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Long-term behavioral adaptation of Oldowan toolmakers to resource-constrained environments at 2.3 Ma in the Lower Omo Valley (Ethiopia)

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Abstract

The long stratigraphic sequence of the Shungura Formation in the Lower Omo Valley documents 3 million years of hominin evolution, which, when combined with detailed paleo-depositional environmental data, provide a unique window onto the complex interactions between hominin landscape use and the development of stone tool mediated behaviors. It remains to be seen whether this behavior was related to a unique brief occupation event or the expression of an emerging long-term tradition. The hominins, *Paranthropus aethiopicus* and/or early member of the genus *Homo*, who occupied the Lower Omo Valley developed tool assisted behaviors from ~ 2.3 Ma in the stable riverine environments of the ancestral Omo River. This new technological behavior is concomitant in the Shungura Formation with the emergent ability of the toolmakers to deal with an environment poor in lithic resources. Here we report on the newly investigated site complex of OMO 79, which produced the first evidence for multiple phases of hominin settlement dedicated to non-ephemeral mixed activities. The development of this long-lasting techno-economic tradition could relate to a more generalized cognitive tipping point around 2.3 Ma marked by hominin increased capacities in resource processing.

Introduction

The earliest undisputed evidence for stone tool production in the Lower Omo Valley (southern Ethiopia) comes from Member F of the Shungura Formation, dated to between 2.324 ± 0.020 Ma and 2.271 ± 0.041 million-years (Ma)^{1,2}, in an area that was frequented by hominins for more than 3 million years³⁻⁵. This emergent behavior is documented by a large number of hominin occupations in varied environmental contexts, all related to meandering river floodplain deposits of the ancestral Omo River. This sudden development of tool-assisted behaviors in Member F⁶ is unlikely linked to either biological or environmental factors as the two hominin taxa documented in Member F, *Paranthropus aethiopicus* and *Homo sp.*, are equally present in underlying Member E^{4,5} and from a similar environmental setting. Member F deposits are composed of low-energy alluvial sediments laid down by the meandering Omo River under semi-arid environmental conditions that emerged much earlier, as early as 2.8 Ma (e.g.⁷⁻⁹). Importantly and in stark contrast with all other Early Pleistocene sites in eastern Africa¹⁰⁻¹⁵, the landscapes occupied by the Shungura hominins were devoid of predictable sources of abundant raw materials in the form of cobble conglomerates^{6,16}. Whether this unprecedented behavioral adaptation of hominins to a raw material-poor environment is related to a unique brief occupational event or the expression of an emerging long-term tradition remains to be seen. Here we report on a recently discovered site complex, OMO 79, which provides important new data on the ability of early Oldowan toolmakers to deal with challenging environments.

Results

Overview of the archeological occurrences in the Shungura Formation

Extensive archaeological surveys and excavations in the Shungura Formation during the late 1960s and early 1970s⁴, followed by new field work since 2008^{17,18}, confidently place the first appearance of stone tool manufacture in the lower part of Member F, around 2.3 Ma. Abundant paleontological collections, including hominin fossils, provide a wide range of data for exploring the interactions between environmental fluctuations and faunal communities from Member A, dated to ~ 3.6 Ma¹⁸⁻²⁰. The more than one million years that separates these two members sees the appearance of the earliest known stone artifacts²¹ and Oldowan assemblages^{11,22} in Africa. In the Lower Omo Valley, no *in situ* stone tools have been recovered from sediments deposited during this time range despite survey works and test trenches. In Member F, 56 *in situ* archaeological occurrences have been recorded, completed by 65 surface artifact concentrations found in close spatial and stratigraphic association (for more details see *SI Appendix*). Of these, 78 are distributed across nine different site complexes^{17,18,23} (Fig. 1A), which correspond to concentrations of at least two spatially distinct occurrences that can be directly correlated stratigraphically with each other. While major tuff deposits can be traced across the Shungura Formation, intercalated fluvial deposits do not permit similar long-distance stratigraphic correlations, mainly due to the significant lateral variations induced by the migration of the ancestral Omo River across the floodplain, the discontinuous nature of outcrops and benchmark levels, as well as faults. The relative chronology of hominin occupations can be reliably addressed only through the stratigraphic correlations observable at each site complex.

All nine site complexes of Member F (Fig. 1A) primarily record a unique occupation phase within a single layer of fine sediments. These occupations take the form of several primary or sub-primary occurrences (e.g. OMO 371N and OMO 371S), or multiple occurrences of artifacts remobilized in the same channel lag deposit, as at FtJi1^{4,6,10,24} and OMO 57^{4,25}. A similar scenario of a unique occupation phase likely applies to site complexes with two artifact-bearing deposits: an upper archeological layer most often found in primary/sub-primary fine sediments from river bank deposits and a spatially offset lower channel lag containing redeposited artifacts from the upper layer which was eroded as the channel migrated²⁶, as seen at FtJi2^{4,6,24}, OMO 123^{4,25} and OMO 1/E. By contrast, OMO 79 evidences successive phases of hominin occupation, a unique situation in the Shungura Formation. The OMO 79 site complex comprises 13 archaeological occurrences spread over approximately 8,000 m² (Fig. 1B) in the lower part of Member F, in various sedimentary units that can be tied to discrete river margin environments.

