21. The phytoliths

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21.1 Introduction

Phytoliths are composed of microscopic bodies of opaline silica that form within plant cells. They are very durable, only corroding and eventually dissolving when subjected to alkaline conditions for prolonged periods of time (Albert *et al.* 2003). As such, they do not suffer from the same preservational problems as macro-botanical remains and can provide an overview of the plants utilised at a site when macro-botanical remains are scarce or absent. In this regard, phytoliths from WF16 can potentially provide further knowledge about plant use and palaeoenvironmental conditions to that gained from its wood charcoal (Austin, Chapter 19) and plant macro-fossils (Kennedy, Chapter 20).

Phytoliths come in single- and multi-celled forms. It is rare that single-cell phytoliths can be ascribed to genus but this is often possible with multi-celled phytoliths (composed of single-celled phytoliths conjoined), the size and form of which may also indicate whether cereals had been grown using irrigated or dry-land farming procedures (Rosen and Weiner 1994; Rosen 1999). Both single- and multi-celled phytoliths can be classified into monocotyledons (monocots) and dicotyledon (dicots). Monocotyledons are a group of plants, which include grasses, whose seed has the embryo of one flowering leaf, whereas dicotyledons (typically consisting of 'woody' types such as shrubs and trees) have the embryos of two flowering leaves. Phytoliths can be further classified into a range of morphological categories for both monocots and dicots. Some of these are indicative of specific plants (e.g. reeds, *Cyperaceae*), while others can be used to determine which plant parts (e.g. leaves, stems) are represented in archaeological deposits, potentially answering questions about plant-processing (Rosen 1999; Harvey and Fuller 2005).

This study analysed 20 sediment samples from WF16 for phytoliths. The samples were taken from the blocks of sediment used for micromorphological analysis (Roe, Chapter 7) and examined a range of contexts in Trenches 1 (six samples), 2 (eight samples) and 3 (four samples), along with two samples of natural sediment believed to be contemporary with WF16 but taken from beyond the area of occupation. These samples are referred to in the following text initially by the micromorphology unit number assigned by Roe (Chapter 7) followed by the context number, in square brackets. Table 7.1 provides the results of the micromorphological analysis for each of the samples from which phytoliths have now been examined, and interpretation of those sediments, while full context descriptions are provided in Appendices 7.1, 7.2 and 7.3.

21.2 Materials and method

Phytoliths were extracted from sediment using the protocol of Rosen (1999) at the Institute of Archaeology, University College London. Each sample was initially screened through a 0.5 mm mesh to remove any coarse sized particles, after which one gram was taken using a Sartorius LE2250 analytical balance. Calcium carbonate was dissolved by adding a dilution of 10% hydrochloric acid and then each sample was washed in distilled water three times, with the suspense being poured off between each wash after centrifugation. Clay was removed using settling and sodium hexametaphosphate (Calgon) as a dispersant. Distilled water was added and the samples left for seventy-five minutes before pouring off the suspense. This was repeated at hourly intervals until the samples were clear. They were transferred into crucibles using pipettes and left to dry at a temperature of less than 50 °C. After drying, they were placed in a muffle furnace for two hours at 500 °C to remove any organic matter present. The phytoliths were then separated from the remaining material using sodium polytungstate, calibrated at 2.3 specific gravity. The samples were centrifuged and the phytoliths were transferred to clean centrifuge tubes and washed three times in distilled water. They were then placed in small Pyrex beakers and left to dry. Once dry, two milligrams of phytoliths per sample were mounted onto microscope slides, using the mounting agent Entellan.

The slides were counted on a Zeiss microscope at 400× magnification. The results were calculated using

the absolute count method developed by Albert and Weiner (2001). The aim of this method is to show the absolute counts of phytoliths per gram based on the original weight of the total sediment sub-sampled. For each slide 300 to 400 single-celled phytoliths were recorded and 100 multi-cells. For some slides it was not possible to count 100 multi-celled varieties due to their scarcity. In these instances every other row was counted until the end of the slide was reached. Identifications were made using the phytolith reference collection of Rosen.

