New excavations in the MNK Skull site, and the last appearance of the Oldowan and *Homo habilis* at Olduvai Gorge, Tanzania

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Abstract

MNK Skull is one of the most significant archaeological sites in Olduvai Gorge, particularly due to the previous discovery of human fossils referred to in the paper where the *Homo habilis* taxon was originally defined. An important archaeological assemblage is contained in the same horizon as the hominin fossils, constituting the last evidence of both *Homo habilis* remains and handaxe-free tool kits in the Olduvai Gorge sequence. Our excavations at the site are the first to be conducted since the original work in the 1960s, and sought to refine the archaeological context wherein the *Homo habilis* remains were discovered. Chronostratigraphic results place the MNK Skull sequence in Middle Bed II prior to deposition of Tuff IIB. The assemblage was deposited near the shoreline, as Palaeolake Olduvai withdrew into the basinal depocentre, and fossils and stone tools were subjected to significant post-depositional processes. The assemblage was affected by mudflow deposits that buried and preserved the assemblage but also entrained surficial bone and lithic elements into the flow. Rather than an occupation site as originally interpreted, the assemblage is better understood as a background deposit, possibly accumulated on an unconformity surface over a long period of time. The stone tool assemblage is typical of the Oldowan, with no technological elements announcing the appearance of the Acheulean, which is well attested to across the Olduvai sequence in post-Tuff IIB times. Our results highlight that, with an approximate age of circa 1.67 Ma, MNK Skull stands as a key site to understand the late Oldowan and the disappearance of *Homo habilis* in East Africa.

Keywords: Early Stone Age; Lower Pleistocene; Early *Homo*; Acheulean Origins

Introduction

One of Olduvai Gorge's most outstanding contributions to palaeoanthropology is the discovery of *Homo habilis*, after the seminal fieldwork of the Leakeys in the early 1960s (Leakey et al., 1964). Regarded at the time as an attempt to redefine the genus *Homo* (Robinson, 1965), the *Homo habilis* taxon was fiercely challenged from the beginning (see debate in Tobias et al., 1965), and the debate has never really been settled over the following decades (e.g., Howell, 1978; Rightmire, 1993; Wood and Collard, 1999; Wood, 2014). The name proposed for the species, suggested by Raymond Dart, alluded to the manipulative abilities of *Homo habilis*, and thus contributed to the controversy by including inferred behavioural features in the definition of a taxon that was otherwise proposed on anatomical grounds. Such manipulative skills were deduced not only from the discovered hand bones, but also based on the Oldowan archaeological contexts –FLK NN, FLK Zinj and MNK Skull– from which the majority of the specimens used for the description of *Homo habilis* derived.

MNK Skull (Geological Locality 88, in Mary Nicol Korongo, MNK) is the archaeological site where OH 13, OH 14, and OH 15 were discovered. OH 13 (nicknamed Cindy, or Cinderella) is a paratype of *Homo habilis* (Leakey et al., 1964), and includes much of the cranial vault, greater part of both maxillae and of the mandible, some of the maxillary cheek teeth and all of the mandibular teeth. According to Tobias (1991), OH 13 also includes a humeral shaft. Leakey et al. (1964) estimated a late adolescent age for OH 13, with Tobias (1991) identifying the remains as corresponding to a female of around 15 years of age. OH 14 is represented by a few fragments of a very thin juvenile skull, and OH 15 by one canine and two upper molars.

The discovery of the MNK Skull hominin remains in October 1963 was first reported by Leakey and Leakey (1964) and, after their use for the definition of *Homo habilis* (Leakey et al., 1964), a systematic description of their anatomical features was made by Tobias (1991). Nonetheless, the most detailed account of the context is by Mary Leakey (1971), who excavated a large trench in the area where OH

13 was found. Alongside the discovery of further remains of OH 13 *in situ*, Leakey (1971) unearthed an important archaeological collection of other mammals and stone tools. She attributed the assemblage to the Oldowan and positioned the archaeological and human remains in Middle Bed II, underlying Tuff IIB. This placed MNK Skull as the last Oldowan assemblage at Olduvai before handaxes appear in the sequence (Leakey, 1971), and also constituted the last appearance of *Homo habilis* in the Olduvai basin. With an age of circa 1.67 Ma, OH 13 may also represent the most recent *Homo habilis* across eastern Africa as a whole (Spoor et al., 2015).

The great relevance of the MNK Skull site and the fact that no excavations had been undertaken there since Mary Leakey's original work, led the Olduvai Geochronology Archaeology Project (OGAP) to initiate a new round of research at the locality in 2010. With the overarching aim to achieve a better understanding of the transition from the Oldowan to the Acheulean at Olduvai Gorge (de la Torre et al., 2012, 2018a), our renewed excavations at MNK Skull have sought to refine the stratigraphic control of Middle Bed II, understand the site formation processes involved in the deposition of OH 13, OH 14, and OH 15, and characterise the taphonomic and technological features of the assemblage. This paper summarizes the results of such efforts, and represents a multidisciplinary approach to the tephrochronology, sequence stratigraphy, sedimentology, taphonomy and archaeology of the new excavations in the context of Leakey's previous work at MNK Skull, an Early Stone Age site of the utmost importance at Olduvai Gorge and elsewhere in Africa.

Materials and Methods

Our results stem mainly from new archaeological trenches excavated in the MNK Skull area. The geological study included the mapping and a geochemical analysis of trench backwalls and nearby outcrops. Site formation processes were investigated by considering spatial patterns in Leakey's and OGAP's trenches, and the properties of items retrieved during excavation by OGAP. Primary features of fossils and lithics from OGAP's excavations are presented per archaeological unit, but the assemblage was considered as a whole to present the main zooarchaeological and technological results.

Archaeological excavation

We created a virtual grid with a local coordinate system that encompasses not only MNK Skull but all our archaeological excavations in the Side Gorge of Olduvai. Northing (Y-axis) of this relative coordinate system is aligned with the geographic north, and trenches at MNK were positioned accordingly within this virtual grid. Trenches were also positioned with GPS so that they could be geolocated into the Digital Elevation Model (DEM) available for the wider Olduvai region (Jorayev et al., 2016).

Two trenches (T3 and T36) were excavated by OGAP in the MNK Skull area (Figure 1): T3 is OGAP's main trench at MNK Skull and extended the southern limit of Leakey's backwall into the hillside, exposing an area of 32 m² during two field seasons (2010 and 2013). T36 is a 4 m² trench excavated in 2014, located 22 metres to the NE of T3. This test trench was designed to determine the lateral extent of the OH 13 horizon, which in this part of gully does not outcrop near the surface, and therefore required digging a deep (> 4 m) booth (Figure 2).

Archaeological excavation followed protocols detailed elsewhere (de la Torre et al., 2015), which aim to plot in 3D with a total station all findings visible during excavation, as well as relevant features such as stratigraphic contacts and geological samples, among others. We conducted wet sieving for a selection of clay samples and dry sieving with 6 mm mesh sieves for all the sediment unearthed during the excavations. All lithics (both natural clasts and stone tools) and fossils were recovered and

catalogued, with the exception of natural chert nodules from the limestone unit exposed at the bottom of T3. All items plotted during excavation were given a unique ID. Among the material from sieving, all lithics plus identifiable bones also received a unique ID, and the rest was collected in level bags. All items from sieving were positioned to their nearest m² at the trench and assigned to an archaeological unit. Differentiation of archaeological units was based mainly on vertical clustering of items separated by gaps, although lithological changes were also considered in their definition.

Georeferencing of Leakey's excavations at MNK Skull

Mary Leakey's material on the OH 13 level (Leakey, 1971: 119) was vectorized from her plan drawings following methods by Benito-Calvo and de la Torre (2011). The SW corner of Leakey's trench at MNK Skull, still visible when we resumed fieldwork at the site, was positioned within the OGAP's virtual grid of the Side Gorge. The OH 13 level plan was then oriented and scaled according to our virtual grid, and georeferenced in the aerial photography orthomosaics created by Jorayev et al. (2016) for Olduvai Gorge (Figure 1).

Stratigraphic and sedimentologic analysis

Stratigraphic sections were measured near the MNK Skull trench for all of Bed II, where exposed, and for Tuff IIA through the level of the Bird Print Tuff where exposures were more limited. The measured sections made use of natural exposures with minimal scraping, and hence the exposure pre-dates the excavations. They are thus not always directly associated with a trench, and lack the sedimentological detail later achieved during the measurement of the trench backwalls. They are, however, sufficient to identify the major lithological units and their relative stratigraphic positions, and help tie in the stratigraphy to those of Leakey (1971) and Hay (1976). A rock hammer was used to clear exposures, measurements were made using a Jacob's staff (with level) and metre stick, and sedimentological observations were made using a hand lens. Tuff samples were collected for compositional comparison against previously characterized marker tuffs (see McHenry et al., 2016). Following excavation, the detailed stratigraphies of trenches excavated in the MNK Skull area were mapped on the backwalls and/or sidewalls, and lithological contacts were measured to <1 cm-accuracy with a total station and positioned in the same reference system as the archaeological material. Particular facies types were defined on the basis of grain size, sorting, fabrics, bedding, compositional, and grain characteristics, providing the basis for their process-related sedimentological interpretation. Lithostratigraphic units and facies associations were also classified as to whether they were bounded by conformable, hiatal or incisional surfaces. Incisional surfaces were differentiated into Type 1 (pronouncedly incisional disconformity) or Type 2 (hiatal or slightly incisional paraconformity) (Stanistreet, 2012, Stanistreet et al., 2018b, 2020a).

Analysis of lithics and fossils

All natural and archaeological lithics, plus plotted bones, were measured regardless of their size. For taphonomic purposes, artefact size distribution was analysed using relative frequency and cumulative length histograms. Data were normalized using the relative percentage of each assemblage (de la Torre et al., 2018b). Histogram classes were defined every 2 mm, and standard descriptive frequencies were calculated for lithics <20 mm. Particle shape of archaeological and natural items was calculated using the standard bivariate triangular method of Sneed and Folk (1958), based on their three main dimensions, i.e., length (axis a), width (axis b) and thickness (axis c).

Taphonomic analysis of fossils followed methods prescribed by Blumenshine et al. (1996). Bones were first inspected with the naked eye under a 60-watt light source and then using a 10x hand lens. Features observed included bone weathering following Behrensmeyer (1978), the presence of

exfoliation and mechanical rounding, the general breakage of the material, and the presence of bone surface modifications including cut marks, hammerstone percussion marks, and mammalian carnivore/crocodile tooth marks (Njau, 2012; Njau and Blumenschine, 2006). Bone surface modifications were further scrutinized using a portable microscope with 200x magnification capability. The taphonomic analysis of stone tools focused on the analysis of edge rounding.

Bones and teeth were identified to the highest taxonomic level possible, and follow Bibi et al. (2018) in the identification of mammals. The T3 bone assemblage was also sided and identified to skeletal part and portion with the aim of determining the minimum number of elements (MNE) and minimum number of individuals (MNI) in the assemblage (Pante et al., 2018). Once sided and identified to skeletal part and portion, bones were laid out on a table and the presence of overlapping portions was used to increase the MNE and MNI in the assemblage.

All natural and archaeological lithics were attributed to one of the raw material groups detailed by McHenry and de la Torre (2018). Lithics above 2 cm were subjected to refit analysis, to which 36 h of effort were devoted. Following Isaac et al. (1997), stone tools were classified as either flaked, detached or pounded artefacts, and analysed according to the attributes proposed by de la Torre and Mora (2018). Flaking methods were analysed following de la Torre (2011) and de la Torre and Mora (2018). Non-parametric data of lithics were compared, applying the Pearson's chi-squared, Kruskal Wallis and Fisher tests, and correspondence factor analysis.

Orientation, fabric, and spatial analysis

Orientation and dip angle of the longest axis of archaeological items excavated by OGAP were recorded with compass and clinometer, respectively. Compass bearings from T3 were considered both as azimuth (0-360°) and axial (0-180°) data through angular histograms and statistical tests. Rayleigh's and Kuiper's tests were used to differentiate isotropic (uniform) from non-uniform (unimodal, bimodal, or multimodal) orientation patterns of archaeological items. Compass and clinometer bearings from T3 were represented in stereographic projections and analysed using the three-dimensional Eigenvector Method, which calculates several fabric indices to investigate shape represented in the triangle fabric (Lenoble and Bertran, 2004; McPherron, 2005; Benito-Calvo et al., 2009). In this work, we used Woodcock (1977) indices K and C, the bivariate Sneed and Folk's triangle (Benn, 1994), and the trivariate Vollmer fabric (Vollmer, 1989; Benito-Calvo et al., 2011).

Axial angles (0-180°) of items excavated by Leakey (1971) at MNK Skull (Figure 3) were extracted through geometric procedures outlined by Benito-Calvo and de la Torre (2011) and de la Torre and Benito-Calvo (2013), namely the polygon diameter (D), minimum bounding rectangle of items (MBR) and polygon main angle (PMA). Analyses were conducted on items with elongation index >1.6.

General spatial patterns of the T3 assemblage were investigated by means of the Average Nearest Neighbour (ANN), Global Moran's I statistic, General G spatial test, and K de Ripley (de la Torre and Wehr, 2018; Sánchez-Romero et al., 2020). Location and identification of clusters were studied with kernel density analysis (KDE) of all items and hotspots analysis (Gi* de Getis-Ord) (Sánchez Romero et al., 2016, 2020; Mora et al., 2020) of three variables (count, length and weight). General shape and orientation of main clusters were calculated using the standard deviational ellipse (de la Torre et al., 2013; Sánchez-Romero et al., 2020).

Results

Stratigraphic position

The MNK area contains natural outcrops covering all of Olduvai Bed II, from Tuff IF at the base of the sections to the base of Bed III in the MNK “hill” site to the south of the main exposures (Figure 4). The Tuff IF through Tuff IIB interval is particularly well exposed along a cliff face to the west of the MNK Skull locality, though at the MNK Skull site itself colluvium conceals some of this stratigraphy. Tuff IF, at the boundary between Beds I and II, is exposed near the base of local exposures. Tuff IIA is also extensively exposed at the western end of MNK, along with a distinctive chert-bearing occurrence above, which manifests as two distinct chert-rich layers in some outcrops and as more disseminated chert in others. The Tuff IIB stratigraphic interval, which locally includes layers of conglomerate and orange-coloured sandstones and tuffaceous siltstones, is also well developed at the western end of MNK, though its thicker, conglomerate-bearing units are not observed at the MNK Skull site. Less than two metres above Tuff IIB near the MNK Skull site lies a conglomerate or sandstone that includes fragments of the Bird Print Tuff (BPT), a stratigraphic marker throughout the Olduvai Junction area in Middle Bed II, confirmed geochemically in McHenry et al. (2016). One exposure between the western MNK cliff face and the MNK Skull site has a thin layer of in-situ BPT (Figure 4).

At MNK Skull, the interval that contains the fossil and artefact bearing units lies between the chert-bearing unit above Tuff IIA and the orange tuffaceous siltstone of Tuff IIB. The interval is significantly thicker than the same span at the western end of MNK, or at sites further to the east in the Side Gorge (PEK and VEK). The fossil and artefact bearing strata of the MNK Skull site are thus not laterally extensive.

Lithofacies

Eleven lithofacies are distinguished from the T3 backwall (Table 1 and Figure 5). In general, the stratigraphy subdivides into a lower clay-dominated lithofacies sequence and an upper sand-dominated lithofacies sequence, although a degree of continuity is attested to by the presence of some elements of one within the other. The T3 backwall also displays a branching fracture, whose gravel-fill (clasts <5 mm, including red claystone clasts) is mapped in red in Figure 5B. A slight displacement is indicated, with westerly downthrow, synthetic to the down-to-the-northwest FLK Fault system (Hay, 1976; Lu et al., 2019) that trends NE-SW through the MNK site. A measured section was generated from the backwall measurements, taking out any effects of fault displacement (Figure 5A), and significant lithological boundaries could be correlated to the measured section published by Leakey (1971), although different and extra lithofacies were also recognised.

The claystone dominated lower half of the backwall sits upon a thickly developed irregular diagenetic nodular limestone layer, also containing small chert nodules, that extends across the trench and is figured by Leakey (1971) and stratigraphically positioned by Hay (1976). The trench penetrated this layer in a test pit, where the top of a salt (feldspar) and pepper (augite) textured medium sandstone was encountered, that corresponds to Hay’s (1976) mapped position of Tuff IIA at MNK (his Loc. 88). The claystone-rich facies sequence itself starts with a thick unit of olive sandy claystone, eroded at the top by a Type 2 incision surface (Figure 5B). On top of this sits a discontinuous thin medium augitic sandstone unit, containing sparse pumice fragments (<5 mm), succeeded with apparent conformity by a thick brown claystone unit, whose topmost 10 centimetres contain scattered small (<20 mm) calcite nodules.

A Type 1 more deeply incised surface cuts down into the claystone sequence, on top of which were deposited two diamictites. The first diamictite has a clay-dominated matrix and is only preserved in a lens on top of the surface. The second is a sandy diamictite, which sits on an erosion surface that cuts through the clay diamictite onto the top of the claystone sequence. Deposited on top, with apparent

conformity is a brown sandy claystone unit and then the eroded remnant of a dark violet grey medium augitic sandstone.

The upper sandstone-dominated sequence fills and then covers the most pronounced Type 1 incision surface exposed in the T3 backwall, which cuts down through the diamictites almost to the brown claystone on the western side of the trench. On top sits a thick 0.6 m to 1 m thick coarse augitic sandstone unit, which becomes pebbly towards the top. The top of this unit was also eroded by a Type 1 surface, whose presence is now only denoted in its deepest part by a lateral series of pockets of very coarse sandstone, preserved beneath a Type 2 erosion surface. On top of the last sits a relatively tabular (~20 cm thick) unit of less augitic, pebbly, coarse sandstone, and this is conformably overlain by a thin brown sandy claystone unit. At the top of the backwall, immediately below the colluvial overburden, is a unit of medium augitic sandstone sitting on top of a Type 2 incision surface that erodes into the underlying brown sandy claystone.

The T36 backwall exposes additional section, helping to complete the stratigraphy above the levels exposed in T3. Most stratigraphic units present in T3 can be identified in T36. Most artefacts recovered from T36 were found at or near the interface between the thick brown claystone unit and the overlying unit, identified in T3 as a diamictite. The clay-dominated diamictite lens observed in T3 appears to be absent, with the sandy diamictite directly overlying the eroded Type 1 surface. A series of sandstones, similar to those observed in T3, overlies the sandy diamictite. Above these sandstones and the brown sandy claystone lies an orange tuffaceous siltstone consistent with siltstones in similar stratigraphic positions in other MNK sections, attributed to the Tuff IIB stratigraphic interval. This orange siltstone layer, identified laterally to the east and west of the MNK Skull site, sits less than two metres below a sandstone that contains BPT fragments, confirmed compositionally by McHenry et al. (2016).

The archaeological sequence

OGAP excavated a main trench (T3) of 8 x 4 m at MNK Skull, which reached a maximum of 4.2 m in depth and unearthed ~130 m³ of sediment, where four separate archaeological units were distinguished (Table 2, Figure 6 and Interactive Model 1), all of them excavated in an area of 32 m².

MNKSL6 is the uppermost archaeological unit and corresponds to a few isolated pieces within augitic sandstones at the top, and brown sandy claystone at the bottom. Figure 5 shows that items in the coarse sandstone at the top are clearly unrelated to those in the brown sandy claystone at the bottom of the unit, with the latter being most likely associated with reworking of the underlying archaeological unit (MNKSL10). While the absolute frequency (Table 2) and density (Table 3) of stone tools in MNKSL6 may appear relatively high compared to some of the archaeological levels underneath, most items in this unit are angular fragments < 20 mm (n=247), only three undisputable artefacts were documented, and the stone tool overall weight contribution (~749 g) is marginal (1.6%) when compared to the rest of the assemblage (Table 4). The bottom of MNKSL6 is correlated with the unit where Leakey (1971) found the teeth of OH 15.

MNKSL10 yielded the highest number of stone tools, fossils, and unmodified lithics in MNK Skull. The assemblage spans ~34 cm of thickness and includes materials below and within clayey diamictite, on top of the brown claystone unit and, on occasion, within this claystone. Kernel density cross-sections show consistent vertical clustering of the MNKSL10 assemblage, which is supported by the artefact plots (Figure 6). MNKSL10 is therefore the main archaeological unit excavated by OGAP at MNK Skull, and corresponds to Leakey's (1971) OH 13 level.

MNKSL12 is separated neatly from MNKSL10 by a vertical gap void of archaeological material and a conspicuous thin layer of coarse grained augitic sandstone that separates the olivine sandy claystone

from the brown sandy claystone (Figure 6). Embedded in the olive claystones and lying on top of centimetric carbonate nodules, artefact density in MNKSL12 is substantially lower than in MNKSL10 (see Table 4).

MNKSL14 refers to scattered artefacts on top of the nodular limestone, which was the bottom of the T3 excavation.

Despite the thick sequence (over 4 m in depth) exposed in nearby trench T36, only one archaeological assemblage was identified:

T36L30 is a thin (< 4 cm) unit of stone tools, unmodified pieces and fossils (Figure 2) below and within clayey diamictite lying on top of a bioturbated brown claystone. Although in the same stratigraphic position as MNKSL10, the density of artefacts in T36L30 is significantly lower than across T3- MNK Skull site (table 3).

The entire assemblage at MNK Skull excavated by OGAP (that is, all archaeological units in T3 and T36 together) includes 1672 stone tools (46.2 kg in total), 253 unmodified lithics (21.7 kg) and 3578 bone remains (which include 339 individualized specimens and are mainly represented by small fragments recovered from sieving) (Table 2), most of them from one single archaeological unit, MNKSL10 at T3.

