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## Phytoliths in a Silo: Micro-botanical Evidence from Zilum (Lake Chad Basin), NE Nigeria (C. 500 Cal BC)

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**Abstract:** Phytoliths, amorphous silicon dioxide (SiO<sub>2</sub>. H<sub>2</sub>O), are durable and can be separated from layers where other plant remains fail like charcoal, pollen and seeds. A pit has been discovered empty of organic botanical material at the archaeological site of Zilum in NE Nigeria (600-400 cal BC). Zilum is one of several settlements of the so-called Gajiganna Complex (c. 1800-400 BC), the first food-producing society colonizing the fringes of Lake Chad. Unlike other analogous pits in the area, it was found bare of domestic refuses of any kind including charred organic (botanical) remains. An assemblage of fossil phytoliths of the family Poaceae has been separated from this pit using heavy liquid ZnBr<sub>2</sub>/HCl. Integration of the present results with earlier palaeoethnobotanical studies from the region is highly suggestive that this pit was used to store a *Panicaceae* grass.

**Key words:** Phytoliths, panicoidae, Gajiganna Complex, palaeoethnobotany, NE Nigeria

### INTRODUCTION

Phytoliths consist of amorphous silicon dioxide (SiO<sub>2</sub>.H<sub>2</sub>O). They are part of plant tissues and only separate from them when decay sets in. Their high specific gravity makes them more resistant to wind than pollen. Phytoliths are durable and can be recovered from archaeological layers where other archaeobotanical evidence, like pollen and charcoal, has disappeared. Grass phytoliths are of particular interest, as they possess morphological features that encourage many investigators to identify the plants from which such fossil phytoliths derived. A phytolith assemblage can still indicate the dominant subfamily of the Poaceae composing a particular grass association (Fredlund and Tieszen, 1994). Moreover, phytolith assemblages are relevant to distinguish C3 from C4 grasslands. Alexandre *et al.* (1997) were able to differentiate between dry and wet C4 grasslands in West Africa.

Zilum in NE Nigeria, is one of several settlements of the so-called Gajiganna Complex (c. 1800-400 BC), the first food-producing communities colonizing the fringes of Lake Chad (Breunig *et al.*, 1996; Breunig and Neumann, 2002). The site consists of a 12-13 ha large, once walled settlement dated to the mid-first millennium BC and characterized by a large number of pits (Magnavita and Schleifer, 2004). Magnavita *et al.* (2004) interpret the

intensive pit digging as the utilization of clay to construct houses and in which to store food reserves. The pit focused on in this study is one of a circular arrangement of eleven features of this kind, presumably associated to a household area. Unlike most of the other pits, it was found absolutely bare of domestic refuses of any kind, including charred organic (botanical) remains. Its contents merely consisted of brown, coarse-grained and musty sediment, the origin of which is most likely organic. Phytoliths analysis has been applied in this study to substitute decay/absence of organic botanical material. This is because phytoliths are durable and can be classified into relevant taxonomic categories. These facts have led the authors to use phytolith analysis in order to look for micro-botanical evidence that could substantiate an interpretation on the primary function of this and other pits from the same site.

Charred plant macro remains were retrieved from archaeological sites in the region of Lake Chad and dated to the last two millennia BC (Zach and Klee, 2003; Klee *et al.*, 2004). These remains include grains and plant imprints of *Sorghum*, *Panicum* and *Pennisetum glaucum*. These taxa had formed the staple food for inhabitants who lived in this area.

The presumed contents' origin, the lack of archaeological finds and its bell-shape (Fig. 1 and 2) most likely point to a specific purpose of the pit up to the



