Piping, a geomorphological process relevant to African palaeontology and archaeology : sedimentary, taphonomic and biostratigraphic implications

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Abstract: This paper investigates the role of piping, a geomorphological process relevant to interpreting the fossil and archaeological records of Africa. Until now, piping has not been reported from African palaeontological or archaeological contexts. However, under suitable circumstances piping processes were active in the continent as elsewhere in the world, throughout the Neogene and Quaternary, which could explain some apparent anomalies in the African fossil record such as the presence of Middle Miocene fossils at Bukwa II, Uganda, in strata that have traditionally been correlated to the Early Miocene on the basis of radio-isotopic dating of subjacent volcanic layers. Examples of fossil-rich pipe sediments are described from Napak, Uganda, and at two sites on Rusinga Island, Kenya, one of which was previously interpreted to be the infilling of a hollow tree. Neogene and modern examples from Namibia are important for understanding the implications of the process. Implementiferous pipe deposits are known in South Africa, and are likely to be present in East Africa, but are currently unrecognised as such.

Key words: Piping; Geomorphology; Biochronology; Archaeology; Kenya; Uganda; Namibia.

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Introduction

In geomorphology « piping » is a term that refers to the development of subterranean channels as a consequence of water flowing through relatively insoluble, indurated, incoherent or unconsolidated rocks, the water transporting insoluble clasts away from the channel zone, the process sometimes being called underground erosion or internal erosion (Wilson *et al*. 2012). Piping occurs at various rates and mechanical scales, because sediment removal is achieved by a variety of processes including suspension (clay-sized fraction colouring the water), suffusion (silt and fine sand moving between immobile coarser clasts but not necessarily in suspension in the water) and bedload transport (sand, grit and cobbles transported along the underground channel bed by the flowing water). Hydraulic parameters are crucial, water percolating slowly through the bedrock transporting and removing clastic particles more slowly than more rapidly flowing water.

Pipes differ from classic karst channels in that the removal of rock matter is predominantly by mechanical means (transport of clasts and microclasts by flowing water) rather than in solution. In the field there is a continuum from purely karstic tunnelling (subterranean voids formed solely or predominantly by solution) to pure piping due exclusively to mechanical removal of clasts (in suspension, by suffusion or as bedload transport inside the pipe). There is no clear-cut boundary between karstic and piping processes (Halliday, 2007) many rocks in which underground voids form being an admixture of soluble and insoluble fractions, meaning that both solutional and mechanical processes can operate at the same time. Indeed some authors refer the entire spectrum of subterranean channels, including animal burrows, to ‘karst’ (Frank *et al*. 2011) but herein, a distinction is made between ‘karst’ (Pickford & Senut, 2010), so-called ‘pseudo-karst’ or piping (Calvo *et al*. 2013; Parker, 1963; Parker & Higgins, 1990) and ‘pipes’ due to root activity (McKee, 1993) or animal burrows (Frank *et al*. 2011). Pipes often develop from animal burrows, but the two categories are normally kept apart by geomorphologists, even though it is evident that animal burrows can facilitate the development of pipes in loose soils (Bond, 1941) just as pipes can be entered by animals that then modify their walls and roofs (Frank *et al*. 2011).

In general, if the subterranean channels run through rocks with a predominantly insoluble composition, and are discontinuous, with open sections alternating with closed but permeable or porous sections, they correspond to piping. If the country rock in which the subterranean voids form is soluble and the channels are more or less continuous, then they generally correspond to karst. In many cases, piping channels possess a downstream exit or outlet on a hillslope or cliff which is blocked a short way upstream by a permeable but impassable section. In many karst channels in contrast, access to the inner parts of the network can be made via the downstream exit but, of course, there are exceptions due to roof collapse, outlet narrowing, passage infilling, speleothem formation and other phenomena.

Piping channels can be vertical, sloping or horizontal and of various dimensions from a few cm to several metres in diameter (Parker, 1963) and from a few metres to hundreds of metres long. An almost universal feature of pipes is that the subterranean channels are discontinuous, with open sections interspersed with closed but porous, permeable sections (in some ways analogous to household pipes blocked by a sponge, permitting the passage of water, but not of particles). Thus it is usual that pipes close downwards from the entrances or inlets, and close upwards from their outlets, but the 'closed' sections generally remain permeable to water, including that carrying sediment in suspension or minerals in solution.

In soils, and other near-surface rocks, piping is often triggered off by the burrowing activity of animals or the rotting of plant roots, whereby surface waters seep into the ground preferentially at such sites, whereupon they can achieve their mechanical effects underground.

When pipes open upwards to the land surface they can form pseudo-karst complexes or when completely unroofed will mature into erosion gullies (Ferrer *et al*. 2017). Connections between underground pipes and the surface occur by many means. They can be due to the presence of animal burrows or plant roots which connect downwards eventually with pipes, which can, for convenience be called 'top-down' conduits, or they can occur by upwards sapping of sediments or rock from the roof of a subterranean pipe, in ways analogous to the formation of avens in karst systems, co-called 'bottom-up' conduit formation, and expressed at the land surface as surface depressions, collapse holes, swallow holes, disappearing streams, 'craters', 'funnels' and a variety of related geomophological or descripitive terms.

The compositions of the roofs, walls and floors of the underground channels are important factors influencing the rates of pipe formation, their longevity and evolution after forming and what happens to them in the long term. Well-indurated pipe roofs such as calcretes and silcretes or volcanic agglomerates and lava flows tend to prolong the life of the pipes, sometimes for centuries or millenia, whereas loose roof materials such as soils tend to collapse into the pipes, and thereby eventually form erosion gullies, often on the time scale of weeks or a few years. Root systems of vegetation can prolong the life of underground pipes developing in relatively loose soils by providing coherence to the surface soil, thereby maintaining the roof longer than would be the case if there were no root mats (Bernatek, 2017; Bernatek-Jakiel & Kondracka, 2016; Bernatek-Jakiel *et al*. 2016, 2017).

When part of a pipe roof collapses, the entrance so formed generally has steep to vertical walls which can be undercut at depth (variably named as swallow holes, craters, dolines, sink holes, collapse holes etc.). If an animal falls into such an entrance it may be difficult or impossible for it to get out. In some cases, roof collapse can result in a more gentle entrance slope, especially if slumps occur preferentially on one side of the entrance. In such cases an animal entering the system can usually get out again without difficulty. In the Ugab region of Namibia, for example, there are several long-lived pipe systems with resistant calcrete roofs that have gently sloping entrances due to the accumulation of rubble on the upstream sides of the entrances. The resultant caves are frequently entered by animals in search of water and shade and to escape from the heat of the midday sun.

At Kabarsero, in the Tugen Hills, Kenya, in contrast, the pipes that form at the present time in the Middle Miocene clays and silts have steep, unstable, rubbly entrances up to two metres wide at the rim, narrowing steeply downwards like a funnel. In the early 1970's, while the author was mapping the area as part of his PhD Thesis field work, a cow that was grazing in the badlands, fell into one such pipe entrance and could not get out. As it fell in, its head twisted sideways and it rapidly suffocated to death, but not before making the most aweful struggles trying to breathe and to straighten its neck, which is what alerted the author to the occurrence of this mishap. By the time that he and his field assistant pulled the unfortunate creature from the sink hole (its hindquarters were not even in the hole) it was already dead, the entire episode over in about ten minutes. Examination of other pipe entrances in the area revealed the presence of animal bones including those of goats, sheep and porcupines, suggesting that such entrances were places where animals often became trapped and died.

Piping occurs in the vadose zone as well as in the phreatic zone. In areas such as floodplains, the altitude of the water table can fluctuate seasonally, with the result that pipes can undergo periods of active hollowing (internal erosion) interspersed with periods of rest, or even of infilling (internal deposition) as the carrying capacity of the waters flowing through the pipes is reduced. Whilst the bulk of sediment transported during the genesis of pipes is in suspension, or moves by suffusion or by bedload transport (muddy water flow, i.e. mechanial as opposed to solutional erosion) there are well-known examples of mass flow of thixotropic and semi-consolidated sediment inside pre-existing pipes. The latter kind of mass flow can be inferred from the presence of slickensides within the pipe deposit which must be consolidated to semi-consolidated in order to preserve the slickensides. Under certain circumstances the country rock surrounding the pipes can also show evidence of slickensides and in some pipes (both vertical and horizontal) there can develop a centrimetric layer of calcitic deposit between the country rock of the pipe walls and the material infilling the pipe (Houston, 2004).

Taphonomic implications of piping

Sediment introduced into pipes from the land surface can be transported by various means, including surface runoff during rain showers, but if the pipe is blocked (which is the case in most piping systems), the water soon backs up and sediment transport within the pipe dwindles and the pipe clogs up, thereby slowing down, but seldom stopping, the passage of water. In cases where pipes are connected to the surface by a doline-like vertical or sub-vertical conduit or funnel, mud can accumulate in the funnel, and then continues to slump or flow downwards into the pipe as the subterranean water empties slowly from the pipe. In cases where the surficial layers of the land are coherent, such as calcretes, silcretes and other well-indurated rocks, the surface expression of a pipe can look like a shallow pond during the wet season, which dries up when the water table falls during the dry season. As the water in the pipe empties, the mud in the drying pond can flow into the pipe, often as semi-consolidated to almost dry mud, the movement achieved by gravity-driven mass flow.

