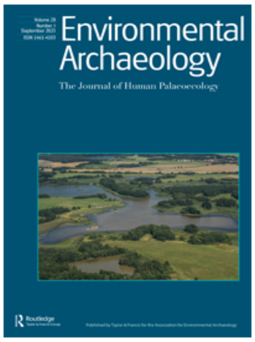

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Using Phytolith, Geochemical and Ethnographic Analysis to Inform on Site Construction and Activities in the Neolithic of Southwest Asia: Case Studies from Wadi Faynan 16 and 'Ain Ghazal, Jordan

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ABSTRACT
This paper explores what can be learned about settlement construction and use in the southwest Asian Neolithic from phytolith, geochemical and ethnographic analysis. This period was targeted because, despite its importance, our understanding of building practices and use of space within settlements is sometimes limited. We chose the sites of WF16 and 'Ain Ghazal as case studies and compared them with ethnographic samples of known origin from the similarly constructed twentieth century village of Al Ma'tan, Jordan. We split our samples into different context categories for example middens, hearths and floors, and found that phytolith and elemental signatures are strongest for categories linked to construction practices rather than activities. Geology, age and the availability of local plant materials were found to be key sources of signature variability. Fire contexts have particularly distinct activity signatures, which are heavily influenced by fuel choice yet are relatively analogous. We suggest that the use of micro-proxies such as phytoliths and geochemistry should be considered when sampling strategies are devised and integrated with other forms of archaeological evidence to enhance site interpretation.

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Phytoliths; geochemistry; Neolithic; SW Asia; Levant; pXRF

Introduction

The development of settled societies was one of the most profound lifestyle changes ever made. For the first time, humans chose to limit their mobility and invest time and effort into constructing permanent architecture. One of the regions where this transition first occurred was in the Levant of southwest Asia. While the first indications of sedentism in this region can be found with the Early Natufian culture (14,500–12,800 cal B.P. (Belfer-Cohen and Bar-Yosef 2000)), it was not until the Neolithic period (11,840–6250 cal B.P. (Blockley and Pinhasi 2011; Kuijt and Goring-Morris 2002; Rollefson, Rowan, and Wasse 2014; Wicks et al. 2016)) that we see a clear trajectory from small-scale settlements to what became known as 'megasites', housing up to 4000 people (Rollefson and Kafafi 2013).

Despite the importance of this critical transition period, building practices and the past purpose and use of some of the structures is not always clear. For example, at Wadi Faynan 16 (WF16), numerous small semi-subterranean buildings were found that were unlikely to have acted as 'houses' in the contemporary sense, yet we are unable to ascertain their purpose.

Ethnographic analysis focusing on phytolith and/or geochemical approaches has been successfully used to aid the understanding of building construction and activity areas within a variety of archaeological sites, for example, a traditional earthen house, Oaxaca, Mexico (Middleton and Price 1996); Masai penning sites, Ethiopia (Shahack-Gross, Marshall, and Weiner 2003); a seventeenth Century Colonial dwelling in Virginia, USA (Sullivan and Kealhofer 2004); rural villages, Greece (Tsartsidou et al. 2008; 2009); open areas and houses in a Swahili stone town, Songo Mnara, Tanzania (Sulas and Madella 2012); wattle-and-daub structures, Gujarat, India (Rondelli et al. 2014); specific contexts relating to dung, penning, storage, fallow fields, mud brick making and fuel in traditional households, Syria (Portillo et al. 2014) and Bedouin campsites, Jordan (Vos, Jenkins, and Palmer 2018). There have also been a considerable number of ethnographic studies focused on the identification of dung

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using phytoliths and/or geochemical approaches (e.g. Elliott et al. 2015; Gur-Arieh et al. 2019; Lancelotti and Madella 2012; Portillo et al. 2014; 2021; Portillo and Garcia-Suárez 2021; Portillo Ramirez and Matthews 2020; Shahack-Gross, Marshall, and Weiner 2003). None of these studies, however, are fully analogous with the types of sites and range of features and contexts found in the built Neolithic of Jordan.