Fig. 1: The sectioned bell-shaped silo. The arrow indicates the sampling point

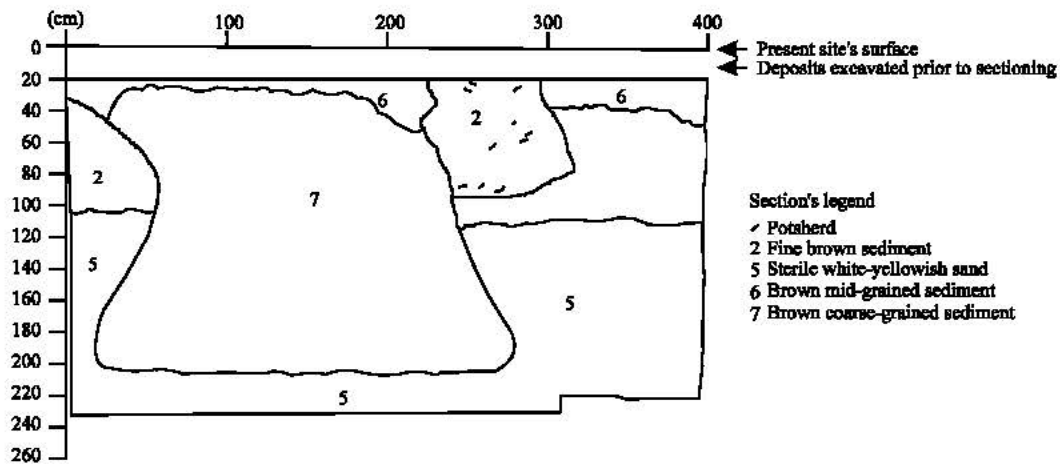


Fig. 2: Stratigraphic drawing of the section. Note that a second and smaller pit containing some finds was disturbed by the construction of the feature focused on in this paper

moment the settlement was abandoned. In this very region, bell-shaped pits are ethnographically recorded as silos used for the storage of crop surpluses (Platte and Thiemeyer, 1995; Fig. 5). This has also been the interpretation for similar features found at younger archaeological sites (Holl, 2002).

Objective of this study is the separation and identification of phytoliths from the archaeological soil sample collected. Determinations of this pit function through integration of present results with plant macro remains have been separated from similar pits in the region.

## MATERIALS AND METHODS

The current study presents the analysis of a soil sample collected at a depth of about 100 cm below the present surface. The sample originates from a 2,500-year-old pit at the archaeological site of Zilum in Northeast Nigeria (Fig. 3).

There is no definite protocol to be followed as a standard procedure in order to separate fossil phytoliths from archaeological sediments. However, four major steps were recognized (Pearsall, 2000) and followed in this study: removal of carbonates from 5 g of archaeological

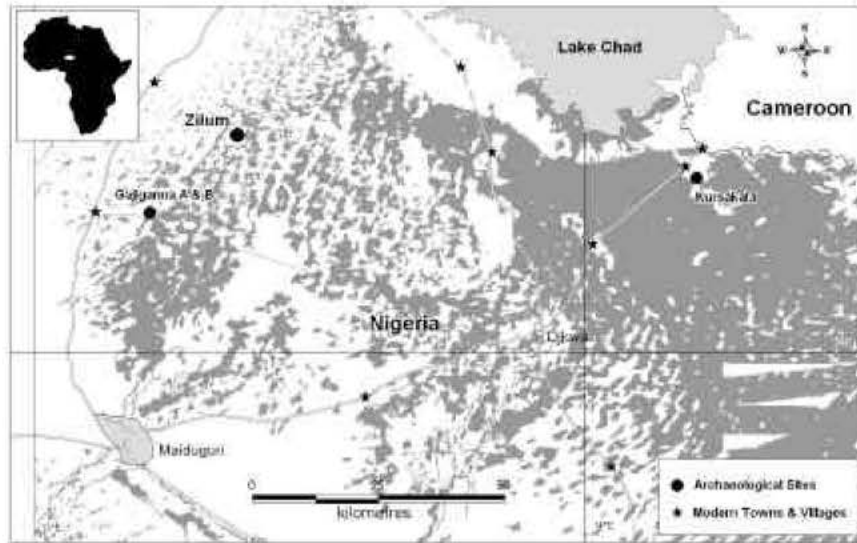


Fig. 3: The location of Zilum and other archaeological sites mentioned in the text

