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A reconstruction of the paleolandscape during the earliest Acheulian of FLK West: The co-existence of Oldowan and Acheulian industries during lowermost Bed II (Olduvai Gorge, Tanzania)

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ABSTRACT

Based on detailed stratigraphic correlation and framework studies for FLK-W, in lowermost Bed II and containing the oldest Acheulian artifacts (dated to 1.7 Ma) in Olduvai Gorge, it is possible to document significant changes in the paleolandscape. This study uses outcrops up to 1.6 km from the FLK-W locality to aid in the understanding of the environmental setting available to Acheulian tool-makers. The reconstruction of the FLK-W isochronal paleosurface also provides a means to correlate FLK-W with other contemporary sites found at other lowermost Bed II localities. These sites, such as HWK, HWK-E and HWK-EE are associated with Oldowan artifact assemblages. The reconstruction of the sedimentary environment and geomorphology of the paleosurface indicates these sites are all part of the same fluvial system, although located at different sections along its course. The Oldowan levels are found in a set of small, shallow braided channels. The Acheulian artifacts are associated with a deeper, wider channel formed by the merging of several channels within the drainage network. Based on this analysis, water may have been more readily available at FLK-W and there might have also been a thicker vegetation cover when compared to the Oldowan localities. The sedimentologic and geomorphic contexts appear to help explain the typological/technological variability observed within this section of Bed II.

1. Introduction

The origin of the Acheulean complex is one of the key moments in human evolution. In order to solve numerous anthropological, environmental and functional problems, few archaeological sites provide evidence for this research: Kokiselei in Kenya (Beyene et al., 2013; Lepre et al., 2011), Konso in Ethiopia (Asfaw et al., 1992), Gona (Quade et al., 2004) and Olduvai Gorge in Tanzania (Diez-Martín et al., 2015). Although the industry's appearance is associated with or postdating the emergence of *Homo erectus* and *Homo ergaster*, the co-occurrence of Acheulean and Oldowan industries in the same landscape is certainly possible (Beyene et al., 2013), which could imply a differentiation in ecological niches or landscape occupation distribution (Díez-Martín and Eren, 2012). Stone tool use, including meat and plant processing (Clark, 1975; Jones, 1980; Keeley, 1980; Schick and Toth, 1993; Jones, 1994; Domínguez-Rodrigo, 2001; Schick and Toth, 2001) among other possible uses, has not been precisely studied and contrasted since only FLK-W site contains fauna in association with the oldest Acheulean (~1.7 Ma; Diez-Martín et al., 2015). This is the main reason landscape reconstruction is of key importance to archaeological studies concerning environmental dependence and Acheulean and Oldowan coexistence in the same landscape.

Geology offers valuable information when reconstructing paleolandscapes about human interaction with natural resources, such as the extraction of primary lithic materials and water. Open-air Paleolithic archaeology can receive helpful and vital information from geological research (Butzer, 1982; Herz and Garrison, 2004; Goldberg and McPhail, 2008; Rapp and Hill, 2006), such as extensive landscape reconstructions and isochronal paleosurfaces. This becomes more interesting and impactful when different archaeological populations occupy specific ecological niches and/or make use of diverse lithic tool.

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Site reconstructions must contemplate two fundamental aspects: detailed stratigraphic contextualization and paleosurface geometry delineation (Uribelarrea et al., 2014). This not only allows documentation of depositional environments and the distribution of natural resources, but also serves as an aid for detailed paleoenvironmental sampling, since precision is key to sample exact levels deposited during site formation. Taking all this into account, Olduvai Gorge is without a doubt an exceptional research area (Fig. 1), since it hosts an extensive variety of depositional environments (alluvial, fluvial, lacustrine and volcanic) coexisting throughout 2 million years of human evolution, studied throughout abundant and extraordinarily preserved archaeological sites.

Since Olduvai Gorge hosts such a significant sedimentary and fossil record, it was thought that Bed II (1.8–1.3 Ma) should contain the earliest Oldowan/Developed Oldowan to Acheulean sequence. This sequence is thought to be earlier than classic sites discovered by Leakey (1971), in accordance with the new chronological framework for the earliest Acheulean discovered in the cited sites of Kenya and Ethiopia. FLK-W site was discovered by TOPPP (The Olduvai Paleoanthropology and Paleoecology Project) in 2012 after years of geological research driven by this belief. Traditionally, the oldest Acheulean found at the gorge was thought to be above Tuff II-B (Hay, 1976). Geological research and archaeological survey was carried out therefore between Tuff I-F (1.8 Ma) and Tuff II-B throughout extensive areas with archaeological potential, such as the geological blocks delimited by the FLK fault and the third fault. The discovery of the site not only had a great impact on the knowledge of the origin of the Acheulean, but also presented a fluvial depositional environment in a lacustrine dominated environment and posed some stratigraphical concerns being so close to Tuff 1-F (1.8 Ma).

This study focuses on three objectives: 1) FLK-W paleolandscape stratigraphic reconstruction (lowermost Bed II); 2) to distinguish and describe precisely an isochronal paleosurface, correlating FLK-W and other lowermost Bed II deposits, becoming a useful tool for paleoecological (biomarker) sampling and 3) to establish as far as possible the spatial and chronological relationship between lowermost Bed II sites located in the eastern lake-margin described by Hay (1976), such as FC, MNK and HWK.

2. Materials and methods

A stratigraphic analysis was carried out extensively, both spatially and chronologically, studying geological materials from lowermost Bed II covering from Tuff II-A to the Bird Print Tuff (BPT). The stratigraphic analysis consisted of a wide spatial and chronological correlation of the main units of the lowermost Bed-II. Correlation is based on spatial position, facies and lithology during fieldwork. It must be considered the high contrast among the units studied, conglomerates, augitic sands, clays and tuffs). Petrological and sedimentological samples have been obtained for further detailed description of facies, as well as sinsedimentary and postsedimentary processes.