To help resolve this issue, we conducted an ethnographic study of a traditionally built village in Jordan, Al Ma'tan, to determine if phytolith and geochemical signatures could help us identify specific activity areas or building construction practices in southwest Asian Neolithic sites. Results from the site have already been published and so will only be summarised here (Jenkins et al. 2017).

Al Ma'tan, in the Tafileh district of Jordan, was constructed during the 1920s and 1930s and was slowly abandoned from the 1960s to the 1980s (Figure 1). The buildings were constructed out of local stone, clay and plant materials. The walls were usually constructed of stone with mud mortar, though mud brick walls were also found, and then covered in layers of straw tempered clay plaster. The roofs were built using juniper beams (*Juniper phoenicea*) as a support, with reeds (*Phragmites australis*) on top, followed by a layer of what is referred to as 'bilan' (*Sarcopoterium spinosum*), a rough scrubby plant, topped by a thick layer of colluvium with stony inclusions, with the outermost layer being comprised of a straw tempered clay plaster. This choice of building materials made Al Ma'tan a good comparator site for the Levantine Neolithic, with even the internal building features reflecting those found on Neolithic archaeological sites, such as the food storage bins and the wall niches (Bar-Yosef 2011; Bogaard et al. 2009; Finlayson et al. 2011; Flohr et al. 2015; Jenkins et al. 2017; Mithen et al. 2018). We targeted different building features and contexts such as middens, floors, hearths, fire installations, etc to assess how useful the two proxies were at identifying these context categories (Jenkins et al. 2017). Since many of the former inhabitants of the village were still alive, we could speak with them and evaluate how well our results compared with what we knew about the activity categories based on the oral histories provided.

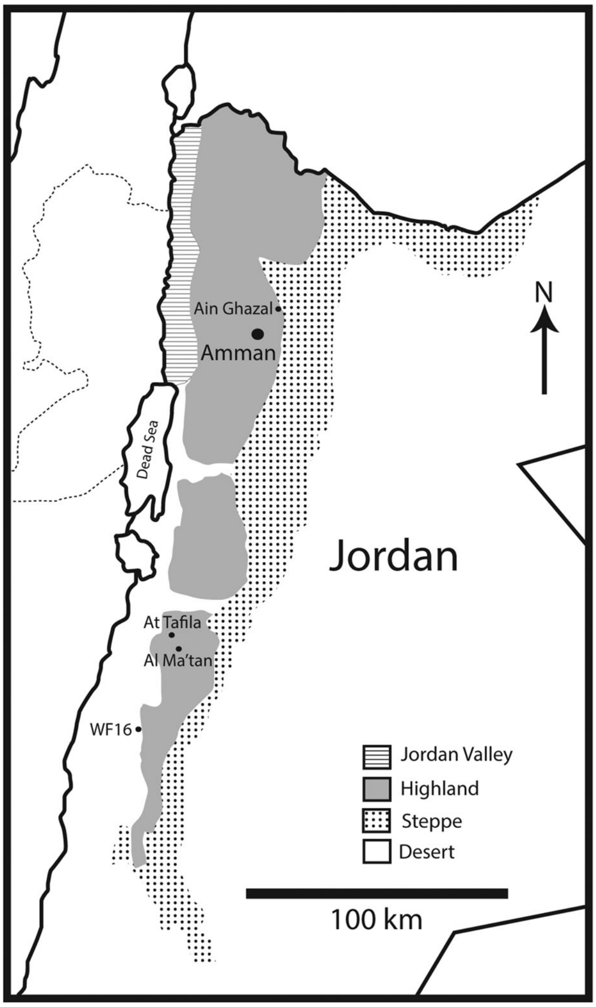

Figure 1. Map of Jordan showing the location of the archaeological study sites Wadi Faynan 16 and 'Ain Ghazal in relation to the capital Amman, and the ethnographic comparison site of Al Ma'tan.