Under the latter circumstances, the flowing mud will transport small to medium-sized objects within it unless there is an obstacle preventing their movement. By this means animal bones and jaws, stones and other hard and heavy objects can be transported into pipes as part of the mass flow, without being subjected to the kind of damage (abrasion, rolling, disarticulation) normally associated with the transport of animal remains by flowing water. Such animal remains can however be subjected to compaction and distortion caused during flow or when flowage is completed and compaction occurs. Furthermore, because pipes are generally narrower than the surface ponds associated with them, the animal remains drawn into them during mass flow, can end up closer together than they were when they were lying in the muds of the surface pond. There is a thus a centripetal flow effect which can result in a denser concentration of animal bones in the sediments infilling the pipe than occurred in the surface deposits. In such deposits, specimens that lay side by side when on the surface, can end up one overlying the other when inside the pipe infilling. The same applies to stones in the mud, including stone tools.

In piping networks in which the roof and walls of the pipes are coherent, the entrance holes and parts of the underground channels can remain open for extended periods and can in effect act much like karstic caves, often being referred to as pseudo-karst (a misnomer because there is nothing false about the process or the resultant cavities). Under such circumstances animals can enter the pipes much as they do with caves, either deliberately or unintentionally. The inlet slopes of pseudo-karst pipes can be relatively gentle or shallow in which case animals can easily enter and leave the tunnels, but in many cases, the inlet is vertical and deep with undercut margins, in which case the pipe can act as an animal trap from which it is difficult or impossible to escape once inside.

In some countries, such as Spain, piping is known to have played an important role in the genesis of palaeontological resources (Dominguez *et al*. 2013). The piping deposits that infilled pseudo-karst hollows at Batallones, near Madrid, for example, are exceptionally rich in fossils, often with the preservation of articulated skeletons (Silva *et al*. 2017a, 2017b). At Batallones, skeletons became included in the pipe sediments by at least two processes : A) animals that entered the subterranean passages when they were open to the surface, and died therein, and B) those that died close to the entrances when the latter were filled with water and mud, which subsequently flowed into the subterranean cavities when the ponds and piping system dried out (Calvo *et al*. 2013; Dominguez *et al*. 2013).

Fossils preserved in pipes will thus often show several characteristics that are rare or unusual in fluvial, palustral or lacustrine depositional environments. There is usually a concentration of fossils (or stone tools) which dwindles rapidly to zero at the pipe walls. Articulated skeletal parts are often preserved together and pieces of the same skeleton are often close to one another. Damage to fossils is mostly by compression and distortion (bending), especially in sediment close to the walls of the pipe. The sediment enclosing the fossils is often marked by slickensides, but cases are known where no slickensides are present.

The distinction between wall-rock and pipe infilling can be subtle and difficult to distinguish, but sometimes the infilling is completely different from the wall rock. In the latter case, outcrops of pipe infillings resemble gully fills, and have often been erroneously interpreted as such, except where the roof of the pipe is preserved and has been observed during excavation.

Finally, the fossils and stone tools preserved in piping deposits are almost always younger than the surrounding layers of rock in which the pipes formed, with accumulation sometimes occurring only a short lapse of time after deposition of the surrounding rock, but on occasion millions of years later. Rarely, fossils in the subjacent rocks can be reworked into pipe infillings, and thus provide a challenge to their interpretation.

Biochronological implications of piping

The realisation that piping played an important role in the genesis of the Spanish fossil record led to the elucidation of several previously enigmatic biostratigraphic problems. In some instances, fossil faunas found in a specific patch of sediment differed from other faunal elements seemingly from the same sediment horizon. It was only after realisation that the anomalous faunal elements accumulated in pipes that the enigmae were resolved, the piping faunas being younger than the *in situ* faunas from the horizon, sometimes by several million years.

The Middle Miocene fossiliferous locality at La Retama (Spain) was initially interpreted to be a fan delta formed in a small lake (Morales *et al*. 1993) but is now thought to be a piping deposit (Morales, pers. comm.). Its age (MN 5) was anomalous for the region in the sense that the bulk of sediments in the vicinity of Loranca, where La Retama occurs, correlates to MN 2 (Pickford & Morales, 1998). Interpreted as a piping deposit, the biochronological anomaly is resolved. The country rock in which the pipe formed correlates to MN 2 and the piping activity and subsequent infilling occurred during MN 5 (Pickford & Morales, 2003).

The fossiliferous deposits at Artesilla (MN 4A) and Manchones I (MN 6) (Pickford & Morales, 2003) are also likely to represent piping deposits, but they have not yet been decribed as such (Morales, pers. comm.).

Piping in Africa

Piping has long been known to occur in Africa, especially in the agricultural and soil engineering sectors, which have witnessed massive soil erosion and dam failures in which piping processes played a major role. Bernatek-Jakiel & Poesen (2018) published a map of piping occurrences worldwide which includes a summary of pipes reported in Africa, notably southern Africa, the East African countries, West Africa and the Mediterranean countries (Fig. 1). There are undoubtedly many more occurrences in Africa which have not been reported or published, either because of lack of survey, or because sheet erosion subsequent to piping has eradicated or altered the evidence of piping, making it difficult to recognise.

Figure 1. Examples of piping in Africa. Black stars are those included by Bernatek-Jakiel & Poesen (2018) the red ones are first mentioned in this paper.

Piping phenomena are known to occur in the southwestern Cape region, where there are pipe inlets cutting through a widespread calcrete horizon which overlies insoluble marine and terrestrial deposits in which generally horizontal pipes have formed. Pipe outlets are evident on scarps edged above by calcrete, and in cases are large enough to permit medium-sized to large mammals to enter (Avery & Klein, 2018). By these means, bones and teeth of prey animals have accumulated in the sediments which cover the floors of some of the pipe outlets. Artefacts and ceramics have been found in some outlets, as well as in pipe inlet contexts on the surface of the calcrete plateau above. There is a rich literature on the archaeology of the area, but few of them mention piping (Hendey & Hendey, 1968).

Mount Elgon Kenya-Uganda

The existence of pipes in Africa has been recognised for a long time but they were generally not attributed to piping for a variety of reasons. For example, some, but by no means all of the caves on Mount Elgon, on the Kenya-Uganda border, are related to ancient piping processes that were active in volcanic ash and agglomerate layers rich in fossil wood, sandwiched between more resistant coarse, well-indurated agglomerates and/or lava flows. Some of the Elgon pipes flow during the wet season and for a few months after the dry season sets in, but many flow intermittently, often remaining dry for decades (Fig. 2). A significant number of the pipe outlets are large enough to permit the entrance of medium-sized and large mammals, including elephants, which enter the outlets in order to obtain mineral salts exuding from the walls of the pipes and which impregnate the pipe-wall material. As a result of generations of visits by elephants, some of the Elgon Caves, such as Kitum Cave, penetrate over a hundred metres into the mountain, and show tusk marks on the walls where elephants have prised off chunks of the tuffaceous deposits to ingest. Over the long term, this kind of activity has greatly enlarged some of the caves, but there are many smaller ones which retain the classic appearance of pipes.

Figure 2. One of the innumerable caves on the slopes of Mount Elgon, east of Kapchorwa, Uganda. Note the pipe-like openings at the base of the large cave, penetrating into the insoluble tuffs that comprise the walls of the cave. The roof consists of a thick and resistant volcanic agglomerate and the floor has been partly backfilled by sediment transported by flowing water, subsequently altered by human and livestock activity.

Figure 3. Pipe outlet on the northern slopes of Mount Elgon, east of Kapchorwa, Uganda, piercing insoluble coarse tuffs exposed at the base of a cliff of resistant volcanic agglomerate. These pipes are no longer active, having been formed during a more humid period when there were greater quantities of groundwater flowing through the substrate. The resistant walls, floors and roofs of these pipes ensures their long-term survival, spanning centuries, if not millenia.

Because of the presence of extremely erosion-resistant layers of volcanic agglomerate underlying and overlying the tuffaceous layers on Mount Elgon, the pipes have persisted for an extremely long time, probably hundreds to thousands, if not millions, of years (Fig. 3). It is also likely that the piping process in such circumstances was exceptionally slow, and that pipe formation could have taken thousands of years to complete. Other examples of pipe caves developed in tuffs in Kenya have reached the literature (Halliday, 2007).

Münsterhöhle, Namibia

Namibia is another country in which piping cavities have been confused with karst caverns. The northern edge of the Ugab drainage, for example, is comprised of an elongated calcrete-capped plateau that extends for over 100 km and contains numerous seeps along its cliff-like margins. The calcrete plateau beyond to the north is the site of numerous disappearing streams, many of them of small dimensions, but some of the entrances are large enough for medium-to-large animals to enter (Fig. 4). One such piping system southwest of Outjo, is known as Münsterhöhle and consists of a « cave » with two entrances broken through the capping calcrete large enough for people to enter without difficulty and without having to crouch down. Water flowing into this pipe during the rainy season eventually seeps out of the cliffs overlooking the Ugab, but there are no passages large enough for humans or other animals, even small ones, to go from the entrance to the exit via the pipe, because it closes a few dozen metres downstream from the entrance. However, the rock layer in which the pipe formed is permeable enough for water to percolate slowly through to the outlet seeps on the cliff edges (Fig. 5). The seeps are often somewhat hollowed out, but close off after a short distance upstream, usually less than a metre.

Figure 4. Münsterhöhle, Namibia, a large, almost horizontal pipe. It has two entrances and insoluble walls and roof. The roof of the cavern is comprised of impure calcrete about two metres thick.

Figure 5. Seeps on the cliffs overlooking the Ugab River Valley. These outlets drain the Münsterhöhle and similar pipes immediately beneath the calcrete plateau to the north. In general the outlets do not penetrate far into the cliffs.

Simanya, Namibia

The southern bank of the Kavango River in northern Namibia, is comprised of steep ground rising some 30 metres above the river. The slopes consist of thin layers of silicified sediment intercalated with softer horizons, and there is a significant slope deposit composed of sand and soil. Excavations into the slopes reveal the presence of pipes and infilled tunnels of various sorts. Some are pipes in the strict sense of the term (Fig. 6) but some are probably animal burrows (Fig. 7) likely excavated by aardvarks (*Orycteropus afer*) and which upon abandonment were infilled with soil and sand infiltrating from the entrance.