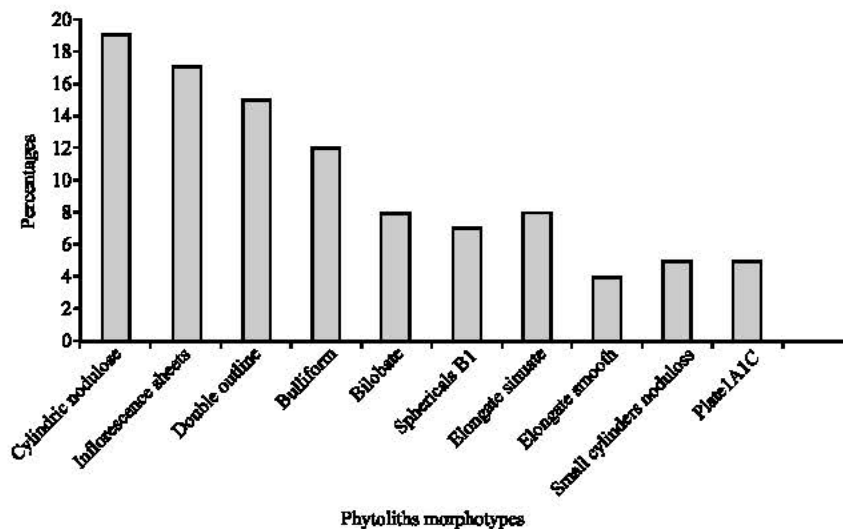


Fig. 4: Percentages of phytolith morphotypes from a silo at the archaeological site of Zilum in NE Nigeria

sediment using dilute HCl (1 M); removal of organic matter using 35% H<sub>2</sub>O<sub>2</sub> dispersion by Na<sub>2</sub> H<sub>2</sub> EDTA; heavy liquid floatation using Zn Br<sub>2</sub>/HCl (density = 2.35 g cm<sup>-3</sup>). The prepared sample was separated several times by centrifugation (2 min/2000 rpm).

The resulting phytolith concentrate was mounted on a slide with glycerine. The margins of the glass cover were sealed by transparent nail polish. The examination was conducted using a Leitz LabourLux microscope connected to a Leica camera. Magnifications were 300 X and 500 X. The detailed procedures on phytolith analysis were reviewed in Pearsall (2000). Well-preserved fossil phytoliths were recovered from the soil sample under analysis. All phytoliths on the slides were counted. It was

possible to attribute 215 phytoliths to 10 identified morphotypes. Figure 4 shows the percentages of each morphotype in the sample. The assemblage of fossil phytoliths was identified and classified according to the classification systems of Twiss *et al.* (1969) and Brown (1984) and Twiss (1992). The studies of Piperno (1988), Rapp and Mulholland (1992), Fredlund and Tieszen (1994) were used to improve and complete the morphological descriptions of the phytolith shapes. A reference collection including 236 species of West African grass phytoliths was used for comparison with our assemblage of fossil phytoliths. This collection is kept at the Institute of Archaeological Sciences and Archaeobotany of Africa, J. W. Goethe-University, Frankfurt am Main, Germany.