Our results found that certain categories did have distinct geochemical and phytolith signatures. For example, *animal occupation*, *external fire installations and ashy* deposits, and *middens* all had high levels of Phosphorous (P) and Sulphur (S) and were dominated by grass inflorescence phytoliths and hair bases. This similarity was because they were all largely comprised of animal dung. We know from the information provided by the former inhabitants of the village that the *external fire installations*, the tabun ovens, were used to bake bread and that the fuel of choice was dung and not wood because dung provides a more constant burning temperature. The ashy deposits from the tabun ovens were then raked out directly into adjacent middening areas which were largely used as an area to dump the oven waste rather than any other discard material. This was the only midden available for sampling at Al Ma'tan and so represents a midden comprised of ashes from burnt dung. It is therefore not surprising that these categories were similar in their geochemical and phytolith signatures. It is noteworthy, however, that the *internal fire* installations, were not directly comparable with the *external fire installations*. While geochemically they were similar each recording higher levels of Potassium (K) and P, elements typically associated with burnt ashy deposits (Custer et al. 1986; Holliday 2004; Middleton and Price 1996; Price and Burton 2012), the phytolith assemblages differed. This is because wood rather than dung was used as fuel in the *internal fire installations* resulting in dicot phytoliths being more abundant in the *internal fire installations* than the *external fire installations and ashy deposits*.

Features that were largely constructed from the local available clay but had some anthropogenic additions had comparable geochemical and phytolith signatures with higher levels of Calcium (Ca) and Chlorine (Cl) and phytolith assemblages dominated by rondels and elongate forms, the latter presumably deriving from the addition of ‘tibn’ (chopped barley straw) as a temper; these were *storage features*, *plasters and clay features*, *platforms and benches* and *floors and surfaces*. This indicates that it is the construction material that was largely influencing the geochemical and phytolith signatures of these categories rather than reflecting what was being stored in the bins or the activities taking place on the floors. This is probably because the bins were largely empty aside from ‘tibn’ which also appears to have been used to line the base of the bin.

Construction material rather than on floor activities dominating floor signatures was also found to be the case at Neolithic Çatalhöyük, Anatolia where the floor make-up and plastering proved more significant in the geochemical analyses than any activity related signature (Middleton, Price, and Mieggs 2005). This is in contrast to research at Neolithic Tell Seker al-Aheimar, Syria where phytolith signatures found on plastered floors could be used to discern different activity areas (Portillo et al. 2010 (cited in Portillo et al. 2014); Portillo et al. 2014), although at both sites the floors were swept which could have erased or blurred some evidence for different activities (Matthews 2010 Matthews et al. 1997; Matthews and Farid 1996).

The final category grouping that was apparent at Al Ma’tan consisted of the *control/background*, the *mortars* and the *hearth make-up* categories. The geochemical and phytolith signatures for these categories was largely dominated by the local clay used in their construction with minimal anthropogenic alteration. These categories were dominated by higher levels of Titanium (Ti), Ca and Magnesium (Mg) and dicot and reed phytoliths which were largely incorporated into the clay from the local vegetation.

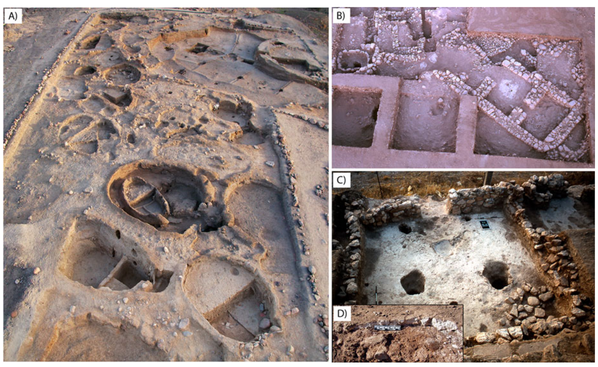

Figure 2. Key structural features at Wadi Faynan 16 and ‘Ain Ghazal. (A) Aerial overview of WF16 and the circular-oval structures that were excavated; (B) ‘Ain Ghazal Yarmoukian structure; (C) ‘Ain Ghazal plaster floor in structure 3083 (AG84); (D) ‘Ain Ghazal Pre-Pottery Neolithic C (PPNC) huwwar floor in section.