Figure 6. Pipe in the consolidated sediment on the slopes south of the Kavango River, near Simanya, Namibia. The outcrop is in a quarry, but it shows the cross section of the pipe well, including an infilling of clay and sand. Diameter of the pipe is ca 1 metre. Note the calcitic ‘veins’ traversing the consolidated sediments, part of which acted as a floor of the pipe.

Figure 7. Infilled animal burrow with an ovoid section narrowing downwards, exposed in the wall of a quarry on the southern flank of the Kavango River Valley, near Simanya, Namibia. The burrow penetrates poorly consolidated, pale nodular sand and silt, and has been infilled by dark grey clayey-silty soil and fragments of the subjacent country rock. The side-to-side diameter of the hole is ca 1 metre from which it is concluded that the burrow was probably excavated by an aardvark (*Orycteropus afer*).

Kogole, Uganda

Recent soil piping is a problem in agricultural areas of Africa, as has been widely recognised in Europe and elsewhere (Bernatek-Jakiel & Poesen, 2018). It is also a problem in pastoralist areas, such as Kogole, north of Moroto Mountain, Uganda, where it affects Recent black soils which developed on middle Miocene sedimentary deposits and Pre-Cambrian gneisses (Fig. 8). The area is semi-arid, with infrequent but heavy storms during the rainy season. Because of the rather poor vegetation cover in the region, once a pipe forms it tends to mature rapidly (a few years) and then to collapse in sectors, eventually forming a continuous gully which broadens and deepens with each succeeding storm. In favourable areas with combined tree and grass cover, pipes can maintain their roofs for several years, but eventually they collapse to form a gully.

These pipes can be a hazard to cattle, especially calves, because an unwary animal can step onto a weak part of the roof and break through into the gulley beneath, or if the herd of cattle panics and stampedes, some animals may fall into the pipes or into the nearby gullies partly hidden by grass and sometimes by trees growing in the gullies (for other examples of trees growing preferentially in piping gullies see for example Bernatek-Jakiel & Wrońska-Wałach, 2018).

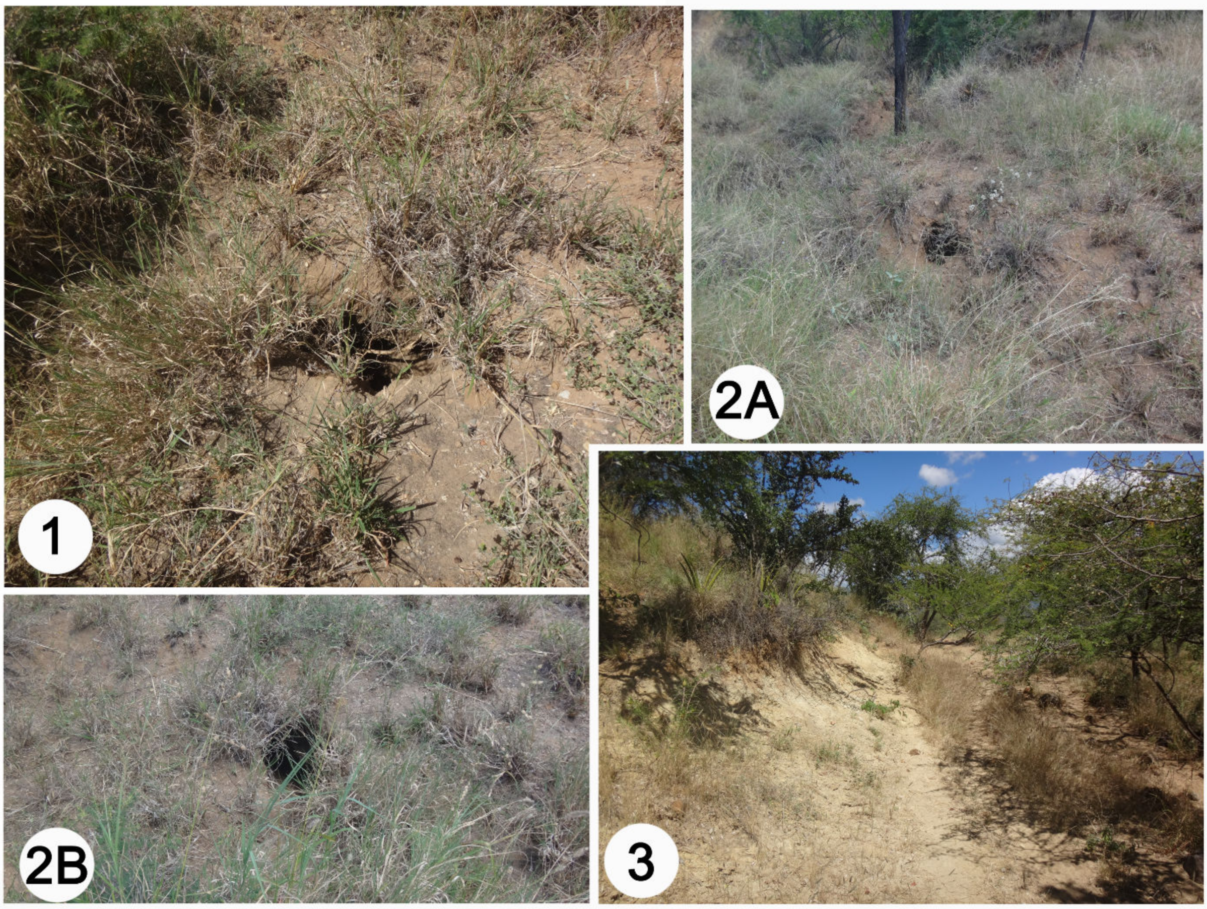

Figure 8. Recent piping in friable soils at Kogole, near Moroto, Eastern Uganda. 1) and 2) are the inlets of the pipes, partly supported by a mat of grass roots, while 3) is the nearby 3-metre deep erosion gully into which the pipes drain, the outlets being at the contact between the Middle Miocene pale sands and grits forming the lower slopes of the gully, and the Recent vegetated black soils above. Note the tree in 2A) growing within a collapsed part of the pipe, suggesting that the pipe is several years old.

Palaeopipes in East Africa

Uganda

Napak I Rhino Site

The Early Miocene Napak I Rhino Site is here interpreted to be a piping deposit that accumulated in a tunnel which developed in bedded carbonatite-nephelinite tuffs (Fig. 9, 10). The pipe infilling yielded associated parts of a rhinocerotid skeleton along with fragments of a juvenile deinothere and a tragulid. In recent times, the ensemble was affected by a second phase of underground erosion resulting in the formation of a fissure in which some reworked fossils accumulated, some bones having one end *in situ* in the hardened pipe infilling and the other in the unindurated fissure filling.

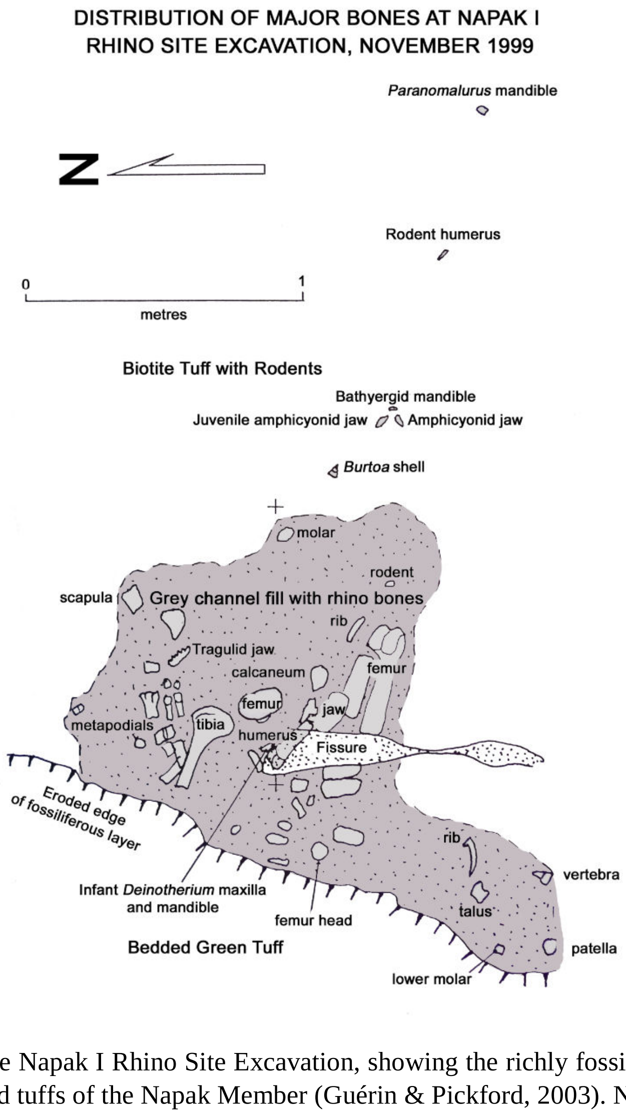

Figure 9. Sketch map of the Napak I Rhino Site Excavation, showing the richly fossiliferous piping infill (grey) sandwiched between bedded tuffs of the Napak Member (Guérin & Pickford, 2003). Note the more recent fissure in which some reworked fossils accumulated.

