PHYTOLITH AND SPHERULITES STUDY OF HERBIVORES DUNG FROM THE AFRICAN SAVANNAH AS A TOOL FOR PALAEOCOLOGICAL RECONSTRUCTION

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ABSTRACT

Dung is mostly composed of organic matter, which degrades with time and disappears from the archaeological record. However dung is also composed of more durable remains which can resist the taphonomic processes through time. Faecal spherulites are calcium carbonate crystals formed in the intestines of certain animals and after that they are excreted in their dung. They can be found in different proportions in the dung of some herbivorous, mainly ruminants. Silica phytoliths, although they are formed in plants, they are also commonly found in the dung of herbivorous animals. Their number and morphology will depend on the vegetal diet of these animals. This study is centred on the microscopical analyses of both phytolith and spherulites, identified in fresh dung of several wild herbivores collected during the long dry season in the Olduvai Gorge in Tanzania. Phytoliths and spherulites were both identified following a morphological and quantitative approach. Phytoliths were then compared to a modern plant reference collection from the same area to asses the diet component of each one of the animals analyzed and then the results were related to the spherulites production of the same animals to study the relationship between phytolith number and morphology and spherulite number and morphology for each one of the animal dung analyzed. The purpose of this study consists on evaluating the usefulness of combining both techniques, first to identify faecal remains in the archaeological record, and second to address questions related to diet and migration habits for these animals and the paleovegetation and paleolandscape of the specific region.

KEY WORDS

Olduvai Gorge, Phytoliths, Spherulites, Faecal remains, Herbivorous ruminants, Paleovegetation.

RESUMEN

Los restos fecales están compuestos mayoritariamente por materia orgánica, la cual se degrada con el tiempo despareciendo finalmente del registro arqueológico. Sin embargo, estos restos fecales también contienen ciertos elementos resistentes al paso del tiempo y a los efectos postdeposicionales. Las esferulitas son cristales de carbonato cálcico formadas en los intestinos de ciertos animales herbívoros, principalmente rumiantes y que posteriormente son depositados en los restos fecales. Los fitolitos de sílice, aunque se forman en las plantas, son también comúnmente identificados en los restos fecales de animales herbívoros. Su número y morfología dependerá de la dieta vegetal de estos animales. El estudio que aquí se presenta se centra en el análisis microscópico de ambos elementos, fitolitos y esferulitas, identificados en restos fecales, de varios animales herbívoros, recolectados durante la estación seca en la Garganta de Olduvai en Tanzania. Los fitolitos y las esferulitas fueron identificados y analizados siguiendo un método morfológico y cuantitativo. Los fitolitos fueron luego comparados con una colección de referencia de plantas modernas de la misma zona geográfica con el propósito de estudiar la dieta de cada uno de los animales analizados. Finalmente los resultados fueron relacionados con los obtenidos del estudio de esferulitas, con el propósito de analizar la relación entre morfología y número de fitolitos y morfología y número de esferulitas para cada uno de los restos fecales analizados. El objetivo de este trabajo consiste en evaluar la utilidad de combinar ambas técnicas para identificar restos fecales en el registro arqueológico y, consecuentemente, responder a cuestiones relacionadas con el animal productor de estos restos, su dieta y movimientos migratorios y, paralelamente, la paleovegetación y el paleopaisaje en una región determinada.

PALABRAS CLAVE

Garganta de Olduvai, fitolitos, esferolitas, restos fecales, rumiantes, paleovegetación.

1. INTRODUCTION

Faecal remains from herbivores are commonly found as a component of soil. Higher concentrations of these remains are common where animals congregate (e.g. drinking sites), or maintain latrine areas, or otherwise preferentially deficate (e.g. hippo trails). Once deposited in the soil, different taphonomic processes, depending on the specific conditions of the area, act on the dung to enhance preservation or destruction. Faecal remains from herbivores are composed mostly of organic matter which degrades with time, but also of other more durable microremains such as silica phytoliths, spherulites, calcium-oxalate phytoliths, pollen, starches, etc. (Courty *et al.*, 1991; Brochier *et al.*, M., 1992; Horrocks *et al.*, 2003). In archaeological sites important information can be obtained through the study of these components, including the types of animals that produced the remains, diet habits, landscape, vegetation, and local climate (Pearsall, 2000; Horrocks *et al.*, 2003). However, it needs to be taken into account that preservation of each of these components depends on different taphonomic conditions. Shahack-Gross *et al.*, (2003) distinguished archaeological sites occupied by pastoralists from those occupied by hunter-gatherers in Southern Kenya. Shahack-Gross took into account the presence of silica phytoliths and spherulites, and related the results obtained to other types of analyses such as FTIR, X-Ray diffraction and micromorphological analyses to study the mineral composition of the soil and therefore to analyze the taphonomic processes of the dung once deposited on the soil.

In this paper we deal only with silica phytoliths and faecal spherulites present in fresh dung in the stage previous to the deposition on the soil and therefore to their interaction with taphonomic processes which can affect to their preservation. Silica phytoliths are ingested by herbivores together as a compound of plants consumed. Phytoliths are usually well preserved in dung, since the digestive processes suffered by the plants after ingestion do not affect the silica (Brochier *et al.*, 1992; Canti, 1999).