Post depositional and spatial patterns

Mechanical rounding of artefacts (Supplementary Online Material, SOM S1) is very low (91% of stone tools are fresh), whereas the proportion is higher among fossil remains (39% are fresh vs. 52% that present minor rounding); as shown in Table 5, nearly all bones exhibit some level of mechanical rounding or exfoliation, although the majority of specimens only have minor damage and most are minimally weathered, suggesting a relatively quick burial.

Unmodified and modified lithics maintain similar proportions throughout the sequence (Table 3); for instance, MNKSL10 contains ~78% of all artefacts in the sequence, but also 73% of all unmodified material, thus indicating a correlation in the proportions of both types of lithics. Such correlation is maintained in the relative abundance and size ranges of types of modified/ unmodified lithics (SOM S2), reinforcing a co-variation of flaked/pounded artefacts with natural cobbles/nodules, and of pebbles with debitage.

Size patterns of the smallest (≤ 20 mm) lithic fraction in MNKSL10 (Figure 7B) show a similar range between 16-18 mm for unmodified pebbles, and lava and chert shatter, while the main peak (8 mm) in metamorphic shatter coincides with a secondary peak or mode for lava and chert. The distribution of metamorphic items shows slightly positive skewness (i.e., a right tail) and kurtosis (i.e., leptokurtic distribution) whereas lava and chert shatter plus unmodified pebbles present slightly negative (left tail) skewness and negative kurtosis (SOM S3).

Shape analysis of MNKSL10 unmodified lithics based on the Sneed and Folk's triangle and definition of particle morphologies, indicates a bimodal distribution dominated by compact-bladed and bladed shapes (Figure 7D). There are differences per raw material, with bladed shapes being more abundant in metamorphic unmodified rocks (25.5%), as opposed to lavas where compact-bladed shapes dominate (22.4%), and to compact-elongated shapes in chert (35.7%) (SOM S4). Metamorphic stone tools follow a pattern similar to unmodified metamorphic rocks, with predominance of bladed shapes (24%) (Figure 7D and SOM S4). Conversely, human-modified lavas see a decrease of compact-bladed shapes 12.24% against platy shapes (15.65%) and very-bladed shapes (12.24%). The shape of chert stone tools also differs from unmodified materials, shifting the main peak to platy shapes (30%) and

show a substantial increase of very-bladed shapes, from 0% in unmodified chert rocks to 20% in chert stone tools (SOM S4).

Orientation patterns of MNKSL10 artefacts and fossils show a scattered distribution with a slight predominance of N-S and E-W directions (Figure 7A). Statistical tests (SOM S5) do not reject the null hypothesis of uniformity for axial data, whereas uniformity in azimuth data can be rejected against both unimodal ($p\text{-value}=0.05$; Rayleigh's test) and multimodal ($p\text{-value}<0.05$; Kuiper's test) distributions (SOM S5). Therefore, statistical tests of azimuth measurements support a preferred orientated distribution for MNKSL10, with predominance of classes towards the north.

Fabrics of MNKSL10 archaeological items ($n=52$) in the stereographic projection show a pattern around the periphery (Figure 7C1). While this may be indicative of a low-angle planar distribution, a significant number of measurements are nonetheless located around the stereograph centre, a pattern that corresponds to high dips (25% of bearings are $>30^\circ$, and 13% = 90°). This is also observed in the fabric triangles (Figure 7C2-3), where the MNKSL10 assemblage shows a fabric shape dominated by a high isotropy, and a secondary planar trend ($K\text{ index}<1$) (SOM S6). This distribution is similar in Vollmer's and Sneed and Folk's triangles (Benn, 1994), with Vollmer's method characterizing MNKSL10 patterns with a uniform (isotropic) fabric distribution (95% confidence level).

Spatial distribution of archaeological and unmodified material in MNKSL10 (Figure 8) shows main concentrations of artefacts on the sides of the trench, with a lower quantity of material in the centre. Such concentrations are better observed in a density map of the assemblage (Figure 6E), which also shows the elongated shape of density clusters following SSE-NNW and S-N axial directions. ANN analysis produced a mean distance of 70 mm, while the expected distance considering the area analysis is 81 mm; this confirms a clustered pattern for the distribution of remains where there is a less than 1% likelihood that clustering is random. Clustered patterning is also confirmed by Moran's I and General G spatial tests. The most pronounced clustering occurs between 1.4 and 1.5 m, whereas the K-Ripley tests indicates that clustering shifts towards a dispersed pattern at larger distances starting at 1.8 m. Hotspot analysis of frequency of remains (variable count in Figure 8D) in MNKSL10 indicates the presence of a main cluster in the SE corner of the trench, and a minor concentration in the NE edge (Figure 8D1-count), both identified with 99% confidence. The main cluster shows an elongated shape and follows a $145\text{-}215^\circ$ orientation axis (SSE-NNE). This hot spot is mostly made of stone tools (Figure 8D2), although it is also recognizable in bone (Figure 8D3) and unmodified material (Figure 8D4) distributions. Fossil and unmodified lithic distributions include other scattered hotspots in the W and to the E sectors of the trench. Distribution analysis based on length (see Figure 8D) indicates that the main hotspot defined through the variable count contains coldspot clusters with overabundance of smaller items (Figure 8D1-length). Although some hotspots exist when remains are sorted by length, they show a scattered distribution that forms a diffuse SW-NE arc. Two coldspots can also be detected within the main cluster (Figure 8A) when the variable weight is analysed, which are defined by high concentrations of low weight values. Weight hotspots follow a scattered pattern, where local, poorly defined SW-NE and NW-SE clusters are discernible.

Refits were only attempted for lithics, and only two sets (one in MNKSL10 and another in MNKSL12) were found, thus providing a very low yield rate (one refit every 18 h) for the total time invested in the refitting effort (36h). Nonetheless, the MNKSL10 refit (Figure 8A) is valuable in providing further support to the definition of this archaeological unit; the significant horizontal distance (4.8 m) between the two artefacts connects the two main clusters at the trench (Figure 6E), and their vertical distance (57 cm) speak to the considerable depth differences of materials that are contextually related.

The fossil assemblage

Nearly all of the bone fragments come from MNKSL10 (see Table 2), which are the focus of the following results. Most bones could not be assigned to a skeletal part due to their small size or poor preservation (Table 6). The minimum number of elements in the collection is 34 with appendicular bones being the most common by NISP and MNE, followed by axial specimens, and then skull specimens. Only a single specimen in the collection of bones is larger than Bunn (1982)'s animal size group 3 with the majority of individual specimens coming from both size groups 2 and 3.

Only eight individuals are represented within the MNKSL10 collection of mammal bone and teeth (Table 7). However, there are also remains of birds and tortoise. The most common taxa by MNI are bovids, which represent 50% of the total for mammals. The bovid tribes comprise alcelaphini (including *Megalotragus isaaci*), antilopini, and tragelaphini (*Tragelaphus strepsiceros*). Also present are *Equus cf. oldowayensis*, Hippopotamidae, Rodentia, and Suidae.

Focusing on the appendicular skeleton, most bones were broken while fresh (57.5%), but there were a few traces of the feeding activities of hominins or carnivores (Table 5, Figure 2B3 and 2B4). Only one limb bone exhibits a high-confidence cut mark, with one additional mark found on a bovid scapula spine. Percussion marks ($n=3$) are also rare, while carnivore tooth marks are more common, being found on 13.7% of specimens (Figure 2B4). The overall incidence of surface modifications may have been higher if surfaces were in better condition, but the comparably low incidence of tooth ($n=2$) and percussion notches ($n=2$) suggests the effect of surface condition was not extreme and the relative absence of bone surface modifications is also at least in part the result of limited hominin and carnivore feeding activities at the site (Table 5).

Lithic raw materials

The T3 and T36 assemblages contain volcanic and metamorphic cobbles and pebbles from streams, quartzite blocks from primary metamorphic rock outcrops, and chert from nodules and fragments formed in sedimentary beds. Stream cobbles and pebbles (see dimensions in SOM S7) are dominated by lavas which, given the paleogeographic position of MNK Skull, are likely to have flowed from the Sadiman/ Lemagurut volcanoes to the south (see regional maps in Hay, 1976). Most of the quartzite blanks derive from angular blocks typical of Naibor Soit and they were likely collected directly from the outcrops, located 3.2 km north of the site. Nonetheless, some of the metamorphic rocks at MNK Skull appear as fluvially-transported blanks, which include medium to fine grained samples different from the coarse-grained Naibor Soit quartzite, and coarse-grained gneiss (see details in SOM S7). Finer-grained quartzite is potentially derived from Naisiusiu to the northwest and other sources of quartzite inselbergs to the southwest (Hay, 1976; Soto et al, 2020), and gneiss appears in primary outcrops in the Kelogi hills to the west (Hay, 1976). However, both the considerable distance from MNK Skull to these sources (8.2 km to Kelogi and 10.8 km to Naisiusiu) and the rounded shape of blanks suggest that, other than Naibor Soit quartzite, most metamorphic rocks were collected by hominins from streams. Chert nodules were formed in situ in the lower part of the sequence excavated at MNK Skull; archaeological unit MNKSL14 was deposited on the chert bed, and it is assumed that this raw material would be immediately available during the formation of the main archaeological unit (MNKSL10). Syn-sedimentary faulting along the FLK Fault Zone (Stollhofen and Stanistreet, 2012; Lu et al., 2019), that runs through and to the northwest of MNK and FLK localities (SOM S12), would have exposed chert beds shortly after their deposition, providing access for hominin exploitation. This also explains the position of the "chert factory" at MNK, reported by Stiles et al. (1974) and Stiles (1991) in an assemblage slightly older than MNKSL10.

Considering unmodified and worked lithics together, lavas make the largest mass contribution to the assemblage (53.7 kg; 79% of the stone collection), followed by metamorphic rocks (11.6 kg; 17%) and chert (1.9 kg; 4%) (see details in Table 8). This pattern is repeated when only modified lithics (46.2 kg) are considered, although then the predominance of lavas (71.4%) is slightly lower. Within lavas, there is clear evidence of intentional selection of phonolites and trachyte/trachyandesite (T/Ta) by hominins; Figure 9B shows that naturally occurring basalts are far more abundant than other types of lavas, but are underrepresented in the worked lithics when compared to phonolite and T/Ta. Such selectivity can also be discerned even within the basalts, with Figure 9D showing that the overwhelming predominance of vesicular, poor flaking quality basalts (group 3.10.1) among the unmodified material is not matched by its presence within the stone tool assemblage.

Figure 9B also indicates that nearly all the mass of quartzite present in the assemblage was used by hominins. This is particularly evident when number of items, rather than mass contribution, is considered; Figure 9A indicates an acute predominance of quartzite stone tools, whereas most of lavas are unmodified, an observation that is confirmed by the Chi-squared test ($\chi^2(9) = 595.3$, $p < 0.0001$). Considering all raw materials from SOM S7 and not only those illustrated in Figure 9, Pearson's adjusted residuals ($p=0.05$) primarily highlight the relative abundance of quartzite stone tools against unmodified quartzites, followed by a reverse pattern in basalt and feldspar, represented mostly by unmodified lithics. While in the case of quartzite such overabundance reflects the large number of debitage artefacts (see below) –and therefore not so much mass contribution of metamorphic rocks to the assemblage (Figure 9B)–, overrepresentation of basalt and feldspar unmodified lithics is linked to natural depositional processes at MNK Skull independent from hominin reduction sequences.

Composition of the stone tool assemblage

The stone tool collection excavated at MNK Skull contains 1672 artefacts which weigh a total of 46.2 kg. Detached pieces ($n=1509$; 90.3% of the stone tool assemblage) dominate numerically over flaked ($n=122$; 7.3%) and pounded ($n=41$; 2.4%) artefacts in all the MNK Skull archaeological units (Table 2). In terms of weight, however, flaked pieces (29.5 kg) contribute substantially more to the overall assemblage (46.2 kg) than pounded (11.5 kg) and detached (5.1 kg) materials.

Chi-squared results indicate that there is no uniform distribution of categories per raw material ($\chi^2(22) = 847.9$, $p < 0.0001$). While the numerically-dominant debitage is overwhelmingly made up of quartzite ($n=1408$; 93.3% of detached pieces), cores are mostly on lavas, both in terms of absolute frequency ($n=49$; 53.2% of cores) and weight (19.1 kg; 69.4% of overall core mass). This discrepancy is particularly acute when considering that detached lavas only contribute 1.5 kg (3.2%) to the weight of the assemblage and are a minute part ($n=72$; 4.3%) of the entire stone tool collection. Differences in the proportion of raw materials per category are corroborated by a correspondence factor analysis (CFA) (Figure 10C) showing close association of metamorphic rocks and smaller debitage, and between chert and retouched pieces, as well as the clustering of cores and pounded pieces around lavas.

Detached artefacts

The smallest fraction (i.e., shatter <20 mm) amounts to 78.5% ($n= 1185$) of detached pieces (Table 9). Chert ($n=4$) and lava ($n=15$) are significantly underrepresented against quartzite ($n=1166$; 98.4% of shatter <20 mm). Overabundance of quartzite applies to all fragmented debitage and presents a reverse pattern to that observed in all other categories (see Figure 10A and B), where percentages of lava and chert are consistently higher than of quartzite.

Fractures produced by knapping accidents such as split flakes ($n=10$; 1.67% of flake fragments) are not well represented, and yet detached whole artefacts ($n= 107$) represent only 6.4% of the entire stone

tool assemblage. Still, in terms of weight contribution, whole flakes (2.6 kg; 5.7%) are the most important category in the entire assemblage after cores and knapping hammerstones (see Table 9). Quartzite flakes predominate numerically ($n=74$) and in terms of weight (1.7 kg) over lava ($n=23$; 0.7 kg) and chert ($n=9$; 0.1 kg), although relative frequencies of categories per raw material indicate a larger percentage of lava (38.2%) and chert (23.1%) flakes over those of quartzite (5.1%), which is a pattern clearly conditioned by higher fragmentation rates in quartzite products.

Flake dimensions (Figure 11A and B) show some variation according to raw material (Table 10), although the Kruskal-Wallis test indicates that differences are not statistically significant (e.g., length: $X^2 = 2.38$, $p = 0.303$, $df = 2$; weight: $X^2 = 2.18$, $p = 0.334$, $df = 2$). As a whole, chert flakes show more homogeneous dimensional patterns, with consistently lower standard deviations than the other two raw materials (Table 10). Length pattern differences per raw material (Table 10 and Figure 11B) are not statistically significant ($X^2 (8) = 8.7$, $p = 0.36$), although lava (42.3 mm) and chert (41.7 mm) flake mean lengths are larger than in quartzite flakes (37 mm), whereas chert flakes (mean = 11.9 g) are lighter than those of lava and quartzite (34 g and 23.4 g, respectively).

Most flakes present unifaceted (66.7%) or cortical (27.1%) striking platforms (Table 11 and Figure 11C), with a very low percentage of bifaceted butts (6.3%); no statistically significant differences per raw material ($X^2 (4) = 2.4$, $p = 0.05$) are detected. Table 11 shows that 60% of flakes retain cortex on their dorsal side, although only 6.7% of flake dorsal faces are fully cortical. Presence of cortex on both dorsal and striking platform surfaces (Table 11 and Figure 11D) shows differences between flakes of each raw material that are statistically significant ($X^2 (10) = 23.3$, $p < 0.009$); as illustrated in Figure 11D and corroborated by Pearson's adjusted residuals ($p = 0.05$), there is a significant underrepresentation of cortex-free lava flakes [Toth (1982)'s type VI] and quartzite flakes with fully cortical dorsal faces (type IV), whereas fully cortical chert flakes (type I) and quartzite type VI flakes are strongly overrepresented.

At least 32 flakes (29.9% of all complete flakes) can be attributed to bipolar knapping, but due to frequent underestimation of bipolar attributes in Olduvai raw materials (Byrne et al, 2016; de la Torre and Mora, 2018), it is likely that this technique is even more prevalent in the MNK Skull assemblage. Although most commonly found in quartzite flakes (34.7%), bipolar knapping is also relatively abundant in both chert (30%) and lava (31.7%) flakes (Table 11). Kruskal-Wallis comparison of dimensions in bipolar and freehand flakes indicates no statistically significant differences in length, width and weight, whereas thickness is significantly larger in bipolar flakes ($X^2 = 8.47$, $p = 0.036$, $df = 1$).

Detached pieces produced a total of 8.42 m of cutting edges, mostly from complete flakes (4.52 m) and flake fragments (3.68 m). Complete flakes (Figure 12A-E) yield an average cutting edge of 42.6 mm (st. dev.=31.7), which in flake fragments is reduced to 22.4 mm (st. dev.=17.7). Considering edge length productivity as the function of mean edge length: mean weight (de la Torre and Mora, 2018), whole flakes yield a value of 0.17 at MNK Skull.

Cores

Cores ($n = 92$) are the most relevant category in the MNK Skull assemblage in terms of weight contribution (27.7 kg). Lava cores include similar proportions of phonolite, basalt and T/Ta (see table 9) and are the most abundant in the assemblage ($n=49$; 19.1 kg), followed by quartzite ($n=29$; 6.7 kg) and chert ($n=10$; 0.7 kg).

Differences per raw material are evident both in size and weight (Table 12 and Figure 13), and Levene's comparisons of the variance in length ($p=0.007$), width ($p=0.035$) and weight (0.006) indicate that such differences are statistically significant. This variability is underlined when the dimensions of lava cores

(mean length: 79 mm; mean weight: ~390 g) to that of chert cores (~52 mm and ~74 g) are contrasted (Table 10), and is particularly evident when comparing core length (Figure 13C) and weight classes (Table 12 and Figure 13D); the Chi-Squared test reveals significant differences in both length ($X^2 (8) = 33.008$, $p < 0.0001$) and weight ($X^2 (10) = 44.35$, $p < 0.0001$) classes, with Pearson's adjusted residuals ($p=0.05$) highlighting the overabundance of lava cores in the 80-99 mm and 401-800 g classes and their underrepresentation in the two lower length and weight groups of Figure 13C and D. Chert presents an essentially reverse pattern to lava (with chert core overrepresentation in the 20-39 mm and less than 50 g classes), whereas Pearson's residuals indicate that metamorphic cores are significantly overrepresented within the 40-59 mm and 50-100 g classes.

Virtually all chert cores preserve cortex (Table 12 and Figure 13E), a pattern that extends to 96.7% of the entire core sample, within which 61.5% of cores are mostly cortical (Table 12). Despite this consistency in cortex prevalence, statistically significant differences ($X^2 (4) = 20.543$, $p < 0.0004$: Fisher test $p = 0.03$) exist per raw material and, according to Pearson's adjusted residuals ($p=0.05$), predominantly cortical cores are overrepresented in lavas and underrepresented in metamorphic rocks, whilst the reverse pattern applies to cores with less than 50% of cortex coverage.

With an average of 4.1 removals per core for the entire assemblage, chert has a considerably higher mean (6.9 flakes per core) than metamorphic (3.9) and lava (3.7) cores. The number of scar classes established in Table 12 and Figure 13H, however, do not present statistically significant differences per raw material ($X^2 (6) = 11.147$, $p < 0.08$; Fisher test, $p=0.0956$), which contradicts expectations for a link between cortex coverage and reduction intensity (as based on the number of core removals).

It is well documented in the Olduvai assemblages that lava cores are usually made on cobbles and quartzite on blocks (Leakey, 1971; Hay, 1976), and MNK Skull is no exception; as shown in Table 12 and Figure 13F, lava cores are all made on cobble blanks (89.8%) or derivatives, whereas block blanks are the majority (54.2%) in metamorphic cores. It is interesting to note, however, that at MNK Skull up to 25% of metamorphic cores are on cobble blanks, making a significantly larger proportion than in other Beds I and II sites (e.g., de la Torre and Mora, 2018). Virtually all chert cores derive from whole (60%) or fragmented (40%) nodules (Table 12 and Figure 13F), thus accentuating the statistically significant differences ($X^2 (10) = 110.6039$, $p < 0.0001$) of core blanks per raw material.

Blank type also has a strong effect on core size patterns; virtually all lava cores derive originally from cobble blanks, and dimensions of cores in this raw material are practically identical to those of unmodified lava cobbles (Table 8). Quartzite core dimensions are more variable, and respond to the dual pattern of blank selection from angular blocks and river cobbles. Variability in chert core size responds majorly to the selection of either whole nodules or fragments (the latter being highly common in the Olduvai chert beds) as core blanks.

A significant number of cores (48.3% of the entire sample) bear battering traces, either in the form of esquillees (14.1%), impacts (31.8%), and/or percussive fractures (2.4%) (Table 12 and Figure 13G). While esquillees are associated with bipolar knapping (see discussion below), impacts and percussive fractures indicate the polyvalent function of many of the MNK Skull cores as hammerstones, in most examples before they were flaked; this observation is confirmed in 20 cores out of the entire core sample ($n = 92$), and it can tentatively be applied to many others presenting percussive fractures or impacts (most often on cortical areas), which may also be recycled hammerstones.

Flaking methods

Both freehand and on-anvil methods are observed in the MNK Skull assemblage. While there is no indication of passive hammerstone flaking (i.e., block on block), on-anvil knapping methods are well

attested to by the presence of bipolar cores (n=17), pitted stones (see discussion below), and, potentially, split cobbles (n=8). It has been argued elsewhere that the latter may be produced either intentionally (as tools or to prepare core blanks) or as hammerstone fracturing by-products (de la Torre and Mora, 2018). However, most of the MNK Skull split cobbles bear damage at opposite ends, which indicates their involvement in bipolar flaking motions. Additionally, some cores were made over split cobble blanks (see Table 12) –a pattern that has been linked to the preparation of striking platforms (Delagnes and Roche, 2005; de la Torre and Mora, 2018)–, which supports the hypothesis that at MNK Skull split cobbles were produced intentionally.