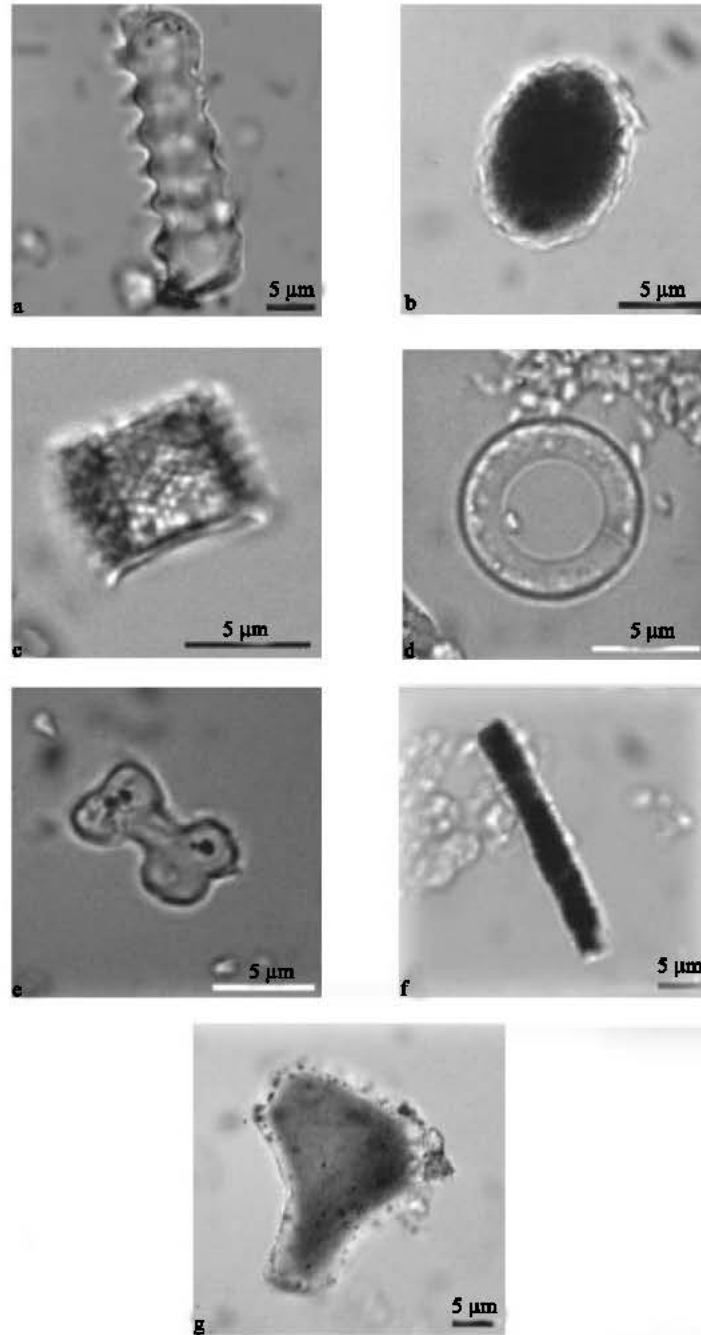


Fig. 5: Morphotypes of phytoliths recovered from a silo at the archaeological site of Zilum in NE Nigeria: a) Elongate sinuate; b) Spherical; c) Small cylindrical nodulose; d) double outline; e) Bilobate with notched margins; f) Inflorescence sheets and g) Bulliform

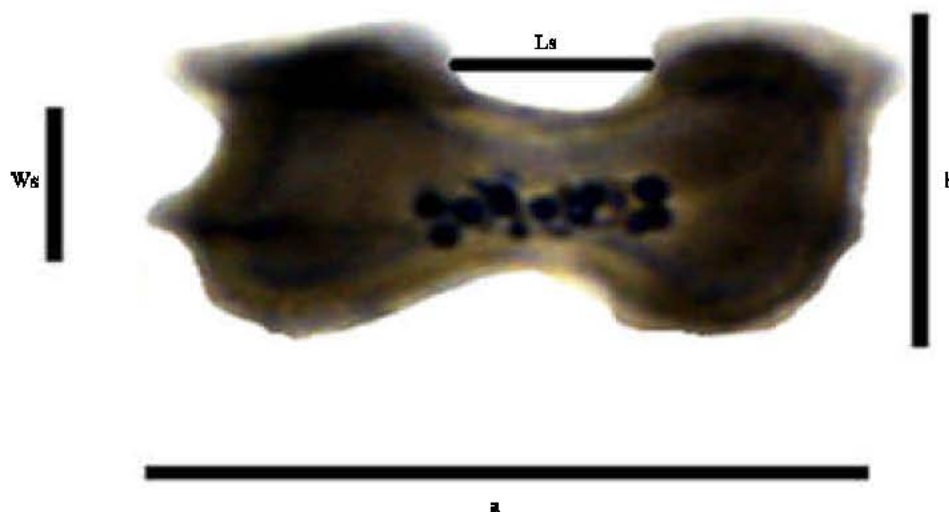


Fig. 6: Measured dimensions in modern and fossil bilobate phytoliths. a) length of the phytolith (the longest dimension of the particle on the X axis); b) width of the phytoliths (the distance perpendicular to length on the Y-axis; Ls: length of the shank; Ws: width of the shank

## RESULTS

Figure 5 shows the different phytolith morphotypes which have been identified from the site in question. Most of the morphotypes were attributed to the Poaceae family.

### Description of phytolith morphotypes

**Elongate sinuate:** This type of phytolith is represented with 8% and characterized by sinuate margins (Fig. 5a). It is recorded in all Poaceae subfamilies (Brown, 1984). It was also found in the modern spike parts of *Pennisetum glaucum* in our reference collection.

**Spherical:** This category includes regular and irregular spherical phytoliths with smooth or slightly rough surfaces (3-9, 9-25  $\mu\text{m}$ , Fig. 5b). They occur in dicotyledonous and monocotyledonous plants (Runge, 2000). Seven percent of the total phytoliths were attributed to this category.

