).



Extended Data Fig. 6| Obsidian handaxes (1-3) and core (4) with cortical remains typically found on nonabraded cobbles and pebbles.