Most of the bipolar cores are on quartzite (70%; see Table 13), although on-anvil lava flaking is not uncommon (30% of bipolar cores are on lava, and so are all the split cobbles discussed above). The MNK Skull bipolar cores are not particularly small (mean length= 57 mm; mean weight= 187 g) and show remarkably similar metric patterns, especially among the quartzites (see SOM S8 and Figure 14F), where average length (50 mm) and weight (111 g) have relatively low standard deviations (12.1 mm and 73 g), compared to freehand cores (mean length= 71 mm, std. dv.= 22.4; mean weight= 304 g; std. dv.= 252).

Freehand methods make up 81.1% of core reduction in the assemblage (Table 13), in which bifacial flaking (40%) is slightly more abundant than unifacial flaking (31.1%), followed by multifacial (10%) reduction. Partial rotation of cores dominates, particularly through alternating removals (BALP= 17.8%) or short sequences of bifacial strikes (BSP= 11.1%; BAP = 5.6%), but often also through unidirectional removals from natural platforms (USP= 10%; UAU1= 13.3%) (Table 13 and Figure 15A). There is a wide range of blanks used for flaking (Table 12), and no statistically significant differences are observed between knapping scheme and core blank (X^2 (45) = 49.0633, $p=0.3135$). In contrast, flaking schemes are mediated by raw material type, a pattern confirmed by the Chi-squared test (X^2 (18) = 33.6491, $p<0.0139$) and illustrated by correspondence factor analysis (Figure 15B), which clusters lavas with unifacial schemes, metamorphic rocks with BSP and BALT flaking, and chert with most of the schemes involving longer reduction sequences.

Retouched artefacts

All MNK Skull retouched tools (n= 21; 435 g) are made on flakes (65%) –including bipolar blanks– or flake fragments (35%). Average dimensions of retouched artefacts (mean length = 40 mm; mean weight = 20 g) are similar to those of complete flakes, and no statistically significant differences are observed between the two samples (Kruskal-Wallis test of length: X^2 = 0.4354, p = 0.5094, df = 1; weight: X^2 = 0.1141, p = 0.7355, df = 1). There is, however, strong preference for chert to produce retouched tools, as shown by factorial correspondence analysis (Figure 10C). A selection for particular rock types is also found within specific raw materials such as quartzite; for instance, 5 out of 9 retouched tools are on medium or fine-grained quartzite (types 7.2, 7.5, and 7.6 of McHenry and de la Torre, 2018), whereas the dominant quartzite in the rest of the assemblage is coarse-grained (type 7.1). Engelosin phonolite (type 1.6) is aphyric and very rare in MNK Skull (see SOM S7), and yet the most intensively shaped tool in the assemblage (Figure 12G) is precisely made on this raw material.

Most retouched artefacts are unilateral, unifacial denticulates (n=11), but there are some notches (n=5), convergent tools (n=4), and one sidescraper. Whereas retouch is mostly casual and unstructured, some of the convergent tools show a more systematic trimming of edges that may be considered as shaping (Figure 12G-I), similar to convergent shaping reported at HWK EE (de la Torre and Mora, 2018).

Pounded tools

A total of 41 pieces (11.5 kg) were classified as primary pounded tools, but the number of artefacts used *de facto* in battering activities is considerably larger; as discussed above, at least 20 cores were initially used as hammerstones, and an additional core was also involved in tasks producing pits (see Table 4). The relevance of pounding activities in MNK Skull is, therefore, considerable, and certainly larger than what can be deduced from direct recounts of technological categories (e.g., Table 4).

Many of the hammerstones show localized areas with intense battering, and qualitative observations indicate a preference for blanks with high density properties. With the exception of one gneiss hammerstone, all other artefacts primarily employed in battering are made of lava. Basalt and T/Ta show an almost identical distribution, whereas phonolites appear in lower frequencies and were exclusively used for hammerstones (Table 9).

Pounded tool types are overwhelmingly dominated by knapping hammerstones, either complete (n=32) or fractured (n=4), which together are 87.8% of pounded artefacts, and sum 9.7 kg. The morphology (cobbles with ergonomic smooth surfaces) and mean dimensions (e.g. length = 73 mm; weight = 290g) of hammerstones are generally consistent with their use in the reduction of cores represented in the assemblage, although some of them are small (see Table 10) and would have been suitable for retouching.

Pitted stones (n=5, including one that is also a core) include at least one depression produced by repetitive friction, although in MNK Skull they often show battering marks in other parts of the objects, reminiscent of knapping hammerstones. Pitted stones are slightly longer, wider and heavier than the typical knapping hammerstones (see dimensions in Table 10), but also thinner on average. This pattern is consistent with the different battering motions we attribute to them, either as active or passive elements (see discussion in Arroyo and de la Torre, 2018), since pitted stones involve orthogonal gestures for which a flat surface is better suited. The considerable number of cores and debitage associated with bipolar knapping at MNK Skull, alongside observations from other Olduvai sites (Jones, 1994; Arroyo and de la Torre, 2018), leads us to link pitted stones with the bipolar reduction sequence, most likely as anvils. Depressions on pitted stones from Olduvai Beds III and IV are often deep and clustered (Arroyo and de la Torre, 2020), whereas pits on the MNK Skull specimens are wider and shallower. We hypothesize that the latter were involved in bipolar knapping of cores, rather than in the production of *écaillés* / punches (i.e., scaled tools), which would lead to deeper and more narrow depressions like some of those documented in Beds III and IV (see discussion in Arroyo and de la Torre, 2020).

Discussion

Chronostratigraphy

The MNK Skull archaeological levels are well constrained within Hay's (1976) stratigraphy of Middle Bed II, above the level of Tuff IIA and the overlying erosional surface, which is topped by a chert-bearing limestone unit in the Olduvai Side Gorge and which Hay (1976) correlated to the erosional disconformity below the Lower Augitic Sandstone (LAS) of the southern Olduvai Junction area sites (Leakey's (1971) "Sandy Conglomerate"). The main archaeological unit in MNK Skull (MNKSL10) starts about three metres above the top of this chert-bearing unit. A tuffaceous siltstone attributed to the Tuff IIB compositional zone is identified near the top of the backwall in T36, about 3 metres above the level of artefact concentration. No exposure above this level is available from the backwalls, but nearby outcrop exposures reveal that this Tuff IIB tuffaceous siltstone lies less than 2 metres below the level of the BPT, identified as fragments within conglomerate at multiple sites in the MNK area and *in situ* in one exposure (McHenry et al., 2016).

Recent paleomagnetic and $^{40}\text{Ar}/^{39}\text{Ar}$ dating of OGCP Core 3A from Palaeolake Olduvai provide chronological control for this interval (Deino et al., in press). A likely Tuff IIA equivalent in OGCP Core 3A, associated with a chert occurrence, provisionally recognized as the widespread chert unit overlying Tuff IIA in the Side Gorge (including at MNK) (McHenry et al., 2020; Stanistreet et al., 2020a), has an age model date of $1.697 (-0.064/+0.054)$ Ma. Díez-Martín et al. (2015) provide an age of 1.698 ± 0.015 Ma for a tuff (their FLKW-A) near FLK, likely at the level of the Lemuta sandstones and stratigraphically below the level of Tuff IIA, in good agreement with this model age.

Other correlatives of tuffs identified at MNK have been previously dated in outcrop elsewhere at Olduvai, including Tuff IF (1.803 ± 0.002 Ma, Deino et al. 2012) and Tuff IID (1.338 ± 0.024 Ma, Díez-Martín et al., 2013). While the BPT has not yet been dated directly, Díez-Martín et al. (2015) determined an age of 1.664 ± 0.019 Ma for a tuff 20 cm below the BPT near the FLK site (stratigraphic position from Uribe Larrea et al., 2017). These dates constrain the interval at the MNK Skull site to between Tuffs IIA ($1.697 (-0.064/+0.054)$ Ma) and below the BPT (which is younger than 1.664 ± 0.019 Ma). However, extra account needs to be taken of the time contained in the major unconformity between Tuff IIA and the remainder of the MNK Skull backwall. An age of around 1.67 Ma can thus be inferred for the main artefact-bearing level at the MNK Skull site.

Palaeoenvironments and sedimentary processes

Figure 5B shows the facies sequences developed during the formation of T3 and the lake-parasequences (Stanistreet, 2012; Stanistreet et al., 2018a, 2018b, 2020a, 2020b), or lake-transgressive units, that can be interpreted from the succession. The claystone-dominated facies in the lower half of the sequence show the claystone and sandy claystone facies association that also mainly characterises the deeper portions of Palaeolake Olduvai in the basinal depocentre between the FLK and Fifth Faults (see SOM S12), during the deposition of Bed II, as determined from OGCP borehole cores (Stanistreet et al., 2020a; Njau et al., 2021). Initially nearshore-deposited olive clays, contaminated by windblown sand (Stanistreet et al., 2018a, 2020a), were deposited. Lake withdrawal caused incision of a Type 2 surface, on top of which was deposited the thin fluvial medium augitic sand unit for a short time, prior to the rapid return of the lake to deposit offshore brown clays over a protracted period. At this time the lake would have been extensive, transgressing far over its hinterland, as far as the middle of the DK Horst, according to the measured sections of Hay (1976).

Subsequently, the lake withdrew into the basinal depocentre, exposing the lake-bed at the MNK site. Downcutting occurred and immature soils developed in the claystone unit, signified by the precipitation of small nodules within the subsurface. The land surface developed during this interval likely hosted the main hominin activities, as represented by the MNKSL10 assemblage. This assemblage was transported and/ or reworked, and then buried by mudflows (lahars) derived from the Ngorongoro Volcanic Highlands (NVH), which deposited diamictites (for other Olduvai examples of assemblage burial and entrainment by lahars, see Stanistreet et al., 2018a; de la Torre et al., 2018d) on this incision surface. The first diamictite is characterised by a clayey matrix, itself eroded, prior to the emplacement of a mudflow with a sandy clay matrix. The mudflows filled and then covered the incision surface to result ultimately in a rather planar surface, on top of which Palaeolake Olduvai once more transgressed to deposit nearshore sandy brown clays. The facies association of diamictite and claystone units is reminiscent of that at EF-HR (de la Torre et al. (2018d) and Stanistreet et al. (2018b). The sequence is terminated by lake withdrawal, followed by deposition of a medium augitic sandstone.

Then, the lake substantially withdrew into the basinal depocentre beyond the FLK Fault zone (Stanistreet et al., 2020a, b), to provide the potential to erode the most conspicuous Type 1

disconformity exposed in T3. It is this event that demarcates the sandstone-dominated lithofacies sequence above from the claystone-dominated lithofacies sequence below. Pronounced fluvial downcutting produced channel-forms in that incision surface <1 m across and <0.3 m deep. The repeat of these channel-forms laterally suggest that the erosive agent was the multi-channel architecture of a braided river system. With the initiation of the subsequent lake transgression, additional accommodation space allowed the deposition of a thick, coarse augitic sand unit, which filled and covered the erosion surface and levelled the topography of the MNK Skull site.

The next Type 1 incision was less pronounced and is only represented by remnant, narrow channel forms <35 cm across and <20 cm deep, filled with very coarse sandstone. These channel forms are themselves remnant below a subsequent Type 2 disconformity, on top of which were deposited coarse sands of a sandy braided river system, less augitic than those below. The top of the coarse sandstone unit is a relatively flat surface, over which the lake transgressed to deposit a brown sandy claystone, the first evidence of the return of Palaeolake Olduvai to the MNK Skull site during the deposition of the sandy facies sequence. However, it is known from borehole core (Stanistreet et al., 2020a; Njau et al., 2021) that the lake persisted in the basinal depocentre between the Fifth and FLK faults throughout this time. Subsequently, lake withdrawal resulted in a Type 2 incision surface, on top of which, during the subsequent transgression, was deposited a medium augitic sandstone.

The backwall sedimentology records seven withdrawals, followed by transgressions of Palaeolake Olduvai that, together with simultaneous basinal subsidence, provided accommodation space for deposition (Van Wagoner et al., 1988). If the transgression was substantial enough, the lake flooded across the FLK Fault Zone to deposit claystones at the MNK Skull site. Lake sedimentation dominated during the lower half of the backwall record, while fluvial deposition dominated the upper half. Taking a time interval between bracketing dates of 1.697 (-0.064/+0.054) Ma (Deino et al., in revision) or 1.698±0.015 and 1.664±0.019 (Díez-Martín et al., 2015), the cycles of lake withdrawal and flooding developed over ~34 ka, an average recurrence time of 4.9 ka each. These time spans correspond to the fundamental units defined elsewhere as lake-parasequences (Stanistreet, 2012; Stanistreet et al., 2018a, b; de la Torre et al., 2018d; Stanistreet et al., 2020a, b).

Paleoecology

Chert nodules, over which lies MNKSL14, were reworked from the exposed lake floor during a lake level drop. The subsequent sediments are lake deposits, interrupted by lake withdrawals and fluvial deposition, during which the upper archaeological assemblages (MNKSL12, MNKSL10/T36L30 and MNKSL6) accumulated. According to Hay (1976) and our paleogeographic reconstruction, the MNK Skull site was located on the lake margin at the southeastern side of Palaeolake Olduvai, whose extent was defined during lake minima by the FLK Fault Zone (Stanistreet et al., 2020a), which extends NE-SW through and just to the west of the MNK location. An embayment of the permanent lake remained only a few hundred metres to the east (Hay, 1976: 87), likely controlled by synsedimentary faults (Stollhofen and Stanistreet, 2012). The MNKSL10 and T36L30 assemblages were deposited on open, dried out lake flats which afforded no apparent refugium for *Homo habilis*.

MNKSL10 is sited on top of the FLK Fault footwall, in a setting similar to that deduced for FLK Level 22 (Blumenschine et al., 2012a; Magill et al., 2016), which also sits on the FLK Fault footwall, and HWK E Level 1, which is associated with the KK Fault footwall (Blumenschine et al., 2012b). Refugia provided by trees could have been one of the affordances that attracted hominins to such settings, and trees grow on well drained soils of uplifted fault footwalls (Stollhofen and Stanistreet, 2012; Blumenschine et al., 2012b). It is thus possible that treed areas close to MNK provided potential for refuge, while the MNK site itself was opportunistically exploited by *H. habilis*.

Our samples for phytolith analysis returned too low yields to confidently characterize the local vegetation (Rosa Albert, personal communication) and, while the taxa present in the MNKSL10 fossil assemblage are primarily adapted to grazing, the limited size of the collection prohibits confident inferences about the nature of the paleoenvironment based on the fauna.

There is evidence of both hominin and carnivore consumption of carcasses in the MNKSL10 assemblage, but the overall proportion of modified bones is low, particularly for hominin-induced butchery traces. Given the low density and features of the faunal material, much of the faunal assemblage may have accumulated naturally, rather than being the result of the feeding activities of either hominins or carnivores, which supports our interpretation based on other site formation proxies.

Site formation processes

Our analysis indicates that the deposit that includes MNKSL10 and T36L30 accumulated over a long period of time, when the lake had withdrawn from the MNK area, and lake mudflats ensued. With the withdrawal of the lake, the regional drainage eventually incised into the exposed brown claystone, but this destructive trend was halted by the emplacement of two lahar mudflows (see Stanistreet et al., 2018a, b; de la Torre 2018d for other Olduvai basinal examples). This emplacement had two effects. Firstly, the assemblage was preserved and protected from further disintegration, by a flow process not associated with destructive basal erosion, such as would be experienced with more fluid river processes (for example Behrensmeyer, 1975; Schick, 1984, 1986). Secondly, bone and lithics lying on the surface were partly entrained by the mudflow and moved laterally, but also higher into the viscous flow.

Although MNKSL10 shows a great deal of entrainment of bone and lithics from the brown claystone into the clayey diamictite, T36L30 displays a much “cleaner” top as the mudflow travelled over the brown claystone. It can be deduced that material from T36 has been removed and displaced laterally, whereas T3 was much more of a receiving area for material elsewhere/upstream entrained into the lahar. A likely source for the mudflows at this time would have been Olmoti Volcano, ~20 km east of the site (see regional map in Hay, 1976). While Olmoti activity had already ceased after the eruption of Tuff IF (Hay, 1976; McHenry, 2012; Stanistreet et al., 2020a), Olmoti would have still represented a major topographic eminence at this time and a source of mudflows into the basin. In fact, Hay (1976) recognises that mudflows were transporting trachytes from their Olmoti source into the basin as late as Middle and Upper Bed II, and even Bed III. We suggest that the mudflows recognised from MNK Skull are earlier equivalents.

These sedimentological observations are strongly supported by our archaeological results: units MNKSL6, MNKSL12 and MNKS14 at T3 are characterised by vertically scattered materials (Figure 6 and Interactive Model 1) that appear in low densities (Table 3), and which contain few bones and high proportions of unmodified materials; in addition, the anthropogenic origin of angular fragments in MNKSL6 should be considered with caution, for any other lithics that can clearly be attributed to human action are negligible. The MNKSL12 assemblage has an extremely low density of artefacts (Table 3), and the slightly higher density in MNKSL14 is further complicated by the high abundance of naturally occurring chert at the bottom of the archaeological unit, which makes the link of lithics to anthropogenic agency more tenuous. In summary, MNKSL6, MNKSL12, and MNKS14 are scattered and poorly cohesive assemblages that seem to correspond to background deposits where human intervention was marginal.

In trench T36, the sole archaeological unit T36L30 is well-constrained vertically, shows higher density of clearly flaked material and bones than any of the background deposits in T3, and the structure of the assemblage, with spatially associated fossils and stone tools (Figure 3), and a relatively high abundance of natural cobbles, resembles that at MNKSL10, with which it also shares a similar stratigraphic position. The main difference between T36L30 and MNKSL10 is the much greater presence of small lithics in the latter; while debitage only comprises 42.9% of the T36L30 stone tool assemblage, it amounts to 90.6% in MNKSL10. Interestingly, the same size sorting applies to unmodified lithics, where pebbles make 11.7% in T36L30 as opposed to 67.2% of the MNKSL10 unmodified sample. This suggests size sorting of both unmodified and archaeological lithics, which is consistent with the correlation between abundance of artefacts and unmodified lithics across the archaeological sequence. Together these findings are strong evidence for the impact of post-depositional processes on the formation of the MNK Skull assemblage.

Stone tool size ranges are known to be a powerful proxy to assess hydraulic sorting (e.g., Schick, 1984), particularly when considering the proportion of microdebitage (Fladmark, 1982). In MNKSL10, the smallest (< 20 mm) lithic fraction comprises 68.7% of the entire stone tool assemblage, which is slightly lower than at HWK EE (71.4%), an assemblage excavated with the same recovery and analysis procedures, and for which hydraulic disturbance has been suggested (de la Torre et al, 2018c). Flaked: detached ratios yield an identical value of 0.07 for MNKSL10 and the complete HWK EE assemblage (de la Torre et al, 2018c), reinforcing the effect of similar sorting agents in both assemblages. As for the influence of form in particle transport (Sneed and Folk, 1958), metamorphic and lava unmodified lithics are both dominated by compact-bladed and bladed shapes, while natural chert is characterized by elongated shapes. Metamorphic stone tools show similar shape patterns to their unmodified counterparts, whereas lava and chert artefacts are more planar (Figure 7). This is all mediated by the variable nature of raw material sources and shape transformation involved in the flaking process, and therefore it is not possible to link conclusively shape patterns in MNKSL10 with varying degrees of post-depositional bias, as attempted elsewhere (de la Torre et al, 2018b).

Preferred orientation patterns are some of the strongest indicators for post-depositional flow disturbance (e.g., Toots, 1965; Isaac, 1967; Benito-Calvo and de la Torre, 2011; Stanistreet et al., 2018a), but results in the case of MNKSL10 are inconclusive. Results show a generally scattered angular distribution of axial data (Figure 7), for which unimodal and multimodal statistical tests support randomness. In contrast, azimuthal data indicates a significant preferred orientation towards the North (SOM S5). Existence of a slope towards the North produced by the geometry of the depositional surface is a possibility as the archaeological unit dips in this direction (see Figure 6C and D), although sloping is gentle, and the effects of tectonic deformation should also be considered. In any case, divergent conclusions derived from axial and azimuth data –influenced by the relatively low sample size– demand consideration of other proxies such as fabric results. A highly isotropic component dominates the MNKSL10 fabric shape, which is controlled by the large proportion of items resting vertically or subvertically, and which could implicate the effect of several depositional and/or post-depositional processes such as vertical movement of pieces along cracks caused by tectonics (see e.g., SOM S9) or clay plastic deformation, mudflow transport, a rough depositional surface, or imbrication.

A complex picture of site formation processes in the main T3 assemblage emerges when all relevant proxies are considered; archaeological items in the bottom of MNKSL10 are mostly found in an apparently low-energy depositional environment represented by the top of the brown claystone, which is consistent with the well-preserved stone tool edges and the random orientations in axial data. On the other hand, there are a considerable number of unmodified cobbles which, rather than

manuports, are likely unrelated to the archaeological assemblage (see discussion in de la Torre and Mora, 2005a). Natural lithics such as pebbles are rare, but as illustrated in SOM S10, their occasionally large size speaks of the existence of flows that are otherwise hard to detect through bulk sediment inspection. These pebbles, together with the presence of unmodified cobbles, the preferred orientation patterns of azimuthal data, slight rounding in many of the bones, the lower-than-expected proportion of microdebitage, the vertical fabrics, and the considerable thickness of the archaeological unit, all suggest that MNKSL10 represents a palimpsest marked by multiple events. This is consistent with the mudflow processes described above, and suggests that, regardless of whether the material resting on top of the brown claystone was originally deposited in MNK Skull or to what degree it was transported and accumulated at the site by the overlying mudflow, it is evident that at least part of the assemblage was disturbed by lahar events; thus, the upper parts of the assemblage contained within the diamictite represent material on the surface, picked up by the high energy of the mudflow that flowed over the surface, entraining assemblage elements which are in secondary position.