The study has been carried out throughout all lowermost Bed II sites and outcrops accessible from FLK Fault to Long Korongo, including remarkable geolocalities such as Maiko Gully, Leakey's Road, Museum's road (Geolocality 85), Castle (Geolocality 44a), HWK site surroundings (Geolocalities 42a, 42b, 43 and 43a) and Geolocalities 38, 38a and 39 at Long Korongo (Fig. 2). The location of all stratigraphic sections has been represented in an orthophoto and a Digital Elevation Model (DEM) generated with photogrammetry with the use of an unmanned aerial vehicle. Although the outcrops exhibits a very good quality in this part of the gorge, the analysis has been done also along several geotrenches and excavation areas.

3. Results

3.1. FLK-W

FLK-W is located in a fluvial paleochannel embedded in a clay unit, close to the base of Bed II (Fig. 2). The river channel is about 40 m wide with a maximum depth of 1.2 m and is infilled with a sequence of six stratigraphic levels. The lowermost levels (L5 and L6) are the densest and most important in terms of their archaeological contents, since they host Acheulean artifacts (Diez-Martín et al., 2015). Granulometrically, L5 and L6 consist of cobbles, pebbles and gravel, whereas the rest of the levels are sandy (Figs. 3 and 4). Mineralogically, the sediments are mainly augitic, with 50–75% augite and 10–30%

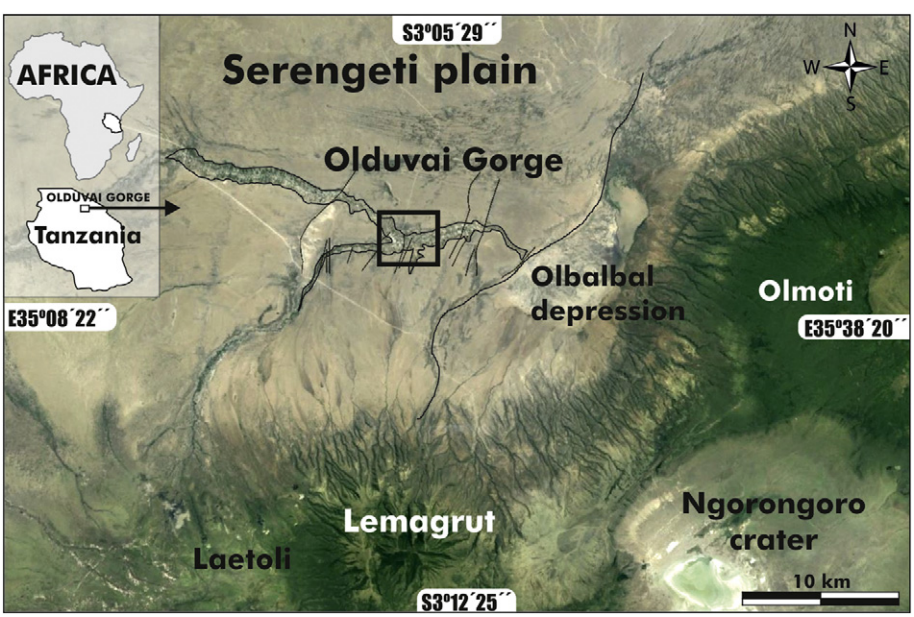

Fig. 1. Olduvai Gorge map, located east from the Serengeti plains with the Ngorongoro Volcanic Highlands towards the east (Tanzania). The area of study, in the junction of the Main Gorge and the Side Gorge, is shown in the black bordered square.