Stratigraphy And Depositional Environments At Omo 79

The 70 m-thick sedimentary deposits of OMO 79 are tilted 15° to the west and comprise four superimposed upward-fining fluvial units between Tuff F and Tuff G (Figs. 2 and 3A).

The main lithofacies are as follows:

- channel lag deposits (CL): massive, trough cross-bedded, decimeter-thick sandy gravel units with an erosional base, which primarily comprise pedogenic concretions and rip-up clasts, as well as small

(1–2 cm) gravels of volcanic and metamorphic rocks (Fig. 3B);

- point bar deposits: large-scale low-angle strata including planar and trough cross-bedded sands with paleocurrent perpendicular to the large-scale stratification (lateral accretion units, LA) (Figs. 3A and 3C) - the absence of major erosional surfaces within the lateral accretion packages is consistent with each sand body corresponding to a single-storey point bar;
- levee and upper point bar deposits (LV): heterolithic sediment package comprised of interbedded deposits of sand and silt (Fig. 3C);
- fine-grained floodplain deposits (FF): decimeter-thick, massive silty clay and clay beds with a prismatic structure occasionally interrupted by silt or sand layers, in which pedogenic carbonate nodules form recurrent horizons (Fig. 3D).

The overall sequence records floodplain accretion and lateral migration of the paleo-Omo channel across the floodplain, in a context of the creation of accommodation space following subsidence and lake transgression. The reconstruction of depositional environments, sedimentary processes and stratigraphic architecture provide evidence for at least four hominin occupation phases above Tuff F, each composed of either a single or multiple archaeological occurrences (Fig. 2 and Table 1). The superimposition of these archeological occurrences in several points of the site complex is consistent with artifacts deriving from multiple occupation phases. The five phases are as follows:

Phase 1: hominin occupations in secondary depositional context

Four archaeological occurrences (A44, A81, A112, A191) were found scattered over the 150 m long OMO 79 outcrop, in the basal part of a sand body overlying Tuff F (sub-unit 1.1) (Fig. 2 and Table 1). These occurrences represent remnants of occupations redistributed in a channel following bank erosion, and ultimately redeposited downstream as small secondary concentrations mixed with lag gravels. Artifact size distributions for the two largest assemblages, A81 and A112, point to the heavy winnowing of the fine fraction (Fig. 4A). Macro- and microscopic analysis of surface alterations of quartz artifacts (*SI Appendix*, Fig. S1) produced contrasting results. No to little macroscopic abrasion was evident on more than 90% of artifacts (*SI Appendix*, Fig. S2A, C), whereas moderate and heavy microfracturation (*SI Appendix*, Fig. S2B, C) account for 43% and 32% of the analyzed sample from A112 and A81, respectively (Fig. 4B, C).

Table 1

OMO 79 archaeological occurrences. Number of surface *vs in situ* artefacts collected at OMO 79; lithofacies (Gm: massive gravels, Sh: horizontally bedded sands, Fl: laminated fines, Fm: massive fines), sedimentary sub-units and corresponding occupation phases.

Occurrence	Nb surf. artifacts	Nb <i>in situ</i> artifacts	Total Nb	Lithofacies	Sedimentary sub-unit	Occupation phase
OMO A44	91	0	91	Gm	1.1	1
OMO A81	150	0	150	Gm	1.1	1
OMO A112	129	0	129	Gm	1.1	1
OMO A191	53	0	53	Gm	1.1	1
OMO A41	0	1	1	Gm	2.1	2
OMO A42	165	0	165	Gm	2.1	2
OMO A88	55	0	55	Gm	2.1	2
OMO A125	37	0	37	Gm	2.1	2
OMO A127	11	1	12	Gm	2.1	2
OMO A129	201	0	201	Gm	2.1	2
OMO A43	127	121	248	Sh & Fl	2.2	3
OMO A82	318	2	320	Fm	2.3	4
OMO A128	11	0	11	Fm	3.3?	5?

Artifact size distribution of the main lithic assemblages compared with experimental reduction sequences (see (26) for more details concerning the experimental dataset). **B.** Microscopic surface alterations of the crystals and ridges on quartz artifacts. **C.** Macroscopic surface alterations (details concerning macro- and micro-alterations are provided in *SI Appendix*, Fig. S1).

Phase 2: Second phase of hominin occupation in a secondary depositional context

Six archaeological occurrences (A41, A42, A88, A125, A127, A129) were found in the sand horizon (sub-unit 2.1) overlying the deposits from phase 1 (Fig. 2 and Table 1). These occurrences equally correspond to small secondary concentrations associated with gravel lags (Fig. 2 and Fig. 3B). The distance of transport and, hence, the original depositional context cannot be precisely determined. Isolated *in situ* artifacts were found at A41 and A127 (Fig. 3B). Artifact size distribution for the largest assemblages, A42 and A129, are readily comparable with those of phase 1 (Fig. 4A) and thus reflect similar water transport and size sorting. Identical to phase 1, more than 90% of the quartz artifacts bear little to no macroscopic abrasion (*SI Appendix*, Fig. S2A, C), while 47% and 43% of artifacts from A42 and A129, respectively, exhibit moderate to heavy microfracturation (Fig. 4B, *SI Appendix*, Fig. S2B, C). Among the abundant

faunal remains collected during surface surveys at A42, abraded bones account for 9.14% (n = 1,829) of the total assemblage and no clear traces of anthropic modification were identified²⁶.

