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Geoarchaeology in a meandering river: A study of the BK site (1.35 Ma), Upper Bed II, Olduvai Gorge (Tanzania)

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ABSTRACT

BK site hosts 8 archaeological levels, preserved inside the channel of a meandering river. This river is not found in a floodplain, but encased in a wide karstified carbonate surface with no edaphic development. The river at BK has been recurrently used by hominins for carcass processing in the river channel, coinciding with a high concentration of vegetation and water resources along the channel banks. The spatial distribution of the different archaeological levels is the result of a complex sedimentary record. Such complexity in meandering river deposits is due to processes such as erosion, transport and sedimentation occurring simultaneously and coarse and very fine sediments being deposited at the same time throughout the same isochronal surface. BK site offers a unique opportunity, thanks to its abundance in archaeological remains and the quality of the outcrop, to geoarchaeologically depict and describe an archaeological site in a meandering channel. The geology of this fluvial environment is considered regarding a) fluvial architecture, b) facies distribution and c) fluvial dynamics. Furthermore, the abundance of archaeological remains and megafauna found inside the channel at BK contrasts with the absence of any remains outside the channel. We hypothesize that this area was preferred by hominins since it offers a high concentration of water resources and vegetation, as well as a greater protection against predators than an open plain. A detailed reconstruction of the paleolandscape will try to uncover the reason behind the huge contrast existing between the abundance of remains found inside and outside the channel, leading to the interpretation that an ecological or landscape related factor is conditioning the location and formation of the archaeological assemblage.

1. Introduction

Bell's Korongo (BK, Olduvai Gorge, Upper Bed II) was the first site in the gorge selected by the Leakeys in the 1950s for large-scale excavation due to the presence of numerous megafaunal remains and their association with stone tools. Furthermore, the first *Paranthropus boisei* was found at BK, dated 1.34 Ma (Domínguez-Rodrigo et al., 2013), and important postcranial remains of this taxon were recently discovered here (Domínguez-Rodrigo et al., 2013). The spatial association of lithics and bones from these and other animals led the Leakeys to interpret the site as a swamp to which most of these animals were driven, dispatched and consumed by hominins (Leakey, 1954; Leakey, 1971; Cole, 1963). The original geological interpretation of the site was, therefore, very simplistic and contrasted with the evidence found in later excavations carried out by The Olduvai Paleoanthropology and Paleoecology Project (TOPPP) since 2009. This project showed that the deposits that form part of the BK archaeofaunal assemblages have a diachronic history in which hominin and non-hominin agencies operated on the locus where the assemblages were deposited. Despite this, BK is important for the evidence it has preserved of the exploitation of megafauna by hominins (Domínguez-Rodrigo et al., 2014), as well as for the anthropogenic origin of a significant part of it (Domínguez-Rodrigo et al. 2014). Taphonomic research has shown systematic butchery of small, medium-sized and large carcasses, reflecting the importance of meat in the *Homo erectus* diet. The stratigraphic sequence from BK includes several archaeological levels. The repeated occurrence of exploitation of these resources in a deposit spanning a large amount of time implies that factors other than natural catastrophic processes must have operated on the area. This is of great significance for the understanding of hominin socio-economic behavior since the systematic exploitation of megafaunal resources is rather exceptional in modern human foragers and indicates a complexity in *H. erectus* social groups that needs to be addressed. Hence, the importance of determining what about the location of BK was so important for ecological and behavioral processes to have created such extraordinary assemblages over such a vast time span.

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It may be that the site has not been studied in greater detail because of the lesser knowledge at the time about geomorphology and fluvial sedimentology. Some fundamental concepts in fluvial geomorphology, such as upper and lower regime forms, instream flow or even geomorphic effectiveness were proposed and developed during the 1960s and 1970s (see Wohl, 2014) and became fundamental to completely understand the fluvial dynamics of any given river. Furthermore, the analysis of fluvial sedimentary units (Allen, 1970 and Miall, 1985 amongst others) was also developed decades after M. Leakey and R. Hay worked at BK. The stratigraphic complexity at BK, characteristic of meandering fluvial channels, cannot be interpreted without the aid of these scientific advances. The fact that in a meandering river, processes such as erosion, transport and sedimentation occur simultaneously (Leopold et al., 1964; Schumm, 1977; Elliott, 1984; Bridge, 2003) as well as the concurrent sedimentation of coarse bedload and fine to very fine sediments throughout the same isochronal surface, has a fundamental importance for archaeological inferences.

At BK, the largest fluvial channel documented in Bed II, eight archaeological levels have been found: Levels 1 and 2 (Domínguez-Rodrigo et al., 2009), Levels 3a, 3b, 4a and 4b (Domínguez-Rodrigo et al., 2014) and Levels 4c and 5 (Organista et al., 2015; Organista et al., 2017 in this volume). BK, thus, offers a unique opportunity, thanks to its abundance in archaeological remains and the quality of the outcrop, to geoarchaeologically depict and describe a meandering channel. To do so, the geology of the fluvial environment has been considered regarding, a) fluvial architecture, b) facies distribution and c) fluvial dynamics, which decisively and simultaneously intervene in the formation of the different archaeological levels. In addition, a detailed reconstruction of the paleolandscape, identifying all isochronal surfaces inside and outside the river, will try to uncover the reason behind the huge contrast existing between the abundance of remains found inside and outside the channel. This will hopefully uncover if there is any type of ecological or landscape related factor which is conditioning the location and formation of the archaeological assemblage.