21.3 Results

All samples contained phytoliths, with dicot forms having a significantly greater abundance over monocot forms in all but two instances. The phytoliths from WF16 were placed into twenty categories for monocots and eight for dicots, as listed in Table 21.1 (and referred to in the following text within inverted commas). In all samples, single celled phytoliths were more common than multi-celled forms, as illustrated in Figure 21.1. The results from the natural sediment will be initially considered, followed by those from each of the three trenches.

21.3.1 The natural sediment

The results from the two samples of natural sediment (9.1 and 31.1) indicate that dicots were more abundant than monocots in the vicinity around WF16. This is most apparent in sample 9.1 which has been classified as natural hill-wash (Table 7.1). In this sample the ratio of monocots to dicots is 1:227 and the only monocot phytoliths are smooth long cells that derive from grass stems. As monocots are more prolific producers of phytoliths than dicots – grasses produce 20 times more phytoliths than wood and bark and 16 times as many as dicot leaves – this result is interesting (cf. Albert *et al.* 2003) and suggests that grasses were scarce in the immediate vicinity of WF16. We must, however, be cautious as only two natural sediment samples have been examined and their contemporaneity with the site has not been confirmed by radiometric dating. Moreover, the plant macrofossils (Kennedy, Chapter 20) indicate the presence of grasses within the vicinity. In sample 31.1 the ratio of monocots to dicots is 1:15 and this sample has a greater diversity of monocot phytoliths than sample 9.1. Not only are smooth long cells present, but also crenates and keystones, the latter of which are frequently formed in reeds. Neither of the samples of natural sediment have multi-celled phytoliths.

21.3.2 Trench 1

The six samples from Trench 1 provided phytoliths of similar types and proportions to those from natural sediment (Table 21.1, Figure 21.1) The average ratio of monocots to dicots in the Trench 1 samples is 1:219. There is little variation between the six samples and all of them have a higher density of dicot than monocot phytoliths. Sample 4.1 [145], which is from a pit fill, has the greatest number per gram of monocots. In total, there are 51 monocot phytoliths per gram in this sample, 38 of which are 'long smooth cells' and 13 are 'trichomes'. Sample 8.1 [130] has the second highest level of monocot phytoliths with 21 per gram all of which are classified as 'keystones'. This is followed in abundance by sample 6.1 [184] which has 13 'long smooth cells'. Sample 3.2 [170] has five multi-celled phytoliths per gram from the leaf or stem of a grass plant and the two remaining samples, 5.1 [161/163] and 3.3 [184] do not have any monocot phytoliths. As evident from Figure 21.1, the density of both single and multi-celled phytoliths in Trench 1 is less than that in Trenches 2 and 3.

21.3.3 Trench 2

Eight samples were analysed from Trench 2 and although the samples from this trench had a greater abundance of monocot phytoliths than the samples from Trench 1, the overall density is still low and dicots still far out-number monocots. The average number per gram of monocot phytoliths from the Trench 2 samples is 72 and the ratio of monocot phytoliths to dicot phytoliths is 1:141. Sample 21.1 [242] has the greatest number of monocot phytoliths with a total of 198 per gram. Of these 122 are 'smooth long cells' (from the leaves or the stems of the plant) and 61 are 'dendritic long cells' (from the husk of the plant). This sample was defined as a fill above a floor (Table 7.1). Two samples, 15.2 and 18.2, were taken from context 212, a trampled floor horizon. Whilst sample 18.2 produced no monocot phytoliths, sample 15.2 had 'keystones' and 'bulliforms', both of which frequently form in reeds, and 'leaf/stem' multi-celled phytoliths. A similar situation can be seen in the sample from context 213. Three samples were analysed from this context: 14.1 and 22.1, both defined as floor packing, and 18.1, defined as a floor. Sample 14.1 has no monocot phytoliths, sample 18.1 has 75 'long smooth cells' per gram and sample 22.1 has 58 'long smooth cell' phytoliths and 58 leaf/stem phytoliths per gram. Notably, the two samples from Trench 2 with the highest number per gram of dicot forms, samples 19.1 [277] and 18.2 [212] are also those samples that have no monocot forms. Sample 17.1 [210] has only 12 'long smooth cells' and sample 19.1 [277] has no monocot phytoliths.