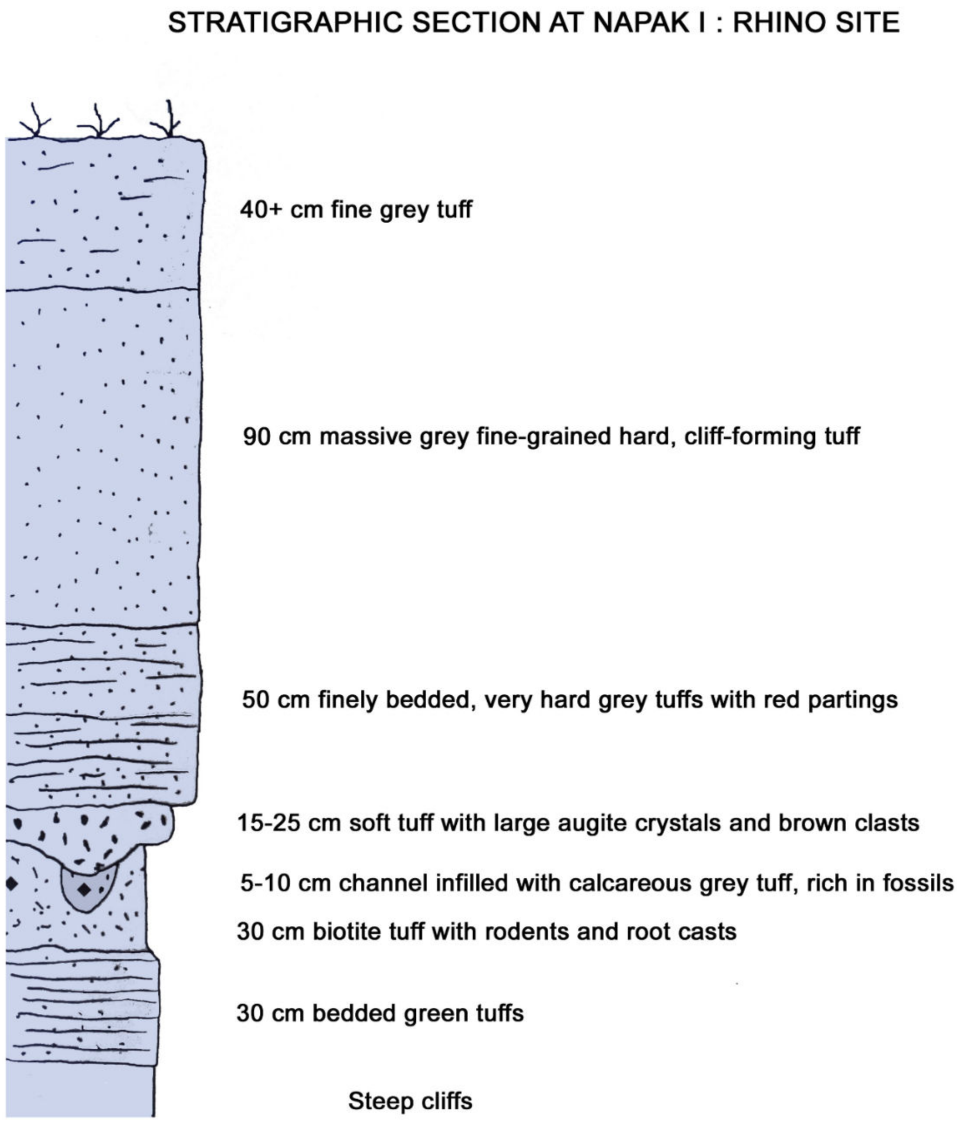

Figure 10. Stratigraphic section at the Napak I Rhino Site Excavation showing the context of the piping infill (dark grey) in bedded tuffs (lighter grey).

The fauna from the Napak I Rhino Site is unusual when compared to the faunas from the other sites in the Napak Member. Firstly, only four taxa were found, a rhinocerotid, a deinothere, a tragulid and a rodent. The first of these taxa (*Ougandatherium*) has never been reported from the other sites in the member while the second is exceptionally rare, being represented by a single doubtful enamel fragment at Napak XV. Secondly, unlike the bulk of fossils from the Napak Member which occur as isolated and broken bone fragments and teeth, the rhinocerotid and the infant deinothere at the Rhino Site comprised partial skeletons.

The rhinocerotid skeleton from the Napak I Rhino Site is the holotype of *Ougandatherium napakense* Guérin & Pickford, 2003. This species has been found only at this site, the other rhinocerotid remains from Napak belonging to *Brachypotherium* and *Aceratherium*.

From this it is inferred that the pipe infilling at the Napak I Rhino Site could be substantially younger than the sedimentary member in which the pipe infilling occurs. Elasmothere rhinocerotids are common in East African deposits correlated to Faunal Sets 2 and 3 of Pickford (1981) (i.e. 17.8 to 16 Ma) (Pickford, 2017) but, with the exception of the Napak I Rhino Site, are unknown from other localities correlated to Faunal Set 1 or earlier deposits (i.e. older than 17.8 Ma).

Napak IV Pipe

The Napak IV pipe (not to be confused with the fossiliferous bedded tuffs and palaeosols at Napak IV through which it cuts) was previously interpreted to be a spring deposit (Bishop, 1962; Musalizi *et al*. 2009). It is poorly fossiliferous, but has yielded some large primate bones (*Ugandapithecus major*). The infilling of the palaeo-pipe is comprised of dark brown silt which has been pervasively cemented in patches by nodular calcium carbonate, while hollows in the system were the sites of speleothem genesis. The presence of speleothems is unusual in pipe infillings, but at Napak, there is a ready source of calcium carbonate in the subjacent carbonatite-nephelinite tuffs, which, under the right conditions can be dissolved and redeposited in hollows within the tuffs, but only if the hollows are not filled with water. Even if the interpretation of the Napak IV deposit as a spring is partly correct, it must have been devoid of water at the time of speleothem genesis.

Despite the fact that Napak IV is by far the richest fossil site in the Napak Member, it has yielded only four specimens of *Ugandapithecus major*, two teeth from surface context and two post-cranial elements (humerus, femur) from the pipe infilling (Fig. 11). Thus the faunal elements from the pipe infilling, restricted though they are, stand out from the rest of the fauna from the Napak IV. In contrast, the large primate *Ugandapithecus major* is common at other localities such as Napak I, V, IX and XV where the deposits comprise palaeosols developed on volcanic tuffs.

It is concluded that the pipe infilling at Napak IV and the fossils that it contains are slightly younger than the flaggy tuffs through which the pipe cuts, but that both the infilling and the fauna correlate to Faunal Set 1 of Pickford (1981).

Figure 11. The Napak IV pipe infilling and fragments of eroded speleothem that formed in it once it became inactive (lower half of image on the right). In the image the soft pipe infill is held together by the vegetation, while part of the clay-silt infilling has been exposed above. This pipe pierces flaggy tuffs showing incipient pedogenesis. The white cobbles at the edge of the pipe are fragments of speleothem and calcified pipe infill.

Speleothems also occur at Napak IV Downhill Site and near Napak XVIII, but these occurrences are more in the nature of infillings of cracks and fissures in the tuffs, possibly of localised tectonic or tectono-volcanic origin, rather than of piping processes.

Napak XXX

Napak XXX is a rich source of articulated and partly articulated skeletons of small and medium-sized mammals. It lies within the Iriri Member, which is the basal member of the Neogene succession in the area. Dominant in the fauna is the rodent *Diamantomys luederitzi*, but there are associated remains of other rodents, tragulids (*Siamotragulus songhor-ensis*) and a carnivoran (*Kelba*). The fossiliferous deposit is localised in a cliff of gritty sediment, and consists of intensely slickensided clays and silts which have been partly calcitised in patches. The contact between the pipe infilling and the grits is sharp, even though the deep red-brown colouring of the two deposits is similar. The grain-size difference between the two deposits is clear as is the fact that the clay infilling is richly fossiliferous, in contrast to the grit which is poorly fossiliferous (Fig. 12).

The fauna from Napak XXX is similar to those from other localities in the area, indicating that there was not a significant time lag between the accumulation of the deposits in which the pipe formed on the one hand, and the formation and subsequent infilling of the pipe on the other.