**Small cylindrical nodulose:** These phytoliths are characterized by smaller measurements (Fig. 5c). The length is between 10-20  $\mu\text{m}$ , the diameter 3-5  $\mu\text{m}$ . They are recorded in all Poaceae subfamilies (morphotype IA2d, Brown, 1984). Five percent of the identified phytoliths were attributed to this category.

**Double outline:** This phytolith type is circular in outline with a slightly raised centre (Fig. 5d). It is represented

with 15% of the total amount of phytoliths. They are recorded in the spike parts of the family Poaceae (Brown, 1984).

**Cylindrical nodulose:** These morphotypes are highly represented in the sample under analysis (19%). The length is between 20-30  $\mu\text{m}$ , the diameter between 10-15  $\mu\text{m}$ . This morphotype is a diatom (Marco Madella, Pers. Comm.).

**Bilobate:** Bilobate phytoliths are represented in our sample with 8% (Fig. 5e). This type of phytolith characterizes the subfamily Panicoideae (Twiss *et al.*, 1969). Table 1 shows the dimensions of the recovered bilobate phytoliths. Figure 6 shows the dimensions measured for each bilobate phytolith, both modern and fossil. The measured dimensions are: Length (a) is the longest dimension of the phytoliths body on the X-axis; Width (b) the distance perpendicular to length on the Y-axis. Length of the shank (Ls) and width of the shank (Ws) have been measured.

**Inflorescence sheets:** Seventeen percent of the morphotypes were attributed to this category (Fig. 5f). They originate from the floral parts in the inflorescence like lemmas, paleas, bristles and glumes (Runge, 2000). The size of the recovered sheets is 15 $\times$ 15  $\mu\text{m}$ . This type is characterized by a papillate surface.



Table 1: Dimensions of fossil bilobate phytoliths from Zilum (n = 5). All dimensions are in  $\mu\text{m}$

Width (b) ( $\mu\text{m}$ )	Length (a) ( $\mu\text{m}$ )	Shaft	
		Length (Ls) $\mu\text{m}$	Width (Ws) $\mu\text{m}$
11.00	18.00	3.00	3.20
12.00	18.00	3.00	6.00
12.00	15.00	3.00	4.50
7.50	15.00	3.00	4.50
12.00	20.00	4.00	6.00

**Elongate smooth:** Phytoliths with smooth margins also were recorded in our sample (4%). These morphotypes are known in the Poaceae family (Fig. 5g).

**Bulliform:** They are produced in the epidermal cells of the grass leaves (Fig. 5h). In the sample, they account for 12%.

**Plate IA1c:** Plates with regular sinuate margins and thick edges were recorded with 4% in the sample under study. They are known in the Poaceae family.

### DISCUSSION

Well preserved phytoliths were recovered from the sample under investigation. Recovery of phytoliths provides microbotanical evidence, which significantly alleviates the problem encountered when organic botanical material is absent. Distinctive forms of phytoliths are produced by some plant taxa (Pearsall, 2000). Many monocotyledons are known to produce abundant, characteristic phytoliths (Metcalfe, 1960, 1971). The grass family is one abundant phytoliths producer among monocots (Piperno, 1988). In present study 73% of the identified morphotypes are attributed to the Poaceae family. Twiss *et al.* (1969) distinguished a taxonomic significance of some phytoliths shapes and three Poaceae subfamilies. Bilobate, quadra-lobate and polylobate shapes are common in the Panicoideae subfamily. Saddle shapes characterize the Chloridoideae subfamily, while the Pooideae subfamily includes rounded, rectangular and crescent morphotypes. There are other phytolith morphotypes, which could not be classified on a subfamily level, like bulliforms, long cells and double outline.

Bilobate phytoliths are represented in our sample with 8%. This would prove that the fossil phytolith assemblage originated from taxa belonging to the Panicoideae subfamily, which includes many important grass species of economic significance belonging to the genera of *Sorghum*, *Panicum* and *Pennisetum*. The outer margins of bilobate phytoliths were confirmed as a valuable attribute in identifying bilobate phytoliths (Lu and Liu 2003; Gallego and Distel, 2004). The bilobate

phytoliths from Zilum are characterized by notched margins. Examination of the reference collection reveals the presence of this attribute in 27 species belonging to the tribe Paniceae. Table 2 shows dimensions of fossil and modern bilobate phytoliths. Bilobate phytoliths observed in *Pennisetum dalzielli* and *P. unisetum* are shorter than the fossil ones. On average, the width (b) of the fossil bilobate is closer to that of *Panicum subalbidum*. Length of the phytolith body (a) and the shank's width (Ws) are similar to those recorded from bilobate of *Pennisetum glaucum*. Length of the shank in the fossil phytoliths is almost equal to *Sorghum bicolor*.