On average, the samples from Trench 2 have a greater number of phytoliths per gram than the samples from Trench 1. Of the samples from Trench 2, sample 19.1 [277] has the highest number per gram of multi-celled phytoliths with 26037. This is the second most abundant sample after 24.1 [310]). The majority of the other samples also have a higher than average number of phytoliths per gram (Figure 21.1).

21.3.4 Trench 3

Four samples were analysed from Trench 3, three of which came from context 310, an occupation horizon

		Monocots																					Dicots								
micromorphology no	Context no	Long smooth cells	Long dendritic cells	Long sinuate cells	Long rod cells	Papillae	Trichomes	Keystones	Bulliforms	Crenates	Ovals	Rondels	Bilobes	Horned Tower	Leaves/stems	Unidentifiable husk	Phramites stem	Reed stem	Setaria husk	Cyperaceae	Bullifom leaf]	**Total monoctos**	Elongate	Scalooped	Smooth Spheroid	Globular granulates	Plateys	Sheets	Single polyhedrons	Silica aggregates	**Total dicots**
NATURAL																															
9.1	NA	53	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**53**	**0**	**0**	53	0	11716	106	159	0	**12034**
31.1	NA	126	0	0	0	0	0	42	0	84	0	0	0	0	0	0	0	0	0	0	0	**252**	**0**	**0**	42	0	2853	462	84	0	**3441**
TRENCH 1																															
8.1	130	0	0	0	0	0	0	21	0	0	0	0	0	0	0	0	0	0	0	0	0	**21**	**0**	**0**	0	21	5201	21	0	13	**5256**
4.1	145	38	0	0	0	0	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**51**	**0**	**0**	0	0	3167	152	0	44	**3363**
5.1	161/163	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**	**0**	**0**	0	0	1815	31	8	7	**1861**
3.2	170	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	**5**	**0**	**0**	0	0	1660	36	0	75	**1771**
3.3	176	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**	**0**	**0**	0	0	4799	0	0	0	**4799**
6.1	184	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**13**	**0**	**0**	0	0	2620	13	38	17	**2688**
TRENCH 2																															
17.1	210	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**12**	71	0	0	0	1011	0	12	209	**1232**
15.2	212	0	0	0	0	0	0	58	58	0	0	0	0	0	58	0	0	0	0	0	0	**174**	0	0	174	0	9241	639	58	1685	**11797**
18.2	212	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**	71	0	71	0	12341	282	71	141	**12977**
18.1	213	75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**75**	0	0	249	0	3068	125	75	1696	**5213**
14.1	213	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**	0	0	0	0	9011	345	0	13	**9369**
22.1	213	58	0	0	0	0	0	0	0	0	0	0	0	0	58	0	0	0	0	0	0	**116**	0	0	58	0	10672	408	233	292	**11663**
21.1	242	122	61	0	0	0	0	0	0	15	0	0	0	0	0	0	0	0	0	0	0	**198**	0	0	30	0	2524	167	30	122	**2873**
19.1	277	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**	0	0	97	0	23811	1839	194	226	**26167**
TRENCH 3																															
12.1	301	52	0	0	0	0	0	52	0	0	17	0	0	0	13	0	0	0	0	0	0	**134**	35	0	0	0	4782	17	17	165	**5016**
24.1	310	8157	7843	941	837	0	418	4706	1464	627	0	732	209	105	1459	220	468	28	28	165	385	**27498**	0	105	523	0	4706	314	0	440	**6088**
25.4	310	2112	1037	185	148	37	185	3928	148	0	0	0	0	0	161	12	0	49	0	0	62	**7941**	0	0	0	0	4002	185	0	86	**4273**
25.3	310	38	0	0	0	0	0	23	8	0	0	0	0	0	4	0	0	0	0	0	0	**73**	0	0	0	0	1907	30	23	222	**2182**

Table 21.1 Phytolithis from WF16.