2. Materials and methods

An exhaustive stratigraphic analysis of uppermost Bed II has been carried out on the BK 100 m wide and 12 m high outcrop (Fig. 1). This outcrop contains deposits which predate the fluvial channel along with the infill deposits themselves. The analysis has been carried out along the outcrop, the geotrenches and excavation areas (Fig. 3). There is no access to the left (western) margin of the channel because it is overlain by the Ndutu formation. Firstly, due to the complex stratigraphy of the infill deposits at BK, wide sections have been selected to work on as a whole, in order to reconstruct the greater geometries or architectural elements of the fluvial deposit. The limits (X, Y, Z) of these large elements were measured with a total station with sub-centimeter precision, especially the lateral accretion units. Surface weathering processes have made the limits of the LA units clearer, making their identification easier (Fig. 3D). These geometrical measurements will make possible to produce a three-dimensional model of the channel infill. A more detailed facies description of each channel infill unit was carried out at exposed sections of BK, where small scale shapes and units can be identified. A total of ten 120 g samples were taken from the most representative units associated with the different archaeological levels. Grain-size analysis allows quantifying the size distribution of particles, giving accurate information of the sedimentation processes (see Table 1 in Supplementary Information and Fig. 4). Grain size and petrographic analyses were made with Robinson's pipette method at the CENIEH (Centro Nacional de Investigación de la Evolución Humana) and in the Geodynamic laboratory of the Complutense University of Madrid's Geology Faculty.

3. Results

3.1. BK fluvial architecture: sloping isochronal surfaces

In a sinusoidal and asymmetric channel, the flow follows a helical trajectory (helical flow, see Corney et al., 2006), which is responsible for the processes of erosion, transport and sedimentation in the channel. In a simplified way, it is safe to say that this helical flow produces erosion on the convex bank, whereas sand or gravel bedload is moved by traction towards the inner sides of the channel bends building a lateral bar and finer-grained sediments are deposited in the concave bank (Brierley and Fryirs, 2013). These processes, which only occur during flood stages and bankfull stages, lead to the lateral migration of the channel and the formation of scroll-bars and point-bars (Figs. 2 and 3D). Point-bars have an acute shape and are attached to the inner (convex) bank, sloping towards the centre of the channel, reflecting the

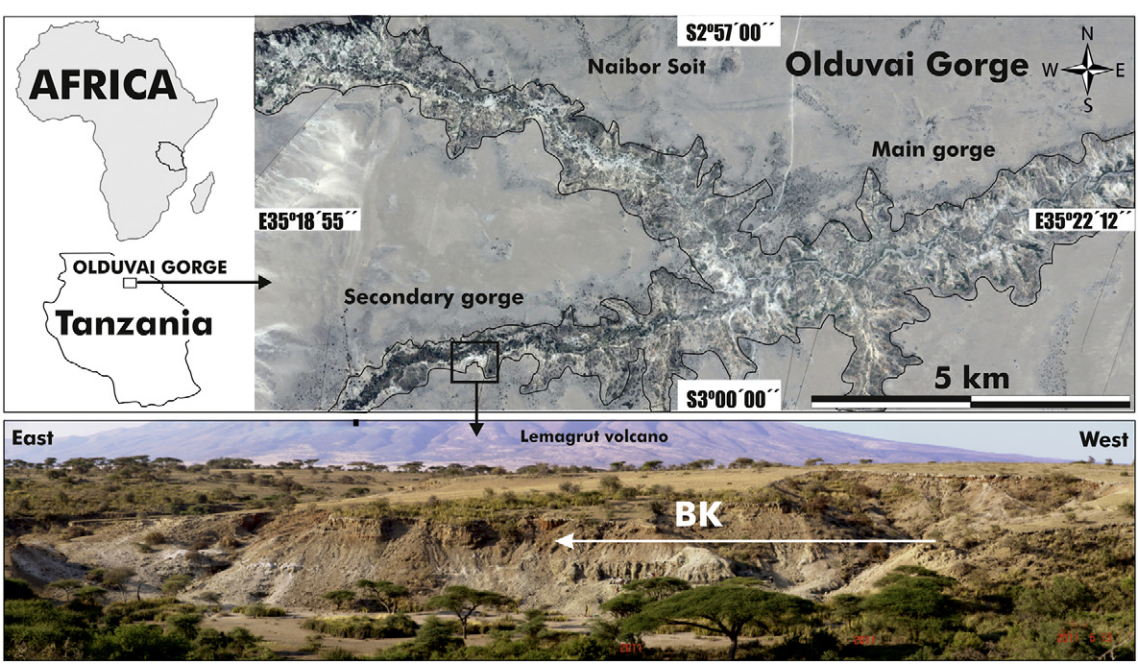

Fig. 1. Olduvai Gorge map. The area of study, in the Side Gorge, is shown in the black bordered square. Below, a panoramic view of BK outcrop.