Phase 3: hominin occupation on a point bar

This phase is represented by a single, primary occurrence, A43 within a 20 to 30 cm thick heterolithic unit at the top of a point bar sequence (sub-unit 2.2) (Fig. 2) yielding both *in situ* and surface artifacts (Table 1 and *SI Appendix*, Fig. S3). In this overbank deposit context, water transport of archeological material is likely to have been limited. Accordingly, artifact size distributions fall within, or close to the zone of experimental reduction sequences (Fig. 4A). The majority of A43 surface and *in situ* artifacts show little to no macroscopic abrasion (91%: *SI Appendix*, Fig. S2A, C), while moderate to heavy microfracturation is present on 24% of artifacts (Fig. 4B and *SI Appendix*, Fig. S2B, C). The presence of a small proportion of heavily altered pieces (2% and 7% at macro- and microscopic scale, respectively) suggests they were transported over significant distances before being mixed with fresh pieces.

Phase 4: hominin occupation on the floodplain

A single occurrence, A82, located at the top of two adjacent hills composed of fine-grained floodplain deposits (sub-unit 2.3) (Fig. 2), provides evidence for a fourth occupation phase. Only the southernmost hill (A82 South) yielded two *in situ* artifacts, 30 cm below the ground surface in a clayey layer with slickensides. This layer has been entirely eroded from the second hill (A82), which also did not yield any *in situ* material, whereas surface artifacts were abundant on its slopes (*SI Appendix*, Fig. 4). Artifact-size distribution (Fig. 4A) and macroscopic surface alterations (88% of artifacts bear little to no macroscopic abrasion: *SI Appendix*, Fig. S2A, C) suggest the assemblage to have experienced very little winnowing and only limited water transport. By contrast, A82 exhibits the highest proportion of moderate to heavily microfractured artifacts (63%: *SI Appendix*, Fig. S2B, C) among all phases (Fig. 4B).

Phase 5: final phase of hominin occupation on the floodplain

The uppermost A128 occurrence can potentially be tied to a fifth phase of hominin occupation on the floodplain, as evidenced by a small concentration of artifacts atop a sedimentary hill capped by clay and carbonated nodules (unit 3.3), some 9 m above A82 (Fig. 2). Two trenches cut into a thick and compact clayey deposit did not yield any *in situ* material, making it likely that the artifact-bearing deposit has been completely eroded.

Assemblage Taphonomy And Composition

The taphonomic analysis of the OMO 79 lithic assemblages reveals contrasting patterns of artifact preservation. Assemblages from primary and secondary contexts share similarly high proportions of artifacts bearing little to no macroscopic surface alterations (Fig. 4C). Macroscopic abrasion due to water transport^{27, 28} is limited for all depositional contexts. On the other hand, the small proportion of heavily

abraded objects in all assemblages reflects the introduction of objects with a different depositional history. The impact of water transport is more apparent in the artifact size distributions, with phases 1 and 2 characterized by heavily size-sorted assemblages. By contrast, size sorting is absent or limited in the assemblages of phases 3 and 4, both in primary or sub-primary depositional contexts. A comparison of micro- and macroscopic surface alterations (Fig. 4B, C) provides complementary information. Both size-sorted (i.e. water-transported) and unsorted (non-transported) assemblages contain moderately to heavily microfractured artifacts (Fig. 4B), the highest amounts being found in the clay floodplain deposits of A82. Microscopic alterations are thus most likely connected to processes other than water transport, most likely the vertical displacement of artifacts by argilliturbation^{29, 30}, as evidenced by the presence of numerous slickensides at A82³⁰.

The lithic assemblages (Fig. 5 and *SI Appendix*, Fig. S6, Table S1) mainly comprise quartz reduced using a simple core-flake technology involving freehand and bipolar percussion, a technological pattern typical of all Member F assemblages^{17, 24, 31}. Raw materials other than quartz are rare and show similar size and technological attributes. Locally available raw materials are scarce, difficult to access and are of poor knapping quality. The only place where pebbles greater than 2 cm have been found at OMO 79 is the gravel lag deposit of A112 (phase 1). An exhaustive survey of this area produced 79 pebbles, of which only five were of knappable size (i.e. greater than 5 cm in maximum length). Such a scarcity of exploitable raw materials suggests that the lag materials could not have served as a main source of raw materials, in addition to the fact that their position as bed load in an active channel would render them difficult if not impossible to access. This pattern applies to the whole of the Shungura Formation (Member F). A significant part of the raw materials might thus have been brought from distant sources^{6, 10}, the closest one being the ephemeral channels of the Hamar Range alluvial fans, some 3 to 15 km to the east. Assemblage composition (Fig. 5 and *SI Appendix*, Table S1) shows that both end-products (i.e. flakes and broken flakes with efficient cutting edges, angle < 60°), and by-products (angular fragments, cores) are present in proportions consistent with core reduction being partially carried out on-site. These multiple tool-assisted activities are consistent with relatively non-ephemeral hominin occupations.