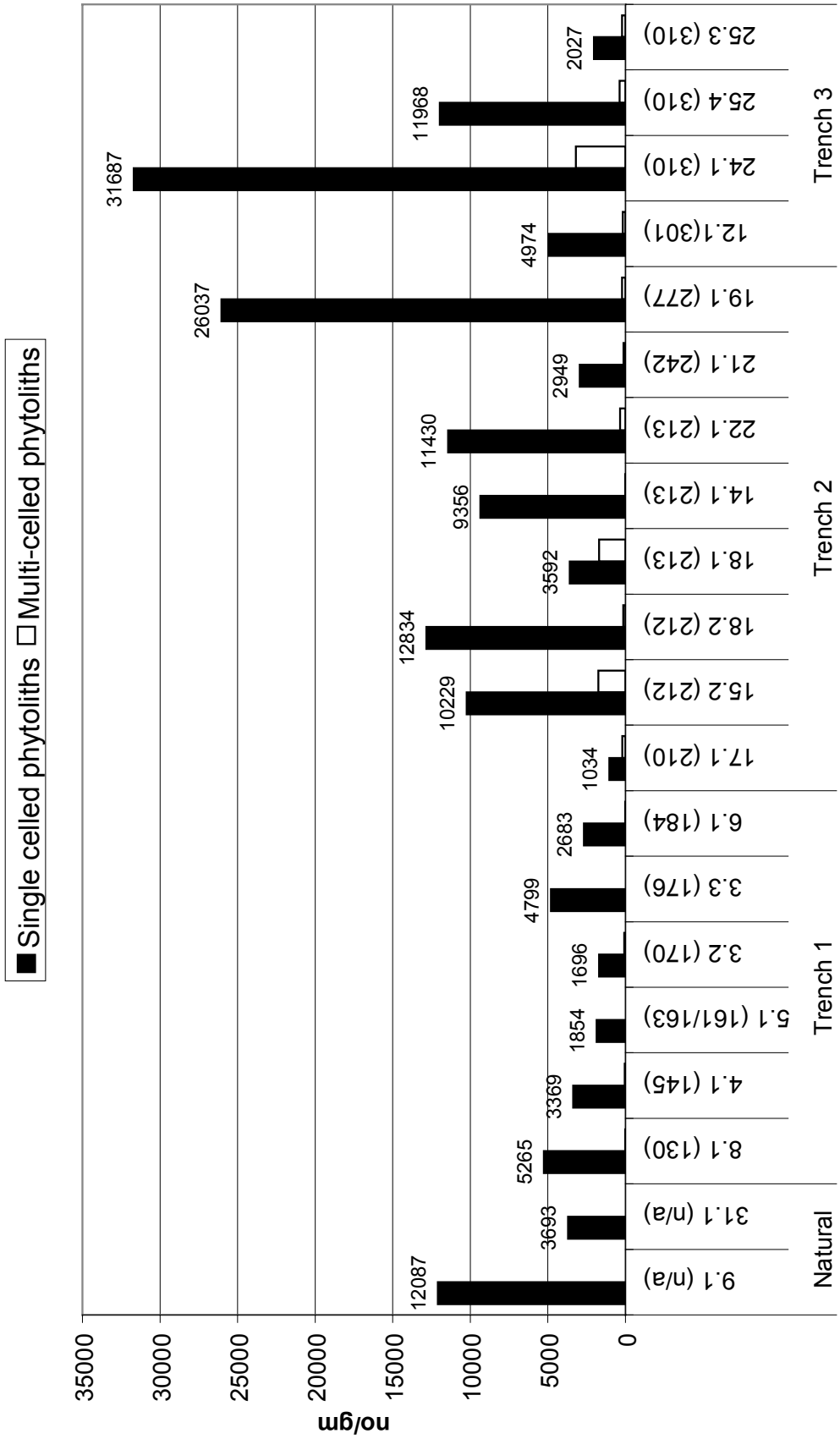

Figure 21.1 Numbers of single and multi-celled phytoliths per gram sediment for samples from WF16.

within Feature 39911 (defined by wall 308, see section 6.5.1, Figures 6.54, 6.55). The micromorphological analysis indicates that context 310 probably represents several discrete layers consisting of a mix of *in situ* natural, slopewash, dumping of occupation debris (including ash) and at least two plastered floors. As described by Finlayson and Mithen (section 6.5.1), discrete horizons were not easily identified during excavation of 310 owing to their discontinuous spatial extent but the northern part of the east-facing section of Trench 3 shows an occupation horizon immediately above mud-plaster floors (Figure 6.55) This part of the section was sampled by the micromorphology units 24.1 and 25.4 (Figures 6.68, 7.3) and shown to be rich in microscopic plant remains, although few plant macrofossils were recovered by flotation of 310 (Table 20.2).