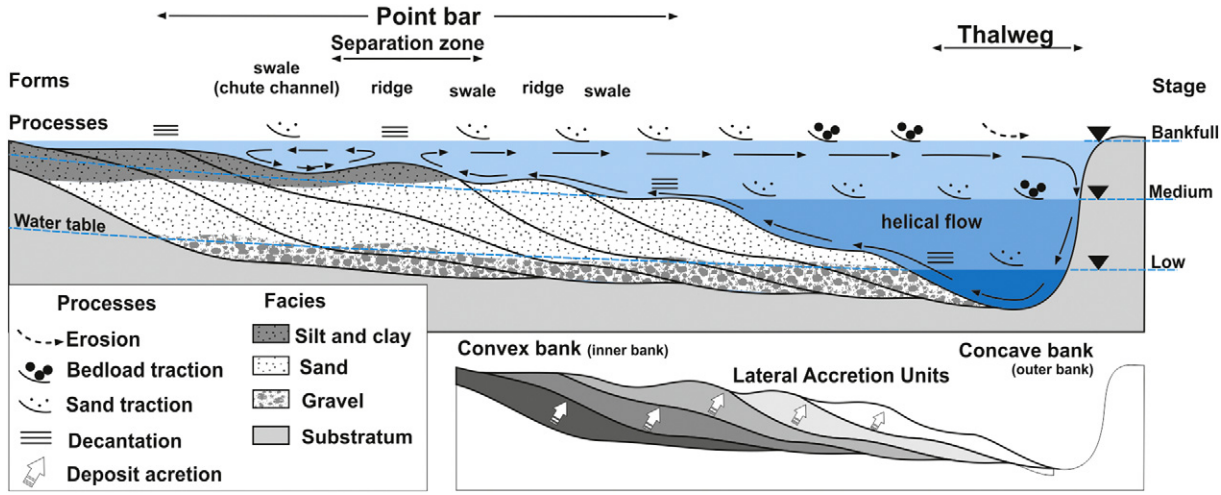

Fig. 2. An ideal cross section of a meandering river, which includes fluvial processes, sedimentary facies and geomorphology is considered. Fluvial processes are based on three discharge stages (low, medium and bankfull). Bellow, the lateral accretion units have been highlighted.

asymmetrical channel geometry at the bend apex (Brierley and Fryirs, 2013). In the sedimentary record, these bars are represented by epsilon cross-bedded units (Allen, 1970), also called Lateral-accretion macroform (LA) according to Miall (1985). The piling of several of these units implies the lateral migration of the thalweg and an increase in sinuosity. In the upper sections, strata tend to be horizontal (off-lap).

Each LA unit is found dipping towards the channel thalweg and is formed, at the same time, by coarse-grained bedload deposits in the lowermost section, medium-grained sized bedload (sand) deposits in the middle and fine sediments in the upper section. Helical flow is responsible for this grain size variation, and is constantly and simultaneously transporting sediments found anywhere from the thalweg to the point-bar surface (Fig. 2).

Frequently, in the upper or middle part of these units, pairs of ridges and swales are formed, which record the position of the former separation zone, between the helical flow cell in the thalweg zone and flow in a separation zone adjacent to the convex bank of a bend (Nanson, 1980). The presence of ridges and swales favours the development of chute channels (Fig. 2), which may short-circuit the bend, cutting a relatively straight channel from the head of the bar (Brierley, 1991).

At BK, an asymmetric channel can be identified, with a gently sloping left margin, descending progressively westward until reaching a minimum depth of 4 m (Fig. 3). The channel infill shows at least 3 LA units (LAU 1, LAU 2 and LAU 3), from the right (eastern) margin up to the thalweg, partially exposed in the opposite western margin. Albeit LAU 1 and 2 are totally restricted to the channel limits, the upper part of LAU 3 and the entirety of unit 4 are deposited outside the channel, over the bank. This last unit ends up filling the channel with very fine overbank sediments, forming a Channel macroform, (CH, per Miall, 1985) which in this case study will be labelled CHU 4. There are two ways to explain this infill: 1) base level increases progressively or 2) channel is abandoned, either by a chute cut-off or a neck cut-off. In this last case, the new channel's position has not been found in the studied area. In any case, the sedimentary record found at BK indicates that at the end of LA Unit 3 and during CHU 4 less water flows and the deposition of silt and clay is much more common, even at the deepest part of the channel. At BK, LAU 1 contains archaeological Levels 3a, 3b, 4a, 4b 4c and 5 whereas LAU 2 hosts archaeological Levels 1 and 2.

3.2. Facies distribution: erosion, transport and sedimentation

Each LA unit is formed by two or three different sedimentary facies with certain characteristics which can be decisive for the formation of fossil assemblages. Considering only sedimentological factors, three greater facies can be described in a meandering river: a) coarse bedload, limited to the lowermost part of the LA unit and belonging to the deepest part of the channel, b) mixed bedload, extending along the point-bar, and c) decantation facies, consisting of in-channel deposits once the channel is abandoned and overbank fines. These facies are distributed overlapping the fluvial architecture, since they belong to different sedimentary processes (Fig. 2).

3.2.1. Facies A, coarse bedload

These facies are related to the most energetic part of the river (i.e. in the lowermost part of the channel or thalweg), which is normally found in a meandering river close to the external margin and is the deepest zone of the river (pool). Geotrenches and outcrops displaying these facies show coarse sand and gravel, distributed in finning upwards sequences, with abundant flow structures (Fig. 3 E). This sediment only moves during high flow regimes and does so either by suspension, saltation or creep processes. Fossil remains found in these facies at BK are very scarce, as well as abraded and fractured. Therefore, no archaeological levels have yet been found in deposits with these facies.

3.2.2. Facies B, point-bar mixed bedload

From a sedimentary and geoarchaeological point of view, these facies, which is related to the uppermost part of the point-bar, is the most complex. Flow is less energetic than at the thalweg, since it is at a shallower position. Mixed bedload deposition in finning upwards sequences takes place. Depending on river size and provenance, this mixed bedload can be made up of any sediment, ranging from gravel and sand to silt and clay. Flow structures are abundant, along with reactivation surfaces. The series of ridges, swales and chute channels locally conditions sediment distribution and bar topography. At BK, silt to clay sequences are very frequent, along with few lenticular levels of coarse sands with cross-bedding (see Table 1 in Supplementary Information and Fig. 4). It is noteworthy that most available sediment in the surroundings of BK paleoriver was fine grained, meaning only fine bedload could be deposited at BK. Rivers nowadays have this zone of the channel frequently visited by animals to drink, thanks to its gentle slopes and easy access to the river. It is surely no coincidence that at BK nearly all archaeological Levels (3a, 3b, 4a, 4b and 4c) are found in these facies. These five levels have shown trampling (Domínguez-Rodrigo et al., 2009, 2014), which is a frequent process in this type of facies by cyclic exposure. Another common process in these facies is load deformation, since they are constantly affected by phreatic level changes. Water saturation of the sediment confers a greater plasticity, which deforms it due to the different densities of clay, silt and sands. Thus, the outer limits of the strata are distorted and flames and convolute structures appear (Fig. 3B). This deformation affects bones and lithic tools, which