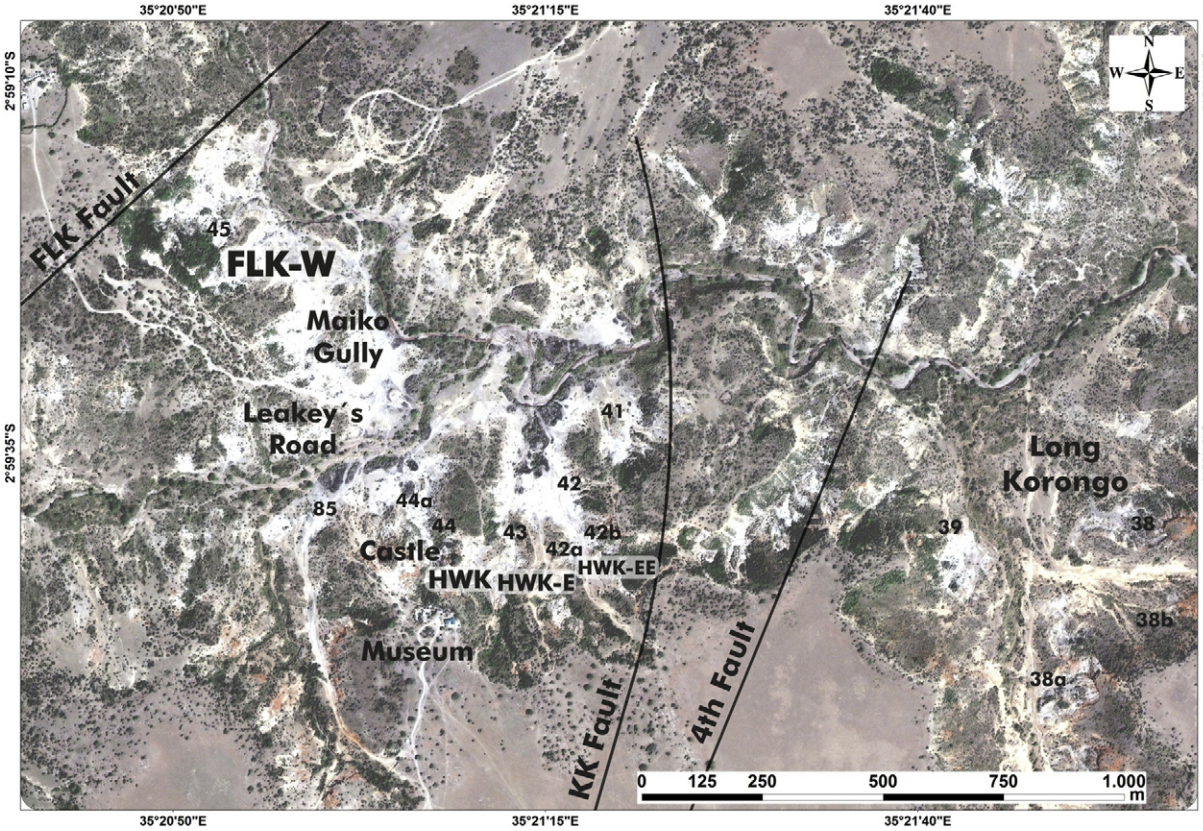

Fig. 2. Area of study, between FLK Fault and Long Korongo. Numbers (geolocalities) have been kept the same as those used by Hay (1976). The image in the background is an orthophoto from Arcgisonline (2016).

volcanic rock fragments, mostly of contemporaneous pyroclastic origin. These two mineral components confer the unit its characteristic dark colour, making it easily distinguishable in the field.

The augitic mineralogical composition of the fluvial deposits of FLK-W could indicate these levels are homologous to one of the augitic units already described by Hay (1976): Lower Augitic Sandstones (LAS), Middle Augitic Sandstones (MAS) and Upper Augitic Sandstones (UAS). An in-depth revision of the work carried out by Hay (1976) and Leakey (1971) showed the Lower Augitic Sandstone unit is deposited over the Lower Disconformity (LD), which erodes Tuff II-A at several places throughout the gorge. Hay (1976) suggested the LD is very close to Tuff I-F in the surroundings of Geolocality 45, and shows a conglomerate in the LAS unit in at least two stratigraphic sections (Figs. 22 and 26 in Hay, 1976). However, this interpretation is contrary to that published by Leakey (1971).

The yellowish tuff immediately above Level 1 at FLK-W (FLK-Wb), dated to 1.66 ± 0.19 Ma (Diez-Martín et al., 2015), is a local tuff which is not represented in Hay's stratigraphic sections. However, the Bird Print Tuff (BPT), appearing 25 cm above FLK-Wb tuff at FLK-W, is shown in the figure cited (Hay, 1976). BPT is described a yellow laminated vitric tuff, 2.5 to 12 cm thick, and contains abundant footprints of shore birds (Hay, 1976), and is always found above LAS.

3.2. FLK-NW

Northwest from FLK-W, next to FLK-Zinj (Fig. 2), lowermost Bed II is represented by various silty units with carbonate nodules and clear signs of bioturbation and aerial exposure. The LAS unit is not well defined at this locality, since it might have suffered a facies change, becoming a lower energy deposit, closely related to overbank sedimentation in a geological context close to paleolake Olduvai, presumably situated in the graben confined by the FLK Fault and the Fifth Fault. The BPT has not been found at this outcrop.

3.3. Maiko Gully

At Maiko Gully, southeast from FLK-W (Fig. 2), lowermost Bed II is comprised of a 2 m clay unit with Tuff II-A in between and the LAS unit above. Throughout the gully, the LAS unit can be found in many outcrops, always at the same absolute height. Within these sandstones, faunal remains and Oldowan lithics can be found. The LAS unit here shows fluvial channels of variable geometrical shapes, up to 1.2 m deep and 4–6 m wide. Imbrication is common and sedimentary structures represent a northwestern flow. There are abundant flow structures, sometimes shadowed by the intensive bioturbation and deformation due to the density contrast between the channels and the silty floodplain. The 1.2 m vertical distance from 1F to the LAS unit is slightly higher than at FLK-W, and the BPT is found 40 cm above the LAS unit (Fig. 4).

3.4. Leakey's Road

In Leakey's Road (Fig. 2), channels very similar to those described at Maiko Gully can be found. These channels have paleocurrents with a north-northwest direction, and are wider and shallower. The central section is narrow and deep, with abundant cross-bedding structures. Towards the top of the unit, the deposit is more tabular, less than 30 cm thick. In this part of the basin it has not been possible to find the outer limits of the channels and the tabular unit is continuous. Horizontal laminations and ripples are predominant, and the top of each channel is heavily cemented with calcium carbonate and bioturbated. Above the LAS unit, Tuff II-B can be easily identified formed by orange sands and clays and the BP tuff can be found above it (Fig. 4).