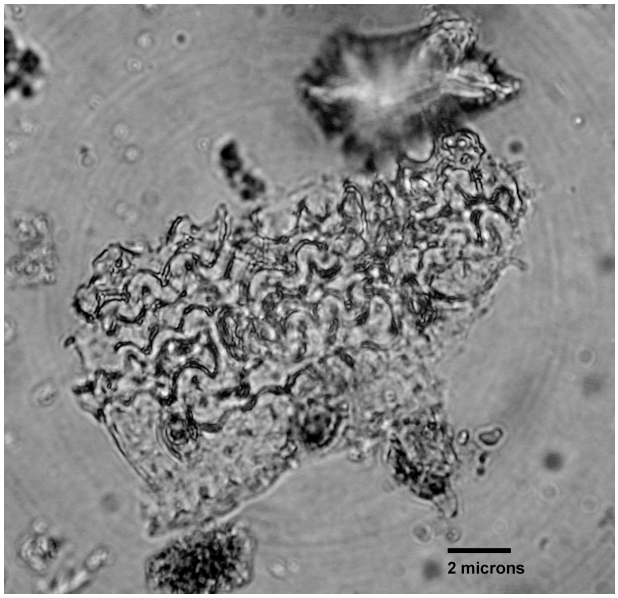

Figure 21.2 Reed stem phytolith from sample 24.1 (310), WF16.

Overall the samples from Trench 3 were richer in monocot phytoliths than the contexts from the other areas of the site, with samples 24.1 and 25.4 being significantly richer in monocots than samples 12.1 and 25.3, and indeed all other samples from WF16. Sample 24.1 has the highest number per gram of both monocot and dicot phytolith forms at WF16, that of monocots being very significantly higher than elsewhere

Many of the forms found in the samples from Trench 3 are indicative of reeds (e.g. Figure 21.2). The number per gram of reed phytolith forms is illustrated in Figure 21.3, showing the particularly high frequency of these in sample 24.1 [310]. This is followed by sample 25.4 [310] with 4273. The two remaining samples 12.1 [301] and 25.3 [310, trampled mud-plaster floor – see Figure 7.3] both have far lower numbers per gram of reed phytoliths. Whilst many multi-celled reed stem phytoliths were found (496 per gram in total), only 'bulliform'