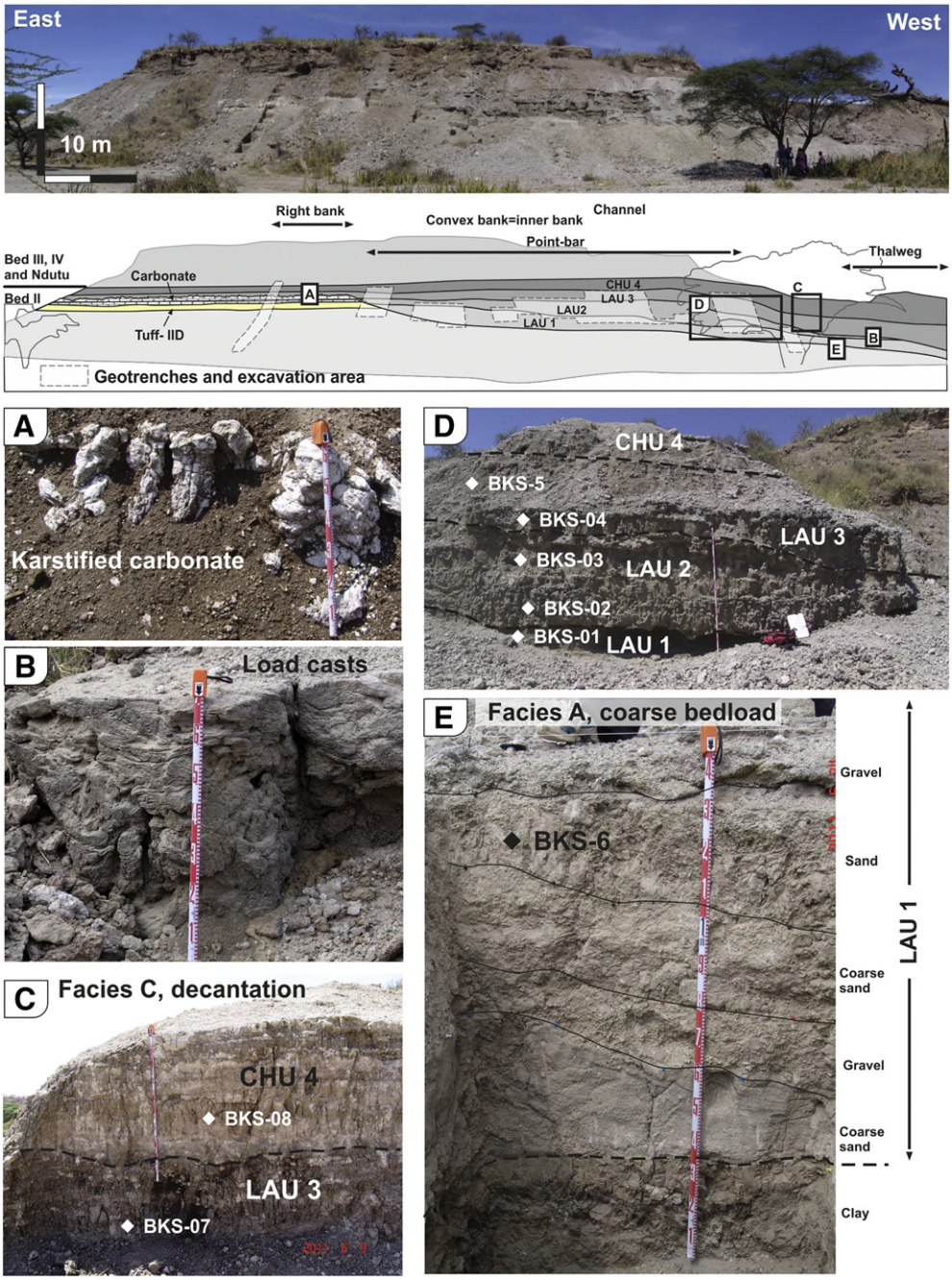

Fig. 3. BK panoramic view in Side Gorge and the corresponding stratigraphic interpretation of the main units. Dotted lines are the limits of archaeological excavations and geotrenches. Pictures: A, a close up view of the karstified surface of the carbonate unit, previous BK river incision. B, detail of load casts in a small channel of sands. C, decantation facies (silt and clay) in the upper part of LAU 3 and CHU 4. D, ondulated and tilted contacts between lateal accretion units. E, bedload facies, composed by coarse sands and small gravels.

occasionally are found in a vertical position. Leakey (1971, pp. 198–199) described at BK similar circumstances, and led her to interpret the site as "a swamp where animals were trapped.".

3.2.3. Facies C, decantation

These facies are only seen at environments where water flows at low velocities. Normally, these facies are found outside the channel, in the floodplain (Nanson and Croke, 1992). Overbank deposits consist of extensive silt and clay laminae, formed in low energy regimes, which tend to preserve archaeological assemblages. It is also possible to find this type of facies in the channel itself, but only after it has been abandoned. With the available outcrops at BK, it seems that LAU 3 correlates to the beginning of the channel infill which ends with CHU 4 (Fig. 3C). In these last units, water overflows over the bank, occupying part of the floodplain. It is noteworthy how these facies which are theoretically more favourable for fossil preservation, contain no remains whatsoever (LAU 3 and CHU 4).