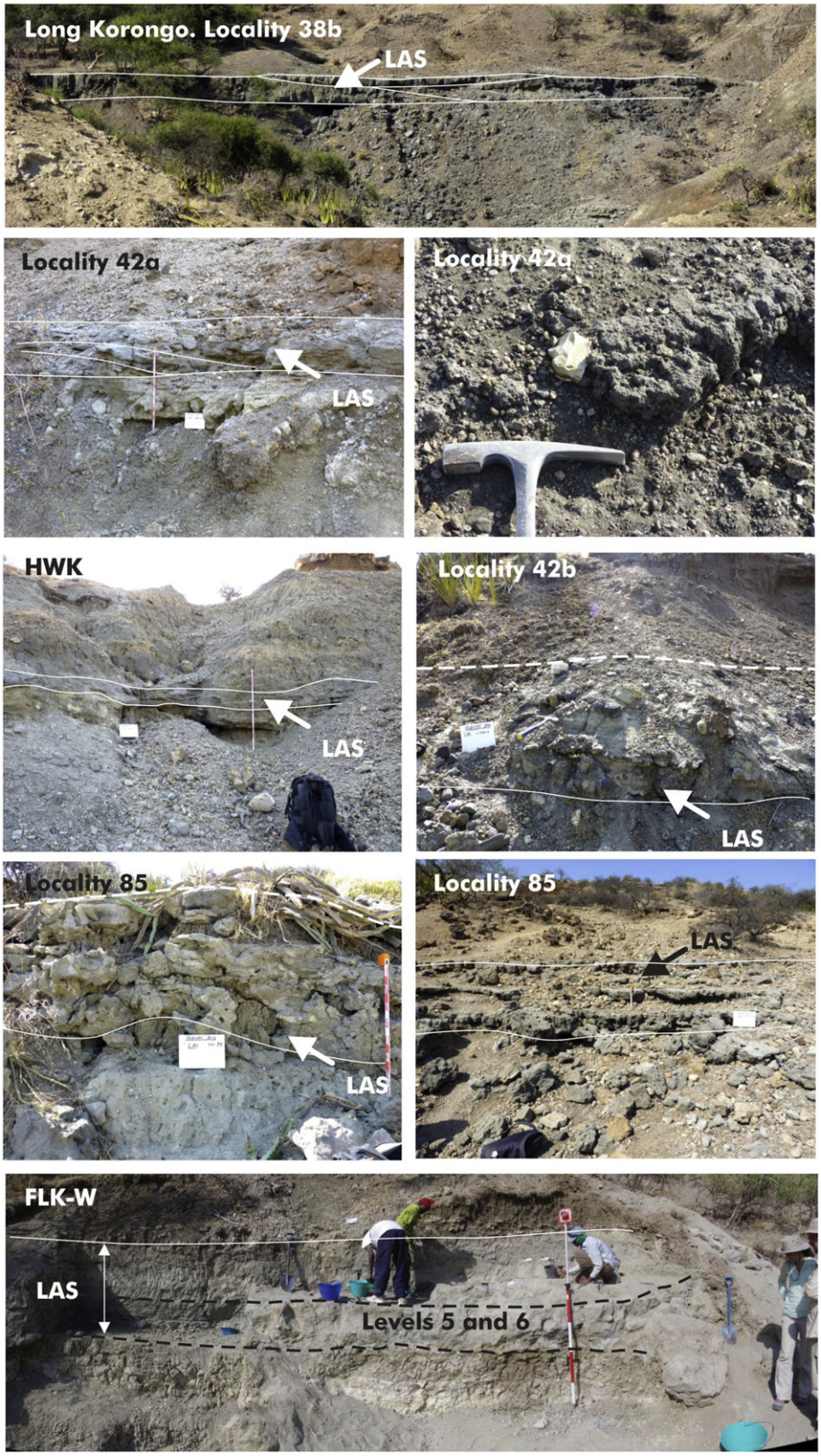

Fig. 3. LAS unit outcrops throughout the studied area.

3.5. Geolocality 85 (Museum's Road, VEK)

Towards the south, Geolocality 85 is the best outcrop to study this unit (Fig. 2). Up to three different channels can be identified, separated one from another by an intermediate clayey silt unit in the outer parts of the channel and in contact at the centermost sections of the channels. The whole set is over 20 m wide and 1.1 m deep (Figs. 3 and 4). The base of each channel is erosive, with many cross-bedding structures,

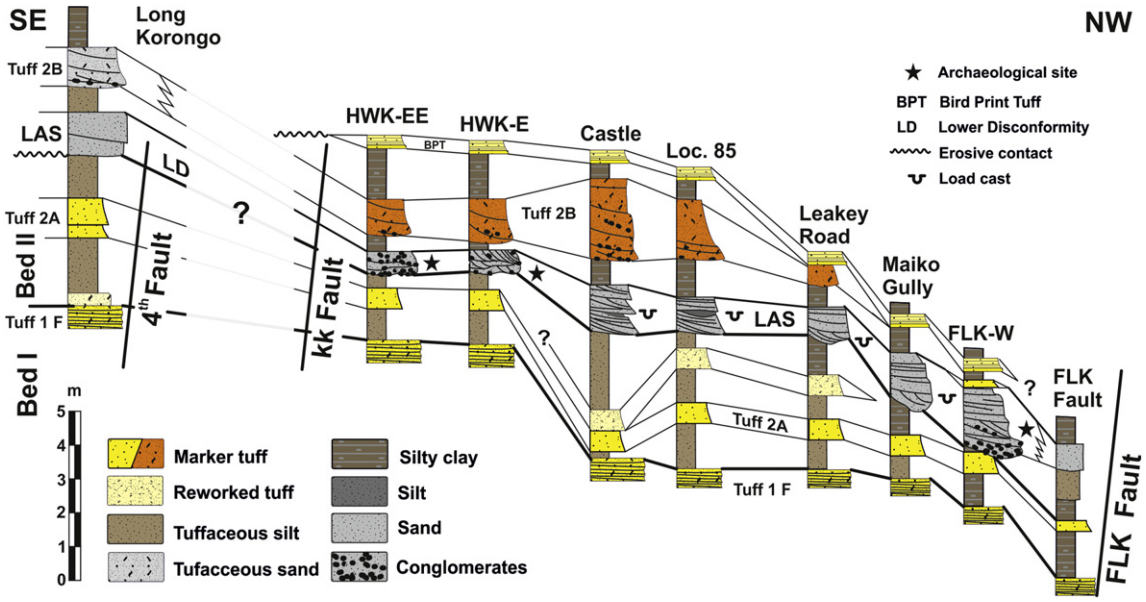

Fig. 4. Lowermost Bed II stratigraphic correlation between Long Korongo and FLK Fault. Tuff 1F has been taken as a reference, although its dip has not been corrected.

coarser grains at the base of the channel and bioturbation at the top. The bedload is mainly fine to very fine sand and in general the sediments are very well sorted. Locally, three cross-bedded units produced by migration of small ripples and horizontal lamination can be identified. The abundant deformation of sedimentary layers is due to the different densities found between the clayey silts and the overlying sands. Studying the central sections of the channels closely, where the depth reaches its maximum (1.1 m), high angle planar crossbedding (up to 45° in several sections) can be found. Here, the direction of paleocurrents point north (18° E). As in previous outcrops, the uppermost part of the channels is cemented with calcium carbonate and heavily bioturbated, which could be indicative of aerial exposure and an absence of sedimentation. Once again, Tuff II-B with a thickness of 1 m and the BPT can be found above the LAS unit.