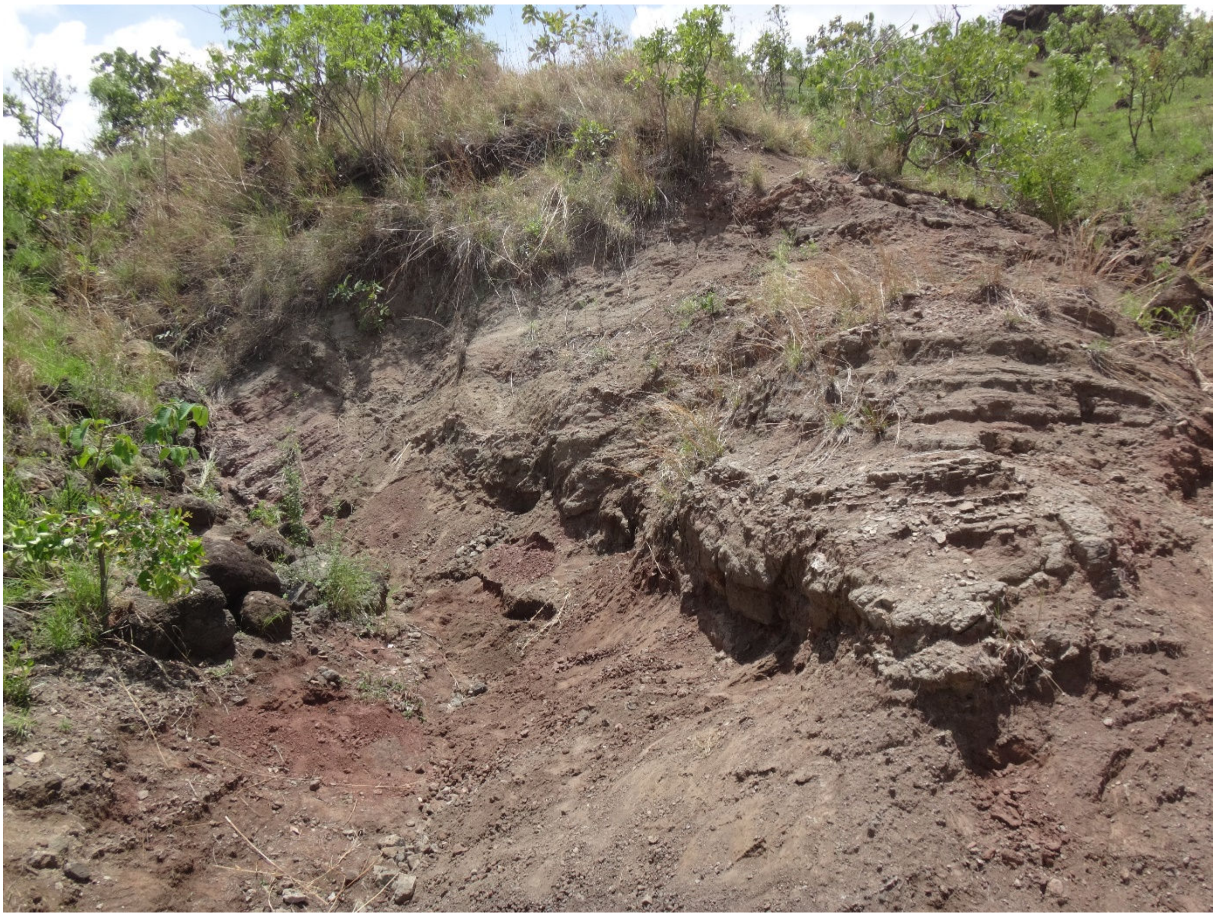

Figure 12. The Napak XXX fossiliferous locality includes a pipe-infilling rich in articulated skeletons of rodents, tragulids and other mammals. The pipe formed in red-brown grits underlying the bedded strata that form the ridge, and are exposed in the right hand side of the present-day gulley, immediately beneath the overhang (in shadow). The clay infilling the pipe is intensely slickensided whereas the surrounding deposits are not affected by this feature.

Bukwa II

The middle Miocene fossiliferous clays at Bukwa II, Mount Elgon, Uganda, were, until recently, considered by some authors to have yielded one of the oldest Neogene faunas of East Africa (MacLatchy *et al*. 2006). As a consequence of this perception, based on its position at the base of Kwongori Hill, topographically lower than lavas capping the hill, dated at ca 19.7 Ma (Walker, 1968; Pickford, 2017) it has been interpreted by some as the first appearance datum of several mammalian taxa, despite the fact that it has yielded relatively few fossils (fewer than 300 specimens, many of which are indeterminate).

However, some of the taxa from Bukwa II are not represented in any of the many sites correlated to East African Faunal Sets 0, 1 and 2 (Pickford, 1981) but are common in basal Middle Miocene faunas correlated to Faunal Set 3, and are even different from the restricted mammalian fauna found at Bukwa I, a few hundred metres from Bukwa II, which has a fauna typical of Faunal Set I (*Renefosor songhorensis*, for example) and which is in demonstrable superpositional relationship with the overlying radio-isotopically dated lava flow which caps Kwongori Hill.

The debate about the age of Bukwa II was dealt with in depth by Pickford, 2107, who concluded that the deposits were in a discordant stratigraphic relationship with the subjacent flaggy tuffs and lavas of Early Miocene age. The form of the deposit is compatible with sedimentation near a pipe outlet, as in Fig. 14, as is the faunal content (ostracods, crabs, the freshwater gastropod *Melanoides*, mammals). On Mount Elgon, there are innumerable pipes developed in the tuffaceous and agglomeratic layers of the volcano (Fig. 13, 14), some of them, such as Keben cho Kumus (1°18’49”N : 34°45’28.9”E) being close to Bukwa itself. It is possible that Bukwa II is a manifestation of the same processes (Fig. 15), but of basal middle Miocene age, ca 16-16.5 Ma (Pickford, 2017).

Figure 13. Pipe outlet in tuffaceous and agglomeratic deposits on the lower slopes of Mount Elgon, near Bukwa, Uganda, with a resistant roof of lava.

Figure 14. Active pipe outlet close to Bukwa II fossil site, Mount Elgon, Uganda. The water is seeping from a pipe eroded through tuffs of the Elgon volcanics which are of Early Miocene age.

Figure 15. Greenish clays and silts at Bukwa II infill a depression cut into flaggy tuffs exposed in the slopes in the background capped by a lava flow at Kwongori Hill, Mount Elgon, Uganda. The flaggy tuffs in the background yield faunal elements typical of East African Faunal Set 1, whereas the green clays being sampled for screening yield a significantly younger faunal assemblage that correlates best with East African Faunal Set 3.

Kenya

Rusinga Kathwanga Primate Site

Walker (2007) described the deposits in which a concentration of primate skeletons at the Kathwanga Primate Site (KPS) including associated parts of at least ten individuals, accumulated, as « *a small channel fill or the remains of an infilled carnivore burrow that was dug in soft sediment* ». He detailed that « *the fossils come from an infilling of Fossil Bed Member silts into a steep but shallow (1 m deep) channel or burrow cut into the underlying Grit Member of the Hiwegi Formation* » and that « *the channels were probably filled in one, very brief, possibly slumping, episode, but the silts and clays point to it being a low energy sedimentary environment* ». Some of the primate remains were in articulation, and the upper parts of the infilling contained fossilised leaves and fruits. Furthermore, some of the primate remains show evidence of carnivore damage. Many of the fossilised bones are bent or distorted.

All the features of the KPS occurrence are compatible with it being the infilling of a pipe eroded into the Grit Member of the Hiwegi Formation rather than a burrow excavated by a carnivore in which it stored partial skeletons of primates. Rather than being a case of preferential prey selection by a carnivore, the primate cadavers in and near the entrance of a pipe could have attracted a carnivore or carnivores to the site. How the primate skeletons entered the pipe is a matter of speculation, but it is clear from the presence of articulated hands and feet that post-mortem disturbance was minimal, while the bending and distortion of bones is compatible with compaction and localised mass flow of semi-consolidated sediment within a pipe.

Rusinga Site R 114

Walker (2007) wrote « *R 114, that contained the type specimen of* Proconsul heseloni*, is the infilling with matrix and bones of a large hollow tree trunk* ». It had previously been described as « *a tiny isolated outcrop* » (Whitworth, unpublished field note book) and as « *a small circular pipe* » (Whitworth, 1953) and that « *the profusion of articulated skeletons found in this limited deposit suggest that it may represent the infilling of a pothole in which animals were trapped* » (Whitworth, 1953). Napier & Davis (1959) wrote that « *the pot-hole may have acted as a trap for unwary animals that came there to drink* ». Walker (2007) concluded that the « *structure that created the 'pipe' was standing when the flaggy series were deposited* » from which he concluded that R 114 « *was obviously the infilling of a large, hollow tree trunk* ». He mentioned the pervasive existence of slickensides in the pipe infilling and in the immediate vicinity of the surrounding flaggy series. He proposed that the concentration of fossils in the pipe infilling resulted from « *animals being carried in or using the tree as a roost* » and « *at least one …. carnivore species …. left tooth marks on the* Proconsul *skeleton* ».

The R 114 structure is essentially vertical, with sub-horizontal bedding in the sedimentary infilling, which warps upwards slightly at the edges, where the infilling is separated from the country rock by a variably developed, but thin calcite envelope. The country rock in contrast, dips at ca 5°, as depicted in the cartoon prepared by T. Prentis (Fig. 16). Walker (2007) took this to mean that the R 114 structure was present prior to deposition of the flaggy tuffs in which it occurs. Such an interpretation seems highly unlikely. Given that the regional dip of the flaggy tuffs is 5°, it implies either that the flaggy tuffs were deposited with this dip around a vertical tree (as proposed by Walker, 2007) or that they were deposited as usual in horizontal layers around a slanting tree but were then tilted in such a way as to bring the tree to the vertical.

A more likely scenario is that the vertical structure represents upward sapping from a sub-horizontal pipe that developed in already tilted flaggy tuffs to produce a doline-like hole connecting at depth to the pipe. As such the vertical part of the pipe is analogous to a doline in karst terrains. Indeed, the flaggy tuffs in which the R 114 pipe formed are rich in calcium carbonate, to the extent that they fizz when weak acid is poured on to them. Thus the pipe could represent a composite structure, formed in part by 'pseudo-karst' processes and partly by 'karst' processes, the two probably acting simultaneously. The calcite cylinder which envelopes the infilling likely derived its calcium carbonate from the surrounding flaggy tuffs.

Once connected to the surface the pipe could then act as a receptacle for sediment and for the occasional animal that fell into it, was carried into it, or lived in it. Compaction of the pipe infilling caused warping of the edges of the infilling, produced slickensides in the sediment and the wallrock close to the pipe, and also led to distortion and compaction of mammal skeletons within the infilling.

Walker & Teaford (1989) published a cartoon of the supposed genesis of the fossil site as a tree (1 in Fig. 16) that was buried to a depth of at least four metres by flaggy tuffaceous sediments (2 in Fig. 16), the tree then dying and hollowing out so that it could act as a receptacle for sediment dribbling into it from the surface and so that animals could roost or den in it (Walker & Shipman, 2005) and so that a small carnivore could bring in mammal cadavers such as those of suids and *Proconsul* (3 in Fig. 16) followed by deposition of a calcite cylinder around the infilling and then erosion to expose the structure at the surface (4 in Fig. 16).