Lithic reduction sequences

The reduction sequence at MNK Skull is heavily fragmented, with a disproportionate abundance of larger-sized categories such as cores and battering artefacts relative to debitage. For instance, there are only 1.17 flakes for each core present at the site, and the flake recovery ratio would be even lower when accounting for removals preserved in cores (see ratios A.1 to B.2 in Table 14). As discussed above, hydraulic winnowing of the assemblage is almost certain, but that does not explain the significant disparities in the proportions of debitage per raw material. While all rock types have a deficit of debitage, the detached: core ratios for lava are up to five times lower than for quartzite. Higher shattering rates for quartzite could explain its greater abundance of debitage, but even when considering complete (i.e., unfragmented) flakes, flake: core and flake: core scar ratios are far higher in quartzite than in lava or chert materials (Table 14). This suggests that the observed fragmentation in the reduction sequences per raw material corresponds to behavioural patterns –yet to be ascertained– rather than to taphonomic or rock mechanics causes.

Differential raw material use also exists in the selection of particular rock types for some technological categories: dense cobbles of basalt, T/Ta and phonolite were preferentially selected for battering over more naturally prevalent vesicular basalts. Most retouched tools were made of either chert, which is otherwise underrepresented in all other categories, or of medium/ finer grained quartzite –which is almost absent in the rest of the assemblage (SOM S11).

As a whole, the T3 assemblage at MNK Skull (Figure 16) is characterised by freehand flaking methods that show poor management of volumes, and where flaking series are short and only rarely exploit the entire circumference of cores. Bipolar flaking is relatively common, and is not necessarily linked to miniaturization of cores; chert cores are the smallest in the assemblage, and yet no traits could be identified to suggest they were reduced through the bipolar technique. Battered artefacts are abundant, with production of ~4 cm long flakes as the main aim of the reduction sequence. Still, performance in sharp edge production is low: measurement of detached pieces yielded a total of 8.4 m of cutting edges in MNK Skull which, given the overall core mass of the assemblage (27.5 kg), results in a remarkably low ratio (0.03 cm/ g; see Table 14), implicating poor management of raw materials and low cutting edge productivity. Retouched tools are relatively rare, both in absolute terms (Table 2), and when contrasted against the debitage sample (Table 14), and are generally unstandardized with similar metric patterns to that of unretouched flakes. No elements of the chaîne opératoire in the MNK Skull assemblage are reminiscent of Acheulean technology.

Contextualizing Leakey's and the new excavations at MNK Skull

Our efforts to position the OGAP and Leakey trenches inside the same grid system facilitate a unified view of the spatial distribution of remains at the MNK Skull site (Figure 3A), as well as a comparison of axial data patterns (Figure 8A). OH 14 was a surface find, while OH 15 was discovered in stratigraphic position within a low-density assemblage with dispersed material throughout the deposit (Leakey, 1971: 118). The scattered appearance of our MNKSL6 is reminiscent of Leakey's observations, and we tentatively correlate the bottom part of this unit with the OH 15 horizon. Archaeological unit MNKSL10 clearly correlates with the OH 13 level, and it is likely that our MNKSL12 (whose vertical separation from the overlying unit is not always evident: see Figure 6A and C) was subsumed into what Leakey (1971) considered as one single level (that of OH 13). Leakey exposed the chert unit in a step trench to the east of the MNK Skull site, but not in the main trench, where her excavations stopped at higher ground, so OGAP's MNKSL14 has no counterpart in the Leakey archaeological sequence.

Focusing on the main assemblage (i.e., Leakey's OH 13 level- OGAP's MNKSL10), most mismatches between Leakey's and our observations can be explained by differing recording techniques; for instance, thickness of the OH 13 level (60 cm) is greater than that for MNKSL10 but, had we calculated level thickness based on the vertical distance between the highest and the lowest item instead of on the average (Table 3), MNKSL10 would present a similar vertical configuration to that reported by Leakey (see Figure 6A), particularly if both MNKSL10 and the underlying MNKSL12, which Leakey may have considered as all corresponding to the OH 13 level (see above), are considered together.

While the small sample of axial data (n=31) retrieved from Leakey's map may visually suggest a slight predominance of N and E-W classes similar to that discussed above for MNKSL10 azimuth data (see Figure 6A), all statistical tests (SOM S5) support a random distribution of orientations (p-values > 0.15). Thus, this comparison does not help to clarify the inconclusive orientation patterns results caused by the divergence between axial and azimuth data for MNKSL10.

Lower density calculations by Leakey (0.03 items per m³ across an area of 40 m²) when compared to OGAP's results (see Table 3), are biased by Leakey's exclusion of the smallest lithic fraction in her estimates. This also explains disparities in the main lithic category proportions; when Leakey's tool types are subsumed into Isaac et al (1994)'s groups, frequencies of unmodified lithics (n=67; 8.8%), detached (n=572; 75.6%), flaked (n=45; 5.9%) and pounded artefacts (n=72; 9.5%) are different from ours (see Table 2), which is certainly influenced by our higher counts of smaller sized debitage.

Mary Leakey's excavations at the MNK Skull site produced a limited collection (n=378) of faunal remains that were large enough for her to describe in detail, along with between 6,000 (Leakey, 1971: 254) and 14,000 (Leakey, 1971: 118) highly fragmented specimens, which thus yield a higher figure than in the OGAP assemblage (Table 2). The taxonomically identifiable specimens were dominated by tortoise remains followed by bovids. Also present were the remains of crocodiles, elephants, zebras, rhinos, pigs, hippos, birds, rodents, and a few fragments of snail shells that Leakey (1971) inferred to be the result of hominin foraging. The MNKSL10 bone assemblage is smaller in size, and some of the taxa found by Leakey, such as elephant, crocodile, rhino, snail, and hominin, are not identified in the OGAP collection. Leakey (1971:118) considered that the MNK Skull assemblage represented "the usual debris found on occupation sites" but MNKSL10 is better explained as a natural accumulation (see discussion above) and, although a first-hand re-study of the Leakey collection is still awaiting, we envisage the same formation processes for her assemblage.

The contexts of OH 13 and OH 15 also merit discussion. Nearly all of the OH 13 skull was found on the surface, and only two small fragments of the right parietal were recovered in situ during the excavation (Leakey, 1971: 231). The relatively good preservation and completeness of OH 13 is at odds with the much higher fragmentation of bone remains in the rest of the collection, while the allegedly

in situ parietal fragments were discovered near the erosion line and not spatially associated with other remains in the archaeological assemblage (see Leakey, 1971: 119 and Figure 3A). Together, this could suggest that the two parietal pieces may have been derived from re-deposited soil –the context to which Leakey (1971: 231) attributed most of the skull– and could have been mistaken for being found in stratigraphic position. On the other hand, Leakey observed ‘spherical lime concretions’ encrusted on OH 13 which she also found during her excavation, and which in our T3 excavations were typical of the bottom part of MNKSL10 (see calcite small nodules in Figure 3D). This evidence, added to the fact that in this part of the MNK outcrop no other rich fossiliferous layer seems to exist, provides further support to Leakey’s original observation on the contextual link between OH 13 and the stratified archaeological assemblage. Thus, we speculate that: (1) Larger and better-preserved fossils are found in the north part of the site, as bones plotted in the upper part of Leakey’s map in Figure 3A, plus OH 13, would suggest. (2) A higher density of remains may have existed in the east side of the site, as the denser cluster in the right section of T3 demonstrates (Figure 3A, Figure 6E). Together, these factors may have contributed to the discovery of the exceptional fossil of OH 13 in an assemblage that, otherwise, is not particularly rich.

With regards to OH 15, the bottom part of the assemblage assigned here to MNKSL6 is vertically close to MNKSL10 (see Figure 6), and it is likely reworked from the main assemblage. Given the low probability of finding hominins deposited consecutively in unrelated assemblages, we propose that OH 15 was most likely buried originally in the same assemblage as OH 13, and then reworked into what Leakey (1971) interpreted as a separate sandstone level, which we identified as the bottom part of MNKSL6 and which corresponds to erosion and redeposition processes of MNKSL10.

MNK Skull and the Oldowan in Middle Bed II

Leakey (1971) proposed that the Developed Oldowan A (DOA) evolved, after the deposition of Tuff IIA, from the Bed I and Lower Bed II Oldowan. She nonetheless attributed MNK Skull to the classic Oldowan instead of to the DOA, despite stratigraphically earlier assemblages such as those in the Sandy Conglomerate (SC) at HWK East and FLK North, being considered DOA. This exception to Leakey (1971)’s proposal for a unilinear cultural evolution in Olduvai Beds I and II was justified by low proportions of spheroids, subspheroids, battered nodules and light-duty tools at MNK Skull, all of which were deemed characteristic of the DOA (see discussions in de la Torre and Mora, 2005b, 2018; Proffitt, 2018).

While a re-analysis of Leakey’s MNK Skull lithic collection is pending, her detailed report (Leakey 1971) is consistent with results from our recent excavations, where spheroids and subspheroids are also absent, and retouched tools are not particularly abundant. Leakey did not exclude that some of the differences with DOA assemblages in a similar stratigraphic interval were raw material dependent, but she did not speculate further. We hypothesize that the relatively low frequency of quartzite cores at MNK Skull compared to other sites may in part explain the absence of subspheroids/spheroids, which are commonly made from metamorphic rocks in the Olduvai Beds I and II sites (Leakey, 1971; de la Torre and Mora, 2005b).

The percentage of retouched pieces relative to the entire assemblage (1.3%) sits between others in similar stratigraphic position like FLK North SC (2%; de la Torre and Mora, 2005b) and HWK EE (0.9%; de la Torre and Mora, 2018), blurring the differences between these sites. Similar also to FLK North SC and HWK EE, retouched tools in MNK Skull are predominantly made from chert. Nonetheless, while sourcing of this raw material may not have necessarily been local in the case of FLK North SC and HWK EE, MNK Skull sits directly over a chert bed, which would make higher proportion of retouched tools expected. The morphologies of retouched tools at MNK Skull are also very similar to those of FLK North

SC and HWK EE, with a prevalence of informal denticulates and other unstandardized types. Still, the MNK Skull assemblage contains some convergent points and more consistently shaped, small-sized tools (see Figure 12), which resemble those from HWK EE and which, despite being too small to fall within the size range of Large Cutting Tools (Kleindienst, 1962), indicate more intensive shaping than in pre-Lemuta Oldowan assemblages (see discussion in de la Torre and Mora, 2018).

In summary, reduction sequences at MNK Skull follow patterns typical of the Oldowan at Olduvai Gorge, to which the assemblage is attributed. MNK Skull presents higher proportions of bipolar flaking and retouched tools than in pre-Lemuta archaeological assemblages which, alongside larger significance of subspheroids/spheroids, absent in the case of MNK Skull, have recently been proposed to characterise the late Oldowan at Olduvai post-Lemuta times (de la Torre and Mora, 2018). Given its stratigraphic position slightly higher than at HWK EE, MNK Skull is the youngest handaxe-free site at Olduvai, and therefore constitutes the last evidence of the Oldowan in the archaeological sequence.

Last Homo habilis and the appearance of the Acheulean at Olduvai

The taxonomic and phylogenetic status of *Homo habilis* was fiercely debated in the decades following its definition—see review by Tobias (1991)—, and the discussion is still far from settled today (e.g., Wood, 2014; Wood and Collard, 1999). While anatomical aspects are beyond the scope of this paper, taxonomic interpretations of early *Homo* remains at Olduvai can briefly be touched upon here due to their relevance for the interpretation of the archaeological sequence. Maintaining his original views (Leakey et al., 1964), Tobias (1991) proposed the existence of one single species of *Homo* (*H. habilis*) in Bed I and the earlier part of Bed II, and explained morphological variability within the fossil sample by age, sexual dimorphism, and temporal trends. This is of relevance, as between the earliest diagnostic (OH 24 in DK, below Tuff IB in Lower Bed I) and the most recent (OH 13 in MNK Skull, below Tuff IIB, in Middle Bed II) specimens there is a time span of ~180k years, if we follow recent $^{40}\text{Ar}/^{39}\text{Ar}$ dates for Tuff IB (1.848 ± 0.003 Ma; Deino, 2012) and estimates for the BPT tuff—which postdates Tuff IIB— (older than 1.664 ± 0.019 , see discussion above), and which is identifiable at MNK (McHenry et al., 2016) (see also SOM S13). While Rightmire (1993) agrees that these two fossils at each end of the chronostratigraphic spectrum of non-*erectus* *Homo*—OH 24 at the bottom and OH 13 at the top—correspond to the same morph, he saw a clear distinction between them and a larger-sized group that at Olduvai would be best represented by OH 7 (FLK NN, beneath a sandstone lying below Tuff IC in Upper Bed I; see Blumenschine et al., 2012a; Njau and Blumenschine, 2012), which is the type specimen of *Homo habilis*. In a similar vein, Clarke (2012) has stressed similarities between OH7 and the more recently discovered OH 65—also in Upper Bed I (Blumenschine et al., 2003), and separates this *Homo habilis* group from OH 24 and OH 13, which in terms of brain size and morphology are a better match with *Australopithecus* cf. *africanus* (Clarke, 2012). Nonetheless, the discussion is still ongoing, as a new reconstruction of OH7 (Spoor et al., 2015) has highlighted its similarities with OH 13, whereas OH 65, which appears in the same stratigraphic interval as OH7, would belong to a separate morph. Spoor et al (2015) firmly place OH 13 within *Homo habilis* and, dismissing their previous claim that younger *Homo habilis* remains existed in Koobi Fora (Spoor et al., 2007), they now see OH 13 as the most recent occurrence of this species, not only at Olduvai Gorge, but elsewhere as well (but see Clark, 2017).

Archaeological proxies in Bed I and Lower Bed II appear, so far, to be less sensitive in capturing the paleobiological variability claimed for the Olduvai human fossil record. Thus, no major differences have yet been observed across the Bed I lithic assemblages, which all share remarkably consistent typological (Leakey, 1971, 1975) and technological (de la Torre and Mora, 2005b; Proffitt, 2018) features, classic of the Oldowan. This techno-typological continuity remains in Lower Bed II, for which no major hominin fossils are available, while divergent interpretations exist for inter-assemblage

variability from Lemuta times onwards: some (e.g., de la Torre and Mora, 2005b; Proffitt, 2018) find no differences between the DOA and the earlier Oldowan, whereas Leakey (1971) and de la Torre and Mora (2018) noticed some trends (see discussion in the previous section). Given the contextual association between OH 13 and the lithic assemblage reported in this paper, late Oldowan technological features can now be more securely linked to *Homo habilis*, should we accept the –not necessarily correct– assumption that the hominin species represented at the site was in fact the one responsible for the lithic assemblage found at MNK Skull. Thus, a complex panorama emerges, whereby more than one gracile-hominin species may exist in Bed I (Rightmire, 1993; Clarke, 2012; Spoor et al., 2015) using the same Oldowan technology (Leakey, 1971; de la Torre and Mora, 2005b), while at the same time the same species –*Homo habilis*– may have introduced from Lemuta times novelties in their late Oldowan toolkits with respect to earlier periods (de la Torre and Mora, 2018; this paper).

This panorama becomes even more intricate when the timing of the appearance of handaxes is brought into the equation. The concept of Developed Oldowan B (DOB) sensu Leakey (1971) is now discredited –see reviews by de la Torre and Mora (2005b, 2014); Semaw et al. (2009)–, and it has been argued that once handaxes and/or associated elements of the large cutting tool reduction sequence appear in the assemblages, inter-site differences should be accounted for in terms of functional and ecological parameters within the Acheulean techno-complex (e.g., de la Torre, 2011; de la Torre and Mora, 2020). In the case of Olduvai, the crux of the matter now is to establish when that happened exactly. The most exhaustive study of the Olduvai archaeological sequence (Leakey, 1971) established that the earliest handaxes appeared in post-Tuff IIB assemblages, and so far, OGAP intensive sampling of deposits below and above this marker (de la Torre et al., 2018a) has confirmed Leakey’s original findings.

Nonetheless, it is now possible that earlier Acheulean occurrences may exist in the FLK West locality (Díez-Martín et al., 2015). No stratigraphic correlations with Lower / Middle Bed II tuffs were originally made (Díez-Martín et al., 2015), so others (McHenry and Stanistreet, 2018; Stanistreet et al., 2018b) placed this handaxe-rich assemblage in the Middle Augitic Sandstone (MAS), which would position this site stratigraphically above late Oldowan occurrences such as HWK EE (de la Torre et al., 2018c) and MNK Skull (this paper). This interpretation has been vigorously contested (Uribelarrea et al., 2019), who now identify one of their previously uncorrelated tuffs as the BPT, and the artefact-bearing deposits underneath as LAS. Should these correlations be correct, late Oldowan assemblages in LAS such as HWK EE (de la Torre et al., 2018c) and FLK North Sandy Conglomerate (Leakey, 1971) would be coeval with early Acheulean sites like the one at the FLK West Locality (Díez-Martín et al., 2015). Both the low likelihood that handaxes will eventually be found in HWK EE –none were documented in a collection of over 20,000 lithic artefacts weighing 686 kg (de la Torre and Mora, 2018), and the fact that the handaxe-free assemblage from FLK North Sandy Conglomerate (Leakey, 1971; de la Torre and Mora, 2005b) is located less than 100 metres from the new Acheulean site at FLK West, make the proposition that the latter is in the same stratigraphic position (Díez-Martín et al., 2015) highly relevant. If correct, these correlations will require revisiting chrono-stratigraphic, paleoecological and technological models across the Oldowan-Acheulean transition at Olduvai.

A reconsideration of biological-technological pairings in the early paleoanthropological record will also be required to accommodate this new proposal. Despite caveats of the history-culture approach to hominin-industry binomials in eastern Africa (see review in de la Torre and Mora, 2014), the frame established by Leakey (1975) for Olduvai had an empirical basis, according to which the earliest *Homo erectus* remains (OH 9 in LLK) appear in a part of the sequence, Upper Bed II, where no handaxe-free assemblages exist anymore, and all *Homo habilis* fossils are found in stratigraphic intervals earlier than

the first handaxes and associated with Oldowan contexts. Since no evidence has yet been presented to link Acheulean sites with *Homo habilis* fossils, nor to suggest that handaxe production was within the cognitive and technical realm of this species, it should be expected that if the Acheulean site at FLK West be placed in LAS (Díez-Martín et al., 2015), *Homo erectus* was present in the Olduvai basin at this time.

This latter scenario is certainly possible, both because the same assumption is made for post-Tuff IIB assemblages in Middle Bed II –where Acheulean tools are found but no diagnostic hominin remains have yet been found–, and because >1.7 Ma evidence of *Homo erectus* already exists elsewhere (see review in Antón, 2003). Nonetheless, the absence of handaxes in other parts of LAS, an interval well sampled both by Leakey (1971) and OGAP (de la Torre et al., 2018a), is puzzling and evidences the need for further efforts to clarify the stratigraphic position of the earliest Acheulean at Olduvai.

In any event, and regardless of whether or not Acheulean assemblages earlier than Tuff IIB do exist at Olduvai, MNK Skull hominins remain as the most recent evidence of *Homo habilis* in the basin –and elsewhere in eastern Africa–, and the associated faunal and lithic collection described in this paper as the last evidence of handaxe-free, Oldowan assemblages at Olduvai Gorge.

Conclusion

The significance of OH 13, a paratype of *Homo habilis*, and the stratigraphic position of the MNK Skull site, which constitutes the last evidence of *Homo habilis* and of a handaxe-free lithic assemblage at Olduvai Gorge, make this one of the most important localities in eastern Africa to understand the disappearance of the *Homo habilis* taxon and of the Oldowan technocomplex. OGAP fieldwork at the site, the first to be conducted since Mary Leakey's (1971) original excavations, has refined the chronostratigraphy of the local sedimentary sequence, reconstructed site formation processes, described zooarchaeological features of the fossil collection and the technological strategies employed by hominins at the MNK Skull location, and provided contextual information for the OH 13 and OH 15 fossils.

Our stratigraphic results firmly place archaeological unit MNKSL10, which correlates with the OH 13 level, in a stratigraphic position overlapping the LAS (that is missing here), onto the unconformity that underlies the LAS in the southern Junction Area, and therefore the assemblage, at about 1.67 Ma, is slightly younger than most of the archaeological sequence at HWK EE (de la Torre et al., 2018c). In accordance with Hay (1976), we observed that Middle Bed II is substantially thicker in MNK Skull than in other Olduvai localities, and therefore the entire archaeological sequence unearthed in T3 was deposited underneath Tuff IIB. The site was located only a few hundred metres from the lake shoreline, and the main assemblage was formed in pedogenically modified clays associated with lake flats, exposed as Palaeolake Olduvai withdrew into the basinal depocentre.

Despite the low energy depositional environment signalled by predominating lithofacies, taphonomic proxies indicate that the T3 assemblage is not in primary position. The relative abundance of unmodified cobbles and pebbles that cannot be considered as manuports indicate natural input of clasts. While orientation patterns are not conclusive, fabrics indicate post-depositional movement of materials. In the same vein, despite the generally fresh stone tool edges, their size distributions suggest post-depositional modification, most likely caused by hydraulic sorting. The same pattern is mirrored in T36 which, despite yielding a lower density assemblage than in T3, otherwise resembles all features of the main site and may imply that the depositional processes that led to the formation of MNK Skull were operating over a wider area of the landscape. The assemblage was covered and

preserved by mudflows originating from the Ngorongoro Volcanic Highlands, which also moved and entrained bone and lithic artefacts into the flow.