3.3. Flow discharge and site preservation

A river is subject to a wide variety of flow discharge rates. Each event will determine the spatial distribution of processes (weathering, erosion and sedimentation) over previous deposits. The result will be the destruction or preservation of assemblages left on the paleosurface after hominin activities in the channel surroundings. In this manner, the preservation of an archaeological assemblage depends both on the position it has on the channel and the flow discharges it suffers after deposition. To further develop this issue, which has not been previously

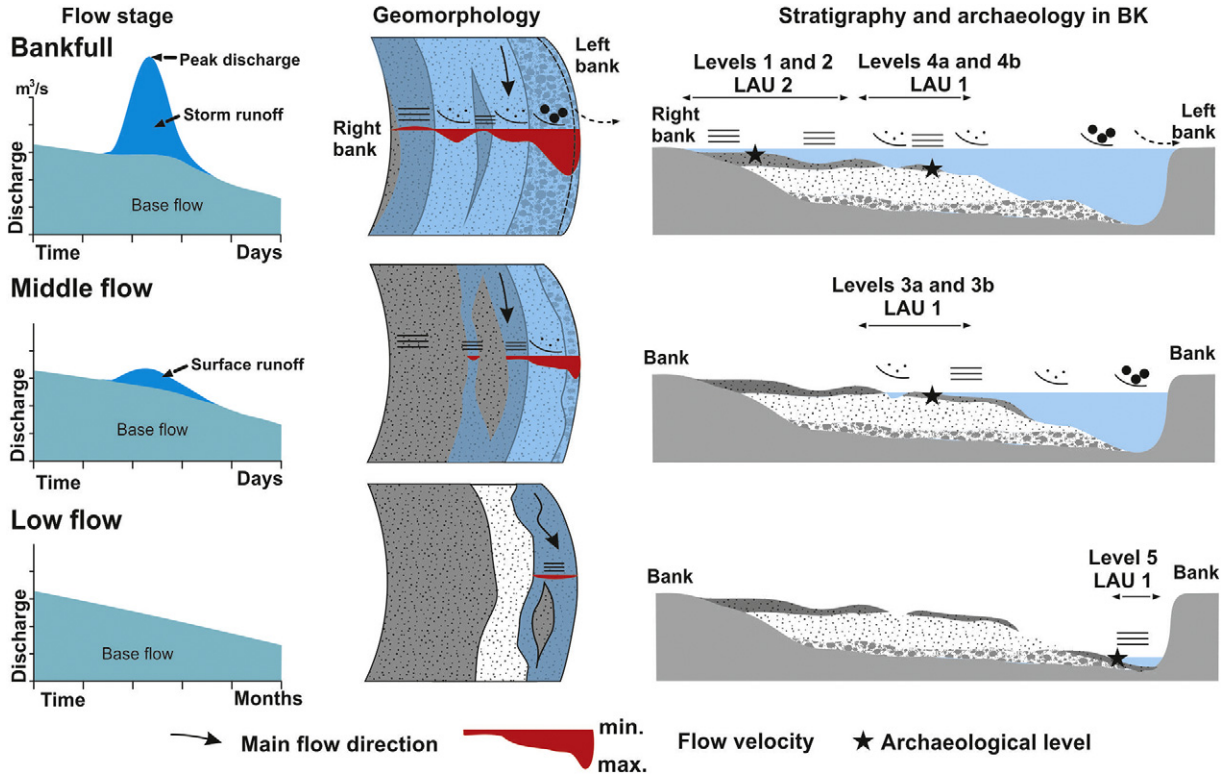

Fig. 4. Representation of three scenarios in BK river, (low, middle and bankfull) through theoretical hidrograms, the corresponding fluvial processes both in plain view and cross-section. The resulting deposits and the formation of different archaeological levels in BK are also represented.

documented in detail, three theoretical scenarios of flow discharge at BK will be addressed: a) bankfull, b) middle and c) low flow discharges. Resulting processes, deposits and archaeological assemblages will be compared and contrasted (Fig. 4).

3.3.1. Bankfull discharge

Periods with the greatest flow discharges tend to be scarce, and are only produced during heavy rains in the wet season or occasional storms. These are reflected on hydrograms as a peak in surface run-off which can last hours or days, during which the river gains the capacity to migrate laterally and form a new LA unit. If flow discharge is exceptionally high, water will overflow from the channel onto the floodplain. At BK, there is no evidence for this until the end of LA Unit 3. During bankfull, the intensity of the processes reaches its maximum at the flooding peak and decreases progressively during flow discharge descent. The result is grain size gradation, leading to the formation of finning upwards sequences. At the thalweg, gravel will be deposited on an erosive surface. Towards the inner part of the point-bar, gravel to sand, sand to silt and/or silt to clay sequences will form, listed from closest to furthest away from the thalweg (Fig. 4). The fact that this event is so energetic means fossil preservation is nearly impossible, except at the furthest part of the point-bar, where silt and clay are being deposited. This is precisely what is thought to occur at archaeological Levels 1 and 2 at BK, where strata of clayey silt preserve hundreds of bone fragments (see Domínguez-Rodrigo et al., 2009). Despite their small size, these bone fragments do not show preferential orientation, since water flow is very slow at this point. During bankfull discharge, archaeological sites will only be found in the uppermost part of point-bars.

3.3.2. Middle flow discharge

This is the most frequent situation, where the hydrogram is less exaggerated, the channel is not totally full and flow velocity is lower (Fig. 4). During these events the river is not capable of forming a LA unit nor can it migrate laterally. In the deepest areas, saltation and creep processes will be the most common, which results in a not very favourable environment for assemblage formation. On the other hand, fine grained deposits in finning upwards sequences are being deposited at the highest part of the point-bar. Such is the case in archaeological Level 4 at BK, a 30 cm thick finning upwards sequence composed of fine sandy mud in the base and very fine sandy mud on top (Domínguez-Rodrigo et al., 2014, p.132). The base of the level preserves archaeological Level 4b which underlies the deposit and archaeological Level 4a overlying the deposit.