Aims

This paper will now focus on what can be learned about settlement construction and use in the Levantine Neolithic from phytolith and geochemical analysis. This will be done by focusing on two globally significant case study sites which fall at either end of this trajectory. The first is Wadi Faynan 16 (WF16), a small early Neolithic settlement, and the other is ‘Ain Ghazal, a Neolithic site which eventually developed into a mega-site; both in modern day Jordan (Figures 1 and 2). Our interpretations will be informed by ethnographic research that was previously conducted at the site of Al Ma’tan, Jordan (Jenkins et al. 2017) and the archaeological evidence from WF16 (Mithen et al. 2018) and ‘Ain Ghazal (Rollefson 1983; 1996; 1998a; 1998b; 2004; Rollefson and Kafafi 1996; 2013; Rollefson and Simmons 1984; 1985; 1987; Rollefson and Suleiman 1983; Rollefson, Simmons, and Kafafi 1992).

Our specific research questions are as follows:

1. Can phytolith and pXRF analyses, combined with our ethnographic understanding from our research at Al Ma’tan, enhance our understanding of construction practices at WF16 and ‘Ain Ghazal, Jordan through similarities in phytolith types and geochemical signatures resulting from the building materials used?
2. Can phytolith and pXRF analyses, combined with our ethnographic understanding from our research at Al Ma’tan, enhance our understanding of the use of space at WF16 and ‘Ain Ghazal, Jordan through similarities in phytolith types and geochemical signatures resulting from materials associated with different activities?
3. How much does the local geology and vegetation cover impact the efficacy of the proposed method? Are common phytolith and geochemical signatures from construction and activities diluted by others that occur naturally in the local environment?

The Levantine Neolithic

The Neolithic in the Levantine region of southwest Asia is split into the Pre-Pottery Neolithic (PPN [c. 11,840–8350 cal B.P.]) and the Pottery Neolithic (PN [c. 8350–6950 cal B.P.]). With the PPN being further sub-divided into the Pre-Pottery Neolithic A (PPNA [c.11,840–10,600 cal B.P.]), the Pre-Pottery Neolithic B (PPNB [c.10,600–8850 cal B.P.]) (Blockley and Pinhasi 2011; Kuijt and Goring-Morris 2002; Wicks et al.

2016) and the Pre-Pottery Neolithic C (or Final PPNB) (PPNC [c.8850–8350 cal yr B.P.]) (Rollefson 2021). This was followed by the Yarmoukian Pottery Neolithic period identified at ʻAin Ghazal, (8350–7450 cal B.P. (Rollefson 2021; Rollefson, Rowan, and Wasse 2014)).

The PPNA saw the exploitation of wild cereals and legumes, with evidence for pre-domestication cultivation (Colledge et al. 2018; Twiss 2007). However, there is no compelling evidence for either fully domesticated plants or animals during the PPNA (Asouti and Fuller 2013; Colledge et al. 2018; Kuijt and Goring-Morris 2002; Russell 2016; Simmons 2010; Twiss 2007; Weide et al. 2022). Settlements at this time were typically comprised of circular and oval buildings made of pisé, mud brick or stone, with many sites having semi-subterranean structures (Bar-Yosef 2011; Finlayson et al. 2011; Flohr et al. 2015). During the succeeding PPNB there is evidence for both plant and animal domestication (Asouti and Fuller 2013; Kuijt and Goring-Morris 2002). PPNB settlements in the Levant were typically comprised of rectilinear stone or mud-brick architecture with some settlements later expanding to become substantial 'mega-sites', including ʻAin Ghazal (Rollefson and Kafafi 2013). WF16 and ʻAin Ghazal represent the two contrasting Neolithic architectural forms, the circular/oval structures of the PPNA and the rectangular structures of the PPNB (Figure 2).