The OGAP faunal assemblage is small and more suggestive of a background scatter than an occupation site. The fauna present are open-habitat adapted, but the small size of the collection does not eliminate the presence of mixed or closed settings near the site. While hominins and carnivores left feeding traces on the fauna, the evidence of such is rare and points towards a more natural accumulation of fossils, including OH 13 and OH 15, perhaps over an extended period of time.

The stone tool assemblage is dominated by a core and flake technology where freehand knapping dominates, but in which the presence of bipolar flaking is also substantial. Despite lying above chert horizons, debitage is dominated by quartzite and an overabundance of lava cores is also observed. Proportions of technological categories and the techno-typological features of the assemblage place the MNK Skull assemblage in the Oldowan. Although in variable proportions, virtually all published sites above Tuff IIB have yielded handaxes, which makes MNK Skull the last handaxe-free site at Olduvai, therefore marking the end of the Oldowan at Olduvai. Ongoing debate over whether or not the Acheulean had appeared in the sequence by that time can now be placed alongside the new data presented in this paper, which has also sought to provide a solid chronostratigraphic and archaeological context for the discussion of the all-important *Homo habilis* remains of MNK Skull.

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Table 1. Lithofacies identified in the MNK Skull site sedimentary sequence.

Lithofacies	Structural and compositional characteristics	Process and depositional environment
Brown claystone	Weakly plane laminated, ≤5 vol.% sand-sized detrital grains, smectite, interlayered illite/smectite	Offshore suspension fallout in deeper portions of saline alkaline Palaeolake Olduvai
Brown claystone with small nodules	Same as above, but with isolated or horizons of small (0.3-10 mm diameter) carbonate nodules developed in top 15-20 cm of brown claystone	Incipient soil developed on subaerially exposed lake mudflats after lake withdrawal
Nodular limestone	Laterally continuous horizons of bright white, micritic and small spherulitic calcite nodules, in places underlying sediment is burrowed and/or rooted	Mature soil, characterized by shallow subsurface pedogenic carbonate precipitation at groundwater/vadose interface during lake withdrawal
Brown sandy claystone	Brown, massive to weakly plane laminated, bimodal grain size distribution, >5 vol.% sand-sized detrital grains	Nearshore saline alkaline lake suspension fallout with windblown sand contamination
Olive sandy claystone	Olive, massive to weakly plane laminated, bimodal grain size distribution, >5 vol.% sand-sized detrital grains	Nearshore saline alkaline lake suspension fallout with windblown sand contamination
Coarse sandstone	Semi-tabular geometry, almost no basal erosion	Sheet flood shallow fluvial deposition
Fine to medium augitic sandstone	Violet grey to black, plane laminated or trough cross-bedded, grain-supported, erosive base, moderate to poor sorting, abundant augite (50-75 vol.%), some hornblende, plagioclase, biotite, and volcanic lithic grains (basalt, nephelinite), few subrounded pumice, and clay clasts, may contain few, quartzite and/or basalt and phonolite pebbles	Shallow ephemeral braided fluvial channel deposits
Medium to coarse augitic sandstone	Same as above, but becoming pebbly towards its top with few pumice < 5mm, and clay clasts, may contain few quartzite and basalt pebbles	Shallow ephemeral braided fluvial channel deposition
Very coarse augitic sandstone	Same as above, but sand grade material more poorly sorted	Shallow high energy ephemeral braided fluvial channel deposition
Clayey diamictite	Redbrown, massive, matrix-supported (≥40% clay matrix), volcanoclastic, contains clay clasts and pebbles of carbonate peds	Low-viscosity lahar mudflow
Sandy diamictite	Brown, massive, matrix-supported (<40% vol. sandy clay matrix), volcanoclastic, rich in detrital grains, abundant clay clasts and carbonate peds, supports large, up to cobble-sized clasts of lava, non-erosive base, clasts randomly dispersed throughout unit	High-viscosity lahar mudflow

Table 2. Absolute frequencies of stone artefacts, unmodified lithics and fossils unearthed in the MNK Skull trenches.

Trench	Archaeological unit	Stone tools (n)				Unmodified lithics (n)				Fossils (n)		
		Total stone tools	Detached	Flaked	Pounded	Total unmodified lithics	Cobbles	Nodules	Pebbles	Total fossils	Plotted specimens	Fossil fragments from sieve
T3	MNKSL6	253	251	1	1	41	1		40	76	5	71
	MNKSL10	1302	1180	91	31	186	48	13	125	3409	316	3093
	MNKSL12	23	14	6	3	8	3	4	1	69	6	63
	MNKSL14	73	55	16	2	1		*	1	17	5	12
	Total	1651	1500	114	37	236	52		167	3571	332	3239
T36	T36L30	21	9	8	4	17	15		2	7	7	
	Total	1672	1509	122	41	253	67	17	169	3578	339	3239

*Nodules in MNKSL14 are not considered.

Table 3. Density in archaeological units at the MNK Skull trenches.

Trench	Archaeological unit	Excavated area	Unit Thickness	Sedimentary Volume ^a	Assemblage Volume ^b	Archaeological material / m ²			Archaeological material/ m ³			Unmodified material/ m ²			Unmodified material/ m ³		
						Total	Stone tools	Fossils ^c	Total	Stone tools	Fossils ^c	Total	Cobbles/nodules ^e	Pebbles	Total	Cobbles/nodules	Pebbles
		m ²	cm	m ³	m ³												
T3	MNKSL6	32	20.35	6.51	2.33	8.1	7.9	0.2	39.6	38.9	0.8	1.3	0.0	1.3	6.3	0.2	6.1
	MNKSL10	32	33.80	10.82	26.67	50.6	40.7	9.9	149.6	120.4	29.2	5.8	1.9	3.9	17.2	5.6	11.6
	MNKSL12	32	21.62	6.92	5.59	0.9	0.7	0.2	4.2	3.3	0.9	0.3	0.2	0.0	1.2	1.0	0.1
	MNKSL14	32	21.26	6.80	6.22	2.4	2.3	0.2	11.5	10.7	0.7	0.0	0.0	0.0	0.1	0.0	0.1
	Total			31	40.81												
T36	T36L30	4	3.70	1.18	0.12	7.0	5.3	1.8	23.6	17.7	5.9	4.3	3.8	0.5	14.4	12.7	1.7

^a Sedimentary volume calculated by dividing excavated area between unit average thickness. ^b

Assemblage Volume calculated by means of the 3D minimum convex hull enclosing all items. ^c Fossils collected from sieving are not included. ^d Densities of material are based on area (m²) and sedimentary volume (m³). ^e Nodules from L14 are not included.

Table 4. Absolute frequencies and total weight of stone tool categories in the MNK Skull archaeological units.

	MNKSL6		MNKSL10		MNKSL12		MNKSL14		T36L30		Total		
	n	g	n	g	n	g	n	g	n	g	n	g	
Detached	Flake			90	1853.4	7	453.8	6	163.4	4	161.4	107	2632
	Flake frag	1	1.2	151	935.9	4	15.7	8	157.4	3	39.2	167	1149.4
	Shatter <20 mm	247	84.8	895	445.7	3	2	39	14.4	1	0.1	1185	547
	Shatter >20 mm	3	14	44	522.6			2	142	1	105	50	783.6
	Total detached	251	100	1180	3757.6	14	471.5	55	477.2	9	305.7	1509	5112
Flaked	Core	1	248.1	66	19042.6	5	2046.8	13	3283.6	7	2929.4	92	27550.5
	Core fragment			1	7.5							1	7.5
	Retouched tool			19	376.4			1	4.4	1	54.4	21	435.2
	Split cobble			5	987	1	191.6	2	397.3			8	1575.9
	Total flaked	1	248.1	91	20413.5	6	2238.4	16	3685.3	8	2983.8	122	29569.1
Pounded	Pitted stone*			3	1202.5					1	237.9	4	1440.4
	Hamm. Fract. Ang.	1	399.8									1	399.8
	Knapping hamm.			26	7325.7	2	353.1	2	719.9	2	682.1	32	9080.8
	Hamm. Frag.			2	134	1	251.6			1	224.7	4	610.3
	Total pounded	1	399.8	31	8662.2	3	604.7	2	719.9	4	1144.7	41	11531.3
Total				1302	32833.3	23	3314.6	73	4882.4	21	4434.2	1672	46212.4
Detached	Flake	0.0	0.0	6.9	5.6	30.4	13.7	8.2	3.3	19.0	3.6	6.4	5.7
	Flake frag	0.4	0.2	11.6	2.9	17.4	0.5	11.0	3.2	14.3	0.9	10.0	2.5
	Shatter <20 mm	97.6	11.3	68.7	1.4	13.0	0.1	53.4	0.3	4.8	0.0	70.9	1.2
	Shatter >20 mm	1.2	1.9	3.4	1.6	0.0	0.0	2.7	2.9	4.8	2.4	3.0	1.7
	Total detached	99.2	13.4	90.6	11.4	60.9	14.2	75.3	9.8	42.9	6.9	90.3	11.1
Flaked	Core	0.4	33.2	5.1	58.0	21.7	61.8	17.8	67.3	33.3	66.1	5.5	59.6
	Core fragment	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
	Retouched tool	0.0	0.0	1.5	1.1	0.0	0.0	1.4	0.1	4.8	1.2	1.3	0.9
	Split cobble	0.0	0.0	0.4	3.0	4.3	5.8	2.7	8.1	0.0	0.0	0.5	3.4
	Total flaked	0.4	33.2	7.0	62.2	26.1	67.5	21.9	75.5	38.1	67.3	7.3	64.0
Pounded	Pitted stone	0.0	0.0	0.2	3.7	0.0	0.0	0.0	0.0	4.8	5.4	0.2	3.1
	Hamm. Fract. Ang.	0.4	53.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.9
	Knapping hamm	0.0	0.0	2.0	22.3	8.7	10.7	2.7	14.7	9.5	15.4	1.9	19.7
	Hamm. Frag.	0.0	0.0	0.2	0.4	4.3	7.6	0.0	0.0	4.8	5.1	0.2	1.3
	Total pounded	0.4	53.5	2.4	26.4	13.0	18.2	2.7	14.7	19.0	25.8	2.5	25.0
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*A piece listed under the category of cores is also a pitted stone.

** Angular fragments in MNKSL6 are considered under shatter (i.e., irregular flaking debris), although their anthropogenic origin is uncertain.

Table 5. Taphonomic features of the MNKSL10 assemblage. NISP = Number of individual specimens.

Weathering Stage	NISP
0	8
1	158
2	49
3	9
4	2
Mechanical Rounding	NISP
None	89
Minor	119
Major	18
Exfoliation	NISP
None	8
Minor	128
Major	90
General breakage	NISP Appendicular only
Green	42
Dry	31
Cut marks	NISP Appendicular only
Present	1
Absent	72
Percussion Marks	NISP Appendicular only
Present	3
Absent	70
Tooth Marks	NISP Appendicular only
Present	10
Absent	63
Notches	NISP Appendicular only
Percussion	2
Tooth	2

Table 6. Skeletal parts and animal size groups based on the MNKSL10 assemblage. Animal size groups based on Bunn (1982). Totals include bones that could not be assigned to a size group.

Skeletal group	Size 1		Size 2		Size 3		Size 4		Size 5		Size 6		Total	
	NISP	MNE	NISP	MNE	NISP	MNE	NISP	MNE	NISP	MNE	NISP	MNE	NISP	MNE
Skull total	1	1	3	1	2	2	0	0	0	0	0	0	9	4
Axial total	3	2	5	2	6	2	0	0	0	0	0	0	14	6
Appendicular total	14	2	29	6	28	9	1	1	0	0	0	0	73	14
Compact total	1	0	0	0	5	3	0	0	0	0	0	0	6	3
Pelvis/scapula total	0	0	5	2	1	1	0	0	0	0	0	0	6	3
Indeterminate Mammal bone	-	-	-	-	-	-	-	-	-	-	-	-	118	-
Grand Total	19	5	42	11	42	17	1	1	0	0	0	0	226	34

Table 7. Minimum number of individuals in the MNKSL10 assemblage.

Taxonomic Identification	MNI
Alcelaphini	2
Antilopini	1
<i>Tragelaphus cf. strepsiceros</i>	1
<i>Equus cf. oldowayensis</i>	1
Hippopotamidae	1
Rodentia	1
Suidae	1
Total	8

Table 8. Absolute frequency and total weight of unmodified lithics and artefacts per raw material.

Archaeological unit																				
	Unmodified								Stone tools											
	Cobbles		Nodules		Pebbles				Flaked/ battered								Debitage			
	Lava		Chert		Lava		Metamorphic		Lava		Metamorphic		Chert		Lava		Metamorphic		Chert	
	<i>n</i>	weight	<i>n</i>	weight	<i>n</i>	weight	<i>n</i>	weight	<i>n</i>	weight	<i>n</i>	weight	<i>n</i>	weight	<i>n</i>	weight	<i>n</i>	weight	<i>n</i>	weight
MNKSL6	1	206.4			2	0.8	38	37.6	2	647.9					3	0.9	248	99.1		
MNKSL10	48	12321.5	13	702.1	77	3075.7	47	142.9	77	23844.3	31	4491.9	12	401.3	70	1343	1090	2309.7	20	104.7
MNKSL12	3	752.7	4	188	1	56.8			6	1996.9	2	764.1			1	89.5	12	381.9	1	0.1
MNKSL14							1	0.1	7	2792.4	6	1030.1	4	423.1			53	321.7	2	155.5
Total T3	52	13280.6	17	890.1	80	3133.3	86	180.6	92	29281.5	39	6286.1	16	824.4	74	1434	1403	3112.4	23	260.3
T36L30	15	4033.3			2	211.6			7	2217.1	5	1911.4			2	110.9	7	194.8		
Total*	67	17313.9	17	890.1	82	3344.9	86	180.6	99	31499	44	8197.5	16	824.4	76	1545	1410	3307.2	23	260.3

*1.7 kg of raw materials classified as “others” is not considered.

Table 9. Frequency and weight of technological categories per raw material in the whole MNK Skull assemblage.

	Phonolite		T-Ta		Basalt		Quartzite		Gneiss		Chert		Others		Total			
	n	g	n	g	n	g	n	g	n	g	n	g	n	g	n	g		
Detached	Flake	14	497.2	5	95.7	4	188.9	74	1730.5			9	107.2	1	12.5	107	2632	
	Flake frag	12	101.2	8	193.3	7	25.8	133	819.5			6	7.6	1	2	167	1149.4	
	Shatter <20 mm	6	4.1			9	4	1166	538.7			4	0.2			1185	547	
	Shatter >20 mm	5	52.7	1	3.5	5	378.1	35	204			4	145.3			50	783.6	
	Total detached	37	655.2	14	292.5	25	596.8	1408	3292.7			23	260.3	2	14.5	1509	5112	
Flaked	Core	17	5948	18	6914.7	14	6242.8	29	6764.8	2	567.3	10	738.1			92	27550.5	
	Core fragment							1	7.5							1	7.5	
	Retouched tool	3	157.2	2	37.7			9	128.6			6	86.3	1	25.4	21	435.2	
	Split cobble	1	112.1	4	1061.8	1	191.6							2	210.4	8	1575.9	
	Total flaked	21	6217.3	24	8014.2	15	6434.4	39	6900.9	2	567.3	16	824.4	5	610.6	122	29569.1	
Pounded	Pitted stone			1	555.3	2	436.2							1	448.9	4	1440.4	
	Hamm. Fract. Ang.			1	399.8										1	399.8		
	Knapping hamm.	7	1856.5	11	3474	11	2524.2			1	616.5			2	609.6	32	9080.8	
	Hamm. Frag.			2	385.6	2	224.7							4	610.3	4	610.3	
	Total pounded	7	1856.5	15	4814.7	15	3185.1			1	616.5			3	1058.5	41	11531.3	
Total		65	8729	53	13121.4	55	10216.3	1447	10193.6	3	1183.8	39	1084.7	10	1683.6	1672	46212.4	
		Frequency %	Weight %	Frequency %	Weight %	Frequency %	Weight %	Frequency %	Weight %	Frequency %	Weight %	Frequency %	Weight %	Frequency %	Weight %	Frequency %	Weight %	
Detached	Flake		21.5	5.7	9.4	0.7	7.3	1.8	5.1	17.0	0.0	0.0	23.1	9.9	10.0	0.7	6.4	5.7
	Flake frag		18.5	1.2	15.1	1.5	12.7	0.3	9.2	8.0	0.0	0.0	15.4	0.7	10.0	0.1	10.0	2.5
	Shatter <20 mm		9.2	0.0	0.0	0.0	16.4	0.0	80.6	5.3	0.0	0.0	10.3	0.0	0.0	0.0	70.9	1.2
	Shatter >20 mm		7.7	0.6	1.9	0.0	9.1	3.7	2.4	2.0	0.0	0.0	10.3	13.4	0.0	0.0	3.0	1.7
	Total detached		56.9	7.5	26.4	2.2	45.5	5.8	97.3	32.3			59.0	24.0	20.0	0.9	90.3	11.1
Flaked	Core		26.2	68.1	34.0	52.7	25.5	61.1	2.0	66.4	66.7	47.9	25.6	68.0	20.0	22.3	5.5	59.6
	Core fragment		0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
	Retouched tool		4.6	1.8	3.8	0.3	0.0	0.0	0.6	1.3	0.0	0.0	15.4	8.0	10.0	1.5	1.3	0.9
	Split cobble		1.5	1.3	7.5	8.1	1.8	1.9	0.0	0.0	0.0	0.0	0.0	0.0	20.0	12.5	0.5	3.4
	Total flaked		32.3	71.2	45.3	61.1	27.3	63.0	2.7	67.7	66.7	47.9	41.0	76.0	50.0	36.3	7.3	64.0
Pounded	Pitted stone		0.0	0.0	1.9	4.2	3.6	4.3	0.0	0.0	0.0	0.0	0.0	0.0	10.0	26.7	0.2	3.1
	Hamm. Fract. Ang.		0.0	0.0	1.9	3.0	20.0	24.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.9
	Knapping hamm.		10.8	21.3	20.8	26.5	0.0	0.0	0.0	0.0	33.3	52.1	0.0	0.0	20.0	36.2	1.9	19.7
	Hamm. Frag.		0.0	0.0	3.8	2.9	3.6	2.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	1.3
	Total pounded		10.8	21.3	28.3	36.7	27.3	31.2	0.0	0.0	33.3	52.1	0.0	0.0	30.0	62.9	2.5	25.0
Total		3.9	18.9	3.2	28.4	3.3	22.1	86.5	22.1	0.2	2.6	2.3	2.3	0.6	3.6	100.0	100.0	

Table 10. Dimensions of main technological categories per raw material.

		Lava						Metamorphic			Chert			All raw materials			
		Mean	Max	Min	Std Dev	Mean	Max	Min	Std Dev	Mean	Max	Min	Std Dev	Mean	Max	Min	Std Dev
Flake	Length	42.3	78	15	17.6	37.0	80	15	13.7	41.7	62	22	12.2	38.5	80	15	14.6
	Width	33.1	59	11	14.2	26.9	68	11	11.1	32.1	50	18	9.5	28.7	68	11	12.0
	Thickness	13.5	35	2	7.0	13.9	38	5	6.5	11.2	25	7	5.4	13.6	38	2	6.5
	Weight	34.0	209	0.9	46.2	23.4	190.2	1.2	29.6	11.9	33.2	2	9.1	24.7	209	0.9	33.1
Core	Length	79.0	100	47	14.0	63.5	104	34	21.9	51.9	72	31	13.2	70.6	104	31	19.5
	Width	65.6	94	35	13.0	52.5	96	25	18.7	41.3	70	23	14.8	58.4	96	23	17.5
	Thickness	53.4	85	22	13.7	38.8	69	19	14.0	30.5	49	17	10.3	45.8	85	17	15.9
	Weight	389.9	873.6	58.2	192.0	236.5	844.9	23.5	225.2	73.8	186.4	6.3	60.8	302.0	873.6	6.3	221.3
Retouched tool	Length	51.4	62	31	13.5	32.6	51	20	9.3	41.7	45	36	3.3	40.0	62	20	11.8
	Width	33.8	46	20	11.1	23.0	35	16	7.3	35.2	42	25	5.9	29.4	46	16	9.6
	Thickness	18.2	22	11	4.3	12.7	18	7	3.7	14.5	19	11	2.9	14.6	22	7	4.1
	Weight	39.0	54.4	14.2	18.8	14.3	47.5	4.4	14.3	14.4	30.9	6.5	8.5	20.5	54.4	4.4	17.3
Split Cobble	Length	79.2	137	48	31.4									79.2	137	48	31.4
	Width	51.7	78	41	14.7									51.7	78	41	14.7
	Thickness	40.5	50	33	6.1									40.5	50	33	6.1
	Weight	227.6	617	65.9	200.0									227.6	617	65.9	200.0
Pitted stone	Length	78.0	90	70	10.6									78.0	90	70	10.6
	Width	65.7	75	58	8.6									65.7	75	58	8.6
	Thickness	39.7	47	35	6.4									39.7	47	35	6.4
	Weight	330.5	555.3	198.3	195.7									330.5	555.3	198.3	195.7
Knapping hamm.	Length	73.6	100	48	13.5	104.0	104	104						74.4	104	48	14.2
	Width	60.6	84	39	10.4	81.0	81	81						60.9	84	39	11.2
	Thickness	46.9	71	27	11.2	60.0	60	60						47.2	71	27	11.9
	Weight	290.4	499.1	82.1	128.2	616.5	616.5	616.5						302.2	616.5	82.1	147.3

Length, width and thickness in mm, weight in g.