Figure 7 is a distribution diagram showing the relationship between our fossil bilobate phytoliths and other bilobates of taxa from the tribe Paniceae based on the ratios of Width/Length (100 b/a) of the bilobate body and Length/Width (100 Ls/Ws) of the shank. Unfortunately, this figure does not show any separation of definite groups based on these dimension ratios. We notice that the fossil phytoliths are within the size range of bilobate phytoliths belonging to *Pennisetum glaucum*, *Sorghum bicolor* and *Panicum subalbidum*. The fossil phytoliths do not show a tendency towards a specific species in the distribution diagram. This could be attributed to the small number of recovered fossil phytoliths. Also, it is not possible to state whether these phytoliths had originated from one taxon or more.

Piperno (1988) recognized ten major classes of phytoliths in dicotyledonous plants. Except spherical phytoliths, none of the dicotyledonous phytoliths occurred in our sample. We should keep in mind that spherical phytoliths are recorded in dicotyledonous and monocotyledonous plants. Their occurrence in dicots is much less frequent than in monocots (Piperno, 1988). Phytoliths are found in quantity in numerous species of dicotyledonous woods as intracellular inclusions (Piperno, 1998). Runge (2000) described four morphotypes produced by arboreal taxa: A4, B2, B3 and C1. These morphotypes originated from wood ray cells (B2 and B3) or from schelerechymatic tissue from lignified plants and silicified terminal tracheids and from sclereids and trachery elements (A4 and C1). None of these ligneous morphotype phytoliths occurred in our sample as well. Perhaps the most significant result of the present phytolith analysis pertains to the homogeneity of the retrieved sample. In addition to the charred *Pennisetum* grains, the archaeobotanical analysis of the plant macro-remains from Zilum revealed the presence in the site's deposits of charcoal in the site's deposits from *Vitex*, *Ziziphus*, *Celtis integrifolia*, *Acacia nilotica* and *Prosopis africana* as well as seeds of *Vigna unguiculata* (Magnavita *et al.*, 2004). Arboreal taxa produce a diversity of characteristic phytolith morphotypes (Piperno, 1988;

Table 2: Dimensions of bilobate phytoliths recovered from the archaeological site in Zilum compared with modern ones in the reference collection. (N: number of measured bilobates, mean (minimum-maximum))

Taxon	N	Width (b) (µm)	Length (a) (µm)	Shank	
				Length(Ls) (µm)	Width (Ws) (µm)
Fossil Phytoliths	5	11.00 (7.50-12.00)	17.20 (15.00-20.00)	3.20 (3.00-4.00)	4.80 (3.20-6.00)
<i>Panicum subalbidum</i>	30	10.44 (8.40-12.00)	16.56 (14.40-20.40)	4.35 (2.40-6.00)	5.16 (4.80-7.20)
<i>Pennisetum glaucum</i>	30	9.43 (7.20-12.00)	16.96 (12.00-21.60)	4.14 (2.40-6.00)	4.95 (3.00-6.00)
<i>Pennisetum dalzielii</i>	30	8.47 (7.20-9.60)	18.63 (16.80-21.60)	4.69 (3.60-6.00)	4.15 (3.00-6.00)
<i>Pennisetum unisetum</i>	30	7.77 (6.60-9.00)	16.29 (12.00-19.80)	2.93 (1.80-3.60)	3.25 (1.80-4.80)
<i>Sorghum bicolor</i>	30	9.75 (7.50-12.00)	15.50 (12.00-18.30)	3.15 (2.70-4.50)	4.26 (3.00-6.00)