Spherulites are small (5-15 microns) crystalline, high birrefringent features. Brochier (1983) identified them in several archaeological sites such as Fontbrégoua (France) and Kitsos (Greece). He defined them as very small crystalline calcitic spherulites of animal origin. He emphasized that the association of spherulites and phytoliths is important for identifying ancient pastoral activities. Later, spherulites have been identified in different archaeological sites such as Ketef Jericho (Israel) (Horwith & Goldberg, 1989), Arene Candide (Italy) (Courty *et al.*, 1991), Ain Abu Nekheileh (Jordan) (Albert, 2001), Valle del Bolsón (Argentina) (Coil *et al.*, 2003). These spherulites have been also found in the dung of extant animals, mainly herbivores (Brochier *et al.*, 1992; Canti, 1997, 1999; Goren, 1999; Korstanje, 2002). Canti (1997, 1998 & 1999) and Korstanje (2002) carried out several studies on spherulites addressing questions such as their chemical composition and morphology, their formation processes, the type of animals that produce them under specific environmental conditions, and the taphonomic processes resulting in their preservation. According to his results, faecal spherulites are composed of calcium carbonate (Canti, 1997) and appear to be formed in the intestine of certain animals, mainly ruminants (Canti, 1999). The higher producers of spherulites are sheep, cow, goats and deer. They are less abundant in omnivorous and carnivorous species (pig, man, cat, fox) and they are absent from other animals such as horse, rabbit and hares (Canti, 1999). Goren (1999) have found that spherulites are present, although in small numbers, in the dung of horses. In relation to the taphonomic conditions needed for their preservation, Canti's experiments suggest that a pH value below 7.7 is detrimental to the spherulite numbers, and under some circumstances dissolution can be active as high as pH 8. Spherulites are well preserved in high alkaline conditions (Canti, 1997, 1999). Canti (1999) observed that the production of spherulites varies depending on the season. Korstanje (2002) also noted that the spherulite production is not constant for the same animals and that there are other external factors that can influence in the spherulites production. The reasons for that need to be further explored.

In this paper we deal with the spherulite production and phytolith presence in different herbivorous dung in order to get a better knowledge on the spherulite production under different climatic conditions and on its relation to phytolith morphology and number present in the same remains. For that, it was decided to carry out a study on the morphology and number of spherulites and phytoliths identified in the dung of Wild African herbivores in the Serengeti Plain, Tanzania, near the paleoanthropological locality of Olduvai Gorge.

The novelty of this study is that, until present, there is no published work on both phytoliths and spherulites identified in dung, from a quantitative and morphological perspective, with an attempt to relate the ecological contexts of the vegetal diet to that of spherulite production. The type of diet will be reflected on the number and morphology of phytoliths present in the dung. If we associate this different phytolith representation to the production and morphology of spherulites for the different animal dung analyzed, then it will possible to identify faecal remains in archaeological or paleoanthropological sites, such as Olduvai Gorge (Tanzania), and consequently to relate the remains to the animal who produced them. At present there is only one work which is being carried out by A. Korstanje (personal communication), but that study is not finished and the results are not yet available.

1.1. The site

Olduvai Gorge (figure 1) is situated in the eastern Serengeti Plain, adjacent to the Great Eastern (or Gregory) Rift Valley and Ngorongoro Volcanic Highlands (made up of several late Cenozoic volcanoes). The plain as a whole covers some 5000 km^2 between ca 1450 m and 1650 m elevation, and in the east is predominantly grasslands on calcareous topsoils derived from carbonatite volcanic ash (Anderson & Talbot, 1965). The easternmost portion of the plain is drained by Olduvai Gorge, whose mouth empties into the Olbalbal Depression, part