Discussion

The OMO 79 site complex provides the first example of multiple, well-defined occupation phases in the Shungura Formation. Spread over a period of several thousand years in the lower part of Member F, the successive phases of hominin occupation were located on the margins of the paleo-Omo River. The archaeological occurrences of phases 3 and 4 (and likely 5) can be confidently placed on an upper point bar (phase 3: A43) and the proximal floodplain of the paleo-Omo River (A82: phase 4 and presumably A128: phase 5). The absence of archeological sites in the uppermost sedimentary units of Member F, which correspond to distal floodplain deposits, is congruent with a strong correlation between hominin settlement and river margin environments²⁶. This echoes the recurrent correlation of hominin localities with riverine and lacustrine contexts³² or springs³³ in the African Late Pliocene and Early Pleistocene record. River floodplains in semi-arid environments are characterized by heavily contrasting habitats, with

an abrupt shift from gallery forests with dense perennial vegetation to edaphic grasslands dominated by annuals and forbs on the floodplain³⁴. In this savannah grassland context, point bars would have been particularly attractive for hominins, as suggested by OMO 79 (A43 and A82), as well as Gona³⁵ and Hadar³⁶ in the Afar Depression. Distributed at regular intervals along the river, these highly productive patches of vegetation would have provided hominins with year-round predictable resources. Beyond an easy access to water, which also attracted other large predators, point bars likely afforded hominins with shelter, including large trees.

What is unique to OMO 79, as well as to the low energy fluvial deposits of the Lower Omo Valley in general, is the lack of abundant local raw materials suitable for stone tool manufacture^{10, 24}. This “resource-rich, stone-poor”³⁷ environment contrasts with all other eastern African Early Pleistocene sites in contexts with a wide variety of locally available resources, including abundant and easily accessible raw materials in cobble conglomerates^{11–15}. Regionally, several dozen kilometers south-east and south of the Shungura Formation, at Fejej and Nachukui, cobble conglomerates offered abundant raw materials to Oldowan groups for the manufacture of stone tools^{15, 38}.

The OMO 79 record reveals that hominin behavioral adaptation to an environment in which lithic resources were rare is not the result of a single phase of ephemeral hominin settlements in the Lower Omo floodplain. Instead, hominins repeatedly occupied the area as part of multi-purpose techno-economic activities, a behavior rooted in a long-lasting local tradition that emerged around 2.32 Ma in the lower part of Member F and continued until ca. 2.0 Ma, in the lower part of Member G, under relatively similar environmental conditions³⁹. Around 2.5 Ma in the Bouri Formation (Hata Member), in an environment devoid of locally available raw materials, hominins only left behind rare and scattered isolated artifacts⁴⁰. Some 200,000 years later in similar settings, the Shungura Formation strongly contrasts with the abundance and recurrence of archaeological occurrences. The adaptive behaviors developed by Oldowan groups in the Shungura Formation echo the widespread distribution of the early Oldowan sites across Africa from at least 2.9 Ma, as recently evidenced by new discoveries in eastern and northern Africa^{41, 42}. Moreover, the time period around 2.3 Ma sees a shift towards an increased anticipation and control in raw material management, as at Lokalalei 1 and Lokalalei 2C in the Nachukui Formation^{43, 44}. These co-occurring patterns potentially signal a tipping point in the relation of the early Oldowan groups to their environment, marked by increased capacities in resource processing from 2.3 Ma onward. This predates discrete forms of complex responses to varied environments and related resources from ~ 2.0 Ma at Kanjera South⁴⁵, Olduvai Gorge⁴⁶ and Koobi Fora⁴⁷. Finally, the considerable planning depth in terms of resource processing evidenced in the Shungura Formation adds a unique new facet to the growing picture of the behavioral flexibility of early Oldowan groups.

Methods

The OMO 79 site complex was discovered in 2008 during extensive archaeological surveys in Member F. It is situated some 400 meters west of the OMO 123 site complex, where Jean Chavaillon carried out

extensive field work between 1972 and 1976^{25,46}. All of the OMO 79 archaeological occurrences have been extensively surveyed, inventoried, with surface and *in situ* material piece-plotted with a Total Station during the 2014 and 2018 field seasons. Test excavations and trenches were made at four occurrences (A128, A129, A82 and A43) following the identification of *in situ* or sub-surface artifacts and/or when abundant surface artifacts were observable (for more details, see *SI Appendix*). Sediments from excavated occurrences were systematically dry sieved with a 3 mm mesh. At two occurrences where the faunal remains were particularly abundant (A42 and A112), all fauna and lithic artifacts were collected following the scraping and screening of the loose, upper 5 cm of sediments over ca. 20 m² area.

The sedimentological study is based on data acquired during two field missions (by PB in 2014 and MC in 2018) and combines conventional sedimentological and stratigraphical observations of several laterally-logged sections in Member F, with lithofacies and stratigraphic architecture characterized via physical bed correlations. The analysis of artifact size distribution follows the method described by Bertran et al.⁴⁷, and uses experimentally-derived size classes specifically adapted to bipolar technology using quartz pebbles collected in the Lower Omo Valley. All occurrences that yielded over 100 artifacts with a maximum dimension of more than 2 cm (n = 6) were included in the analysis of artifact surface alterations. In total, 398 artifacts from the Omo 79 site complex (*SI Appendix* Fig. S2) were observed for macro- and microscopic surface alterations by AG. The recording of macroscopic alterations focused on the examination of edges and the main ridges of the artifacts while the recording of microscopic alterations considered the edges and crystal ridges on the widest surface of the artifacts (*SI Appendix* Fig. S1 for the description of macro- and microscopic alteration stages).

Declarations

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Author contribution

AD, AG, BG, PB and MC wrote the main manuscript text. All authors contributed to data acquisition and reviewed the manuscript.

Competing interests

The authors declare no competing interest.