3.6. HWK area

The surroundings of the HWK sites (HWK and HWK-E) were also studied at Geolocalities 42, 42a, 42b and 43 (Fig. 2). West from HWK, and in the same stratigraphic position, sandy braided shallow channels are abundant and are surrounded by a clayey silt floodplain (Figs. 3 and 4). Above the channels Tuff II-B can be found, formed by coarsening and thickening downwards reddish layers of tuffaceous silt, sand and gravel. The BPT is located 3 m above the LAS unit throughout the whole area.

These channels show a paleocurrent with direction 280°. The sandy sediments include tuff fragments, which are similar to Tuff II-A in appearance. The channels can be separated into two interrelated facies of conglomeratic channels and sandy channels. The first are more abounding towards the East, at Geolocalities 42, 42a and 42b, and display a flat bed with a mean channel width of more than 5 m and a depth of less than 1 m. The conglomerates are matrix supported, with gravel diameters of 5 to 10 cm and centile of up to 15 cm.

Research carried out by Leakey (1971) shows the existence of several archaeological levels, which contain Oldowan artifacts, in a level named "Sandy Conglomerate", present in levels 3, 4 and 5 in HWK and HWK-E. It is noteworthy that this level was also found at FLK-N (Leakey, 1971). A few years later, Hay (1976) renamed this "Sandy Conglomerate" as the LAS unit, and describes archaeological level 4 at HWK-E (Geolocality 43) as 1.2 m of conglomeratic sandstone, part of the Lower Augitic Sandstone unit, and clearly in the same stratigraphical position as other archaeological levels found at Geolocalities 42b (HWK-EE) and 43a (HWK). Oldowan artifacts is very abundant in every conglomerate channel, as well as flakes of brown chert (Hay, 1976). The contemporaneity of these sites and FLK-W will be discussed in detail, giving full consideration to all available data. However, it is worth highlighting that lower levels at HWK sites are separated by a temporal hiatus formed by the Lower Disconformity, which has only been by the stratigraphic analyses carried out as for this study.

3.7. Long Korongo

Three outcrops at Long Korongo, at Geolocalities 38, 38a and 39 have been studied (Fig. 2). The LAS unit is found 5 m above tuff 1-F, overlying homogeneous clayey silts. The unit has straight bedding surfaces, forming a tabular body of up to 1.5 m. Two and sometimes even three non-erosive sand bodies can be identified inside the unit, displaying planar cross bedding (Fig. 3). The sand is very fine, and although its content is clearly augitic, the volcanic ash content is greater than in previous outcrops.

The whole package dips slightly to the northwest. Despite the sediment being homogeneous, some fining upwards sequences can be distinguished. Flow structures such as ripples can be observed. Towards the top of the unit, sediments are cemented with calcium carbonate, probably indicating aerial exposure after deposition.

The geometry and architecture of the deposits found at Long Korongo are interpreted as alluvial fans advancing over a clayey and silty plain towards the northwest. The sandy units appear to advance downstream, with scarce or no erosion over the underlying bodies. No alluvial fan feeder channels have been found due to the scarcity of outcrops. Some Oldowan artifacts have been found along with abundant fossil faunal remains. The unit is overlain by fluvio-lacustrine facies, which can be correlated towards the West with tuff II-B. Above these sediments, the Middle Augitic Sandstones (MAS) unit can be identified. The BPT has not been identified in any of these three outcrops.

4. Lower Augitic Sandstone depositional environment interpretation

During the end of deposition of uppermost Bed I and the beginning of deposition of lowermost Bed II there is very little variation in the landscape and depositional environments. The lake-margin zone incorporates a wide silty and clayey plain which connects the fans and rivers coming from volcanic sources from the southeast with the central lake situated northwest. In this context, several volcanic tuffs are deposited,

with Tuff I-F being the most important of them due to its use a marker tuff separating Bed I and Bed II (Reck, 1951). Above it, eolian tuffs known as "Twiglet" (McHenry et al., 2015), Tuff II-A and the Lower Lemuta Member (Hay, 1976) are deposited discontinuously. After this deposition, a wide graben is formed between FLK Fault and Fifth Fault, inducing a drop in the local base level of several meters and causing at the same time the formation of a wide and extensive erosive surface throughout the basin, known as the Lower Disconformity (LD) (Hay, 1976). This surface is irregular and is infilled discontinuously within the first half of Bed II.

The LAS unit is deposited within the Eastern fluvial lacustrine deposits (eastern lake-margin), all part of the same fluvial system, flowing towards the central lake towards the northwest, overlying plains progressively more clayey towards the inner part of the basin (Fig. 5). All the system is controlled by the base level in the graben between the FLK Fault and the Fifth Fault. Upstream, the LAS system is represented by extensive alluvial fans, possibly coalescent, with a bedload clearly transported from the volcanoes to the southeast.

Feeder channels, which should transport a coarser bedload and would feed shallow braided river systems downstream (around HWK area), have not been found. The absence of outcrops between Long Korongo and Geolocality 42 has hindered the characterization of the transition between the alluvial fans and the braided fluvial system. Sandy channels are clearly more abundant in the HWK area (Geolocality 43) whereas conglomeratic channels are more concentrated around Geolocalities 42 and 42b, in the westernmost limits of the HWK surroundings. Channels are shallow (less than 1 m), laterally continuous, and tend to occupy the whole extent of the plain, as a network of unstable, low-sinuosity channels. Channel margins are rarely identifiable in outcrops and tabular bodies with numerous minor internal erosion surfaces are predominant, indicating an intense dynamic of channel reworking once the base level has stabilized. In these facies, several Oldowan/Developed Oldowan sites can be found (HWK sites), and show the highest brown chert flake concentration of all Bed II (Leakey, 1971; Fig. 3, Geolocality 42a).