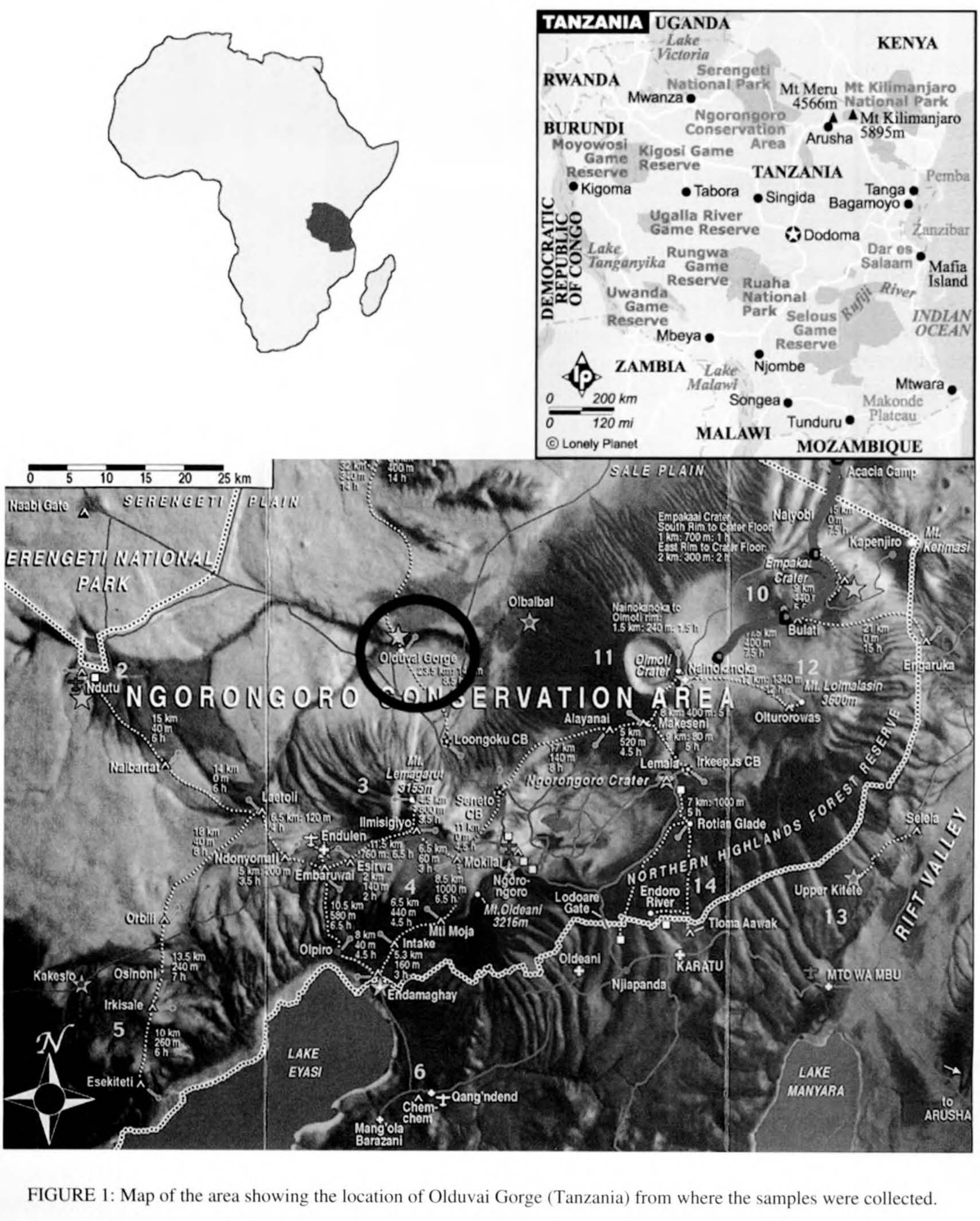

FIGURE 1: Map of the area showing the location of Olduvai Gorge (Tanzania) from where the samples were collected.

FIGURE 2: Photograph of Olduvai Gorge (Tanzania), with the «Castle».

of the Great Rift Valley. The Gorge is about 50 km long and in some places 90 m deep (figure 2). The easternmost plain lies in a rain shadow created by the Volcanic Highlands immediately to the east. Consequently rainfall on the plain around Olduvai Gorge averages less than 600 mm per annum. The area is dry most of the year.

Olduvai area was selected because at present there is an ongoing project to reconstruct the Plio-Pleistocene paleolandscape and ecology of the Olduvai Basin (Tanzania) (Hay, 1976; Peters & Blumenschine, 1995, 1996; Blumenschine & Peters, 1998). Current paleoanthropological excavations at Olduvai Gorge are focused on lowermost Bed II (ca. 1.75-1.70 m.y.a.), an interval comprised of lacustrine and alluvial fan sediments stratified between Tuff IF and the Lemuta Member (Hay, 1976). These sediments are exposed across most of the Gorge, making it possible to compare penecontemporaneous hominid traces in different parts of the basin. The central part of the paleobasin at that time was occupied by a shallow saline alkaline lake (between 9-24 km in diameter) (Hay, 1976). Palynological evidence, oxygen isotope values, and fossil vertebrate fauna suggest that the climate during Lowermost Bed II times may have been more humid than that of present (Peters & Blumenschine, 1995, 1996). Ongoing work will reexamine these earlier conclusions and add new detail through analyses of paleoterrain, hydrology, plant macrofossils, phytoliths, and oxygen isotopic analysis of soils and fauna. Ongoing study of plant and animal recolonization of the eastern paleobasin, following the Tuff IF eruptive phase of Mt. Olmoti, would benefit from identification of fossil faecal remains, which could link animal presence to the type of vegetation succession then occurring in the area, as well as the habits and mobility of the animals during this specific time period.

2. MATERIALS AND METHODS

Four species of African ungulates were selected for dung analysis (table 1). The dung was collected in August (ca. midway through the long dry season) 2001. Samples from three species (giraffe, zebra, and dik dik: figure 3a, b, c) were collected from the edge of the plain immediately above Olduvai Gorge, with the help of a Maasai guide who confirmed the identifications. The giraffe is wide ranging daily while the dik dik has a small local territory year-round, but the effect of both as dung-depositional agents probably is overridden by the affects of taphonomic conditions and hydrology. The vegetation present in that area consists mainly of black thorn (*Acacia mellifera)*, the umbrella tree (*Acacia tortillis)*, poison grub commiphora (*Commiphora Africana),* wild sisal (*Sansevieria ehrenbergiana*), some short grasses, cyperaceae (*Kyllinga*) and other herbs from the compositeae and the papillionaceae families. Samples from the fourth species (impala: figure 3d) were collected

Scientific name	Common English name	Diet
Giraffa camelopardalis	Giraffe	Giraffe occasionally eat grass and fruits, but their principal food source is the foliage of various trees and shrubs, especially acacias. The tree's sharp horns do not seem to stop the giraffe, which has a long, muscular tongue specially adapted to select, gather and pluck foliage. The giraffe is a selective feeder and although it feeds 16 to 20 hours a day, it may consume only about 65 pounds of foliage during that time. It can maintain itself on as little as 15 pounds of foliage per day. The choice is determined by seasonal and local availability.
Mondoqua kirkii	Dik dik	Dik diks eat foliage, shoots, fruit and berries. They are nocturnal, therefore feeding mostly at night. They do not need to drink.
Equus burchelly	Zebra	Zebra rely almost totally on a variety of grasses, along with some additional browse like leaves and twigs. In the dry season, they can live on coarse, dry grass only if they are within a short distance (usually no farther than 20 miles away) of water.
Aepyceros melampus	Impala	Impalas eat tender young grass shoots in the wet season and herbs and shrubs (shoots, foliage and seed pods) at other times. During the dry season they must drink daily.

* Diet information collected from the African Wildlife Foundation

TABLE 1: Species of Wild African Ungulates selected for dung analysis.

from the mud flats of Lake Masek (near the source of the Olduvai River) in August 2002. Maasai confirmed the dung identification. On-site observations made at the time of collection, of fresh spoor and recently clipped plant remains, indicated that the impala seen in the immediate vicinity had been eating the young leaf tips of the saline-alkaline-tolerant sedge *Cyperus laevigatus*. The wetland margins of the lake are dominated by this sedge, the drier vegetated margins being dominated by grasses (*Sporobolus* sp.).