Table 11. Attributes of flakes in the MNK Skull assemblage.

		Raw material						Stratigraphic position			
		Lava		Metamorphic		Chert		MNKSL10		Whole assemblage	
		<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%
Length classes*	<20 mm	2	8.7	7	9.3		0.0	9	10.0	9	8.4
	20-39 mm	9	39.1	36	48.0	3	33.3	42	46.7	48	44.9
	40-59 mm	8	34.8	29	38.7	5	55.6	34	37.8	42	39.3
	60-79 mm	4	17.4	2	2.7	1	11.1	5	5.6	7	6.5
	80-99 mm		0.0	1	1.3		0.0		0.0	1	0.9
	Total	23	21.5	75	70.1	9	8.4	90	84.1	107	100.0
Striking platform preparation	Non-faceted	7	35.0	17	25.0	2	25.0	22	26.5	26	27.1
	Unifaceted	11	55.0	48	70.6	5	62.5	55	66.3	64	66.7
	Bifaceted	2	10.0	3	4.4	1	12.5	6	7.2	6	6.3
	Total	20	20.8	68	70.8	8	8.3	83	86.5	96	100.0
Cortex dorsal side	Cortical	3	13.6	2	2.7	2	25.0	6	6.8	7	6.7
	Cortex >50%	8	36.4	6	8.0	2	25.0	13	14.8	16	15.2
	Cortex <50%	7	31.8	30	40.0	3	37.5	29	33.0	40	38.1
	Non-cortical	4	18.2	37	49.3	1	12.5	40	45.5	42	40.0
	Total	22	21.0	75	71.4	8	7.6	88	83.8	105	100.0
Toth's flakes	I		0.0	1	1.4	1	12.5	1	1.2	2	1.9
	II	7	33.3	10	13.5	1	12.5	16	18.6	18	17.5
	III	1	4.8	7	9.5		0.0	7	8.1	8	7.8
	IV	2	9.5		0.0	1	12.5	3	3.5	3	2.9
	V	8	38.1	25	33.8	4	50.0	26	30.2	37	35.9
	VI	3	14.3	31	41.9	1	12.5	33	38.4	35	34.0
	Total	21	20.4	74	71.8	8	7.8	86	83.5	103	100.0
Flake types	Bipolar	5	21.7	26	34.7	1	11.1	27	30.0	32	29.9
	Regular flake	18	78.3	49	65.3	8	88.9	63	70.0	75	70.1
	Total	23	21.5	75	70.1	9	8.4	90	84.1	107	100.0

*Counts per raw material have one less core than total recounts.

Table 12. Attributes of cores in the MNK Skull assemblage.

		Raw material*								Stratigraphic position			
		Lava		Metamorphic		Chert		MNKSL10				Whole assemblage	
		<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%
Length class*	20-39 mm		0.0	3	9.4	2	20.0	4	6.1	5	5.4		
	40-59 mm	5	10.2	14	43.8	5	50.0	20	30.3	24	26.1		
	60-79 mm	19	38.8	6	18.8	3	30.0	19	28.8	29	31.5		
	80-99 mm	23	46.9	5	15.6		0.0	20	30.3	28	30.4		
	>100 mm	2	4.1	4	12.5		0.0	3	4.5	6	6.5		
	Total	49	53.8	32	35.2	10	11.0	66	71.7	92	100.0		
Weight class	<50 g		0.0	4	12.5	4	40.0	5	7.6	8	8.7		
	50-100 g	2	4.1	11	34.4	3	30.0	15	22.7	16	17.4		
	101-200 g	5	10.2	5	15.6	3	30.0	8	12.1	13	14.1		
	201-400 g	21	42.9	6	18.8		0.0	17	25.8	28	30.4		
	401-800 g	20	40.8	5	15.6		0.0	21	31.8	25	27.2		
	>800 g	1	2.0	1	3.1		0.0		0.0	2	2.2		
	Total	49	53.8	32	35.2	10	11.0	66	71.7	92	100.0		
Cortex	Cortex >50%	39	81.3	12	37.5	4	40.0	41	62.1	56	61.5		
	Cortex <50%	9	18.8	17	53.1	6	60.0	23	34.8	32	35.2		
	Non-cortical		0.0	3	9.4		0.0	2	3.0	3	3.3		
	Total	48	52.7	32	35.2	10	11.0	66	72.5	91	100.0		
Blank	Cobble	44	89.8	6	25.0		0.0	38	63.3	51	60.7		
	Block		0.0	13	54.2		0.0	7	11.7	13	15.5		
	Nodule		0.0		0.0	6	60.0	4	6.7	6	7.1		
	Fragment	2	4.1	2	8.3	4	40.0	6	10.0	8	9.5		
	Split Cobble	3	6.1	1	4.2		0.0	4	6.7	4	4.8		
	Flake		0.0	2	8.3		0.0	1	1.7	2	2.4		
	Total	49	53.8	24	26.4	10	11.0	60	71.4	84	100.0		
Battering	Esquillees	4	8.5	8	29.6		0.0	8	12.7	12	14.1		
	Impacts	20	42.6	7	25.9		0.0	22	34.9	27	31.8		
	Percus. fractures	2	4.3		0.0		0.0	2	3.2	2	2.4		
	Absent	21	44.7	12	44.4	10	100.0	31	49.2	44	51.8		
	Total	47	51.6	27	29.7	10	11.0	63	74.1	85	100.0		
Number of scars	1-3 scars	26	55.3	10	37.0	2	20.0	28	44.4	38	44.7		
	4-6 scars	14	29.8	12	44.4	4	40.0	24	38.1	31	36.5		
	7-9 scars	5	10.6	5	18.5	2	20.0	8	12.7	12	14.1		
	> 9 scars	2	4.3		0.0	2	20.0	3	4.8	4	4.7		
	Total	47	51.6	27	29.7	10	11.0	63	74.1	85	100.0		

*Counts per raw material have one less core than total recounts.

Table 13. Flaking schemes of MNK Skull cores by raw material, blank and assemblage, following types defined by de la Torre and Mora (2018).

	Raw material			Core blank						Stratigraphic position	
	Lava	Metamorphic	Chert	Block	Cobble	Flake	Split cobble	Fragment	Nodule	MNKL10	Entire assemblage
Absolute frequency											
TC	5	1	1	1	5				1	4	7
USP	7	2		2	6		1			8	9
BSP	5	5		2	7					6	10
UAU1	10	1	1		7		2	3		9	12
BAP	3	1	1		4				1	5	5
BALP	6	6	3	1	7	1	1	4	1	12	16
BALT	1	1			2					1	2
BP		1	2		1			1	1	1	3
MLT	5	2	2	2	5				2	8	9
BIPO	5	12		5	5	1				11	17
Total	47	32	10	13	49	2	4	8	6	65	90
Relative frequency											
TC	10.6	3.1	10.0	7.7	10.2	0.0	0.0	0.0	16.7	6.2	7.8
USP	14.9	6.3	0.0	15.4	12.2	0.0	25.0	0.0	0.0	12.3	10.0
BSP	10.6	15.6	0.0	15.4	14.3	0.0	0.0	0.0	0.0	9.2	11.1
UAU1	21.3	3.1	10.0	0.0	14.3	0.0	50.0	37.5	0.0	13.8	13.3
BAP	6.4	3.1	10.0	0.0	8.2	0.0	0.0	0.0	16.7	7.7	5.6
BALP	12.8	18.8	30.0	7.7	14.3	50.0	25.0	50.0	16.7	18.5	17.8
BALT	2.1	3.1	0.0	0.0	4.1	0.0	0.0	0.0	0.0	1.5	2.2
BP	0.0	3.1	20.0	0.0	2.0	0.0	0.0	12.5	16.7	1.5	3.3
MLT	10.6	6.3	20.0	15.4	10.2	0.0	0.0	0.0	33.3	12.3	10.0
BIPO	10.6	37.5	0.0	38.5	10.2	50.0	0.0	0.0	0.0	16.9	18.9
Total	52.8	36.0	11.2	15.9	59.8	2.4	4.9	9.8	7.3	72.2	100.0

Abbreviations. TC: Test core. USP: Unifacial simple partial exploitation. BSP: Bifacial simple partial exploitation. UAU1: Unidirectional abrupt unifacial exploitation on one knapping surface. BAP: bifacial abrupt partial exploitation. BALP: bifacial alternating partial exploitation. BALT: bifacial alternating total exploitation. BP: bifacial peripheral. MLT: Multifacial. BIPO: bipolar flaking.

Table 14. Core, debitage and retouched tool ratios in the MNK Skull assemblages, following indices defined by de la Torre and Mora (2018: 268).

		Raw material			Interval	
		Lava	Metamorphic	Chert	MNKS10	Whole assemblage
A.1	Flake: core	0.47	2.34	0.90	1.36	1.16
A.2	Flake & flake frag: core	1.02	6.53	1.50	3.65	2.98
B.1	Flake: core scars	0.12	0.60	0.13	0.32	0.28
B.2	Flake & flake frag: core scars	0.27	1.66	0.22	0.86	0.71
C	Detached pieces cutting edge (cm): Core mass (g)	0.01	0.08	0.52	0.04	0.03
D.1	Ret. tool: detached pieces ≥ 20 mm	0.10	0.06	0.46	0.09	0.09
D.3	Ret. tool: flake ≥ 20 mm	0.24	0.15	0.67	0.23	0.21

FIGURE CAPTIONS

Figure 1. Location of trenches at MNK Skull. Aerial photograph based on imagery produced by Jorayev et al (2016). Bottom left: beginning of the southward extension of Leakey's trench. Bottom right: OGAP-T3 trench after completion of excavations.

Figure 2. Excavation and archaeological materials from T36 (A) and T3 (B). A1) General view of T36. A2) T36 stone tools: 1-Cores 2-Flakes. 3-Flake fragments. 4- Hammerstones. A3) Archaeological unit T36L30 from the top of the trench. A4). Map of findings in T36L30. B1) Spatially-associated unmodified lithic and fossil fragment in MNKSL10. B2) Vertically-positioned chert flake during the excavation of MNKSL10. B3) Tibia fragment that exhibits mechanical rounding and weathering along with a scratch identified as a low-confidence cut mark, which is not tallied in mark counts. B4) Femur fragment with a mammalian carnivore tooth mark.

Figure 3. Plan (A) and backwalls (B-E) of MNK Skull site. A) Vectorised and georeferenced Leakey trench within OGAP's grid and T3 map of findings. B) Georeferenced picture of the east sidewall of T3 with vertical distribution of archaeological units (remains plotted within 1 m from the wall). C) Georeferenced main backwall (south) of T3 with vertical distribution of all remains in each archaeological unit. D-E) Detail of the relative position of archaeological units MNKSL10 and L12 (D), and MNKSL12 and L14 (E).

Figure 4. Measured stratigraphic sections for Bed II across MNK and for nearby sites PEK and VEK. The base of the Tuff IIB interval is taken as horizontal, and sections are "hung" in relation to that level where possible. The MNK sections cover an east to west range of ~164 meters and are plotted in order, but specific distances between sections are not plotted to scale. Specific marker tuffs and beds are highlighted. Dates for tuffs from previous published studies: (1) Díez-Martín et al., 2013, (2) Deino et al., in review, and (3) Deino, 2012.

Figure 5. A). Correlation between Leakey's (1971: 117) stratigraphic column at MNK and lithofacies identified by OGAP. B) Stratigraphic layers in the backwalls of MNK Skull- T3 (E-W) and T36 (N-S), with cross- sections of archaeological units overlapped. The apparent location of some MNKSL10 materials below the Type 1 unconformity is explained by the 'slope effect' (i.e., the projection of x,z coordinates only, which obviates the topographically varying position of artefacts in the y plane). See Table 1 for a description of lithofacies.

Figure 6. Vertical views (A-D) of all archaeological units in MNK Skull-T3 and horizontal density map of unit MNKSL10 (E). A & C) Cross-sections of plotted remains in E-W (A) and N-S (C) directions. Kernel density analysis of E-W (B) and N-S (D) cross sections, and horizontal distribution of MNKSL10 (E) (search radius: 0.5 m). * Scales apply to both horizontal and vertical distributions.

Figure 7. Relevant proxies for the reconstruction of site formation processes in the MNK Skull main assemblage. A) Angular histograms of compass bearings (OGAP excavations, n=52) and data extracted

from Leakey's (1971) map of findings (n=31). B) Histogram of MNKSL10 lithics < 20 mm, comparing stone tools (broken down by main raw materials: metamorphic, lava and chert) and unmodified items. C) MNKSL10 fabric results (n=52). C1- Stereographic projections. C2- Vollmer fabric triangle. C3- Sneed and Folk fabric triangle. D) Sneed and Folk's shape triangles of MNKSL10 lithics, using length, width and thickness as a, b and c axis.

Figure 8. Distribution maps and refit of archaeological unit MNKSL10 in MNK Skull-T3. A) Refit Set #2, made of two phonolite flake fragments. B) E-W cross section of remains within a 3-m wide area from the north limit of T3. C) Plan view of MNKSL10 with refit line of Set #2. D) Hotspot analysis of the horizontal distribution of remains in MNKSL10, considering count, length and weight for all items* (D1), stone tools (D2), fossils (D3), and unmodified lithics (D4). *Fossils were excluded from the analysis of weight in all items (D1). ** Scales apply to both horizontal and vertical distributions.

Figure 9. Relative frequency (A, C) and weight (B, D) of main raw materials (A, B) and McHenry and de la Torre (2018)'s raw material types (C, D). See details in SOM S7.

Figure 10. Main features of the MNK Skull stone tool assemblage. A-B) Relative frequency (A) and weight (B) of raw materials per technological category. C) Correspondence factor analysis of technological categories and main rock types. D-E) Length (D) and weight (E) of main technological categories per raw material.

Figure 11. Attributes of complete flakes per raw material. A) Mean dimensions (length, width and thickness in mm, weight in grams). B) Length classes. C) Types of striking platforms (NF: non-faceted. UF: unifaceted. BF: bifaceted). D) Cortex on dorsal and striking platforms, following Toth's (1982) types.

Figure 12. Complete flakes (A-F) and retouched pieces (H-J) from MNKSL10. A: basalt. D, E, H, I, and J: quartzite. C and G: phonolite. B and F: chert. See Videoclip #1 for 3D model of retouched piece in Figure 12H, and Videoclip #2 for Figure 12I. All scales = 2 cm

Figure 13. Dimensional and technical attributes of MNK Skull cores per raw material. A) Mean length, width and thickness (in mm) and weight (in grams). B) Scatter plot of core length and width. C-D) Core length (C) and weight (D) classes. E) Cortex coverage. F) Types of core blanks. G) Battering features in cores. H) Number of previous removals.

Figure 14. MNKSL10 cores. A-C) Bifacial alternating partial reduction in phonolite (A), quartzite (B) and chert (C). D) Example of bifacial simple partial exploitation in quartzite [see also Videoclip #3 for examples of BSP reduction]. E) Bifacial abrupt partial scheme in chert core. F) Quartzite bipolar cores.

Figure 15. Freehand flaking techniques per raw materials. A) Relative frequencies. B) Correspondence Factor Analysis. See Table 13 for abbreviations.

Figure 16. The T3- MNK Skull lithic assemblage.

Table 1. Lithofacies identified in the MNK Skull site sedimentary sequence.

Lithofacies	Structural and compositional characteristics	Process and depositional environment
Brown claystone	Weakly plane laminated, ≤ 5 vol.% sand-sized detrital grains, smectite, interlayered illite/smectite	Offshore suspension fallout in deeper portions of saline alkaline Palaeolake Olduvai
Brown claystone with small nodules	Same as above, but with isolated or horizons of small (0.3-10 mm diameter) carbonate nodules developed in top 15-20 cm of brown claystone	Incipient soil developed on subaerially exposed lake mudflats after lake withdrawal
Nodular limestone	Laterally continuous horizons of bright white, micritic and small spherulitic calcite nodules, in places underlying sediment is burrowed and/or rooted	Mature soil, characterized by shallow subsurface pedogenic carbonate precipitation at groundwater/vadose interface during lake withdrawal
Brown sandy claystone	Brown, massive to weakly plane laminated, bimodal grain size distribution, > 5 vol.% sand-sized detrital grains	Nearshore saline alkaline lake suspension fallout with windblown sand contamination
Olive sandy claystone	Olive, massive to weakly plane laminated, bimodal grain size distribution, > 5 vol.% sand-sized detrital grains	Nearshore saline alkaline lake suspension fallout with windblown sand contamination
Coarse sandstone	Semi-tabular geometry, almost no basal erosion	Sheet flood shallow fluvial deposition
Fine to medium augitic sandstone	Violet grey to black, plane laminated or trough cross-bedded, grain-supported, erosive base, moderate to poor sorting, abundant augite (50-75 vol.%), some hornblende, plagioclase, biotite, and volcanic lithic grains (basalt, nephelinite), few subrounded pumice, and clay clasts, may contain few, quartzite and/or basalt and phonolite pebbles	Shallow ephemeral braided fluvial channel deposits
Medium to coarse augitic sandstone	Same as above, but becoming pebbly towards its top with few pumice < 5 mm, and clay clasts, may contain few quartzite and basalt pebbles	Shallow ephemeral braided fluvial channel deposition
Very coarse augitic sandstone	Same as above, but sand grade material more poorly sorted	Shallow high energy ephemeral braided fluvial channel deposition
Clayey diamictite	Redbrown, massive, matrix-supported ($\geq 40\%$ clay matrix), volcanoclastic, contains clay clasts and pebbles of carbonate peds	Low-viscosity lahar mudflow
Sandy diamictite	Brown, massive, matrix-supported ($< 40\%$ vol. sandy clay matrix), volcanoclastic, rich in detrital grains, abundant clay clasts and carbonate peds, supports large, up to cobble-sized clasts of lava, non-erosive base, clasts randomly dispersed throughout unit	High-viscosity lahar mudflow

Table 2. Absolute frequencies of stone artefacts, unmodified lithics and fossils unearthed in the MNK Skull trenches.

Trench	Archaeological unit	Stone tools (n)				Unmodified lithics (n)				Fossils (n)		
		Total stone tools	Detached	Flaked	Pounded	Total unmodified lithics	Cobbles	Nodules	Pebbles	Total fossils	Plotted specimens	Fossil fragments from sieve
T3	MNKSL6	253	251	1	1	41	1		40	76	5	71
	MNKSL10	1302	1180	91	31	186	48	13	125	3409	316	3093
	MNKSL12	23	14	6	3	8	3	4	1	69	6	63
	MNKSL14	73	55	16	2	1		*	1	17	5	12
	Total	1651	1500	114	37	236	52		167	3571	332	3239
T36	T36L30	21	9	8	4	17	15		2	7	7	
	Total	1672	1509	122	41	253	67	17	169	3578	339	3239

* Nodules in MNKSL14 are not considered.

Table 3. Density in archaeological units at the MNK Skull trenches.

Trench	Archaeological unit	Excavated area	Unit Thickness	Sedimentary Volume ^a	Assemblage Volume ^b	Archaeological material / m ²			Archaeological material/ m ³			Unmodified material/ m ²			Unmodified material/ m ³		
						Total	Stone tools	Fossils ^c	Total	Stone tools	Fossils ^c	Total	Cobbles/nodules ^e	Pebbles	Total	Cobbles/nodules	Pebbles
T3	MNKSL6	32	20.35	6.51	2.33	8.1	7.9	0.2	39.6	38.9	0.8	1.3	0.0	1.3	6.3	0.2	6.1
	MNKSL10	32	33.80	10.82	26.67	50.6	40.7	9.9	149.6	120.4	29.2	5.8	1.9	3.9	17.2	5.6	11.6
	MNKSL12	32	21.62	6.92	5.59	0.9	0.7	0.2	4.2	3.3	0.9	0.3	0.2	0.0	1.2	1.0	0.1
	MNKSL14	32	21.26	6.80	6.22	2.4	2.3	0.2	11.5	10.7	0.7	0.0	0.0	0.0	0.1	0.0	0.1
	Total			31	40.81												
T36	T36L30	4	3.70	1.18	0.12	7.0	5.3	1.8	23.6	17.7	5.9	4.3	3.8	0.5	14.4	12.7	1.7

^a Sedimentary volume calculated by dividing excavated area between unit average thickness. ^b

Assemblage Volume calculated by means of the 3D minimum convex hull enclosing all items. ^c Fossils collected from sieving are not included. ^d Densities of material are based on area (m²) and sedimentary volume (m³). ^e Nodules from L14 are not included.

Table 4. Absolute frequencies and total weight of stone tool categories in the MNK Skull archaeological units.