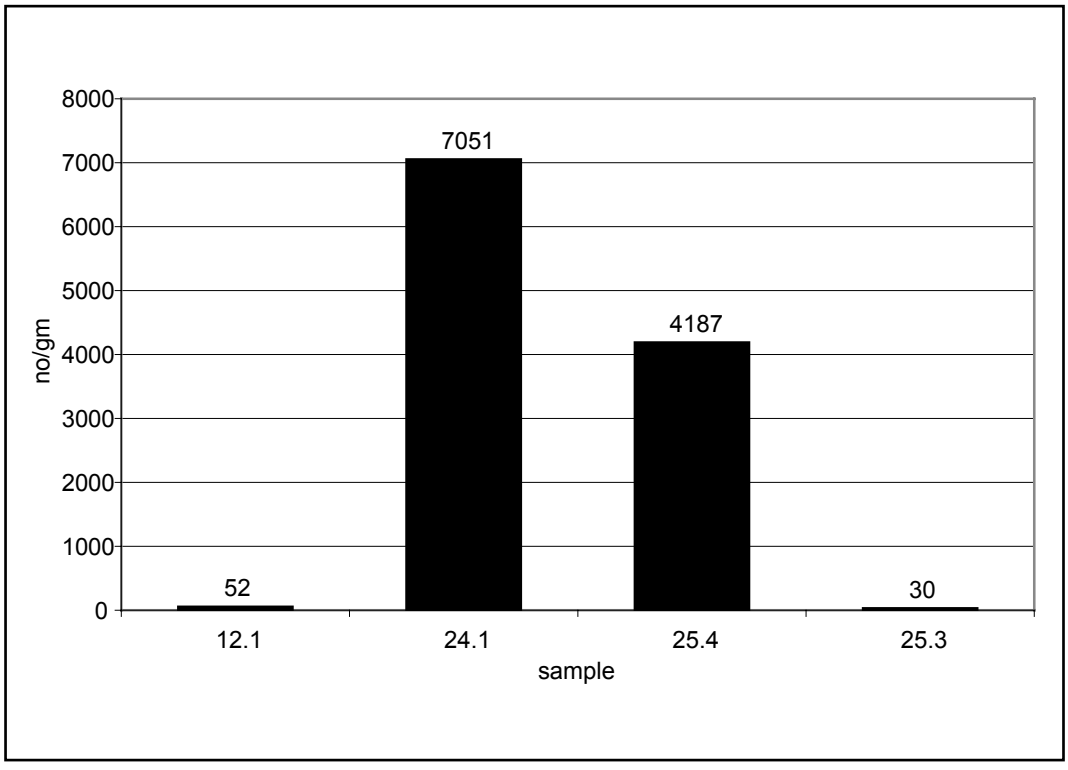

Figure 21.3 Number per gram of reed phytoliths from Trench 3, WF16, sediment samples.

phytoliths are present, two of which are illustrated in Figure 21.4. The multi-celled reed leaf phytoliths with stomata that are characteristic of *Phragmites* sp. were not found in any of the samples from WF16.

Whilst sample 24.1 [310] was rich in reed phytoliths it also had sedge phytoliths. Table 21.1 illustrates that this sample had 165 multi-celled phytoliths per gram of *Cyperaceae* (sedge) and 837 'long rod cells', which are also formed in sedges. In addition to reeds and sedges, sample 24.1 [310] had 28 *Setaria* sp. husks per gram and 228 unidentifiable grass husks per gram. This density is greater than in any of the other samples, with the majority of samples from WF16 lacking any husks at all. The only exception is 25.1 [310] which has 12 unidentifiable grass husks.

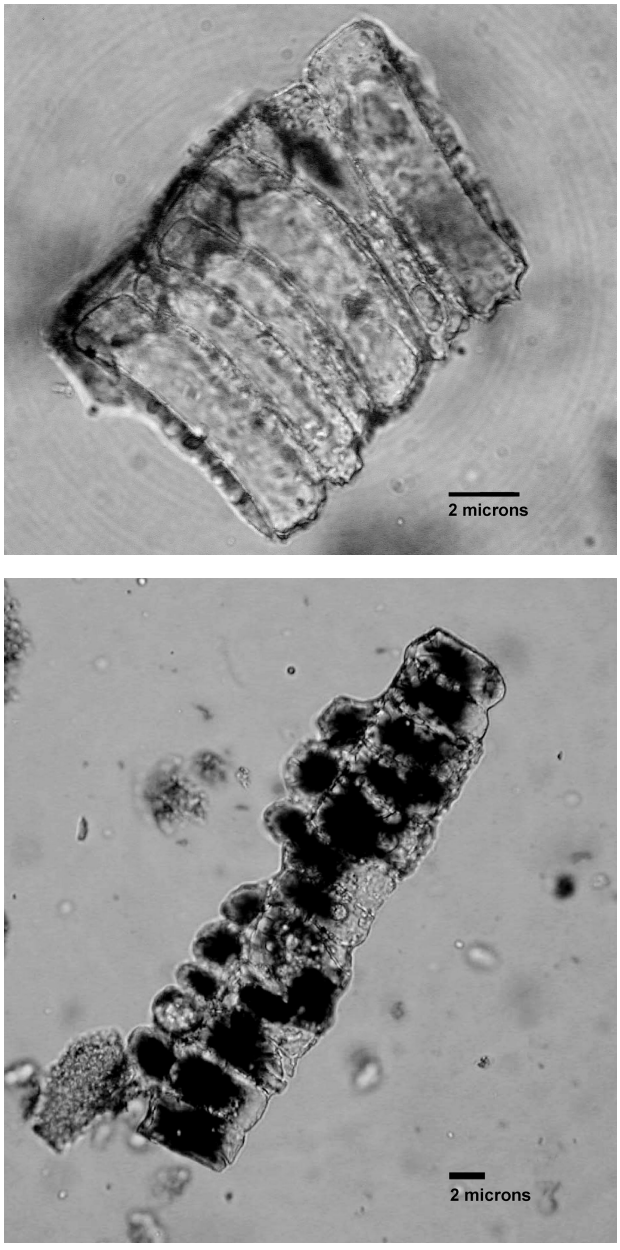

Figure 21.4 Bull form leaf phytoliths from sample 24.1 (310), WF16.