The single method used for preparing both phytoliths and spherulites followed Canti (1998 & 1999) for spherulite extraction. Dung remains from different individuals from the same species were homogenized and air dried. For examination under the optical microscope slides were prepared by weighing around 1 mg of material, with an accuracy of 0.1 mg, and placing it on a microscope slide. The samples were mixed with Entellan New (Merck) as well as possible to obtain a homogeneous suspension. The areal coverage of the sample on the slide was estimated by counting the total number of fields containing sediment grains. Samples were then analyzed using a petrographic microscope at 400x. Spherulites were morphologically identified following Canti's description (Canti, 1997, 1998 & 1999). It needs to be pointed out that for the phytolith extraction, no acid attack was followed to isolate the phytoliths due to the importance of recovering everything present in the sample and to relate the phytoliths presence with the spherulite production. The phytolith morphological description follows Albert & Weiner, 2001. The general rule for describing the phytoliths is as follows: if the cell type in which the phytolith was formed is known, the botanical term to describe the cell is used. If this is not possible, then we follow geometrical characteristics of the phytoliths. Other secondary characteristics such as surface texture, edge shapes etc. follow palynological terminology (Albert & Weiner, 2001).

3. PHYTOLITH AND SPHERULITES RESULTS

Phytoliths and spherulites were present in all the samples analyzed but in different proportions. As it can be observed in figure 4, there are clear differences in the ratio between spherulites presence and phytolith number per gram of sample. For example whereas zebra produces little number of spherulites in relation to the presence of phytoliths dik dik presents an important number of spherulites in relation to the presence of phytoliths.

The morphological analyses indicate that most of the phytoliths identified in the samples correspond to multicellular structures, tracheary elements

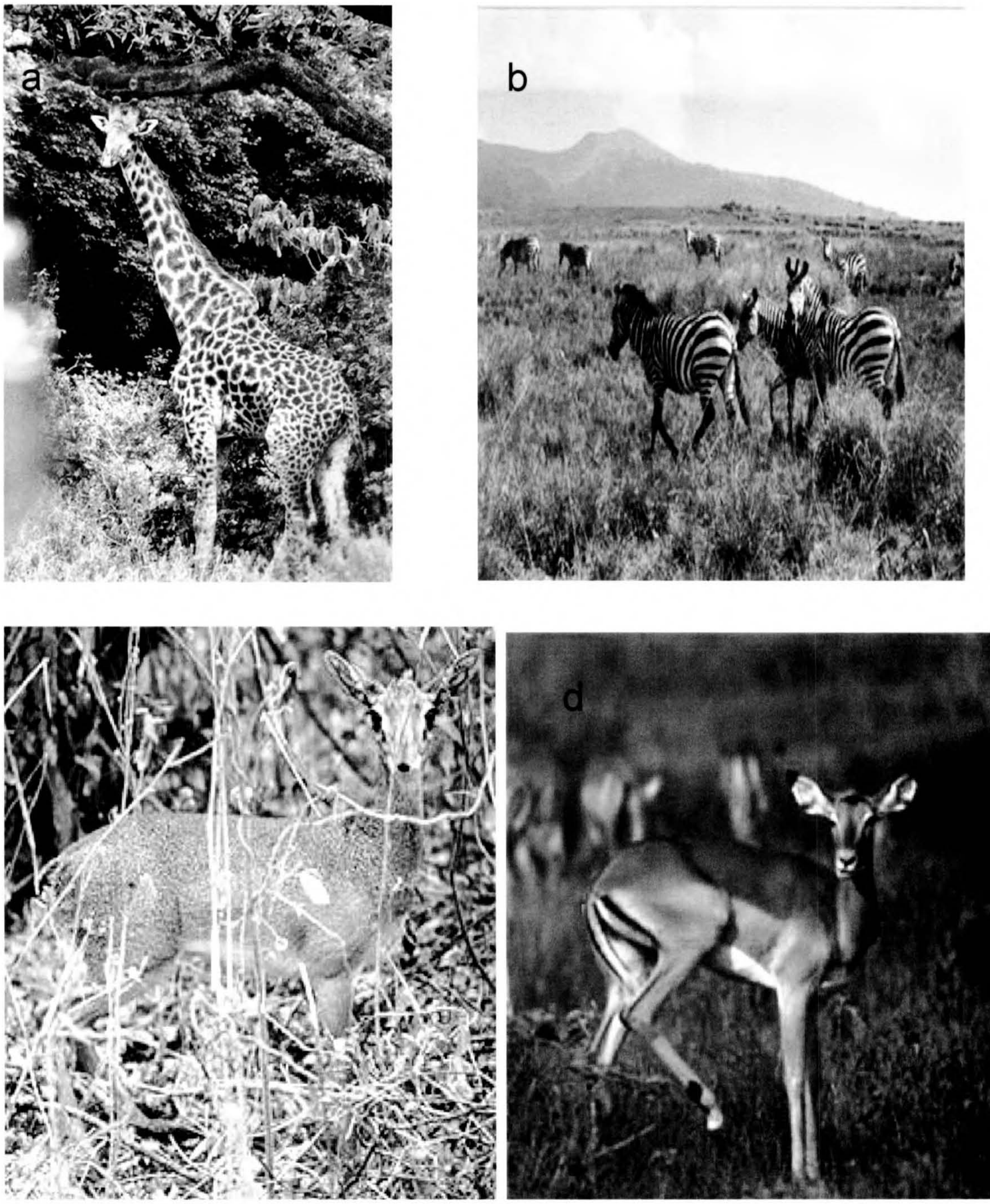

FIGURE 3: a) Giraffe (*Giraffa camelopardalis*); b) Common plain zebra (*Equus burchelly*); c) Dik dik (*Mondoqua kirkii*); d) Impala (*Aepyceros melampus*).

and hairs. Inside these groups there were morphological differences of taxonomical value which allowed the identification of certain plants as well as the recognition of the part of the plants consumed by the different animals analyzed.