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Figures

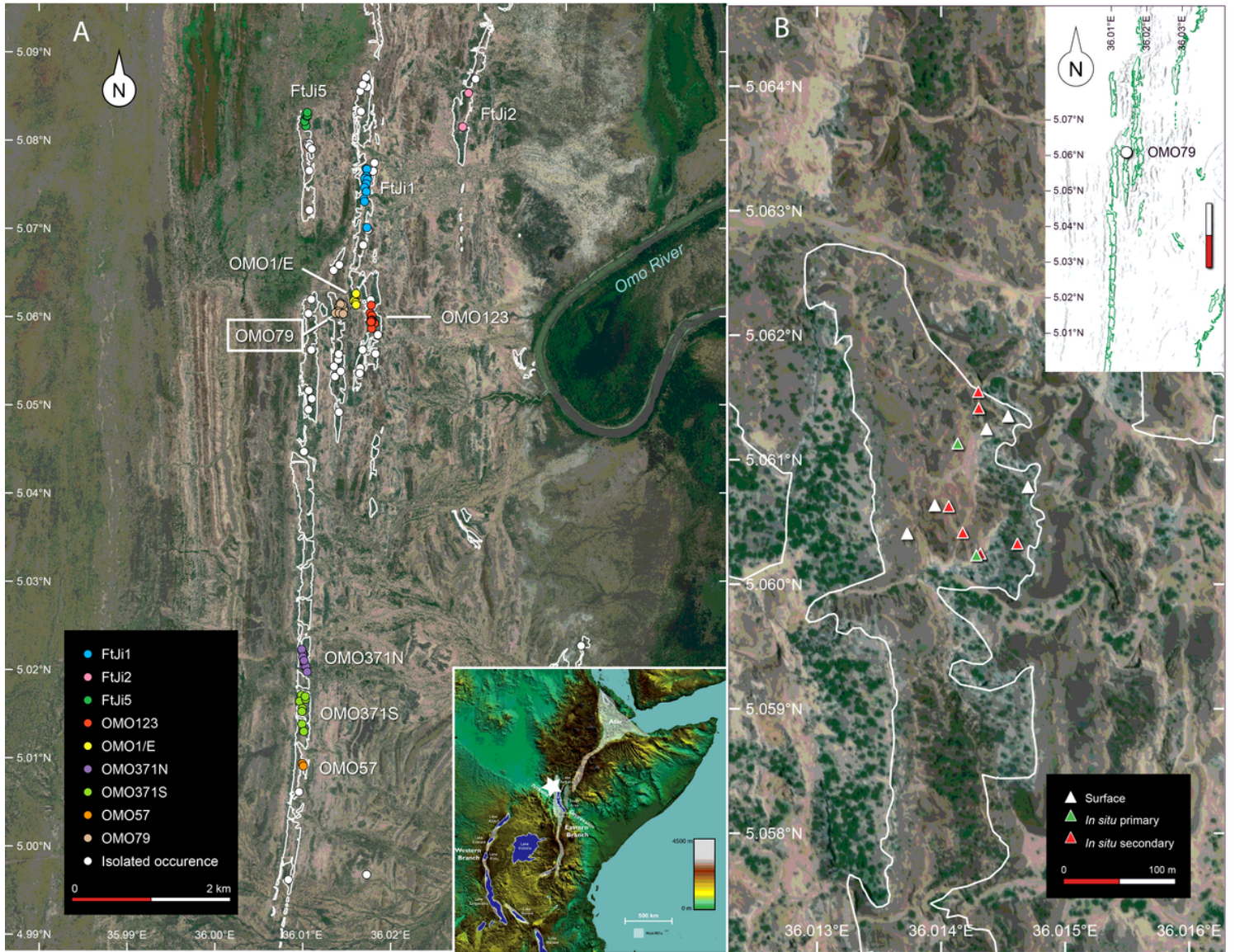


Figure 1

Satellite views of the Shungura Formation. **A.** Archaeological sites complexes and occurrences in the Northern outcrops of the Shungura Formation and in the broader context of the Eastern African Rift System. **B.** Distribution and archaeological context of occurrences at OMO 79 and the site complex's position within the overall extension of Member F (green outline).