Sample 24.1 [310] is also the only sample in which 'rondels' and 'bilobes' were found. These are single-celled phytoliths which are formed in the leaves and stems of grasses. 'Rondels' typically occur in the Pooideae sub-family which are C3 grasses and are adapted to more temperate climates. 'Bilobes' are formed in grasses from the Panicodeae sub-family which represents C4 grasses. C4 types of grasses are more competitive in high temperatures and solar radiation than C3 grasses, though the Panicodeae sub-family typically prefers humid, wet environments and are adapted to high available soil moisture. It is significant that 'saddles' are absent in any of the samples from WF16 as these are indicative of the chloridoid type of grass which is adapted to warm, dry conditions (Barboni *et al.* 1999; Johnston 1996). In sample 24.1 [310], 732 'rondels' per gram were found compared to 209 'bilobes' per gram. In addition, a large number per gram of 'long cells' were found in samples 24.1 [310] and 25.1 [310]. In both of these samples the number per gram of 'smooth long cells' (from the leaves and stems) and 'dendritic long cells' (from the husks) were of a similar magnitude indicating that the husks were not preferentially brought to the site.

Sample 24.1 [310] has the greatest number of phytoliths per gram for both single-celled and multi-celled phytoliths, with 31687 multi-cells and 3192 single cells (Figure 21.1) Sample 25.1 [310] has a relatively high number per gram of single-celled phytoliths and also has multi-celled forms. Samples 12.1 [301] and 25.2 [310] do not have high densities of phytoliths per gram compared to the other samples from WF16.

21.4 Discussion

21.4.1 Plant use

The results of the phytolith analysis from WF16 demonstrates that in the majority of the samples, dicot phytoliths out-number monocot phytoliths. A comparison of the two samples analysed from the natural sediment with those from the archaeological deposits suggests that the majority of the phytoliths analysed from WF16 may have occurred naturally within the environment and were not deliberately brought to the site.

The exceptions to this are samples 24.1 [310] and 25.4 [310], Trench 3, both of which are rich in monocot phytoliths and derive from an occupation deposit immediately above a mud-plaster floor (sample 25.1, Figure 7.3). The results from sample 24.1 indicate that there was an abundance of reeds within this deposit. Sample 15.2 from Trench 2 also probably contained reeds and is associated with a trampled floor horizon. Reed stems can be used for manufacturing a variety of artefacts, as evident from the accounts of the Marsh Arabs (e.g. Thesiger 1964). Mats are often made of plaited reed, whilst baskets can be made of both plaited and coiled

reeds. Reeds are used to make musical pipes, boats, cradles, writing pens, cords, poles, spear shafts, spindles, thread or yarn-covered boxes, amulets, and sometimes as a source of temper. In addition, hunters use reeds as hides when hunting birds. Moreover, ashes from reeds are used for making soap and strips of reed are sometimes used as bandages (Ochsenschlager 2004).

Reeds were also an important source of building material for the Marsh Arabs and can be used as a thatching material. Although wheat straw was traditionally used for thatching in the UK, reeds (specifically *Phragmites australis*) were frequently employed in wetland areas such as Norfolk. The reeds were harvested after the winter frosts and wind had removed the leaves, as only the stems of the reeds were used for thatching. Sometimes a small amount of sedge was used in addition to reed to complete the thatch as it is a more pliable building material than reed. Interestingly, the samples from 24.1 [310] and 25.4 [310] show a mixture of reed and sedge phytoliths. It is possible that the WF16 structures were roofed with reeds, although the association with floors in Trenches 1 and 3 may suggest they were used for flooring.

On the basis of experimental work, Ronen *et al.* (1994,191) argue that PPNA borers – a particularly common early Neolithic artefact type – were used specifically for piercing reeds and suggest that the "PPNA becomes the age of reed perforation". They postulate that reeds were pierced and slotted together and could have been used to make a fence or some other upright structure and that the larger reed pieces were slotted together using reed splinters. Another possibility is that the reeds found at WF16 were attached using the more pliable sedge or grass material. Ronen *et al.* (1994) also suggest that reed structures could have been used for trapping animals such as birds and fish and for fencing gazelle during the PPNA. The WF16 chipped stone assemblage supports the hypothesis that perforation was a frequent PPNA activity, as perforators constitute 18% of the retouched assemblage (Pirie, Chapter 8). In addition, use wear analyses of the WF16 pointed artefacts have shown that many of these were used for piercing and perforating (Smith, Chapter 9).