The phytolith results for the dung of the zebra are shown in figure 5. Phytoliths from grasses (both from the inflorescence and the leaves) represent around 20% of the total count. More than 74% of the phytoliths are from the leaves of dicotyledonous plants. These dicotyledonous phytoliths are represented by multicellular structures from the epidermal tissue, tracheary elements (figure 6a) and hairs. The predominance of dicotyledonous plants in the dung of the zebra is even more evident if we take into account that grasses produce about 16 times more phytoliths than dicotyledonous leaves (Albert *et al.*, 2000). Another type of phytoliths identified was multicellular structures formed in the leaves of the

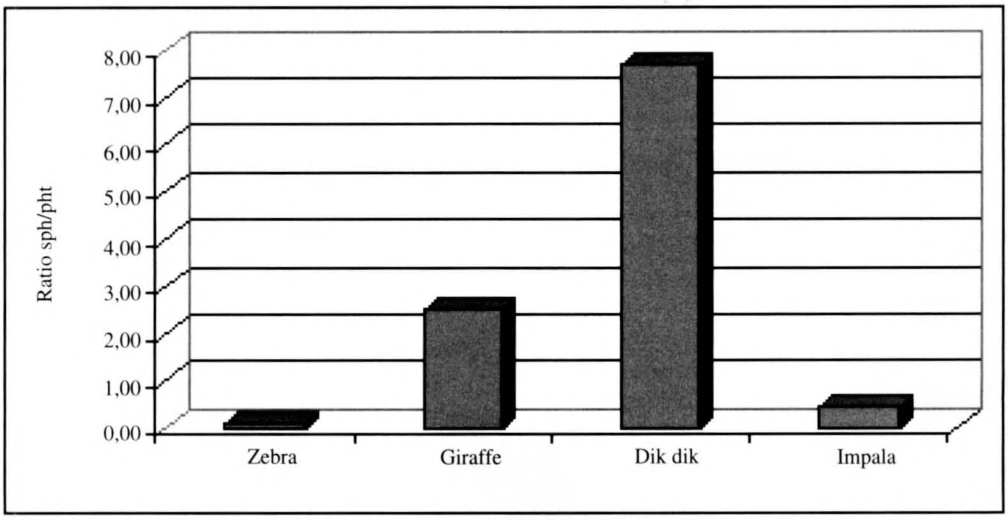

FIGURE 4: Ratio between total number of spherulites per gram of sample and total number of phytoliths per gram of sample.

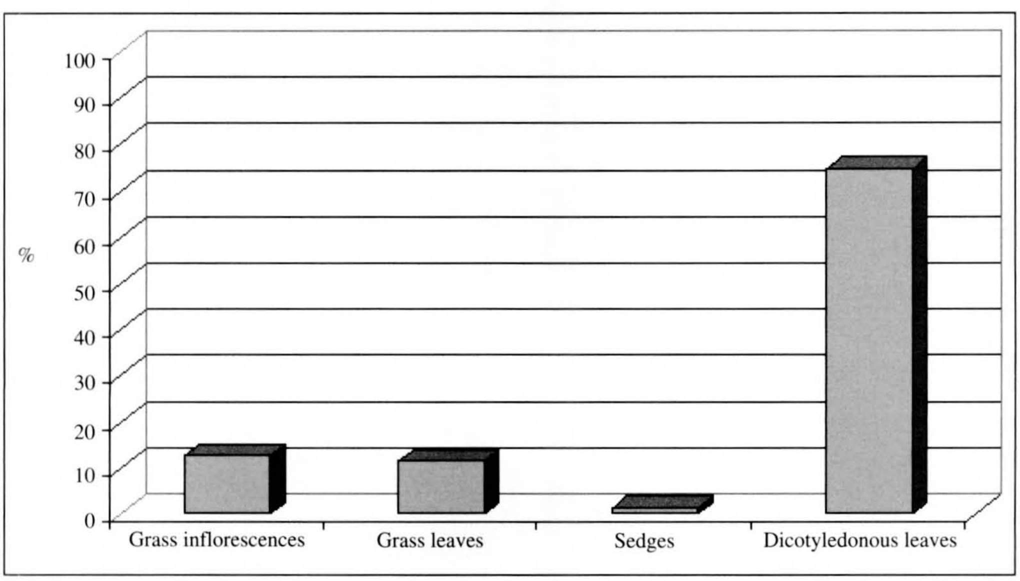

FIGURE 5: Morphological distribution of phytoliths identified in common plain zebra (*Equus burchelly*).

cyperaceae family. These were present in very small numbers.

There were relatively few spherulites observed in the dung of zebra, compared to the other ungulates (figure 4). The estimated number per gram was of 64,500 spherulites.

The phytolith results for the dung of the giraffe are shown in figure 7. Most of the phytoliths are multicellular structures from the epidermal tissue of the leaves of dicotyledonous plants (figure 6b). Morphological study of these multicellular structures and comparison to modern plant reference collection (Albert, personal observation; Runge's CD) allowed the identification of the source as *Acacia mellifera* leaves (figure 6c). Hairs (figure 6d) were also present. Some of the hairs observed were present in groups forming a starshape (stellate). This pattern of hairs has been observed, among other plants, in the Euphorbiaceae family (Theobald, Krahulik & Rollins, 1979) which is common in the area.

Spherulites were found in relatively abundance in the giraffe dung (figure 4). Most of the spherulites