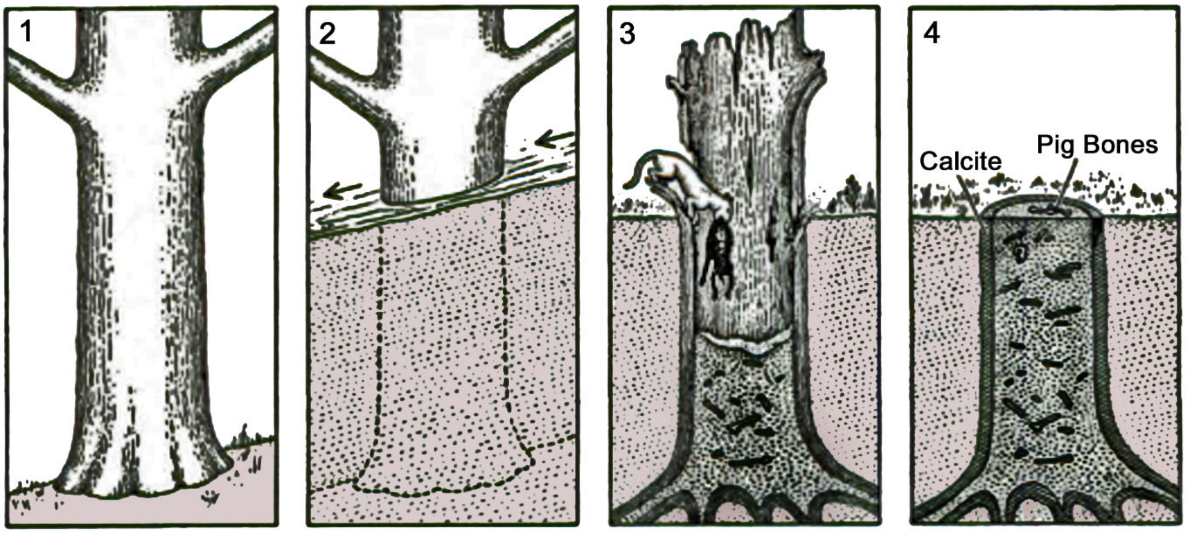

Figure 16. Cartoon sequence interpreting the R 114 fossil occurrence as the infilling of a partly buried, hollow tree which acted as a carnivore den and as a receptacle for sediments dribbling into it. The roots of the supposed tree are hypothetical, not present in the excavation which exposed 4 metres of the pipe-like structure (figure modified from Tom Prentis in Walker & Teaford, 1989).

The published cartoon shows roots splaying out at the base of the supposed tree, yet none are evident in the photograph of the structure. The hollow-tree scenario does not explain the presence of slickensides affecting the infilling of the structure nor of their occurrence in the subjacent flaggy tuffs in which the structure formed, nor does it explain the presence of a cylinder of calcite between the infilling and the country rock. Walker & Teaford (1989) interpreted the calcite cylinder as a replacement of the tree's bark, but this seems unlikely, if only because tree bark is usually softer than the trunk which, had it rotted away would hardly have left the bark in a pristine state to be fossilised once the rotted centre of the tree had been filled with sediment. Furthermore, the scenario that carnivores introduced the cadavers into the hollow tree is unlikely, because almost all the mammal remains found in the infilling were partial to complete skeletons with little carnivore damage. One of the partial skeletons from the infilling is the holotype of the small carnivoran *Exiguodon pilgrimi* (Morales & Pickford, 2017), a second is the holotype of the suid *Kenyasus rusingensis* Pickford, 1986, and a third is the holotype of the basal hominoid *Ekembo heseloni* (Walker *et al*., 1993). In addition there were skeletons of rodents, lagomorphs, snakes, chamaeleons and other animals such as gastropods in the infilling, which show minimal carnivore damage or none at all.

Also unlikely is the assumption, implicit in the hollow-tree scenario of Walker & Teaford (1989), that the outcrop, as found by Whitworth in 1953, happened to coincide with the ancient land surface at the time that it formed. Indeed, when Whitworth found the deposit, it formed a low-relief mound, which indicates that an unknown amount of pipe infilling and surrrounding sediment had already been eroded away in Recent times. Loose blocks of fossiliferous sediment that had already broken away from the infilling were found lying around the pipe, some in the recent soil several metres from it.

In opposition to the hollow-tree scenario, the infilling of the R 114 structure is more likely to be the vertical part of a piping system which filled with sediment, once doline-like upward sapping of the pipe reached the surface. Infilling was episodic, as is often the case with pipes, because piping processes would have continued to remove sediment in the underground downstream sector, liberating space for the loose and partly consolidated sediments in the upper part of the system which could then flow or slump downwards. During mass flow of the sedimentary infilling, slickensides were produced in the semi-consolidated deposits, as well as in the parts of the pipe wall close to the infilling. Skeletons in the sediment did not become disarticulated because they were carried along with the mass of sediment, but they were subjected to compaction and distortion, both of which are evident in the mammal bones from the site. Finally, the cylinder of calcite which surrounds the pipe infilling probably resulted from the replacement of intensely slickensided sediments which lined the infilling, being the site of calcite deposition once the system was no longer functioning as a sink. Alternately, but unlikely, it might have formed by precipitation of calcite on the walls of an open pipe as is reported to be the case in calcite-lined pipes traversing the Jalquinche Formation, Atacama Desert, Chile (Houston, 2004).

In retrospect, Whitworth's (1953) initial interpretation of the R 114 occurrence as a « *small circular pipe* » is likely to be closer to the mark than the hollow-tree scenario of Walker & Teaford (1989). Renaming the R 114 'pipe' deposit as « Whitworth's Pothole » caused confusion because subsequent readers have assumed that the structure formed as a result of fluvial activity in the bed of a river followed by its infilling with fluvial sediments. This was not Whitworth's (1953) intention as far as I can judge.

The fauna from the pipe infilling, even though restricted in diversity, is similar to that of the Hiwegi Member of Rusinga Island, which indicates that piping occurred within a relatively short span of time after deposition of the flaggy tuffs in which the pipe formed, as inferred by Walker & Teaford (1989).

Table 1. East African Miocene fossiliferous deposits interpreted to be piping infills or which have the potential of being pipe infillings (FS - Faunal Set of Pickford, 1981, KPS – Kathwanga Primate Site) arranged in chronological order.

Locality	Lithology of infilling (age)	Country rock (age)	Form of infilling	Slickensides	Articulated skeletal elements	Carnivoran activity	Reference
Bukwa II	Clay-silt (FS 3)	Flaggy tuffs (FS 1)	sub-horizontal channel	?	no	yes	Pickford, 2017
Rusinga KPS	Soft clay-silt (FS 2)	Clay-silt (FS 2)	burrow or gulley	?	yes	yes	Walker, 2007
Rusinga R 114	Silt-grit (FS 2)	Flaggy tuffs (FS 2)	vertical pipe	yes	yes	yes	Walker, 2007
Napak I : Rhino site	Silt (FS 1)	Indurated tuff (FS 1)	sub-horizontal channel	no	yes	yes	Guérin & Pickford, 2003
Nap IV 'Spring'	Calcified silt (FS 1)	Bedded tuffs (FS 1)	steep funnel with short lateral apophyses	no	no	yes	Bishop, 1962, Musalizi *et al*. 2009
Nap XXX	Clay (FS 1)	Grit (FS 1)	sub-horizontal channel	yes	yes	yes	This paper
Meswa Bridge	Silty-grit (FS 0, 1 or 2?)	Silt and grit (FS 0)	sub-horizontal channel	?	yes	yes	Pickford, 1983

Meswa Bridge, Kenya

Meswa Bridge is a richly fossiliferous locality in the Muhoroni Formation, Western Kenya (Pickford, 1982, 1983). It yielded associated skeletal remains of a variety of mammals including the type specimen of *Ugandapithecus meswae* (Harrison & Andrews, 2009). There are almost complete skeletons of the anthracothere *Brachyodus aequatorialis* MacInnes (1951), one of the huge creodont *Megistotherium osteothlastes* Savage (1973), a proboscidean (*Eozygodon morotoenis* (Pickford & Tassy, 1980)), as well as remains of medium-sized and small mammals (*Megapedetes* MacInnes, 1957; other rodents; *Kelba* Savage, 1965, and an Orycteropodidae) and a flamingo-sized bird as well as a large quantity and diversity of land snails (Pickford, 1995) (Fig. 17).