During a middle discharge stage, flow can be divided into small chute channels, adapting to the ridges and swales found at the point-bar or even weathering and creating new troughs which will be later filled (cut and fill shapes). Level 3 at BK is a great example of this type of channels, forming a 30 cm thick finning upward irregular and erosive layer. The base (archaeological Level 3b) is a muddy coarse sand unit with parallel and cross-bed lamination, where mud clasts and bone fragments are also frequent. It is obvious that an archaeological level formed in this surface can be partially or totally altered, such as in the underlying archaeological Level 4a (Domínguez-Rodrigo et al., 2013, p.132). Occasionally, these secondary channels are filled with clay or very fine sediments forming what are known as mud-plugs. During a middle stage, site formation is possible at the point-bar, although due to the irregularity of the geometry and processes, the site can be partially altered.

3.3.3. Low flow discharge

During the lowest flow discharges, and even during drought periods, hominins and animals had access to the riverbed, where the last vestiges of water were available (Fig. 4). Any event with medium to high energy would destroy or disperse any possible assemblages derived from this activity. However, the succession of several low flow stages will favour in situ preservation with the deposition of silt and clay over the riverbed. This process is rare and only happens when the channel is abandoned or its activity is slowed considerably. Although the

outcrop is not exposed towards the west, it seems archaeological Level 5 would have been deposited in circumstances similar to these. It is on top of a 60 cm thick finning upwards sequence, which corresponds to one flow event. It starts with 30 cm of bedload with cross stratification, continues with 20 cm of tuffaceous silt and finally a 10 cm thick layer of silty clay (Fig. 5). Bones and stone tools were accumulated after a flooding event, once the fine sediment was consolidated (Organista et al., 2015). The silt and clay low flow discharge deposited immediately above this archaeological level favoured its preservation despite its proximity to coarse bedload facies. If instead of a low flow discharge, a middle or high one would have taken place, both the remains and the surrounding clay would have been eroded away. Therefore, it is safe to say that during a low flow discharge stage (resulting in aggradation), an assemblage can be preserved provided the next event is not able to erode the deposit containing it. In other words, channel aggradation with low energy processes have to take place consecutively for a site to be preserved.

3.4. BK landscape reconstruction

The absence of archaeological remains outside the channel, even in the areas closest to it, leads us to believe that there must be a landscape related constraint, independent from the in-channel processes. For this reason, the channel and surrounding environment reconstruction could turn out to be very revealing. To do such a task, it is necessary to consider the geological context of uppermost Bed II.

Eastern Fluvial lacustrine facies (Hay, 1976) found in uppermost Bed II show an important development of alluvial fans, progradational towards the centre of the basin. These are very extensive deposits, predominantly formed by silt and scoured by hundreds of small channels. Overlying these deposits, we find Tuff II-D (see Domínguez-Rodrigo et al., 2013), a very recognizable tuff throughout the gorge in uppermost Bed II. Wetland deposits can be found on top of this tuff. Calcium carbonate has been accumulated around plant roots and forms a travertine at the top of the unit, whereas inside the tuff, these same roots fossilize in silica (Fig. 6). The travertine is especially thick (1.2 m) in the secondary gorge. Due to climate change or to a descent of the base level due to active tectonics, the phreatic level decreases and the travertine dries completely. The uppermost part appears very recrystallized and with an irregular morphology, typical of a karst formation. In this surface, unfavourable for soil development and vegetation, the paleoriver at BK would provide a fluvial corridor of vegetation and water resources.

The reconstruction of BK channel and its surroundings is based on fluvial architecture and on the carbonate paleosurface. This surface forms an isochronal surface containing LA Units 1, 2 and the beginning of 3. The main objective is not to recreate the exact geometry of the channel, but to show the distribution of the sites inside the channel and above all, highlight BK as a fluvial corridor in a carbonate plain (Fig. 7). Important parameters, such as the inclination of the channel, its curvature and width for example, are not yet known, making the resulting 3D model semi quantitative.

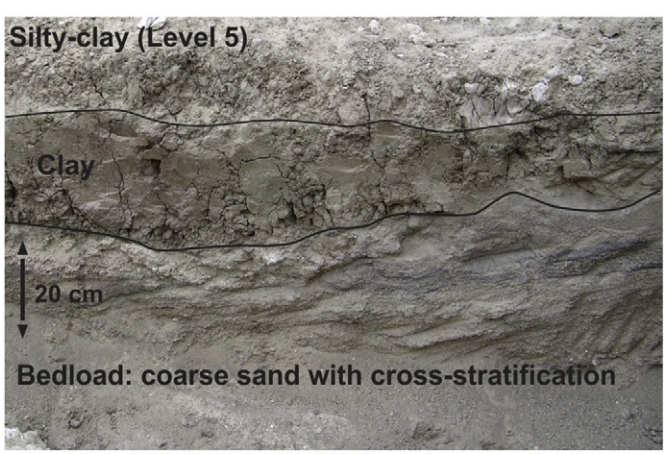

Fig. 5. Detail of archaeological Level 5, preserved in a silty-clay deposit close to the thalweg area, just over bedload sediments.