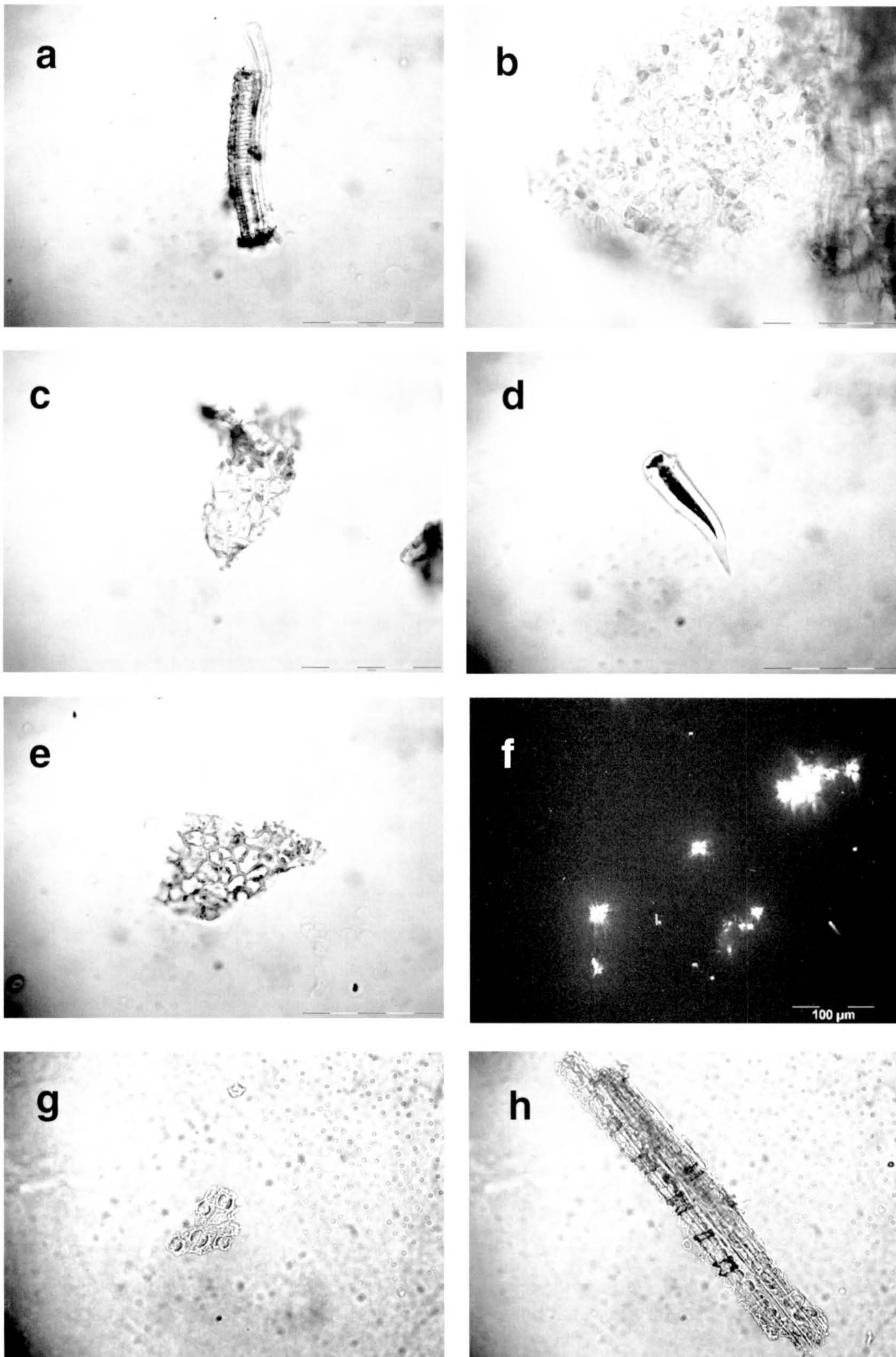

FIGURE 6: Microphotographs of phytoliths identified in the different dung samples analyzed. Bar is 400 X. a) tracheary element identified in the dung of common plain zebra; b) Multicellular structure from dicotyledonous leaf epidermal tissue noted in the dung of giraffe; c) Multicellular structure of the epidermal tissue from *Acacia mellifera* leaf tree identified in the dung of giraffe; d) Hair identified in the dung of giraffe; e) Multicellular structure from dicotyledonous leaf epidermal tissue from dik dik; f) Spherulite identified in the dung of dik dik; g) Multicellular structure from grass epidermal tissue with the presence of short cells —saddle type— identified in the dung of impala; h) Multicellular structure from grass epidermal tissue with the presence of short cells —bilobate type.

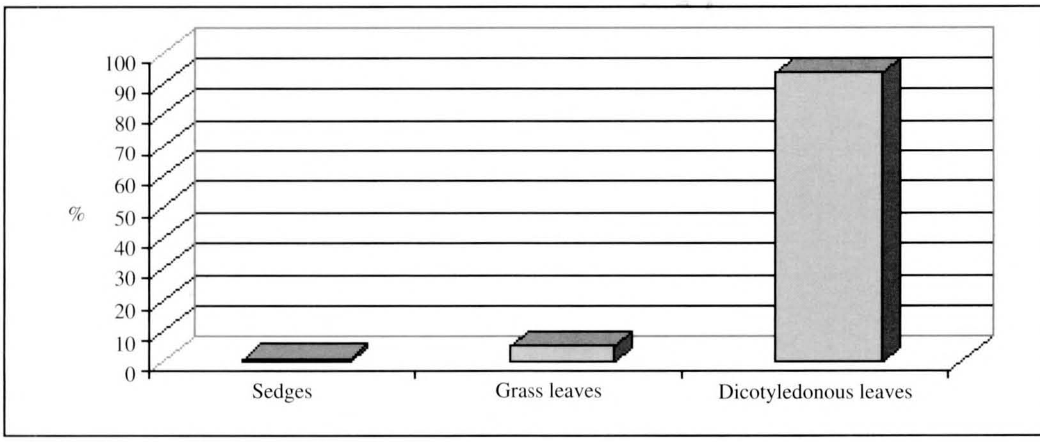

FIGURE 7: Morphological distribution of phytoliths identified in giraffe *(Giraffa camelopardalis)*.