	MNKSL6		MNKSL10		MNKSL12		MNKSL14		T36L30		Total	
	n	g	n	g	n	g	n	g	n	g	n	g
Detached												
Flake												
Flake frag	1	1.2	90	1853.4	7	453.8	6	163.4	4	161.4	107	2632
Shatter <20 mm	247	84.8	151	935.9	4	15.7	8	157.4	3	39.2	167	1149.4
Shatter >20 mm	3	14	895	445.7	3	2	39	14.4	1	0.1	1185	547
Total detached	251	100	1180	3757.6	14	471.5	55	477.2	9	305.7	1509	5112
Flaked												
Core	1	248.1	66	19042.6	5	2046.8	13	3283.6	7	2929.4	92	27550.5
Core fragment			1	7.5							1	7.5
Retouched tool			19	376.4			1	4.4	1	54.4	21	435.2
Split cobble			5	987	1	191.6	2	397.3			8	1575.9
Total flaked	1	248.1	91	20413.5	6	2238.4	16	3685.3	8	2983.8	122	29569.1
Pounded												
Pitted stone*			3	1202.5					1	237.9	4	1440.4
Hamm. Fract. Ang.	1	399.8									1	399.8
Knapping hamm.			26	7325.7	2	353.1	2	719.9	2	682.1	32	9080.8
Hamm. Frag.			2	134	1	251.6			1	224.7	4	610.3
Total pounded	1	399.8	31	8662.2	3	604.7	2	719.9	4	1144.7	41	11531.3
Total	253	747.9	1302	32833.3	23	3314.6	73	4882.4	21	4434.2	1672	46212.4
Detached												
Flake	0.0	0.0	6.9	5.6	30.4	13.7	8.2	3.3	19.0	3.6	6.4	5.7
Flake frag	0.4	0.2	11.6	2.9	17.4	0.5	11.0	3.2	14.3	0.9	10.0	2.5
Shatter <20 mm	97.6	11.3	68.7	1.4	13.0	0.1	53.4	0.3	4.8	0.0	70.9	1.2
Shatter >20 mm	1.2	1.9	3.4	1.6	0.0	0.0	2.7	2.9	4.8	2.4	3.0	1.7
Total detached	99.2	13.4	90.6	11.4	60.9	14.2	75.3	9.8	42.9	6.9	90.3	11.1
Flaked												
Core	0.4	33.2	5.1	58.0	21.7	61.8	17.8	67.3	33.3	66.1	5.5	59.6
Core fragment	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
Retouched tool	0.0	0.0	1.5	1.1	0.0	0.0	1.4	0.1	4.8	1.2	1.3	0.9
Split cobble	0.0	0.0	0.4	3.0	4.3	5.8	2.7	8.1	0.0	0.0	0.5	3.4
Total flaked	0.4	33.2	7.0	62.2	26.1	67.5	21.9	75.5	38.1	67.3	7.3	64.0
Pounded												
Pitted stone	0.0	0.0	0.2	3.7	0.0	0.0	0.0	0.0	4.8	5.4	0.2	3.1
Hamm. Fract. Ang.	0.4	53.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.9
Knapping hamm	0.0	0.0	2.0	22.3	8.7	10.7	2.7	14.7	9.5	15.4	1.9	19.7
Hamm. Frag.	0.0	0.0	0.2	0.4	4.3	7.6	0.0	0.0	4.8	5.1	0.2	1.3
Total pounded	0.4	53.5	2.4	26.4	13.0	18.2	2.7	14.7	19.0	25.8	2.5	25.0
Total	15.1	1.6	77.9	71.0	1.4	7.2	4.4	10.6	1.3	9.6	100.0	100.0

*A piece listed under the category of cores is also a pitted stone.

Table 5. Taphonomic features of the MNKSL10 assemblage. NISP = Number of individual specimens.

Weathering Stage	NISP
0	8
1	158
2	49
3	9
4	2
Mechanical Rounding	NISP
None	89
Minor	119
Major	18
Exfoliation	NISP
None	8
Minor	128
Major	90
General breakage	NISP Appendicular only
Green	42
Dry	31
Cut marks	NISP Appendicular only
Present	1
Absent	72
Percussion Marks	NISP Appendicular only
Present	3
Absent	70
Tooth Marks	NISP Appendicular only
Present	10
Absent	63
Notches	NISP Appendicular only
Percussion	2
Tooth	2
Absent	69

Table 6. Skeletal parts and animal size groups based on the MNKSL10 assemblage. Animal size groups based on Bunn (1982). Totals include bones that could not be assigned to a size group.

Skeletal group	Size 1		Size 2		Size 3		Size 4		Size 5		Size 6		Total	
	NISP	MNE	NISP	MNE	NISP	MNE	NISP	MNE	NISP	MNE	NISP	MNE	NISP	MNE
Skull total	1	1	3	1	2	2	0	0	0	0	0	0	9	4
Axial total	3	2	5	2	6	2	0	0	0	0	0	0	14	6
Appendicular total	14	2	29	6	28	9	1	1	0	0	0	0	73	14
Compact total	1	0	0	0	5	3	0	0	0	0	0	0	6	3
Pelvis/scapula total	0	0	5	2	1	1	0	0	0	0	0	0	6	3
Indeterminate Mammal bone	-	-	-	-	-	-	-	-	-	-	-	-	118	-
Grand Total	19	5	42	11	42	17	1	1	0	0	0	0	226	34

Table 7. Minimum number of individuals in the MNKSL10 assemblage.

Taxonomic Identification	MNI
Alcelaphini	2
Antilopini	1
<i>Tragelaphus cf. strepsiceros</i>	1
<i>Equus cf. oldowayensis</i>	1
Hippopotamidae	1
Rodentia	1
Suidae	1
Total	8

Table 8. Absolute frequency and total weight of unmodified lithics and artefacts per raw material.

Archaeological unit	Unmodified								Stone tools											
	Cobbles		Nodules		Pebbles				Flaked/ battered						Debitage					
	Lava		Chert		Lava		Metamorphic		Lava		Metamorphic		Chert		Lava		Metamorphic		Chert	
	n	weight	n	weight	n	weight	n	weight	n	weight	n	weight	n	weight	n	weight	n	weight	n	weight
MNKSL6	1	206.4			2	0.8	38	37.6	2	647.9					3	0.9	248	99.1		
MNKSL10	48	12321.5	13	702.1	77	3075.7	47	142.9	77	23844.3	31	4491.9	12	401.3	70	1343	1090	2309.7	20	104.7
MNKSL12	3	752.7	4	188	1	56.8			6	1996.9	2	764.1			1	89.5	12	381.9	1	0.1
MNKSL14							1	0.1	7	2792.4	6	1030.1	4	423.1			53	321.7	2	155.5
Total T3	52	13280.6	17	890.1	80	3133.3	86	180.6	92	29281.5	39	6286.1	16	824.4	74	1434	1403	3112.4	23	260.3
T36L30	15	4033.3			2	211.6			7	2217.1	5	1911.4			2	110.9	7	194.8		
Total*	67	17313.9	17	890.1	82	3344.9	86	180.6	99	31499	44	8197.5	16	824.4	76	1545	1410	3307.2	23	260.3

*1.7 kg of raw materials classified as "others" is not considered.

Table 9. Frequency and weight of technological categories per raw material in the whole MNK Skull assemblage.

	Phonolite		T-Ta		Basalt		Quartzite		Gneiss		Chert		Others		Total	
	n	g	n	g	n	g	n	g	n	g	n	g	n	g	n	g
Detached																
Flake	14	497.2	5	95.7	4	188.9	74	1730.5			9	107.2	1	12.5	107	2632
Flake frag	12	101.2	8	193.3	7	25.8	133	819.5			6	7.6	1	2	167	1149.4
Shatter <20 mm	6	4.1			9	4	1166	538.7				0.2			1185	547
Shatter >20 mm	5	52.7	1	3.5	5	378.1	35	204			4	145.3			50	783.6
Total detached	37	655.2	14	292.5	25	596.8	1408	3292.7			23	260.3	2	14.5	1509	5112
Flaked																
Core	17	5948	18	6914.7	14	6242.8	29	6764.8	2	567.3	10	738.1	2	374.8	92	27550.5
Core fragment							1	7.5							1	7.5
Retouched tool	3	157.2	2	37.7			9	128.6			6	86.3	1	25.4	21	435.2
Split cobble	1	112.1	4	1061.8	1	191.6							2	210.4	8	1575.9
Total flaked	21	6217.3	24	8014.2	15	6434.4	39	6900.9	2	567.3	16	824.4	5	610.6	122	29569.1
Pounded																
Pitted stone			1	555.3	2	436.2							1	448.9	4	1440.4
Hamm. Fract. Ang.			1	399.8											1	399.8
Knapping hamm.	7	1856.5	11	3474	11	2524.2			1	616.5			2	609.6	32	9080.8
Hamm. Frag.	2		2	385.6											4	610.3
Total pounded	7	1856.5	15	4814.7	15	3185.1			1	616.5			3	1058.5	41	11531.3
Total	65	8729	53	13121.4	55	10216.3	1447	10193.6	3	1183.8	39	1084.7	10	1683.6	1672	46212.4
Detached																
Flake	21.5	5.7	9.4	0.7	7.3	1.8	5.1	17.0	0.0	0.0	23.1	9.9	10.0	0.7	6.4	5.7
Flake frag	18.5	1.2	15.1	1.5	12.7	0.3	9.2	8.0	0.0	0.0	15.4	0.7	10.0	0.1	10.0	2.5
Shatter <20 mm	9.2	0.0	0.0	0.0	16.4	0.0	80.6	5.3	0.0	0.0	10.3	0.0	0.0	0.0	70.9	1.2
Shatter >20 mm	7.7	0.6	1.9	0.0	9.1	3.7	2.4	2.0	0.0	0.0	10.3	13.4	0.0	0.0	3.0	1.7
Total detached	56.9	7.5	26.4	2.2	45.5	5.8	97.3	32.3	0.0	0.0	59.0	24.0	20.0	0.9	90.3	11.1
Flaked																
Core	26.2	68.1	34.0	52.7	25.5	61.1	2.0	66.4	66.7	47.9	25.6	68.0	20.0	22.3	5.5	59.6
Core fragment	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
Retouched tool	4.6	1.8	3.8	0.3	0.0	0.0	0.6	1.3	0.0	0.0	15.4	8.0	10.0	1.5	1.3	0.9
Split cobble	1.5	1.3	7.5	8.1	1.8	1.9	0.0	0.0	0.0	0.0	0.0	0.0	20.0	12.5	0.5	3.4
Total flaked	32.3	71.2	45.3	61.1	27.3	63.0	2.7	67.7	66.7	47.9	41.0	76.0	50.0	36.3	7.3	64.0
Pounded																
Pitted stone	0.0	0.0	1.9	4.2	3.6	4.3	0.0	0.0	0.0	0.0	0.0	0.0	10.0	26.7	0.2	3.1
Hamm. Fract. Ang.	0.0	0.0	1.9	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.9
Knapping hamm.	10.8	21.3	20.8	26.5	20.0	24.7	0.0	0.0	33.3	52.1	0.0	0.0	20.0	36.2	1.9	19.7
Hamm. Frag.	0.0	0.0	3.8	2.9	3.6	2.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	1.3
Total pounded	10.8	21.3	28.3	36.7	27.3	31.2	0.0	0.0	33.3	52.1	0.0	0.0	30.0	62.9	2.5	25.0
Total	3.9	18.9		28.4	3.3	22.1	86.5	22.1	0.2	2.6	2.3	2.3	0.6	3.6	100.0	100.0

Table 10. Dimensions of main technological categories per raw material.

		Lava						Metamorphic						Chert			All raw materials		
		Mean	Max	Min	Std Dev	Mean	Max	Min	Std Dev	Mean	Max	Min	Std Dev	Mean	Max	Min	Std Dev		
Flake	Length	42.3	78	15	17.6	37.0	80	15	13.7	41.7	62	22	12.2	38.5	80	15	14.6		
	Width	33.1	59	11	14.2	26.9	68	11	11.1	32.1	50	18	9.5	28.7	68	11	12.0		
	Thickness	13.5	35	2	7.0	13.9	38	5	6.5	11.2	25	7	5.4	13.6	38	2	6.5		
	Weight	34.0	209	0.9	46.2	23.4	190.2	1.2	29.6	11.9	33.2	2	9.1	24.7	209	0.9	33.1		
Core	Length	79.0	100	47	14.0	63.5	104	34	21.9	51.9	72	31	13.2	70.6	104	31	19.5		
	Width	65.6	94	35	13.0	52.5	96	25	18.7	41.3	70	23	14.8	58.4	96	23	17.5		
	Thickness	53.4	85	22	13.7	38.8	69	19	14.0	30.5	49	17	10.3	45.8	85	17	15.9		
	Weight	389.9	873.6	58.2	192.0	236.5	844.9	23.5	225.2	73.8	186.4	6.3	60.8	302.0	873.6	6.3	221.3		
Retouched tool	Length	51.4	62	31	13.5	32.6	51	20	9.3	41.7	45	36	3.3	40.0	62	20	11.8		
	Width	33.8	46	20	11.1	23.0	35	16	7.3	35.2	42	25	5.9	29.4	46	16	9.6		
	Thickness	18.2	22	11	4.3	12.7	18	7	3.7	14.5	19	11	2.9	14.6	22	7	4.1		
	Weight	39.0	54.4	14.2	18.8	14.3	47.5	4.4	14.3	14.4	30.9	6.5	8.5	20.5	54.4	4.4	17.3		
Split Cobble	Length	79.2	137	48	31.4									79.2	137	48	31.4		
	Width	51.7	78	41	14.7									51.7	78	41	14.7		
	Thickness	40.5	50	33	6.1									40.5	50	33	6.1		
	Weight	227.6	617	65.9	200.0									227.6	617	65.9	200.0		
Pitted stone	Length	78.0	90	70	10.6									78.0	90	70	10.6		
	Width	65.7	75	58	8.6									65.7	75	58	8.6		
	Thickness	39.7	47	35	6.4									39.7	47	35	6.4		
	Weight	330.5	555.3	198.3	195.7									330.5	555.3	198.3	195.7		
Knapping hamm.	Length	73.6	100	48	13.5	104.0	104	104						74.4	104	48	14.2		
	Width	60.6	84	39	10.4	81.0	81	81						60.9	84	39	11.2		
	Thickness	46.9	71	27	11.2	60.0	60	60						47.2	71	27	11.9		
	Weight	290.4	499.1	82.1	128.2	616.5	616.5	616.5						302.2	616.5	82.1	147.3		

Length, width and thickness in mm, weight in g.

Table 11. Attributes of flakes in the MNK Skull assemblage.

		Raw material						Stratigraphic position			
		Lava		Metamorphic		Chert		MNKSL10		Whole assemblage	
		n	%	n	%	n	%	n	%	n	%
Length classes*	<20 mm	2	8.7	7	9.3		0.0	9	10.0	9	8.4
	20-39 mm	9	39.1	36	48.0	3	33.3	42	46.7	48	44.9
	40-59 mm	8	34.8	29	38.7	5	55.6	34	37.8	42	39.3
	60-79 mm	4	17.4	2	2.7	1	11.1	5	5.6	7	6.5
	80-99 mm		0.0	1	1.3		0.0		0.0	1	0.9
	Total	23	21.5	75	70.1	9	8.4	90	84.1	107	100.0
Striking platform preparation	Non-faceted	7	35.0	17	25.0	2	25.0	22	26.5	26	27.1
	Unifaceted	11	55.0	48	70.6	5	62.5	55	66.3	64	66.7
	Bifaceted	2	10.0	3	4.4	1	12.5	6	7.2	6	6.3
	Total	20	20.8	68	70.8	8	8.3	83	86.5	96	100.0
Cortex dorsal side	Cortical	3	13.6	2	2.7	2	25.0	6	6.8	7	6.7
	Cortex >50%	8	36.4	6	8.0	2	25.0	13	14.8	16	15.2
	Cortex <50%	7	31.8	30	40.0	3	37.5	29	33.0	40	38.1
	Non-cortical	4	18.2	37	49.3	1	12.5	40	45.5	42	40.0
	Total	22	21.0	75	71.4	8	7.6	88	83.8	105	100.0
Toth's flakes	I		0.0	1	1.4	1	12.5	1	1.2	2	1.9
	II	7	33.3	10	13.5	1	12.5	16	18.6	18	17.5
	III	1	4.8	7	9.5		0.0	7	8.1	8	7.8
	IV	2	9.5		0.0	1	12.5	3	3.5	3	2.9
	V	8	38.1	25	33.8	4	50.0	26	30.2	37	35.9
	VI	3	14.3	31	41.9	1	12.5	33	38.4	35	34.0
	Total	21	20.4	74	71.8	8	7.8	86	83.5	103	100.0
Flake types	Bipolar	5	21.7	26	34.7	1	11.1	27	30.0	32	29.9
	Regular flake	18	78.3	49	65.3	8	88.9	63	70.0	75	70.1
	Total	23	21.5	75	70.1	9	8.4	90	84.1	107	100.0

* Counts per raw material have one less core than total recounts.

Table 12. Attributes of cores in the MNK Skull assemblage.

		Raw material*								Stratigraphic position			
		Lava		Metamorphic		Chert		MNKSL 10		Whole assemblage			
		n	%	n	%	n	%	n	%	n	%	n	%
Length class*	20-39 mm		0.0	3	9.4	2	20.0	4	6.1	5	5.4		
	40-59 mm	5	10.2	14	43.8	5	50.0	20	30.3	24	26.1		
	60-79 mm	19	38.8	6	18.8	3	30.0	19	28.8	29	31.5		
	80-99 mm	23	46.9	5	15.6		0.0	20	30.3	28	30.4		
	>100 mm	2	4.1	4	12.5		0.0	3	4.5	6	6.5		
	Total	49	53.8	32	35.2	10	11.0	66	71.7	92	100.0		
Weight class	<50 g		0.0	4	12.5	4	40.0	5	7.6	8	8.7		
	50-100 g	2	4.1	11	34.4	3	30.0	15	22.7	16	17.4		
	101-200 g	5	10.2	5	15.6	3	30.0	8	12.1	13	14.1		
	201-400 g	21	42.9	6	18.8		0.0	17	25.8	28	30.4		
	401-800 g	20	40.8	5	15.6		0.0	21	31.8	25	27.2		
	>800 g	1	2.0	1	3.1		0.0		0.0	2	2.2		
	Total	49	53.8	32	35.2	10	11.0	66	71.7	92	100.0		
Cortex	Cortex >50%	39	81.3	12	37.5	4	40.0	41	62.1	56	61.5		
	Cortex <50%	9	18.8	17	53.1	6	60.0	23	34.8	32	35.2		
	Non-cortical		0.0	3	9.4		0.0	2	3.0	3	3.3		
	Total	48	52.7	32	35.2	10	11.0	66	72.5	91	100.0		
Blank	Cobble	44	89.8	6	25.0		0.0	38	63.3	51	60.7		
	Block		0.0	13	54.2		0.0	7	11.7	13	15.5		
	Nodule		0.0		0.0	6	60.0	4	6.7	6	7.1		
	Fragment	2	4.1	2	8.3	4	40.0	6	10.0	8	9.5		
	Split Cobble	3	6.1	1	4.2		0.0	4	6.7	4	4.8		
	Flake		0.0	2	8.3		0.0	1	1.7	2	2.4		
	Total	49	53.8	24	26.4	10	11.0	60	71.4	84	100.0		
Battering	Esquillees	4	8.5	8	29.6		0.0	8	12.7	12	14.1		
	Impacts	20	42.6	7	25.9		0.0	22	34.9	27	31.8		
	Percus. fractures	2	4.3		0.0		0.0	2	3.2	2	2.4		
	Absent	21	44.7	12	44.4	10	100.0	31	49.2	44	51.8		
	Total	47	51.6	27	29.7	10	11.0	63	74.1	85	100.0		
Number of scars	1-3 scars	26	55.3	10	37.0	2	20.0	28	44.4	38	44.7		
	4-6 scars	14	29.8	12	44.4	4	40.0	24	38.1	31	36.5		
	7-9 scars	5	10.6	5	18.5	2	20.0	8	12.7	12	14.1		
	> 9 scars	2	4.3		0.0	2	20.0	3	4.8	4	4.7		
	Total	47	51.6	27	29.7	10	11.0	63	74.1	85	100.0		

*Counts per raw material have one less core than total recounts.

Table 13. Flaking schemes of MNK Skull cores by raw material, blank and assemblage, following types defined by de la Torre and Mora (2018).

	Raw material			Core blank						Stratigraphic position	
	Lava	Metamorphic	Chert	Block	Cobble	Flake	Split cobble	Fragment	Nodule	MNKL10	Entire assemblage
Absolute frequency											
TC	5	1	1	1	5				1	4	7
USP	7	2		2	6		1			8	9
BSP	5	5		2	7					6	10
UAU1	10	1	1		7		2	3		9	12
BAP	3	1	1		4				1	5	5
BALP	6	6	3	1	7	1	1	4	1	12	16
BALT	1	1			2					1	2
BP		1	2		1			1	1	1	3
MLT	5	2	2	2	5				2	8	9
BIPO	5	12		5	5	1				11	17
Total	47	32	10	13	49	2	4	8	6	65	90
Relative frequency											
TC	10.6	3.1	10.0	7.7	10.2	0.0	0.0	0.0	16.7	6.2	7.8
USP	14.9	6.3	0.0	15.4	12.2	0.0	25.0	0.0	0.0	12.3	10.0
BSP	10.6	15.6	0.0	15.4	14.3	0.0	0.0	0.0	0.0	9.2	11.1
UAU1	21.3	3.1	10.0	0.0	14.3	0.0	50.0	37.5	0.0	13.8	13.3
BAP	6.4	3.1	10.0	0.0	8.2	0.0	0.0	0.0	16.7	7.7	5.6
BALP	12.8	18.8	30.0	7.7	14.3	50.0	25.0	50.0	16.7	18.5	17.8
BALT	2.1	3.1	0.0	0.0	4.1	0.0	0.0	0.0	0.0	1.5	2.2
BP	0.0	3.1	20.0	0.0	2.0	0.0	0.0	12.5	16.7	1.5	3.3
MLT	10.6	6.3	20.0	15.4	10.2	0.0	0.0	0.0	33.3	12.3	10.0
BIPO	10.6	37.5	0.0	38.5	10.2	50.0	0.0	0.0	0.0	16.9	18.9
Total	52.8	36.0	11.2	15.9	59.8	2.4	4.9	9.8	7.3	72.2	100.0

Abbreviations. TC: Test core. USP: Unifacial simple partial exploitation. BSP: Bifacial simple partial exploitation. UAU1: Unidirectional abrupt unifacial exploitation on one knapping surface. BAP: bifacial abrupt partial exploitation. BALP: bifacial alternating partial exploitation. BALT: bifacial alternating total exploitation. BP: bifacial peripheral. MLT: Multifacial. BIPO: bipolar flaking.