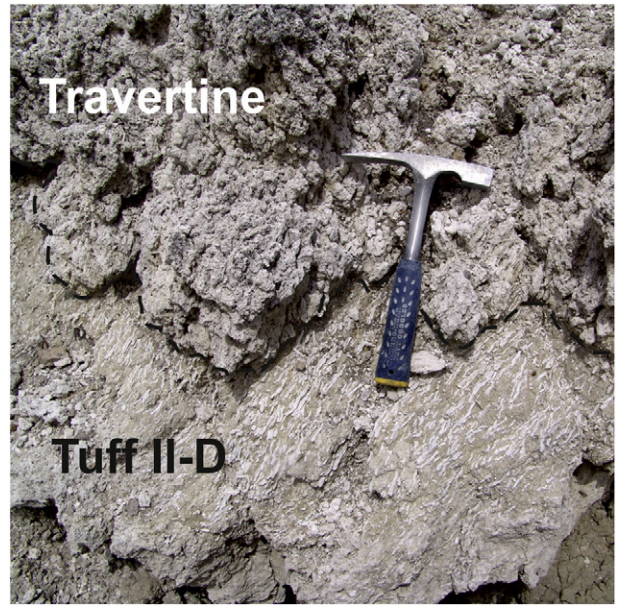

Fig. 6. Carbonate (travertine) developed over Tuff II-D in the uppermost Bed II. BK is incised in this unit, which can be traceable along Side Gorge and part of the Main Gorge (kms).

For this 3D model, the limit between Units 1 and 2 has been used as a guideline, since it is the most extensive isochronal surface available at the site and represents a real transversal section of the channel. Similar profiles have been generated southwards, on 5° intervals according to the rotation axis situated on the right (eastern) margin, to simulate a medium sinuosity (1.4) meander. Therefore, the representation of the river towards the South is merely theoretical, differing from the real geometry of the paleochannel in its curvature and width. Excavation limits and archaeological remains have also been represented in this 3D model. The result is a theoretical 3D model which accurately portrays the landscape and the isochronal surfaces found inside and outside the channel, leading to a greater understanding of the formation of archaeological levels during Units 1 and 2. As seen in the 3D reconstruction, the point-bar is an undulated and slightly sloping paleosurface, where all archaeological levels are concentrated.

4. Discussion

In geomorphological studies, rivers have been analysed from different points of view, in regards to classification, pattern, processes, dynamics and evolution (Leopold et al., 1964; Morisawa, 1968; Schumm, 1977; Richards, 1982; Knighton, 1984), their tight relationship with floodplains (Nanson and Croke, 1992; Bridge, 2003; Brierley and Fryirs, 2013) and of course with the sedimentary record (Miall, 1985). Fluvial sedimentary environments are included in all geoarchaeology manuals (Butzer, 1982; French, 2003; Herz and Garrison, 2004; Brown, 2008; Rapp and Hill, 2006; Goldberg and Macphail, 2006) given the affinity between them and archaeological sites. However, these works lack a more detailed description of the channel from a geoarchaeological point of view, which is necessary to understand archaeological level distribution within a fluvial channel.

Not all fluvial sedimentary environments are equally favourable for archaeological and paleontological site preservation. For example, braided rivers are very energetic (Allen, 1970; Rust, 1972; Miall, 1977) and therefore will result in adverse conditions for in situ site formation.

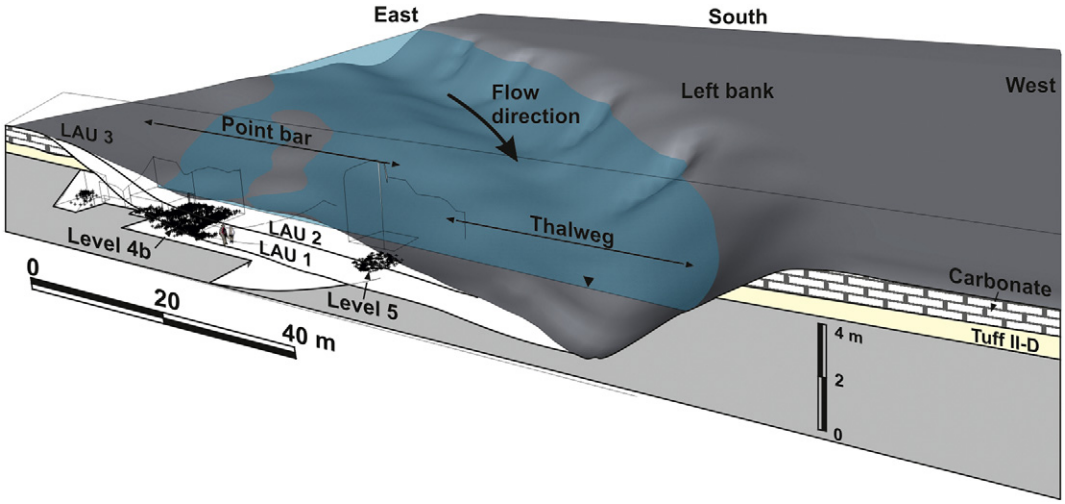

Fig. 7. 3D reconstruction of BK channel. Cross section is based on the geometry identified in fieldwork and measure with total station. The limit between LAU 2 and LAU 3 is represented as it is the best traceable palaeosurface of BK. Levels 4b and 5 have been placed, in the upper part of LAU 1. Width and curvature of the meander is conjectural.