Towards the northwest, this system of braided channels merge progressively into fewer channels downstream (Fig. 6). These channels become deeper (0.8 m at HWK, 1.2 m at Geolocality 85, 1.2 m at Maiko Gully) and narrower, and do not extend over the entirety of the plain.

The incision created by the Lower Disconformity and the LAS unit becomes increasingly noticeable from Leakey's Road (1.5 m in 300 m) and reaches its maximum at FLW-W (Fig. 4). The drainage network converges into a single channel, FLK-W, with dimensions distinctly greater than those observed upstream. Probably, more than one channel with these characteristics was active at the time, but the scarcity of outcrops has only allowed the encounter of the FLK-W channel. It is worth noting this greater incision of the Lower Disconformity and the installment of an associated fluvial system (LAS unit) at FLK-W is clearly coincidental with its proximity to the FLK-Fifth Fault graben (Figs. 5 and 6). FLK-W and HWK sites belong to the same fluvial system, where the fluvial pattern changes from a braided system to a low sinuosity single channel.

5. Discussion

5.1. LAS isochrony and correlation of FLK-W and HWK sites

Unlike many other types of geologic studies, the application of a geoarchaeological approach to landscape reconstruction is based on very detailed spatial and temporal data. This is particularly so for understanding various archaeological sites found in the same paleolandscape and isochronal surface.

From a geological point of view, an isochronal surface is a three-dimensional plane which connects points that are art of the same dynamic system at the same exact moment in time. Sedimentologically, all materials on a point throughout the surface would have been deposited at the same time and therefore reflect the geomorphology of the depositional environment (Dabrio and Hernando, 2003). A geological isochronal surface can be established through lithocorrelation, biocorrelation and chronocorrelation. However, whereas with older geological periods it is critical to keep these different types of correlation separated, this practice is less critical in younger geoarchaeological settings because stratigraphic and temporal resolution is greater and lithologic, paleontologic and chronostratigraphic boundaries tend to overlap or coincide (Goldberg and McPhail, 2008). The most precise geological isochronal surface in an open environment, is that which defines the base of a low energy deposit with a high sedimentation rate (Dabrio and Hernando, 2003), spanning over an extensive surface, such as an ashfall tuff (Sparks, 1976; Wilkson, 1980), clays deposited by decantation over

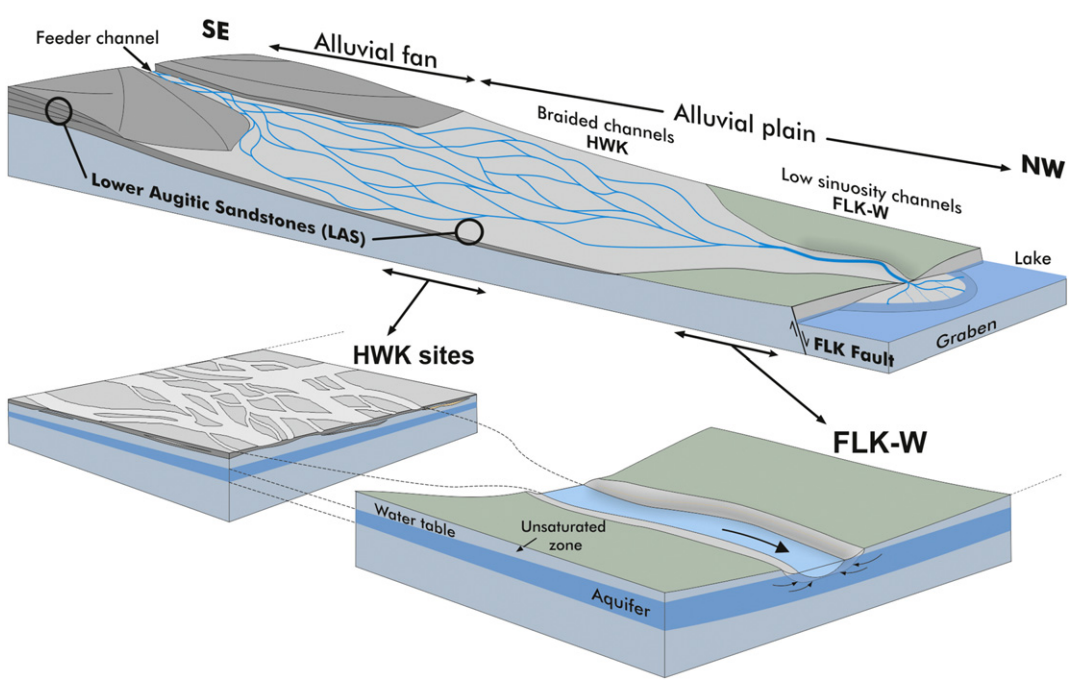

Fig. 5. 3D geomorphological reconstruction of the LAS unit between Long Korongo and FLK Fault.