The Archaeological Sites

WF16

WF16 was excavated between 2008 and 2010 and is a site of international importance being one of the earliest PPNA sites in the Levant. Occupation began by c. 11,840 cal B.P. and lasted until c. 10,240 cal B.P. (Mithen et al. 2018; Wicks et al. 2016). The site lies at the head of a major wadi (a seasonally flooded river valley) between the steep mountains of the Jordanian plateau and the more arid Wadi Araba to the west. Today there is a dry climate (mean temperature of 24°C; mean annual precipitation of c. 60 mm) with a Sudanian vegetation influence including Acacia and *Ziziphus* trees. As altitude increases to the east this intermixes with and then gives way to steppic Irano-Turanian followed by Mediterranean biogeographical zones including Juniper and Evergreen Oak as major forest elements (Palmer et al. 2007; Robinson et al. 2006). Geomorphological and palynological evidence suggests a more steppic environment during the Early Holocene (Barker et al. 2007).

The site is largely comprised of small semi-subterranean circular-oval pisé structures and contains the largest PPNA structure excavated to date in Jordan, known as Object 75 (the term used at WF16 to denote a building or feature-see Mithen et al. 2018 for full site details and the terminology used). This building measured c. 20 m × 18 m (Mithen et al. 2011; Mithen et al. 2018). Due to the small size of most of the structures and their internal arrangement it is unlikely that these structures acted as 'houses' in the contemporary sense. A range of features were exposed during excavation including mud-plastered floors, benches, hearths, middens, walls, collapsed roofs, niches and possible storage areas (Figure 2a).

ʻAin Ghazal

ʻAin Ghazal is an iconic Neolithic site located in the north-western highlands of Jordan in the present-day capital of Amman. The site is situated in the relatively rich setting of the Zarqa valley, adjacent to the Wadi Zarqa, at the junction between the moister Mediterranean and steppic Irano-Turanian vegetation regions (Neef 2004). The current annual rainfall is 187 mm per year and the annual temperature is 17.2°C. The river and spring of ʻAin Ghazal allowed the permanent settlement to flourish. The site was excavated over 11 seasons from 1982 to 1998 and is known for its large plastered anthropomorphic statues and busts with bitumen eye detail (Rollefson 1983; 1996; 1998a; 1998b; 2004; Rollefson and Kafafi 1996; 2013; Rollefson and Simmons 1984; 1985; 1987; Rollefson and Suleiman 1983; Rollefson, Simmons, and Kafafi 1992). ʻAin Ghazal contained many construction features such as stone walls, courtyards, hearths, storage features, and most distinctly, specially prepared plastered floors. The PPNB floors were painted with red ochre decoration but later PPNC and PN floors were comprised of 'huwwar' (crushed chalk) (Rollefson, Simmons, and Kafafi 1992) (Figure 2b–d). ʻAin Ghazal was established in the MPPNB and continued to be occupied until the PN (the Yarmoukian period). Four clear phases of occupation are evident between c 10,450–9450 cal B.P. (MPPNB), c 9450–8850 cal B.P. (Late Pre-Pottery Neolithic B (LPPNB)), c 9450–8850 cal B.P. (PPNC) and c 8850–8350 cal B.P. (Yarmoukian) (Rollefson 2021; Rollefson and Kafafi 2013).