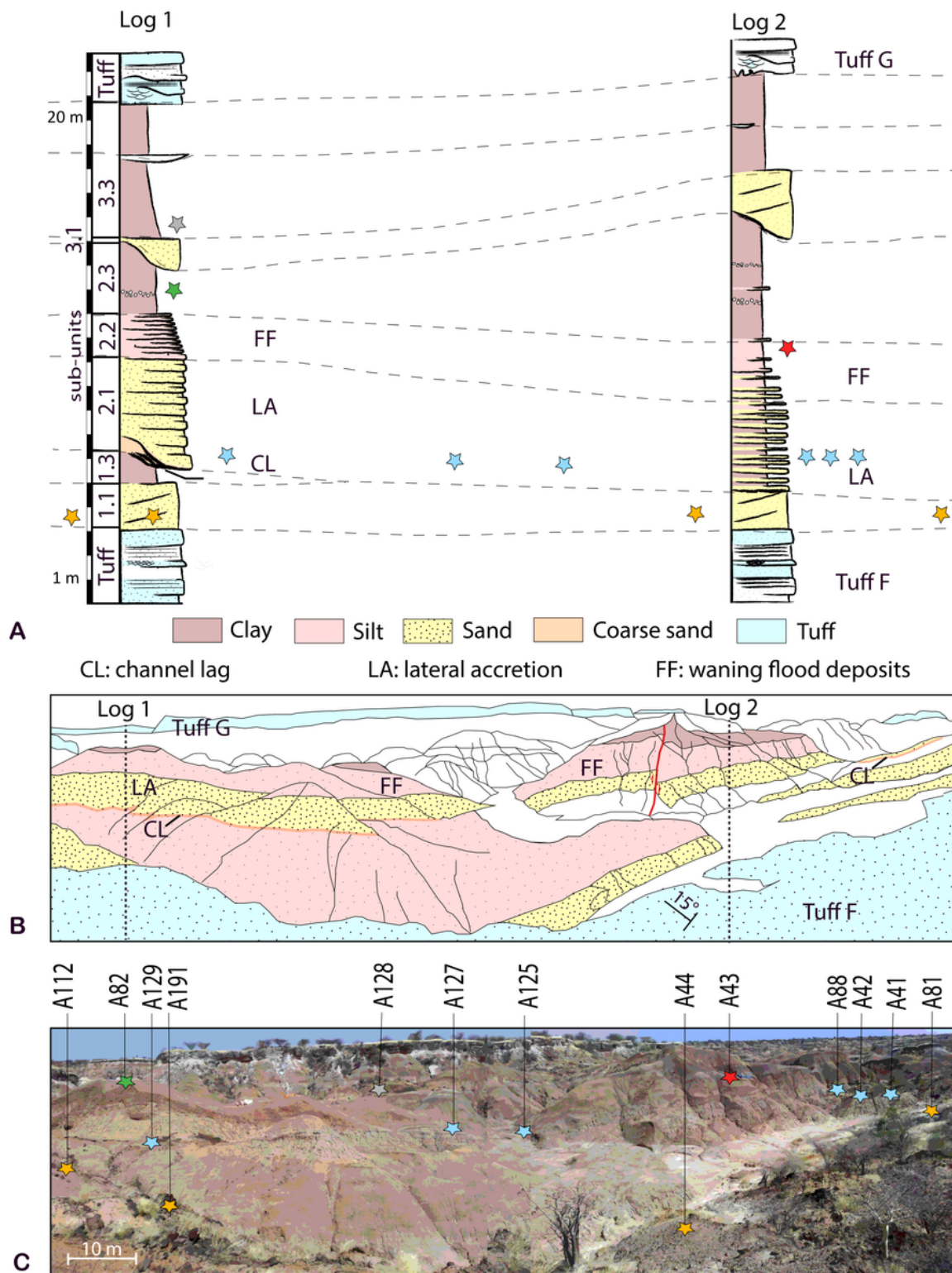


Figure 2

Stratigraphy and distribution of OMO 79 occurrences. **A.** Stratigraphic logs at A82 (log 1) and A43 (log 2). **B.** Schematic panoramic reconstruction of the OMO 79 sequence, view from the eastern edge of the OMO 79 deposits. **C.** Distribution of

archaeological occurrences seen from the same position (phase 1: orange stars, phase 2: blue stars, phase 3: red star, phase 4: green star, phase 5 (?): grey star).