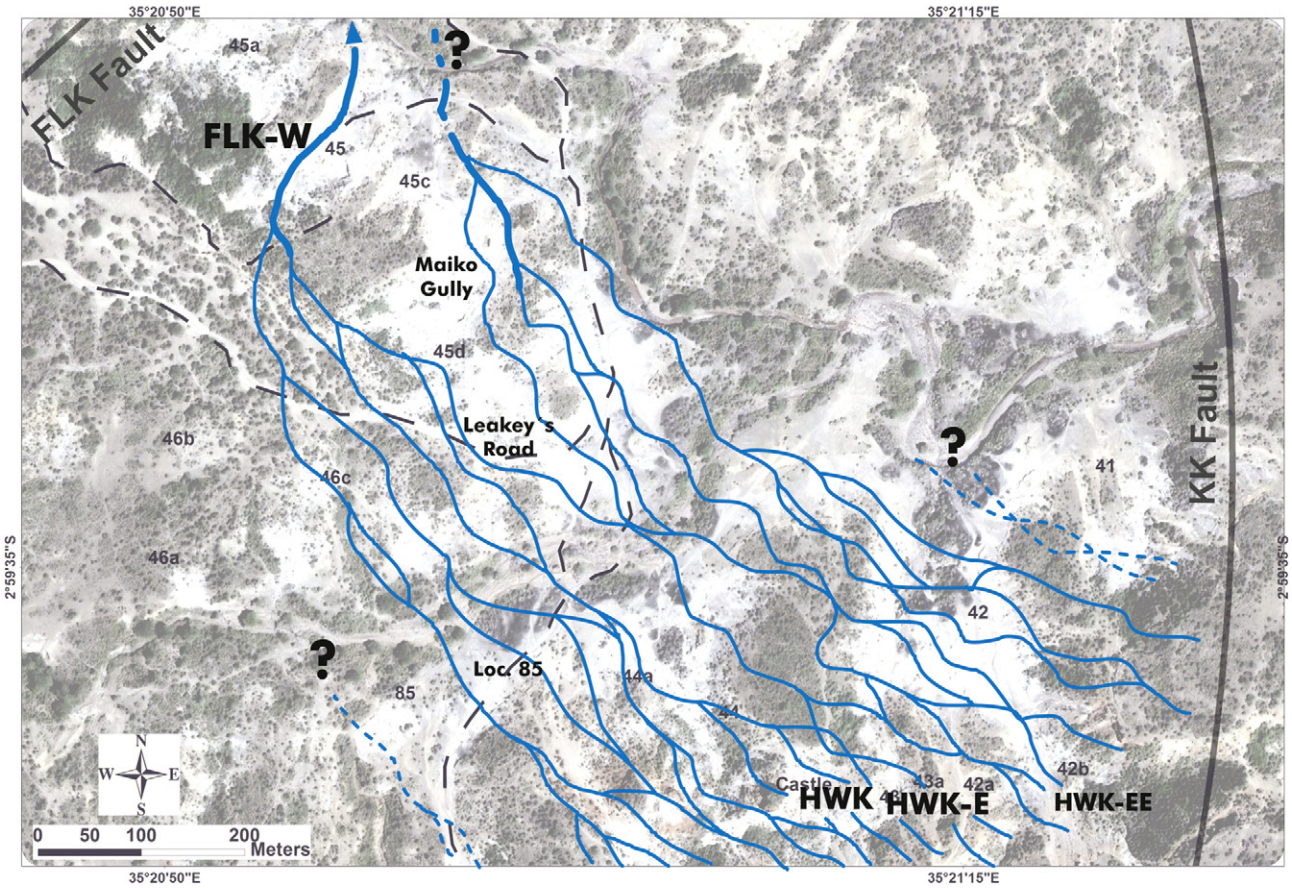

Fig. 6. Fluvial pattern reconstruction for LAS unit fluvial system in lowermost Bed II between FLK Fault and KK Fault.

a floodplain (Nordt, 1998; Brown et al., 2011; Yravedra et al., 2012) or a loess deposit (Pye, 1995; Haesaerts and Teyssandier, 2003; López Jiménez et al., 2009). It is safe to say any of these three deposits can preserve artifacts or fossil remains in situ and will create an isochronal surface between the archaeological paleosurface and the base of the new sedimentary deposit. Of these deposits, tan ashfall tuff is arguably the best option for this practice, in regards to a very high sedimentation rate, vast extent of the deposit and how easily it can be numerically dated. At Olduvai Gorge, a great example is Tuff 1C, which covers simultaneously archaeological sites spread over the gorge such ad FLK-Zinj, AMK, PTK and DS in lowermost Bed I (Uribelarrea et al., 2014). In this case, the geological contact between clays with archaeological content and Tuff I-C represents a perfect isochronal surface.

The paleosurface created by the erosion of the Lower Disconformity in lowermost Bed II is also an isochronal surface from a geological perspective, since it is representing a single geological event: an incision after a lowering of the base level. It is debatable and open to question how erosion, weathering and other processes have affected this surface inconsistently and not uniformly throughout its extent in the time lapse from the erosive main event to the deposition of the overlying sediments. Furthermore, stratigraphic analyses carried out by Hay (1976) reveal this surface was exposed for a long period of time, finally being buried by deposits with different chronologies (LAS, MAS, Lemuta member, etc.). Therefore, the true isochrony of each of the deposits can only be defined with lithocorrelation. However, this can sometimes be problematic due to the nature of fluvial dynamics, with constant lateral migrations, avulsions and reworking of the deposits (Leopold et al., 1964, Schumm, 1977, Elliott, 1984; Bridge, 2003; Miall, 2013).

Nevertheless, the studied archaeological sites (HWK sites and FLK-W) are found in deposits of the same fluvial system, controlled by the same base level. It is accordingly logical to infer that these fluvial processes (erosion, weathering and sedimentation) are all active at the same time across the longitudinal profile of the fluvial system. FLK-W and the HWK sites belong to the same landscape and paleosurface, but it is not possible to establish that they were formed at the same time and buried in the same geological event.