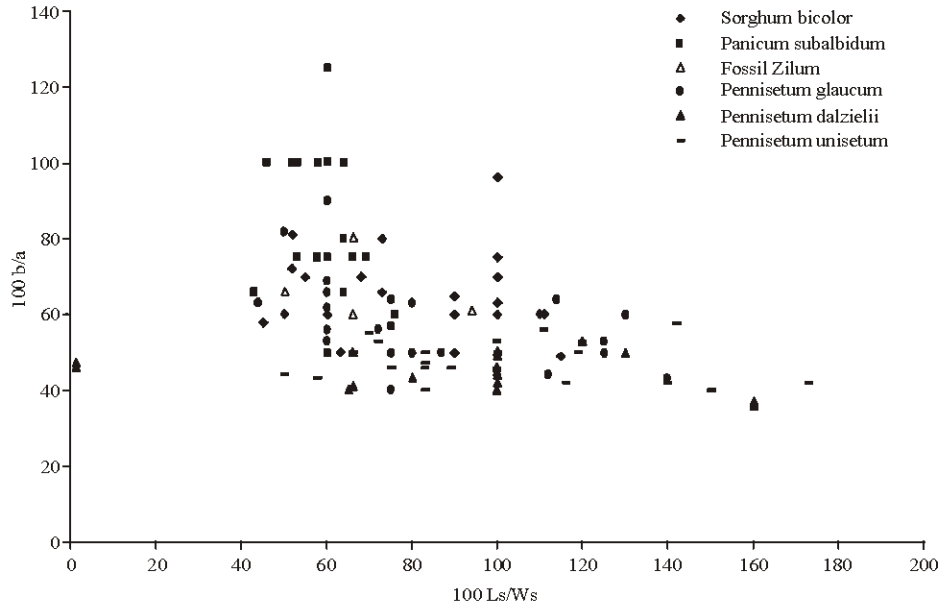


Fig. 7: Distribution diagram of bilobate size ratios: 100 b/a of the bilobate body and 100 Ls/Ws of the shank

Pearsall, 2000; Runge, 2000). In addition, there are distinctive phytoliths in the pods and leaves of *Vigna* sp. (Cummings, 1992). Though the above-mentioned plants were once in use in the settlement and probably grew in its vicinity, the phytolith assemblage identified from the pit in question does not include phytoliths of either arboreal species or *Vigna*. Available evidence in this study suggests that the phytolith assemblage under consideration does not represent the natural plant cover around the site. Instead, it represents plants, which could belong to the Panicoideae subfamily. This is another argument for assessing the purpose of the archaeological pit focused on in this article: storing economically valuable grasses. Due to the presence of phytolith morphotypes originating from the inflorescence parts, the grasses appear to have been stored with their spikes.

For the archaeological sites located around Lake Chad and dated to the last two millennia BC, the use of some of the above-mentioned plants was detected through the sampling of charred macro-remains and plant imprints in potsherds. In Kursakata, a site located about hundred kilometres from Zilum and not belonging to the Gajiganna Complex (Fig. 1), a few grains of wild *Sorghum*

dated to the first millennium BC were found (Zach and Klee, 2003; Table 2). A small number of impressions of the same taxon as well as of *Panicum* sp. was recorded in potsherds from Gajiganna Complex sites (Klee *et al.*, 2004). In contrast to the relatively scanty evidence of wild plants like *Sorghum* and *Panicum*, *Pennisetum glaucum* (L.) R. Br. (pearl millet) was recovered from archaeobotanical samples collected from deposits of Gajiganna settlements and other sites in the region dating from at least ca. 1200 cal BC. The records comprise-amongst others-hundreds of imprints of this taxon from the eponymous sites of Gajiganna A and B, as well as charred grains from some pits at Zilum and from the cultural layers at Krusakata (Zach and Klee, 2003; Magnavita, 2003; Magnavita *et al.*, 2004). Regarding the site focused on in this study, the preliminary analysis of plant macro-remains allows the conclusion that *Pennisetum glaucum* was the staple crop and only cereal of the former inhabitants of Zilum (Magnavita *et al.*, 2004). The archaeobotanical studies currently available point to the major economical importance of *Pennisetum glaucum* for the village-based communities settled at Lake Chad in the course of the last twelve centuries BC.



The nature of the contents and shape of the archaeological pit considered in this study has already provided some indication on the possible storage function of this and analogous features from the site of Zilum. The analysis of its phytolith contents supports this interpretation in that it shows a homogeneous assemblage exclusively originating from Poaceae, with a dominance of Paniceae. Integration of the present results with earlier archaeobotanical studies carried out in the region suggests that the pit studied was used to store a grass of the tribe Paniceae that could have been *Pennisetum glaucum*. Although it is not possible to determine the genus of the plants once stored in this pit, phytolith analysis proves to be a valuable instrument for approaching particular archaeological problems.

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