Nevertheless, it is possible for small channels, with a sandy or mixed bedload, to host archaeological or paleontological remains. Such is the case of several Bed II sites at HKW (see Uribelarrea et al., 2017 in this volume). On the other hand, anastomosing channels are usually related to low energy swamp areas (Smith and Smith, 1980) and subsequently not very favourable for a Paleolithic artefact accumulation. It is without a doubt that single channel floodplains, either of a straight, sinuous or meandering river, are the most favourable locations to preserve an archaeological site. Firstly, it is a matter of quantity, since these morphologies constitute most part of the longitudinal section of nearly any river, no matter the climate, latitude or size. Above all else, flood events can produce low energy deposits in the floodplain and inside the channel during bankfull stages. From an ecological point of view, floodplains and associated channels are home to a wide variety of ecological niches (Malanson, 1993; Hupp and Osterkamp, 1996), offering different land use opportunities. The relationship between rivers, floodplains and archaeological site location has been widely studied (Needham and Macklin, 1992; Brown, 1997, 2008; Howard et al., 2003; Uribelarrea and Benito, 2008; Mandel, 2008). Studies documenting archaeological levels inside overbank deposits are abundant whereas those describing them inside paleochannels are scarce. The main reason for this is quite evident, since in any fluvial environment the river itself contains the most energetic processes, hindering the preservation of archaeological assemblages. Case studies are progressively less abundant in older deposits (Butzer, 2008) and nearly absent in Paleolithic sites. Some authors such as Guccione (2008) describe Holocene sites in active meander belts, abandoned meander belts and tributaries. Another study worth mentioning is that carried out at the Plio-Pleistocene site of Fonelas P-1 in Spain in a meandering paleochannel (Viseras et al., 2004). At Olduvai Gorge, besides BK, other fluvial channel sites have been found, such as SHK (Diez-Martín et al., 2014) and FLK-W (Diez-Martín et al., 2015) along with several archaeological levels in HWK, HWK-E and HWK-EE (Bed II).

BK is an exceptional case, due to the abundance of megafaunal and lithic remains found inside the channel, which might be conditioned by a landscape related or ecological constraint. The highest bone concentration at BK is found during the channel's most active period, in Units 1 and 2. The deposits in these units form an onlap over the left margin bank, depositing Levels 1, 2, 3a, 3b, 4a, 4b, 4c and 5 inside the channel. This leads us to believe hominin activity was conditioned by the fluvial environment. At the same time, the carbonate surface preserves no fossil remains or lithic industry, despite being a contemporary paleosurface to all the archaeological levels. This reinforces the idea that BK has the role of an oasis, concentrating the access to water resources. This is consistent with the fact that climate becomes more arid at the end of Bed II, and water resources are predominantly found at fluvial environments (Hay, 1976). In arid areas, riparian vegetation is more productive than the surrounding landscape (Malanson, 1993). This is not only true in desert environments (Walters et al., 1980) but also in savannah environments (Hughes, 1988). In this case, the carbonate surface hinders soil development, and therefore it is possible that there was a great contrast in vegetation cover.

Nonetheless, it is worth considering the absence of sedimentary processes outside the channel during LA Units 1 and 2, where carbonate dissolution creates an exokarst (Fig. 3A). It is possible that remains were accumulated on the banks but due to the lack of sedimentary processes, these were not ultimately preserved. Weathering processes are especially aggressive on bones (Lyman and Fox, 1989) although not as much on lithic industry. Therefore, the reason remains unknown as to why these have not yet been found outside the channel.

Finally, it is noteworthy how units which a priori are more likely to preserve archaeological levels such as the fine-grained LA Unit 3 and CH Unit 4 contain no remains. This can be due to environmental factors such as climate at the time of deposition. If sedimentation of the units took place during a wet period, when resources were abundant, the hominins could have expanded over the landscape without any limiting factors. This period would also correspond with an increase in base level and therefore a decrease in fluvial activity at BK, as made visible by a lower sedimentation rate. Phytolith analyses carried out at CH Unit 4 reveal a riparian vegetation heavily influenced by humidity. The poor preservation of the phytoliths recovered make further climate inferences implausible (Arráiz et al., 2017-in this volume).

5. Conclusions

The river at BK has been recurrently used by hominins for carcass processing throughout Bed II. This intensive use of a particular area of the landscape coincides with the concentration of vegetation and water resources along the channel banks. It can be hypothesized that this area was preferred by hominins since it offers a greater protection against predators than an open plain. The presence of *Struthionidae, Charadriiforms, Rallidae*, and *Passeriforms* as well as *Galliforms* is related to an open habitat in a fluviatile basin with periodic wetlands. The taphonomic study of the macrofaunal bone remains supports an anthropogenic interpretation for their transport and accumulation at the BK site, with limited presence of birds and a limited carnivore impact in an assemblage that was overall exposed to very fast sedimentation processes.

This contrasts with the total absence of remains outside the channel along the same isochronal surface, which can be traced for kilometers in the side gorge. The absence of any kind of sedimentation outside of the channel is debatably the main reason for the absence of fossil remains being preserved.

The superposition of fluvial processes in a channel complicates notably an archaeological site's geological interpretation. Accordingly, contextualization and interpretation of the different levels inside the channel is only possible when taking into account all geological elements of a meandering fluvial channel: fluvial architecture, facies distribution and flow discharge variation.

Fluvial architecture studies carried out at BK have contributed to the understanding of why archaeological Levels 1, 2, 3a, 3b, 4a, 4b and 4c disappear towards the river's thalweg (westwards). This analysis has made it easier to appreciate why during the same fluvial event in different areas along the same isochronal surface, an archaeological assemblage can either be preserved or destroyed.

Identifying different processes and small-scale geometries in the point-bar has made it possible to explain the formation of heterogeneous archaeological Levels such as 3a, 3b, 4a, 4b and 4c. Some of these were deposited along chute channels and thus influenced by superficial water movement and other weathering processes.

Considering the wide variation of flow discharges throughout the same paleosurface as seen in the uppermost sections of LA units, in situ preservation of archaeological remains in areas closest to the riverbed such as Level 5 can be explained. Flow discharge variation can also lead to an increase and decrease of the phreatic level, continually changing the plasticity of the deposits and favoring deposit deformation. This postsedimentary process affects the limits between the strata and the spatial orientation of the archaeological and paleontological remains.

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