Pickford & Andrews (1981) reported that « *the fossiliferous sediments accumulated as an infilling of an ephemeral channel in fluviatile sands* ». Apart from fossil plants, the Muhoroni Formation is generally poorly fossiliferous, but the Meswa Bridge site, in contrast, is exceptionally rich in vertebrate fossils which are highly concentrated, the fossils occurring packed together in a channel-like structure eroded into the surrounding grits. The deposit was initially interpreted to be a gulley exposed at the land surface in which cadavers accumulated as a result of transport by water in the gulley, but it is herein reinterpreted to be the infilling of a mostly subterranean pipe which had an opening to the surface through which live animals or dead animal remains passed, were deposited and then not disturbed, a process which resulted in the preservation of articulated skeletons

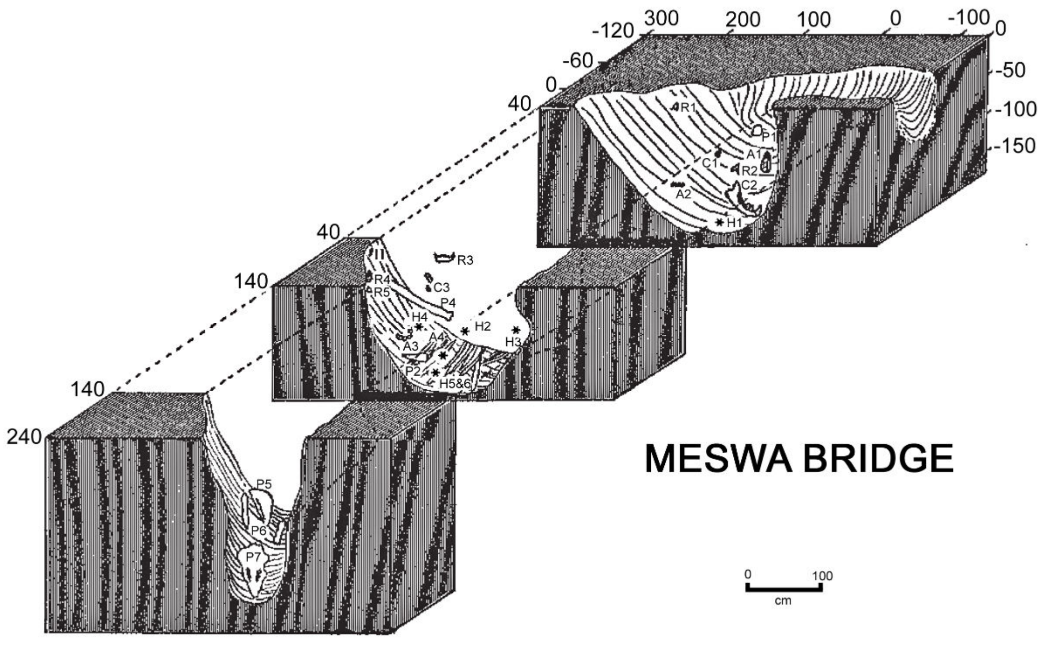

Figure 17. Three dimensional representation of the Meswa Bridge fossil occurrence based on the 1979-1980 excavation records (modified from Pickford & Andrews, 1981). Note the overhanging margin of the gully in the centre section and the narrowing downstream, suggestive of a pipe-like morphology rather than a typical erosion gulley. The fossils illustrated are as follows :- A – *Brachyodus aequatorialis*, C – *Megistotherium osteothlastes*, H – *Ugandapithecus meswae*, I1 - *Rhynchocyon*, P – *Eozygodon morotoensis*, R1 + R2 – *Renefossor songhorensis*, R3 – *Megapedetes pentadactylus*, R4 – *Paranomalurus*, *Paraphiomys* and *Megapedetes*, R5 – rodent scapula. Many specimens are not illustrated, including gastropods and birds among the non-mammalian taxa.

Meswa Bridge is the first appearance datum of a number of mammalian taxa, because it occurs in the basal horizon of the sedimentary system that accumulated in the Nyanza Rift Valley (Pickford, 1982). Most of the taxa are present in Faunal Set I of Pickford (1981) the main exceptions being *Eozygodon morotoensis* and *Megistotherium osteothlastes*, which are rare or absent in Faunal Set 1, but are well known from Faunal Sets 2 and 3. Traditionally, Meswa Bridge has been assigned to Faunal Set 0, as the basalmost Miocene deposit of East Africa, but, interpreted as a pipe infilling, it could correlate to Faunal Set 1 or 2 or less likely to Faunal Set 3.

Namibia

Grillental Carrière and Elisabethfeld

The green silts at Grillental Carrière, an early Miocene valley infilling in the Northern Sperrgebiet, Namibia, yield a few scattered fragments of bones of medium sized mammals and rodents. However, in the middle of the exposure of green silt there is a circular structure half a metre in diameter infilled with brownish silt, crammed with skeletal remains of rodents (*Neosciuromys*, *Apodecter*, *Diamantomys*, *Bathyergoides* and *Protarsomys*), macroscelidids, lagomorphs and snakes. This highly concentrated accumulation of skeletons could represent a small pipe infilling (Fig. 18) or perhaps an animal burrow.

A similar concentration of small mammal skeletons was found at Elisabethfeld, where the dominant small mammal was the macroscelidid *Protypotheroides*, along with the rodent *Diamantomys* and a small bovid. This occurrence could also represent a pipe infilling or similar depositional setting (e.g. an animal burrow).

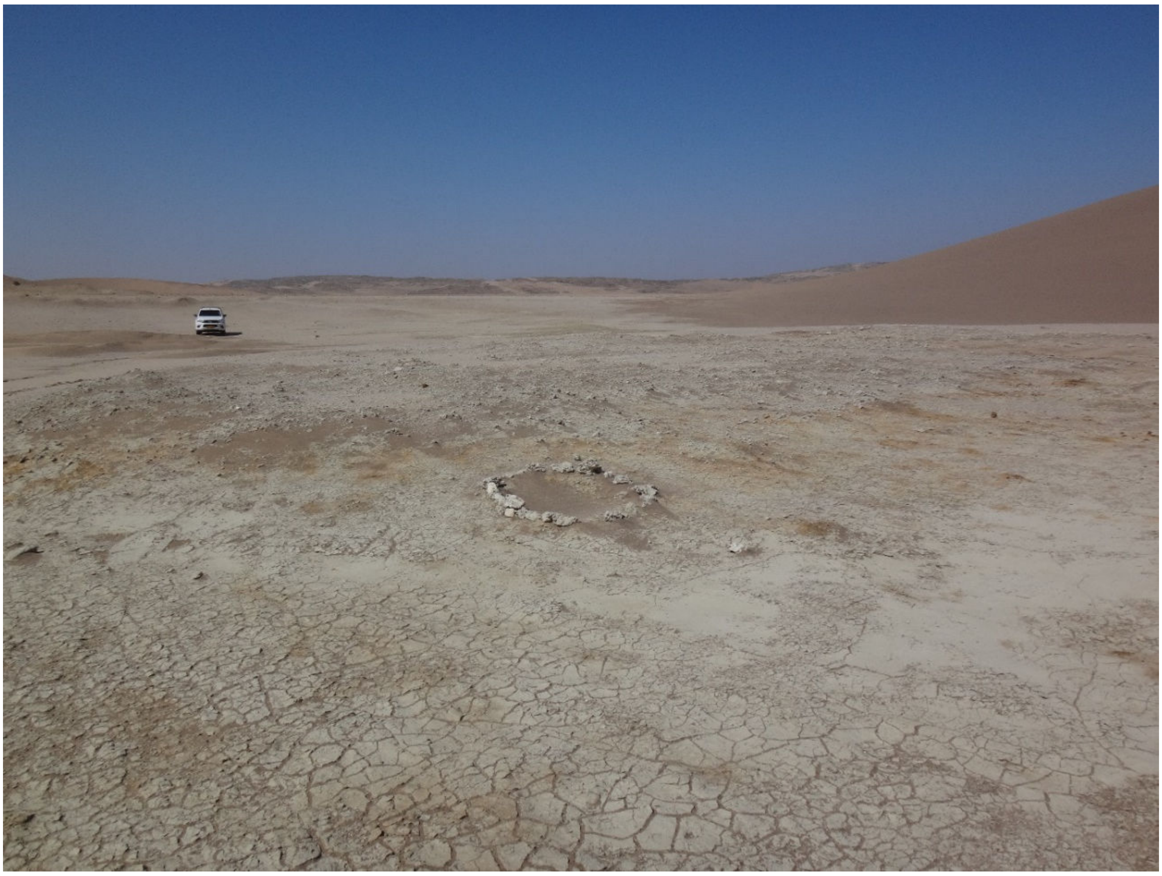

Figure 18. Small circular structure in the greenish silts at Grillental Carrière site, infilled with brownish silt rich in skeletal remains of small mammals (now obscured by windblown sand). The rocks arranged in a circle around the structure were placed there in 2004 in order to record the position of the site which was being over-run by a huge dune, now (14 years later) in the right background. This infilling is interpreted as a pipe infilling, or as an animal burrow.

Kenya

Lomekwi 3

The archaeological site at Lomekwi 3, west of Lake Turkana, Kenya, has been interpreted to have yielded by far the oldest stone tools known in the world, at an estimated 3.3 Ma, some 700,000 years earlier than the previously oldest known tools (Harmand *et al*. 2015). The report has ignited a debate about diverse aspects of human evolution, cognition, pre-*Homo* artefacts, aspects of early hominid behaviour, the mental capacities of early hominids in general, and comparisons with stone-tool-making by chimpanzees and other primates, and it has led to speculation concerning the makers of the stone tools (*Kenyanthropus platyops* or *Australopithecus*) (Lewis & Harmand, 2016). It has also rekindled interest in the possibility of animal butchery by early hominids, such as the Dikika claims, where stigmata on animals bones have been interpreted as cut-marks made by early hominids 3.4 million years ago (McPherron *et al*. 2010; Thomson *et al*. 2015) but which have proven to be controversial to some authors (Dominguez-Rodrigo & Alcala, 2016).

Examination of the excavation plans and sections published by the Lomekwi 3 research team reveals that the '*in situ*' objects (stone artefacts and fossils) occur in an extremely restricted zone some 2-3 metres wide, ca 5-6 metres long and less than a metre thick (estimated from the excavation plans), where they are highly concentrated together (Fig. 19, 20). The subjacent Pliocene deposits are devoid of artefacts and fossils, not only in the sediments either side of the concentration, but also those below and above it (Harmand *et al*. 2015, Extended data figure 1). Furthermore, artefacts lie one above the other within the matrix, a highly unusual feature in undisturbed archaeological contexts, but common in reworked pipe-fill occurrences, as is the presence of three mammal vertebrae connected together. More telling, is a distinct colour change between the implementiferous/ fossiliferous deposits (dark grey) and the subjacent Pliocene sediments (paler). Interpretation of the implementiferous deposits as a pipe-infilling is a distinct possibility.