Table 14. Core, debitage and retouched tool ratios in the MNK Skull assemblages, following indices defined by de la Torre and Mora (2018: 268).

		Raw material			Interval	
		Lava	Metamorphic	Chert	MNKS10	Whole assemblage
A.1	Flake: core	0.47	2.34	0.90	1.36	1.16
A.2	Flake & flake frag: core	1.02	6.53	1.50	3.65	2.98
B.1	Flake: core scars	0.12	0.60	0.13	0.32	0.28
B.2	Flake & flake frag: core scars	0.27	1.66	0.22	0.86	0.71
C	Detached pieces cutting edge (cm): Core mass (g)	0.01	0.08	0.52	0.04	0.03
D.1	Ret. tool: detached pieces ≥ 20 mm	0.10	0.06	0.46	0.09	0.09
D.3	Ret. tool: flake ≥ 20 mm	0.24	0.15	0.67	0.23	0.21

FIGURE CAPTIONS

Figure 1. Location of trenches at MNK Skull. Aerial photograph based on imagery produced by Jorayev et al (2016). Bottom left: beginning of the southward extension of Leakey's trench. Bottom right: OGAP-T3 trench after completion of excavations.

Figure 2. Excavation and archaeological materials from T36 (A) and T3 (B). A1) General view of T36. A2) T36 stone tools: 1-Cores 2-Flakes. 3-Flake fragments. 4- Hammerstones. A3) Archaeological unit T36L30 from the top of the trench. A4). Map of findings in T36L30. B1) Spatially-associated unmodified lithic and fossil fragment in MNKSL10. B2) Vertically-positioned chert flake during the excavation of MNKSL10. B3) Tibia fragment that exhibits mechanical rounding and weathering along with a scratch identified as a low-confidence cut mark, which is not tallied in mark counts. B4) Femur fragment with a mammalian carnivore tooth mark.

Figure 3. Plan (A) and backwalls (B-E) of MNK Skull site. A) Vectorised and georeferenced Leakey trench within OGAP's grid and T3 map of findings. B) Georeferenced picture of the east sidewall of T3 with vertical distribution of archaeological units (remains plotted within 1 m from the wall). C) Georeferenced main backwall (south) of T3 with vertical distribution of all remains in each archaeological unit. D-E) Detail of the relative position of archaeological units MNKSL10 and L12 (D), and MNKSL12 and L14 (E).

Figure 4. Measured stratigraphic sections for Bed II across MNK and for nearby sites PEK and VEK. The base of the Tuff IIB interval is taken as horizontal, and sections are "hung" in relation to that level where possible. The MNK sections cover an east to west range of ~164 meters and are plotted in order, but specific distances between sections are not plotted to scale. Specific marker tuffs and beds are highlighted. Dates for tuffs from previous published studies: (1) Díez-Martín et al., 2013, (2) Deino et al., in review, and (3) Deino, 2012.

Figure 5. A). Correlation between Leakey's (1971: 117) stratigraphic column at MNK and lithofacies identified by OGAP. B) Stratigraphic layers in the backwalls of MNK Skull- T3 (E-W) and T36 (N-S), with cross- sections of archaeological units overlapped. The apparent location of some MNKSL10 materials below the Type 1 unconformity is explained by the 'slope effect' (i.e., the projection of x,z coordinates only, which obviates the topographically varying position of artefacts in the y plane). See Table 1 for a description of lithofacies.

Figure 6. Vertical views (A-D) of all archaeological units in MNK Skull-T3 and horizontal density map of unit MNKSL10 (E). A & C) Cross-sections of plotted remains in E-W (A) and N-S (C) directions. Kernel density analysis of E-W (B) and N-S (D) cross sections, and horizontal distribution of MNKSL10 (E) (search radius: 0.5 m).

Figure 7. Relevant proxies for the reconstruction of site formation processes in the MNK Skull main assemblage. A) Angular histograms of compass bearings (OGAP excavations, n=52) and data extracted

from Leakey's (1971) map of findings (n=31). B) Histogram of MNKSL10 lithics < 20 mm, comparing stone tools (broken down by main raw materials: metamorphic, lava and chert) and unmodified items. C) MNKSL10 fabric results (n=52). C1- Stereographic projections. C2- Vollmer fabric triangle. C3- Sneed and Folk fabric triangle. D) Sneed and Folk's shape triangles of MNKSL10 lithics, using length, width and thickness as a, b and c axis.

Figure 8. Distribution maps and refit of archaeological unit MNKSL10 in MNK Skull-T3. A) Refit Set #2, made of two phonolite flake fragments. B) E-W cross section of remains within a 3-m wide area from the north limit of T3. C) Plan view of MNKSL10 with refit line of Set #2. D) Hotspot analysis of the horizontal distribution of remains in MNKSL10, considering count, length and weight for all items* (D1), stone tools (D2), fossils (D3), and unmodified lithics (D4). *Fossils were excluded from the analysis of weight in all items (D1).

Figure 9. Relative frequency (A, C) and weight (B, D) of main raw materials (A, B) and McHenry and de la Torre (2018)'s raw material types (C, D). See details in SOM S7.

Figure 10. Main features of the MNK Skull stone tool assemblage. A-B) Relative frequency (A) and weight (B) of raw materials per technological category. C) Correspondence factor analysis of technological categories and main rock types. D-E) Length (D) and weight (E) of main technological categories per raw material.

Figure 11. Attributes of complete flakes per raw material. A) Mean dimensions (length, width and thickness in mm, weight in grams). B) Length classes. C) Types of striking platforms (NF: non-faceted. UF: unifaceted. BF: bifaceted). D) Cortex on dorsal and striking platforms, following Toth's (1982) types.

Figure 12. Complete flakes (A-F) and retouched pieces (H-J) from MNKSL10. A: basalt. D, E, H, I, and J: quartzite. C and G: phonolite. B and F: chert. See Videoclip #1 for 3D model of retouched piece in Figure 12H, and Videoclip #2 for Figure 12I.

Figure 13. Dimensional and technical attributes of MNK Skull cores per raw material. A) Mean length, width and thickness (in mm) and weight (in grams). B) Scatter plot of core length and width. C-D) Core length (C) and weight (D) classes. E) Cortex coverage. F) Types of core blanks. G) Battering features in cores. H) Number of previous removals.

Figure 14. MNKSL10 cores. A-C) Bifacial alternating partial reduction in phonolite (A), quartzite (B) and chert (C). D) Example of bifacial simple partial exploitation in quartzite [see also Videoclip #3 for examples of BSP reduction]. E) Bifacial abrupt partial scheme in chert core. F) Quartzite bipolar cores.

Figure 15. Freehand flaking techniques per raw materials. A) Relative frequencies. B) Correspondence Factor Analysis. See Table 13 for abbreviations.

Figure 16. The T3- MNK Skull lithic assemblage.

35°20'31"E

35°20'32"E

MAP DATA (AXIAL DATA) (n= 31)

A)

COMPASS DATA (n= 52)

Azimuth data

Axial data

B)

C1)

C2)

C3)

METAMORPHIC UNMODIFIED ROCKS

LAVA UNMODIFIED ROCKS

CHERT UNMODIFIED ROCKS

D)

METAMORPHIC STONE TOOLS

LAVA STONE TOOLS

CHERT STONE TOOLS

a

b

c

d

e

f

g

h

i

j

A)

B)

C)

D)

E)

F)

G)

H)

New excavations in the MNK Skull site, and the last appearance of the Oldowan and *Homo habilis* at Olduvai Gorge, Tanzania

Ignacio de la Torre et al.

The authors declare that there is no conflict of interest

Supplementary Online Material

SOM S1. Roundness of artefact edges in MNKSL10 and in the whole assemblage (all archaeological units in T3 and T36).

	Lava			Metamorphic			Chert		Interval	
	Debitage	Flaked/ battered	Total	Debitage	Flaked/ battered	Total	Debitage	Flaked/ battered	MNKSL10	Whole assemblage
Absolute frequency										
Fresh	56	58	114	203	41	244	15	15	327	388
Slight	3		3	32	2	34			31	37
Medium				1		1			1	1
Severe										
Total	59	58	117	236	43	279	15	15	359	426
Relative frequency										
Fresh	94.9	100.0	97.4	86.0	95.3	87.5	100.0	100.0	91.1	91.1
Slight	5.1	0.0	2.6	13.6	4.7	12.2	0.0	0.0	8.6	8.7
Medium	0.0	0.0	0.0	0.4	0.0	0.4	0.0	0.0	0.3	0.2
Severe	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	13.8	13.6	27.5	55.4	10.1	65.5	3.5	3.5	84.3	100.0

SOM S2. Dimensions and weight of unmodified and main types of stone tools in the whole assemblage.

			Minimum	Maximum	Mean	Std. Deviation
Unmodified		Cobbles (n=66)				
	Length		64	104	77.6	10.9
	Width		37	81	60.5	10.9
	Thickness		23	73	46.2	10.4
	Weight		71.4	562.9	261.8	116.7
		Nodules (n=16)				
	Length		19	142	40.5	29.6
	Width		10	82	30.0	19.0
	Thickness		7	72	21.6	16.2
	Weight		1.2	633.2	55.6	157.9
		Pebbles (n=131)				
	Length		5	63	28.2	17.7
	Width		4	55	21.6	15.0
	Thickness		1	45	15.1	11.5
	Weight		0.1	181.5	26.7	40.0
Stone tools		Flaked/pounded (n=163)				
	Length		16	137	67.1	21.6
	Width		14	96	54.2	18.5
	Thickness		7	85	40.9	17.4
	Weight		2.6	873.6	253.7	209.2
		Debitage (n=1505)				
	Length		1	85	13.7	10.7
	Width		1	82	9.9	8.1
	Thickness		1	38	5.9	4.0
	Weight		0.1	262.4	3.3	13.9

SOM S3. Table 3. Descriptive statistics for lithic items < 20 mm. Units in mm.

DESCRIPTIVE STATISTICS	METAMORPHIC	LAVA	CHERT	UNMODIFIED
Mean	10.13	14.08	14.29	12.82
Error	0.11	0.57	1.58	0.50
Median	10.00	14.00	16.00	13.00
Mode	8.00	16.00	17.00	16.00
Standard deviation	3.56	3.47	4.19	3.91
Variance	12.66	12.02	17.57	15.25
Kurtosis	0.07	-0.54	-0.04	-1.01
Skewness	0.51	-0.43	-0.87	-0.33
Range	18	12	12	14
Minimum	1	7	7	5
Maximum	19	19	19	19
Suma	9975	521	100	782
Count	985	37	7	61
Highest (1)	19	19	19	19
Lowest (1)	1	7	7	5
Confidence level (95.0%)	0.22	1.16	3.88	1.00

SOM S4. Relative frequencies of Sneed and Folk's shape classes for unmodified materials and stone tools in MNKSL10.

SOM S5. Statistical tests of artefact and fossil orientations in the MNK Skull assemblage.

	MNKSL10		Leakey's excavation		
Variable			D	MBR	PMA
Data Type	Azimuth	Axial	Axial	Axial	Axial
Sample size	52	52	31	31	31
Mean Vector (μ°)	7.23	106.07	11.87	175.61	20.43
Rayleigh Test (Z)	2.929	0.19	1.514	0.275	0.895
Rayleigh Test (p)	0.05	0.83	0.221	0.762	0.412
Kuiper's Test (Uniform, V)	1.787	1.214	1.447	1.102	1.333
Kuiper's Test (p)	< 0.05	> 0.15	> 0.15	> 0.15	> 0.15

MNKSL10: OGAP compass bearings. Leakey's excavation: data calculated from Leakey's (1971) map of findings, following methods by Benito-Calvo and de la Torre (2011).

SOM S6. Fabric indices calculated following methods by Woodcock (1977), Vollmer (1989) and Benn (1994).

Woodcock's indices	Value
K ratio	0.228
C ratio	0.656
Vollmer's indices	
Cluster	0.048
Girdle	0.305
Uniform	0.648
Benn's indices	
Isotropy index	0.159
Elongation index	0.248
Flatness index	0.211

SOM S7. Frequency and total weight of rock types present in the MNK Skull assemblage, according to the raw material groups defined by McHenry and de la Torre (2018).

Rock type	Unmodified		Stone tool		Unmodified		Stone tool		Total		Total	
	n	%	n	%	g	%	g	%	n	%	g	%
Phonolite	20	7.9	65	3.9	2991	13.8	8729	18.9	85	4.4	11720	17.2
1.1	9	3.6	26	1.6	1649.6	7.6	4442.4	9.6	35	1.8	6092	9.0
1.2	5	2.0	15	0.9	975.7	4.5	1198.9	2.6	20	1.0	2174.6	3.2
1.3	2	0.8	3	0.2	61.1	0.3	734.7	1.6	5	0.3	795.8	1.2
1.5		0.0	3	0.2		0.0	16.7	0.0	3	0.2	16.7	0.0
1.6	2	0.8	5	0.3	282	1.3	64.4	0.1	7	0.4	346.4	0.5
1.7		0.0	1	0.1		0.0	255.9	0.6	1	0.1	255.9	0.4
1.8		0.0	3	0.2		0.0	1550	3.4	3	0.2	1550	2.3
1.10	1	0.4	3	0.2	21.7	0.1	461.9	1.0	4	0.2	483.6	0.7
Non-classified	1	0.4	6	0.4	0.9	0.0	4.1	0.0	7	0.4	5	0.0
Trachyte	25	9.9	53	3.2	3916.5	18.0	13121.4	28.4	78	4.1	17037.9	25.1
2.1	4	1.6	9	0.5	322.9	1.5	1806.6	3.9	13	0.7	2129.5	3.1
2.2		0.0	3	0.2		0.0	746.7	1.6	3	0.2	746.7	1.1
2.3	8	3.2	6	0.4	855.6	3.9	770.5	1.7	14	0.7	1626.1	2.4
2.4	7	2.8	20	1.2	1612.8	7.4	5644.5	12.2	27	1.4	7257.3	10.7
2.6	3	1.2	4	0.2	638.7	2.9	1549.2	3.4	7	0.4	2187.9	3.2
2.7	3	1.2	11	0.7	486.5	2.2	2603.9	5.6	14	0.7	3090.4	4.5
Basalt	83	32.8	55	3.3	12393.6	57.0	10216.3	22.1	138	7.2	22609.9	33.3
3.2	13	5.1	13	0.8	1539.5	7.1	2737.1	5.9	26	1.4	4276.6	6.3
3.2.1	3	1.2		0.0	599.2	2.8		0.0	3	0.2	599.2	0.9
3.7a	1	0.4		0.0	202	0.9		0.0	1	0.1	202	0.3
3.7b	1	0.4	1	0.1	272.5	1.3	714.6	1.5	2	0.1	987.1	1.5
3.7.1a	5	2.0		0.0	1231.5	5.7		0.0	5	0.3	1231.5	1.8
3.7.1b	2	0.8		0.0	134.8	0.6		0.0	2	0.1	134.8	0.2
3.7.2	3	1.2		0.0	784.4	3.6		0.0	3	0.2	784.4	1.2
3.9	5	2.0	11	0.7	804.9	3.7	2652.9	5.7	16	0.8	3457.8	5.1
3.9.1	6	2.4	6	0.4	657.8	3.0	432.7	0.9	12	0.6	1090.5	1.6
3.10	10	4.0	6	0.4	897.3	4.1	1561.3	3.4	16	0.8	2458.6	3.6
3.10.1	28	11.1	7	0.4	5260.8	24.2	2110.1	4.6	35	1.8	7370.9	10.8
Non-classified	6	2.4	11	0.7	8.9	0.0	7.6	0.0	17	0.9	16.5	0.0
Chert	18	7.1	39	2.3	890.8	4.1	1084.7	2.3	57	3.0	1975.5	2.9
6.1	2	0.8	8	0.5	183.7	0.8	582.5	1.3	10	0.5	766.2	1.1
6.2	6	2.4	28	1.7	651.1	3.0	352.3	0.8	34	1.8	1003.4	1.5
6.3	9	3.6	2	0.1	55.3	0.3	9.7	0.0	11	0.6	65	0.1
Non-classified	1	0.4	1	0.1	0.7	0.0	140.2	0.3	2	0.1	140.9	0.2
Quartzite	71	28.1	1447	86.5	172.1	0.8	10193.6	22.1	1518	78.9	10365.7	15.3
7.1	14	5.5	242	14.5	108.3	0.5	4601.3	10.0	256	13.3	4709.6	6.9
7.1.1	1	0.4	17	1.0	8.1	0.0	1732.8	3.7	18	0.9	1740.9	2.6
7.1.3		0.0	1	0.1		0.0	11.7	0.0	1	0.1	11.7	0.0
7.2		0.0	10	0.6		0.0	2218	4.8	10	0.5	2218	3.3
7.3		0.0	2	0.1		0.0	764.1	1.7	2	0.1	764.1	1.1
7.5		0.0	4	0.2		0.0	273.9	0.6	4	0.2	273.9	0.4
7.6		0.0	5	0.3		0.0	29.8	0.1	5	0.3	29.8	0.0
Non-classified	56	22.1	1166	69.7	55.7	0.3	562	1.2	1222	63.5	617.7	0.9
Quartz		0.0	1	0.1		0.0	2	0.0	1	0.1	2	0.0
8.1		0.0	1	0.1		0.0	2	0.0	1	0.1	2	0.0
Feldspar	15	5.9	2	0.1	8.5	0.0	37.9	0.1	17	0.9	46.4	0.1
9.1	1	0.4	2	0.1	2.9	0.0	37.9	0.1	3	0.2	40.8	0.1
Non-classified	14	5.5		0.0	5.6	0.0		0.0	14	0.7	5.6	0.0
Pegmatite		0.0	1	0.1		0.0	87.4	0.2	1	0.1	87.4	0.1
10.1		0.0	1	0.1		0.0	87.4	0.2	1	0.1	87.4	0.1
Gneiss		0.0	3	0.2		0.0	1183.8	2.6	3	0.2	1183.8	1.7
11.1		0.0	1	0.1		0.0	616.5	1.3	1	0.1	616.5	0.9
11.2		0.0	1	0.1		0.0	145.9	0.3	1	0.1	145.9	0.2
11.3		0.0	1	0.1		0.0	421.4	0.9	1	0.1	421.4	0.6
Others	21	8.3	6	0.4	1357.7	6.2	1556.3	3.4	27	1.4	2914	4.3
				0.0		0.0		0.0		0.0		0.0
Total	253	13.1	1672	86.9	21730.2	32.0	46212.4	68.0	1925	100.0	67942.6	100.0

SOM S8. Length (mm) and weight (g) classes of MNK Skull core flaking schemes (see Table 12 for abbreviations).

	Length class (mm)					Weight class (g)						Total
Absolute frequency	20-39	40-59	60-79	80-99	>100	<50	50-100	101-200	201-400	401-800	>800	
TC		1	3	2	1		1		4	2		7
USP		2	2	4	1		2	1	2	4		9
BSP		2	3	2	3		2	2	3	2	1	10
UAU1	1	2	2	7		1	2	1	1	6	1	12
BAP	1		2	2		1			2	2		5
BALP	1	5	7	3		3	3	2	7	1		16
BALT		1		1				1		1		2
BP	1		1	1		1		1	1			3
MLT		1	4	3	1			2	2	5		9
BIPO	1	10	4	2		2	6	3	5	1		17
Total	5	24	28	27	6	8	16	13	27	24	2	90
Relative frequency												
TC	0.0	4.2	10.7	7.4	16.7	0.0	6.3	0.0	14.8	8.3	0.0	7.8
USP	0.0	8.3	7.1	14.8	16.7	0.0	12.5	7.7	7.4	16.7	0.0	10.0
BSP	0.0	8.3	10.7	7.4	50.0	0.0	12.5	15.4	11.1	8.3	50.0	11.1
UAU1	20.0	8.3	7.1	25.9	0.0	12.5	12.5	7.7	3.7	25.0	50.0	13.3
BAP	20.0	0.0	7.1	7.4	0.0	12.5	0.0	0.0	7.4	8.3	0.0	5.6
BALP	20.0	20.8	25.0	11.1	0.0	37.5	18.8	15.4	25.9	4.2	0.0	17.8
BALT	0.0	4.2	0.0	3.7	0.0	0.0	0.0	7.7	0.0	4.2	0.0	2.2
BP	20.0	0.0	3.6	3.7	0.0	12.5	0.0	7.7	3.7	0.0	0.0	3.3
MLT	0.0	4.2	14.3	11.1	16.7	0.0	0.0	15.4	7.4	20.8	0.0	10.0
BIPO	20.0	41.7	14.3	7.4	0.0	25.0	37.5	23.1	18.5	4.2	0.0	18.9
Total	5.6	26.7	31.1	30.0	6.7	8.9	17.8	14.4	30.0	26.7	2.2	100.0

SOM S9. Tectonic cracks in T3- MNK Skull site.

1: vertical view of tectonic cracks in the east wall. 2: sand-infilled tectonic crack during the excavation of archaeological unit MNKSL10. 3: MNKSL10 lithics.

SOM S10. Unmodified cobbles (1) and pebbles (2) from MNKSL10.

SOM S11. Raw material groups in MNK Skull, based on rock types defined by McHenry and de la Torre (2018).

SOM S12. Main faults in the central part of Olduvai Gorge. Map based on Jorayev et al. (2016) and position of faults after Hay (1976).