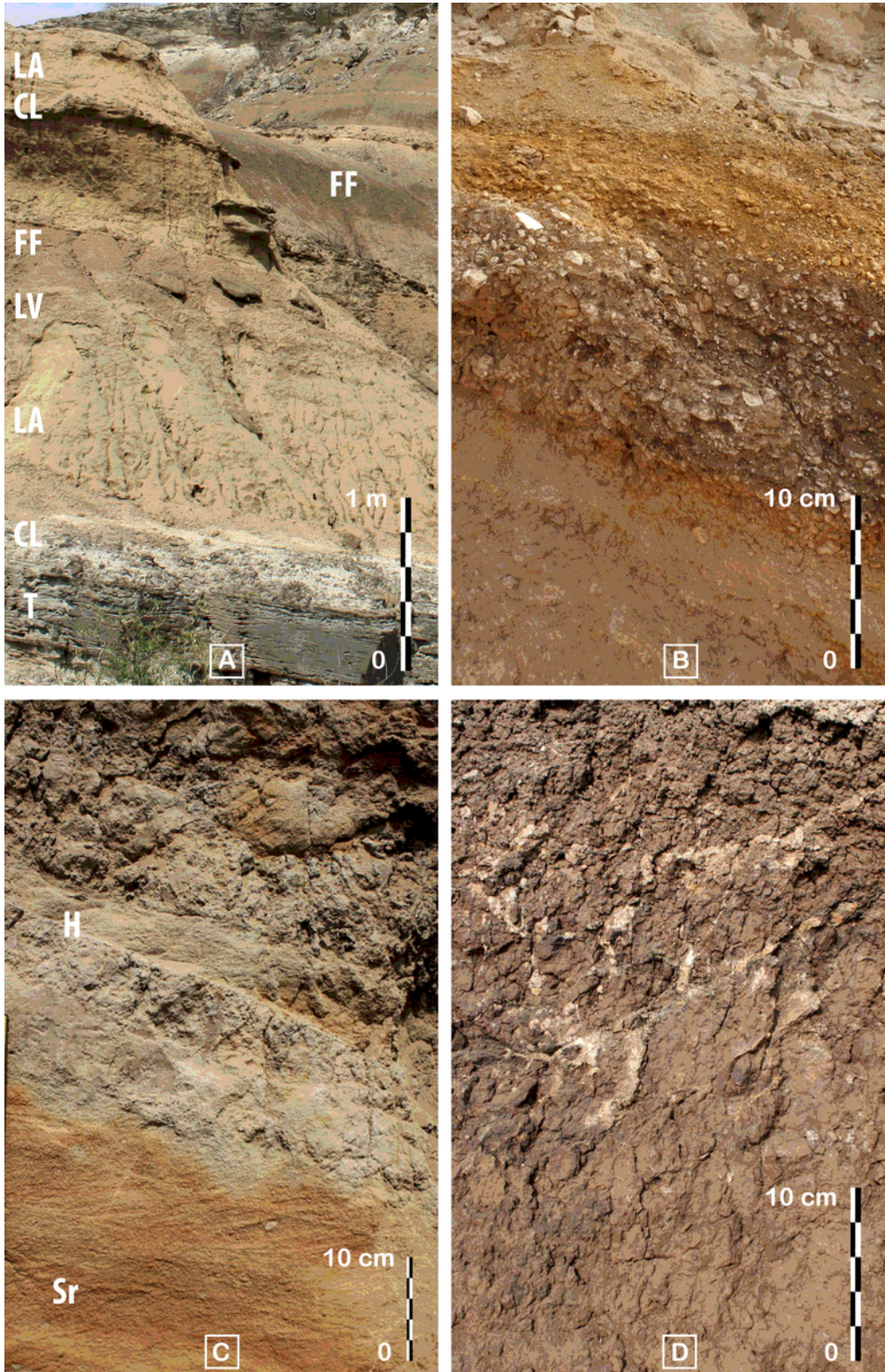
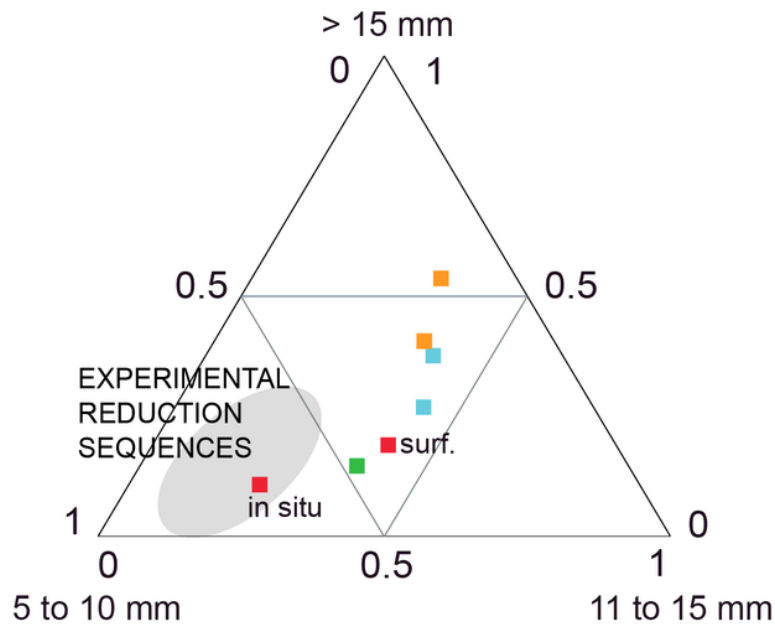
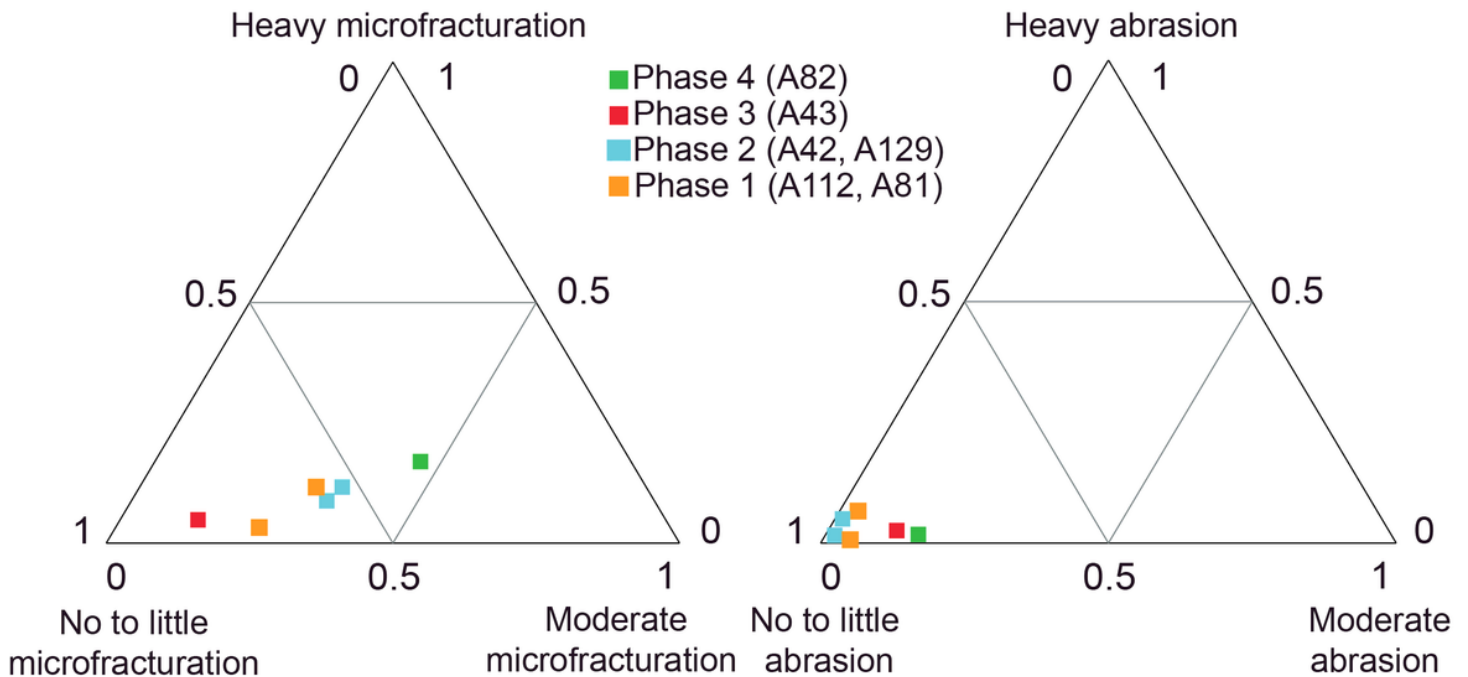