The contrast in phytolith types and densities between the samples from the natural sediment, and from Trenches 1 and 2 compared to the samples from Trench 3 are striking. As discussed above, it suggests that some form of specific activity was associated with the samples from Trench 3. The differences in the phytolith samples may also correlate with the results from the analyses of the chipped stone, which show that the Trench 3 assemblage is typologically distinct from those recovered from Trenches 1 and 2 (Pirie, Chapter 8). This may suggest either that the structures and spaces excavated from Trench 3 represent different activity areas from those excavated in Trenches 1 and 2, or that Trench 3 may represent a different phase of occupation than Trenches 1 and 2 (see further discussion by Mithen and Finlayson, Chapter 25).

Cereal phytoliths were absent in the samples analysed. The results from the macro-botanical analysis suggest that cereals were not abundant at WF16 (Kennedy, Chapter 20). It is possible that this is a reflection of the samples chosen for analysis and/or the areas chosen for excavation rather than being a true picture of cereal use at the site. However, analysis of 24 samples from the PPNA site of Dhra (situated north of WF16 in the Jordan valley, see Figure 24.1) demonstrated that, with the exception of three contexts which are believed to be associated with a storage structure, there is a paucity of grasses and that dicots far out number monocots (Jenkins, pers. observation). Similarly, phytolith analysis at Netiv Hagdud, although still ongoing, has illustrated that dicots are also more abundant than monocots at this site (Rosen, pers. observation). This indicates that cereals were not exploited on a large scale during the PPNA. It is noteworthy, however, that grass husks are found in samples 24.1 [310] and 25.4 [310] which indicates that the area represented by Trench 3 was occupied during the springtime when the grasses were flowering.

21.4.2 Environmental implications

The results from the phytolith analysis indicate that trees and/or shrubs were abundant in the environment around WF16. This is apparent from the results from the natural deposits as well as from the excavation areas, which all yielded high numbers of dicot phytolith forms as well as 'silica aggregates', which form in the bark of trees (Albert *et al.* 2003). This interpretation is supported by the evidence from the charcoal analysis which demonstrates that woody species were more prevalent during the PPNA than at present (Austin, Chapter 19).

The abundance of reeds in some of the samples indicates that there were wetland areas around the site from which these could be collected. In addition, the presence of 'rondels' and 'bilobes' which are formed in the Pooideae and Panicodeae sub-families respectively, suggest that there must have been areas of high humidity or high soil moisture content around WF16, whilst the absence of 'saddle' phytoliths, and hence the chloridoid grass type, indicates that dry soil conditions were not prevalent (Barboni *et al.* 1999). However, the current conditions at Wadi Faynan suggests that the boundary between moist and arid areas can be sharp, and hence arid soils unable to support grasses can nevertheless be in close vicinity of moist areas. The interpretation of the PPNA Wadi Faynan being wetter in the past than at present correlates with the results of the charcoal analysis which indicates that riverine woodland associated with a permanent water course was in the vicinity of WF16. The results of the microfaunal analysis lend further support to this interpretation as the marsh or lake frog (*Rana ridibunda*) was found amongst the microfaunal remains which is an aquatic creature associated with

almost all forms of water including ponds, ditches, streams, lakes and rivers (Edwards and Martin, Chapter 16; Arnold and Ovenden 2002).

21.5 Conclusion

The phytolith analysis WF16 sediment samples has demonstrated the value of recovering phytoliths as well as macro-botanical remains and charcoal from archaeological sites. It suggests that the activity represented by samples 24.1 and 25.4 [310] involved the used of reeds, while grass husks in these samples 24.1 suggests occupation during the Spring when the grasses were flowering. More generally, the phytolith analysis has confirmed the results of the charcoal analysis (Austin, Chapter 19) which suggests that woody species were more abundant during the PPNA than they are currently, and that in all probability Wadi Faynan was wetter during the PPNA than it is at present.