The situation reported by Harmand *et al*. (2015) is unusual in archaeological and palaeontological contexts, as was recognised by Dominguez-Rodrigo & Alcala (2016) but is typical of piping deposits. In contrast to the usual situation by which bones and tools accumulate on an ancient land surface (the objects are usually scattered rather randomly on the surface and seldom lie on top of each other) piping processes tend to bring them together as a result of sediment flowing downwards into a restricted space, transporting the objects with it. Transport can be as little as a metre or two or three, and the mud carrying the objects cushions them from abrasion, rolling, scattering, disarticulation and other taphonomic processes, so that they often arrive at their final destination without any obvious signs of having moved from their initial place of accumulation. However, even though the distance travelled can be as little as a metre, because pipe infillings are always younger than the rocks in which the pipes formed, in terms of geological time, the chronological distance traversed can be substantial.

If the Lomekwi 3 assemblage is a pipe infilling, then it is possible that the artefacts and faunal remains could be substantially younger than the 3.3 Ma deposits that comprise the bulk of the landscape in the area. Further excavation into the subjacent Pliocene deposits may or may not lead to elucidation of the matter, as was appreciated by Dominguez-Rodrigo & Alcala (2016).

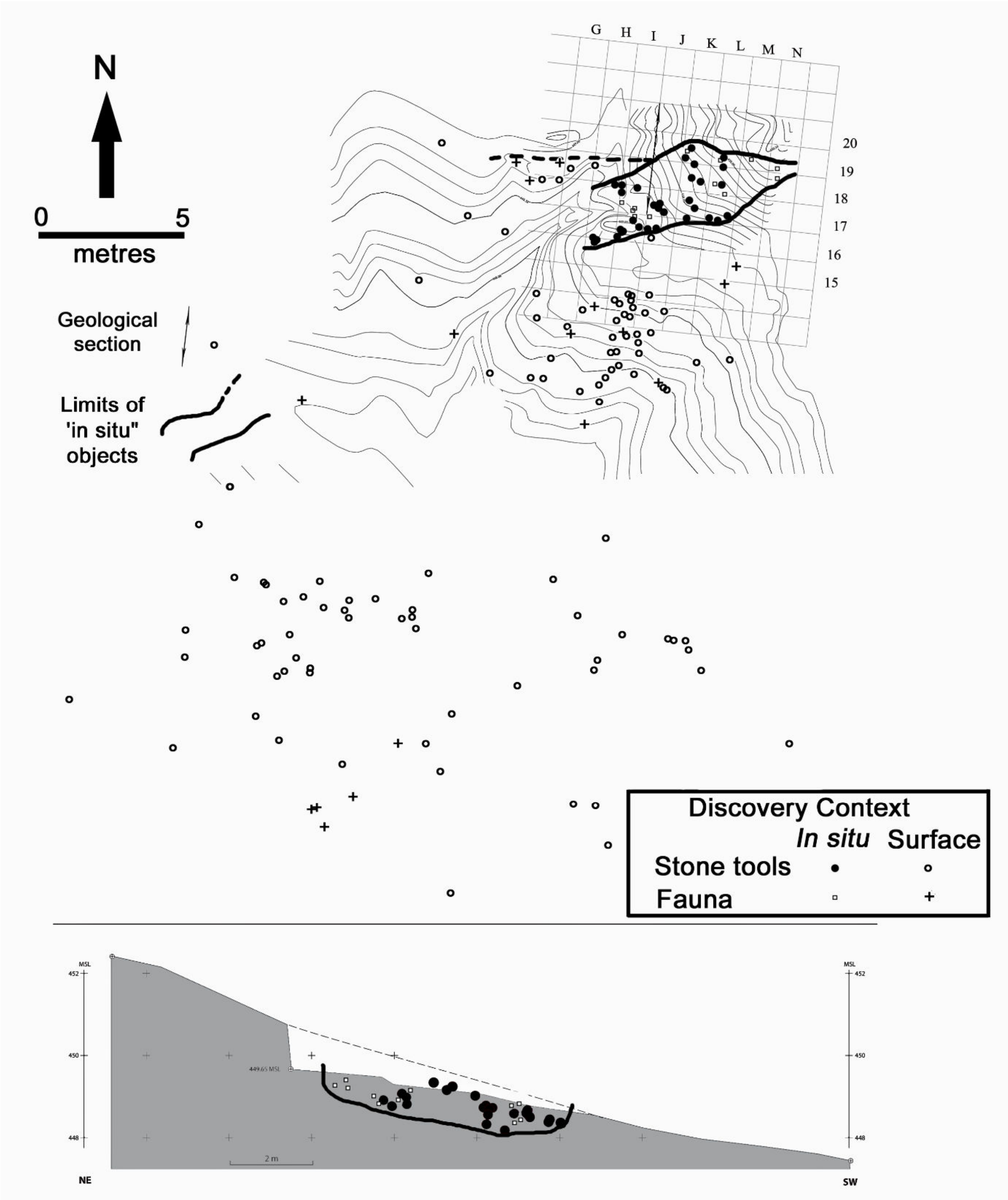

Figure 19. Excavation plan and section at Lomekwi 3, Turkana, Kenya, reinterpreted as a pipe infilling, as suggested by the marked concentration of objects in a restricted space with a sharp cut-off laterally, above and below, contrasting strongly with the wide scatter of surface finds which eroded from the concentration (modified from Harmand *et al*. 2015). The thick dotted line shows a possible extension of the pipe wall to account for the few tools and fossils collected uphill from the others.

Lewis & Harmand (2016) made further excavations at Lomekwi 3, which showed that indeed there are no tools or fossils in the subjacent Pliocene deposits. The discovery of artefacts in subjacent deposits of undoubted Pliocene age would undoubtedly strengthen their dossier, but the currently available evidence suggests that it is too early to rewrite the mid-Pliocene chapters of human evolution and proto-human behaviour on the basis of the Lomekwi 3 stone tool occurrence.

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Figure 20. Excavation at Lomekwi 3 in 2012 (1) and in 2015 (2) modified from Lewis & Harmand (2016). In (1) the implementiferous, fossiliferous deposits appear darker (above the dotted lines in the walls of the excavation) than the subjacent Pliocene deposits which are paler in tone. The 2105 excavation (2) advanced northwards beyond the implementiferous deposits into Pliocene sediments which are locally devoid of archaeological content. Interpreted as a pipe infilling, the implementiferous deposits could be Plio-Pleistocene, but interpreted as a gully infilling, they would probably be extremely young, related to Recent or Late Pleistocene topography of the surroundings.

Discussion and conclusion

Understanding the proper geological and stratigraphic contexts of fossils and archaeological remains is crucial to interpretations of the palaeontological and prehistoric records. In the literature there are many examples of incorrectly dated fossils and artefacts which led to spurious debates about their meaning to science. The Kanam, Kenya, human remains for example, were originally dated to the Pliocene (Leakey, 1936) but proved to be Late Pleistocene once their context was properly established (Pickford, 1987).

This paper deals with a geomorphological process that is well understood in agricultural and engineering communities, and in the domain of karst studies, but which has generally been ignored by the palaeontological and archaeological communities who deal with non-karstic sedimentary deposits. It concerns « piping » or the development of subterranean tunnels which can communicate with the surface and thereby act as receptacles for sediments, animal and plant remains, human artefacts and other debris.

The East African fossil record, predominantly associated with non-karstic deposits, has produced its fair share of enigmatic fossils and stone tools which do not fit comfortably into reasonably well-established biostratigraphic and palaeo-cultural contexts of the region. On occasion, the offset in correlations is so obvious that a contextual trap is immediately evident. An exception is the report of Soricidae, supposedly from Early Miocene deposits at Rusinga (Butler & Hopwood, 1957) which turned out to be based on subfossil material preserved in the the soils overlying the Miocene strata which had slumped into dessication cracks in the underlying Early Miocene sediments (Butler, 1984). On other occasions, the chronological offset is relatively short, and this can lead to spurious claims of earliest records of taxa that, on the face of it, may seem reasonable downward chronological extensions of their fossil registers. This paper deals with several localities of Miocene age, and one archaeological site of supposedly Pliocene age, for which claims have been made concerning earliest records of taxa and of human palaeo-cultural activities.

Reinterpretation of the geological context of the localities which have yielded these chronologically anomalous or unusual assemblages reveals that most of them could be related to piping processes which were active during the geological past. In every case, as would be expected, the piping infills yield faunas or archaeological assemblages that are younger than the subjacent sedimentary deposits, although *a priori* it is also possible that pipe infillings might contain fossils or artefacts reworked or derived from the sediments in the immediate vicinity of the pipes and incorporated into the younger piping infills. Whilst the latter situation is rare it is nevertheless a possibility that needs to be kept in mind, if only because present-day piping systems at Kabarsero, Tugen Hills, Kenya, contain fossils derived from the Miocene strata in which they formed.

Examples of palaeo-pipe infillings are documented from Namibia, Uganda and Kenya, with mentions of the presence of pipes in South Africa, thereby extending the data base of piping phenomena in the continent (Bernatek-Jakiel & Poesen 2018). A great deal more basic information about piping in Africa is undoubtedly waiting to be amassed and described. In this contribution, only a few examples are given in order to illustrate some of the geomorphological processes involved and to discuss the implications of the processes for understanding and interpreting the fossil and archeological records of the continent.

The East African localities suspected to represent pipe infillings are the Napak I Rhino site, Napak IV 'Pipe', Napak XXX, and Bukwa II in Uganda, and Rusinga Kathwanga Primate Site, Rusinga R 114 (Whitworth's Pothole) and Meswa Bridge in Kenya. Two localites in Namibia, of Early Miocene age, are also either pipe infillings or animal burrows infilled with sediment and animal skeletons. The Lomekwi 3 archaeological occurrence in Kenya is also likely to be a pipe deposit considerably younger than the subjacent mid-Pliocene strata in which the pipe formed.

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