Figure 3

Views of the main lithofacies. **A.** General view of the OMO 79 deposits (occupation phases 1 and 2), T: volcanic tuff, CL: channel lag, LA: lateral accretion unit (point bar), LV: heterolithic levee/upper point bar package, FF: floodplain fines. **B.** Channel lag composed of CaCO₃ concretions, quartz gravel, rip-up clasts, and an *in situ* quartz artifact (blue triangle) in secondary context (occurrence A127). **C.** Upper point bar ripple cross-laminated sands (Sr) and heterolithic sediment package (H). **D.** Clayey silt floodplain deposit with CaCO₃ concretions.



A. Artifact size distribution



B. Microscopic surface alterations

C. Macroscopic surface alterations

Figure 4

Size distribution and surface alterations of the OMO 79 lithic assemblages. **A.**

Artifact size distribution of the main lithic assemblages compared with experimental reduction sequences (see (26) for more details concerning the experimental dataset). **B.** Microscopic surface alterations of the crystals and ridges on quartz artifacts. **C.** Macroscopic surface alterations (details concerning macro- and micro-alterations are provided in *SI Appendix*, Fig. S1).

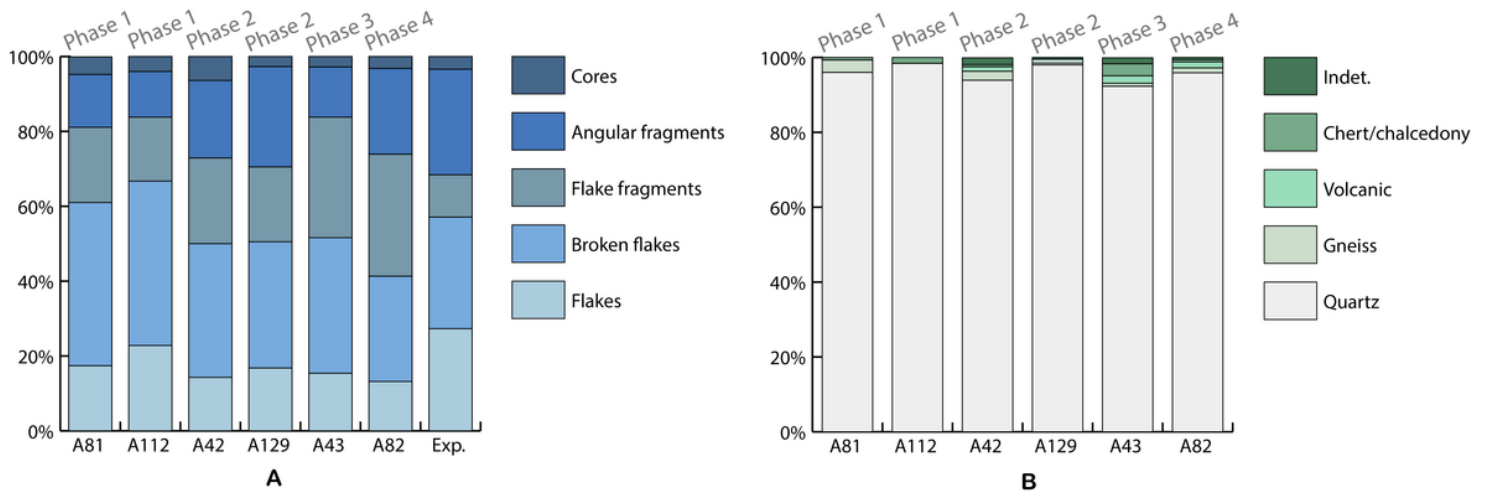


Figure 5

Main attributes of the OMO 79 lithic assemblages (total number of artefacts > 100) – occurrences A81, A42, A43, A82, A112, A129 - for all lithics > 1 cm, excluding the unmodified clasts. **A.** Technological composition of the archaeological assemblages compared with experimental data (Exp.). **B.** Raw material frequencies (see *SI Appendix*, Table S1 for data source and <https://doi.org/10.34847/nkl.3e292r29> for the experimental dataset).

Supplementary Files

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