The accumulation of stone tools in the LAS unit paleosurface could have taken place either when the river was dry or during low flow stages. FLK-W was formed in the first scenario (Diez-Martín et al., 2015) which would mean that the vast majority of channels found upstream would also be found dry. In this same interval, it is also possible that HWK sites were formed. During medium or low flow stages, a braided river only occupies some of the channels, leaving several islands (Allen, 1970; Rust, 1972; Miall, 1977; Ashmore, 2013). In this situation, with no bankfull, it is very probable that flooded and dry braided channels coexisted, whereas downstream, the convergent channel would always carry the same amount of water (Fig. 7). During these periods, hominins would have been able to accumulate tools in these abandoned riverbeds around the HWK sites, whereas this could not be possible in the FLK-W channel. In any case, the only Acheulean industry accumulation is found at FLK-W, in a single downstream channel, which could be explained by some kind of ecological or landscape related limitation or condition.

5.2. Geoarchaeology and landscape

Three main factors are considered fundamental when reconstructing an open-air Paleolithic landscape: landscape primary material location, water availability and landscape geomorphology. In this study, the last two factors are considered.

In the wet season, the phreatic level is clearly the main factor controlling water availability, making water available throughout the

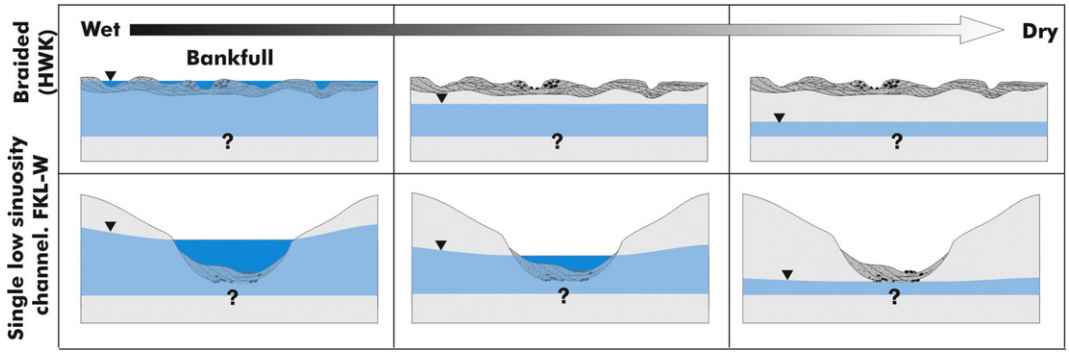

Fig. 7. Theoretical cross-section of the LAS unit fluvial system in braided and sinuous channels and phreatic level evolution from wet season to dry season. A hanging aquifer has been considered for all these situations.

landscape when the levels are high. However, at the beginning of the dry season, water availability would be influenced heavily by the geometry and characteristics of the fluvial system. Although the hydraulic gradient cannot be known exactly, according to Darcy's law, infiltration rate is proportional to the wet surface. In braided channels, with an elevated width/depth ratio, water extends over an extensive surface, favoring water loss through evaporation and infiltration to the subsaturated zone. In the beginning of the dry season, water availability would decrease until dry (Fig. 7). The FLK-W channel, with a much lower width/depth ratio, would lose less water due to infiltration and direct evapotranspiration. Notably and above all else, since it is in the lowest position in the valley, it would still feed from the aquifer for longer than at HWK. This difference in water availability is very significant between these two areas.

Closely related to fluvial geomorphology is the distribution of the vegetation cover. Braided rivers favor the constant renewal of sediment and hinder the deposition of fine sediments (Bridge, 2003) and therefore, soil formation. In fact, a riparian forest is more easily developed in the surroundings of a single channel, rather than braided channels (Malanson, 1993). Greater water availability benefits the formation of a riverine forest. Taking this into account, it might be questioned whether or not Acheulean presence is conditioned by this denser vegetationcover and abundance in vegetable resources at FLK-W compared to those found upstream at HWK-E. A denser vegetation cover would provide a protected zone, as has been explained in the past at FLK-Zinj and FLK-NN in Bed I (Domínguez-Rodrigo et al., 2007), and is another hypothesis to be taken into account. Another possible explanation about the differences between the Developed Oldowan and Acheulean industries could be a different use of the space. The use of lithic tools for vegetable processing at FLK-W, as well as the vegetation distribution throughout the LAS isochronal surface is being studied (Mercader et al., 2016; Patalano et al., 2016).

The presence of archaeological levels in fluvial depositional environments is especially noteworthy in Bed II, where 90% of all faunal remains are found associated with fluvial systems (Hay, 1976). The progressive aridification of Bed II could explain this faunal concentration near fluvial environments where water is more accessible. However, the effects of this aridification have not been studied in lowermost Bed II, and this is the first case of an archaeological site in this part of Bed II in a fluvial environment.

6. Conclusions

- The stratigraphic reconstruction of the FLK-W isochronal surface provides empirical data needed to understand the paleoecological background of the early Acheulean: chronology, coexistence with Oldowan/Developed Oldowan industries, landscape differences, etc. In order to do so, a stratigraphic study has been of vital importance, including many outcrops studied throughout the gorge.
- The oldest (1.7 Ma) Acheulean site at Olduvai Gorge (FLK-W) is contemporary with several archaeological levels found at Oldowan/Developed Oldowan sites at HWK (HWK, HWK-E and HWK-EE). Oldowan/Developed Oldowan and Acheulean assemblages are therefore stratigraphically contemporary at Olduvai Gorge.
- The extensive stratigraphic analysis confirms FLK-W and HWK sites were part of the same paleolandscape, found along the same fluvial system, which changes pattern in the last 1.5 km of its course. The Upper levels at HWK would have been deposited in sandy and conglomeratic braided shallow channels, whereas downstream, at FLK-W, they would converge into at least one sinuous channel, deeper and narrower over a clayey and silty floodplain.
- A geomorphological reconstruction clearly indicates HWK sites and FLK-W were deposited in environments with significant ecological differences. FLK-W would have better access to hydric resources and would probably offer a denser vegetation cover.
- Biomarker samples have been taken exhaustively and precisely throughout the isochronal paleosurface defined in this study to characterize the paleoecology of the environment.

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