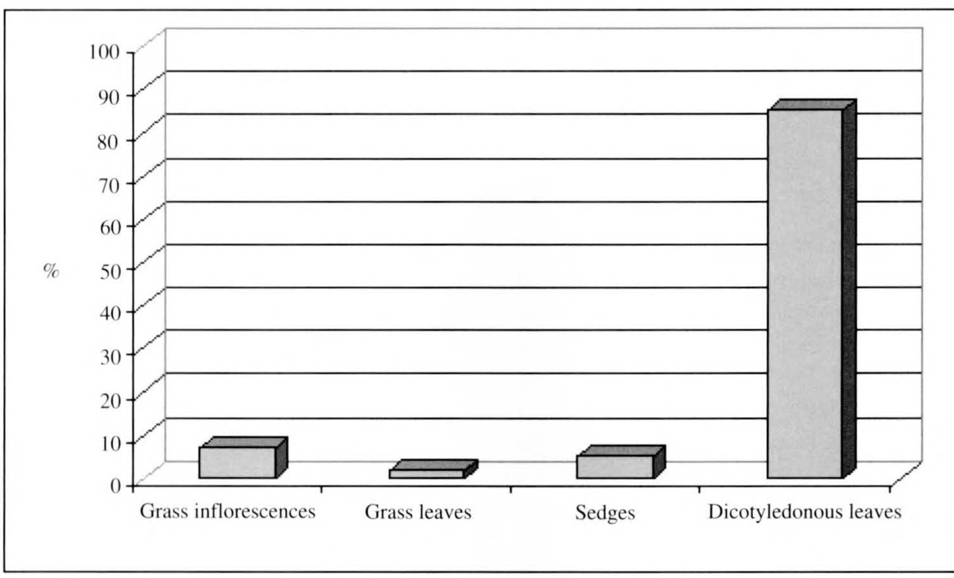

FIGURE 8: Morphological distribution of phytoliths identified in dik dik (*Mondoqua kirkii*).

were grouped together and showed bright interference colors. The size ranged from 3 to 7 µm with an average size of 5.64 µm.

The phytolith results for the dung of dik dik are shown in figure 8. The most common forms belong to dicotyledonous leaves (figure 6e). Tracheary elements were abundant in this sample, together with hairs. Some of the hairs were similar to those observed in the compositeae family. Phytoliths from grass inflorescences, grass leaves and cyperaceae are also present, although in much lower frequencies.

Spherulites were extremely abundant in the dik dik sample (figure 4). Their size ranged from 2 to 6 µm, with an average of 3.75 µm. As with the spherulites from the giraffe, most of them showed bright interference colors (figure 6f). Spherulites with bilobate shape (Canti, 1998) were also observed in this sample.

The phytolith results from the dung of the impala are dominated by grasses. Dicotyledonous leaves are also present. Inside grasses most of the phytoliths corresponded to multicellular structures both from the leaves and the inflorescences (figure 9). Shorts cells and stomata cells were identified as part of the multicellular structures (figure 6g and 6h). The short cells were represented by the saddle and bilobate types. Saddles are characteristic of short grasses from the chloridoid group, most probably from the inflorescence, which is the most common in the area. Spherulites were not common in

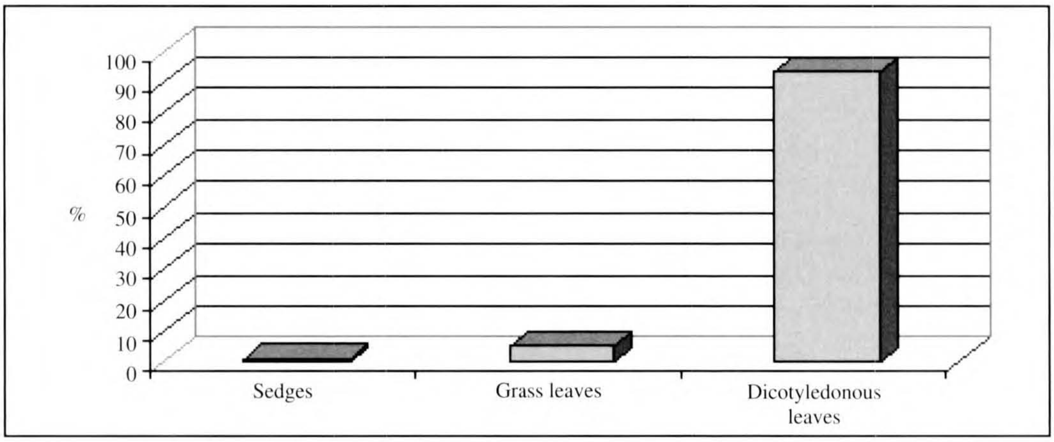

FIGURE 9: Morphological distribution of phytoliths in impala (*Aepyceros melampus*).

the impala sample, and not enough were counted to reliably measure them. The estimated number per gram of sample was of 666.700 spherulites.

4. DISCUSSION

The morphological analyses of the phytolith showed little morphological variation among samples. Only multicellular structures from the epidermal tissue of both dicotyledonous and monocotyledonous plants, hairs and tracheary elements were identified. The multicellular structures from dicotyledonous plants belonged to the leaves parts whereas the multicellular structures from monocotyledonous plants belonged to both leaves and inflorescences. Other type of phytoliths such as short cells (bilobates, saddles, etc.) and stomata cells were noted only as a part of the multicellular structures. These little morphological variation could be explained by the fact that only certain parts of the plants are consumed (leaves and inflorescences), and/or on the other side the low variety of plant availability during the dry season in the area.

It is important to note the high presence of multicellular structures in all the samples analyzed. The fact that no acid attack was followed to isolate the phytoliths might have influenced in the better preservation of the multicellular structures. Another reason for this abundant presence could be the fact that phytoliths were very fresh. They had not gone through any taphonomic process going directly from the plant to the stomach of the animal and to the dung. Due to the acidity of the stomach contents, phytoliths do not weather and do not suffer of any important process that can break them down (Canti, 1999). In any case this is an interesting question closely related to the alteration of the phytoliths once separated from the plant and that can only be answered through more experimental analyses. Hairs are commonly present in all the samples. Hairs have the inconvenient of showing similar morphological characteristics among different type of plants. However when identifying faecal remains this problem can be minimized knowing exactly the vegetal composition of a specific region, their adaptability to specific soil conditions and the phytolith production and morphology for each one of the species. The short cells identified belonged mostly to the chloridoid group. This is consistent with the type of vegetation present in the area, mainly short grasses, and is indicative of a dry climate. Although tracheary elements were not of taxonomical value their identification confirmed the presence of whole epidermal dicotyledonous leave tissues in the samples.

Our primary goal when analyzing the phytoliths was knowing the vegetation of the area and the possible diet habits of the different animals studied, to establish the correspondence between the phytolith presence in the dung remains, both in number and morphology, and the phytoliths produced in the different plants from the area at that specific time of the year. This information can be useful to better understand the diet for each of the animals analyzed under these specific conditions.

The relationship between phytolith morphology and number and spherulites production and morphology can, first of all, to help to identify the presence of faecal remains in archaeological sites, and secondly to identify the type of animal producer of these remains as well as the habitat, in which this animal was living. Surprisingly and according to our results the phytoliths identified in the dung of zebra do not correspond with the diet expected for these animals: «a variety of grasses, along with some additional browse like leaves and twigs. In the dry season, they can live on coarse, dry grass only if they are within a short distance (usually no farther than 20 miles away) of water holes» (African Wildlife Foundation). According to this information we would expect to identify phytoliths mostly from grasses, which is not the case. One of the reasons to explain this difference, and therefore a fact to take into account when analyzing dung remains, is the time of defecation from the moment they ingested the food. An explanation to these results would be that the zebras were browsing leaves and twigs from the plants present in the gorge. In this area, close to the site where the dung was collected, the vegetation consists mainly on dicotyledonous bushes and trees. Nevertheless more samples should be analyzed to better analyze this information.

The phytolith results from giraffe and impala, on the contrary fit perfectly with the type of diet expected for them. In the dung from giraffe, phytoliths from dicotyledonous leaves were the most common components. Most probably the giraffes analyzed consumed *Acacia mellifera* and, according to the type of hairs identified, other plants from the euphorbiaceous family (Theobald, Krahulik & Rollins, 1979). These plants are common in the area and are also a common part of the diet of these animals (table 1). The results from impala dung indicated a huge consumption of grasses, mainly the inflorescences and the leaves. This does not fit with the on-site observations of the impalas eating the upper part of *Cyperus laevigatus* which is sedge. These results give more emphasis on the necessity of taking into account the relationship between time of consumption and time of defecation, and the vegetation present in the surroundings. The presence of grass inflorescences in the impala which was not observed in the dung of the other animals might be explained by the fact that the impala dung was collected from another area (Lake Masek) with a more humid environment. It is probable that the grass phytoliths identified belonged to *sporobolus spicatum*, which is the short grass common in the area. The morphological analyses of the modern plant reference collection, which is being carried out at present, supports this hypothesis (Albert, in preparation).

4.1. Spherulites discussion

Spherulites were present in all the samples, although in different concentrations. Most of the spherulites identified had a high birrefringent colour, although the ones with no colour were also noted. The results showed important differences both in number and morphology between spherulites from dung of dik dik and spherulites from dung of giraffe. Spherulites from giraffe were bigger with an average size of 5.64 μm, whereas the average for the spherulites from dik dik was of 3.75 μm. Moreover spherulites with bilobate forms were only observed in the dung of dik dik.

Although the positive results obtained it was obvious that more studies should be carried out in order to better classify the number and morphology of spherulites for each species analyzed. The vegetal diet of the animal will vary depending on the type of vegetation and on the time of the year. We are not sure on this for the spherulites production. In any case it will be necessary, when carrying out a modern dung reference collection to take into account these parameters to have a more complete view on these microremains.

5. CONCLUSIONS

The results obtained through this study were positive in the sense that both, phytoliths and spherulites were present in the samples in good preservation state. Phytolith assemblages were different in number and morphology according to the different animal's dung and so were spherulites. However the results obtained raised at the same time several questions that will only be answered through a further study following a hard methodological approach.

To continue with this work it will be necessary to test more animals' dung from the same species collected in the same area during different seasons and from different areas with different vegetation landscapes. According to Canti (1999) and Korstanje (2002) spherulites production varies depending on the season and other external factors not well understood yet. Phytoliths number and morphology will also vary depending on the season and type of vegetation for the same animal. In order to better understand the variations for both spherulites and phytoliths we need to set a data base which can give us statistical information on the relation of phytolith presence and morphology with the production and morphology of spherulites under different climatic, vegetation and soil conditions. Other observations such as mobility, time of defecation and diet behaviours should also be taken into account. In parallel phytolith analyses from modern plants from the same area should be carried out to identify the phytolith morphology and proportion for each one of the species present. Analyses of soil samples will be also necessary to study the preservation of spherulites and phytoliths once deposited on the soil.

The results obtained from these studies can be then applied to archaeological sites and correlate them with mineralogical analyses, such as FTIR, X-ray diffraction and micromorphology following Shahack-Gross *et al.* (2003) approach to study the mineral composition of the soil and therefore to analyze the taphonomic processes of the dung once deposited on the soil.

In the Olduvai area the results obtained from this study will focus on specific geographic areas taking into account modern landscape analogues and surface taphonomic processes that interact with dung remains. Informal observations in the Olduvai area during the rainy season reveal that the decomposing remains of dung on the land surface are microlocally pooled during light rains, and moved as part of surface sheet flow downhill even on minimal relief during normal rain storms. The hydrological process of surface water movement would ultimately bring the surface dung-remains into wetland contexts: small closed basins, overbank deposits, the catchments delta, and (freshwater) lakeshores. The signal in some of these settings potentially would be a cumulative one, except for physical diagenesis and prior insect removal of selected components to underground chambers. At Olduvai the dung beetle is the most obvious insect involved. The transport bifurcation would be droppings locally taken in to the lower soil profile by insects, vs. a cumulative decomposition, deposition and reworking-from-bioturbation of material in closed basin (± seasonal) wetlands. The final purpose of this study will be the identification of faecal remains in these areas previously recognized by the geological studies and this way to get a deeper knowledge on the animal's behavior, diet habits and mobility and their interaction with the hominid land use in the area during the plio-pleistocene.

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