During the early MPPNB ʻAin Ghazal was a small village of approximately two hectares but following population expansion in the LPPNB became a 'mega-site' of almost 15 ha (Rollefson 2004). The MPPNB saw a shift in architecture to two to three-story apartment-like complexes with structures that were detached but densely clustered (Gebel, Nissen, and Zaid 2006; Rollefson and Kafafi 2013). Two new building 'types' emerge during the LPPNB: small (5 × 2.5 m) apsidal buildings and larger buildings (6 × 3.5 m preserved dimensions (Rollefson 1998b: 51)). The smaller structures were probably kin-related cult buildings, while the larger ones were community-wide cult structures (Rollefson 2010). The rectangular structures were built of stones secured with mud mortar (Figure 2b–d), and their interior faces were covered with mud plaster.

By the end of the LPPNB, population pressures on local resources (and a possible short-lived but severe decrease in precipitation) resulted in an outright abandonment of many megasites or a severe reduction in settlement population. PPNC ʻAin Ghazal appears to have had a fluctuating population, where some inhabitants took their caprids from the immediate vicinity to pastures at considerable distances until the end of the harvest season, when the 'tethered pastoralists' and their flocks returned (Köhler-Rollefson 1992, 14; Miller et al. 2019). Those part-time caprine herders maintained small (c. 3 × 3 m) semi-subterranean buildings where family possessions were stored. The sedentary component of the ʻAin Ghazal population resided in walled compounds in small (c. 5 × 3 m) one-room structures (with either dirt or 'huwwar' floors (Rollefson and Kafafi 2013, 14)).

Population size at ʻAin Ghazal remained relatively low in the early phases of the Yarmoukian period, although across the ensuing millennium the site area (but not structural density) seems to have expanded again. Architecture was rectangular and larger than in the PPNC: one Yarmoukian house measured 9 × 4 m, with three rooms arranged along a single axis. At least one house had an exterior curvilinear addition at the rear of the building, possibly serving as a storage room. A new structure type appeared during the Yarmoukian: 'kitchen compounds' that may have been places for cooking for several nearby households (Kafafi and Rollefson 1995, 14–15; Figure 2). At the end of the Yarmoukian sequence at least two examples of tent foundations with puddled mud floors appear at ʻAin Ghazal, probably the residences of mobile pastoralists after ʻAin Ghazal had been abandoned.

Materials and Methods

Field Methods and Sample Selection

Samples from both archaeological study sites were selected from contexts that matched the categories used at the ethnographic site of Al Ma'tan (Jenkins et al. 2017). Table 1 shows the number of samples in each category for both study sites.

WF16 samples were extracted from archived material stored in Jordan. In addition, 10 samples were included from an earlier pilot study conducted by Elliott. Unfortunately, degradation of materials stored since 2010 meant that not all the samples originally identified for analysis were retrievable, resulting in few or no samples for some categories. Seventy-three samples were selected (SM Table 1), which came from 11 of the excavation objects. In addition, eight control samples were selected from the archived WF16 material that represented three different environmental and geological settings starting from the wadi system, situated below the archaeological site up along a transect towards the mound of the site itself.

At ʻAin Ghazal, 61 samples (SM Table 2) were taken by Allcock, Elliott and Rollefson from exposed and cut back sections (see SM Figure 1). These were from extended transects to ensure sample retrieval from different spaces and activities. To illustrate, from the main archaeological section (Tr III.I) (SM Figure 1) floors were sampled across ∼5 m of deposits, on a transect through the structures to safeguard capture of all activity signatures associated with floors. Based on the method of construction, the nature of the fill, and the plaster (Kafafi et al. 2016), the samples taken from section TR III.I belong to the PPNC. Samples taken from section TR III.II (SM Figure 1) are probably Yarmoukian in date, the majority of this section having been dated on the basis of recovered pottery finds (Kafafi et al. 2016), with the only C14 date (7786–7658 cal. B.P.) coming from a storage feature (Kafafi et al. 2016, 169). Samples from sections 3070, 3071, 3072 (SM Figure 1) were assigned to the MPPNB (8200–7500 cal BC) based on room size and architecture (Rollefson, Simmons, and Kafafi 1992). Samples from section 3273 (SM Figure 1) belong to the latest MPPNB with associated C14 samples having been dated 9925–9580 cal B.P. (lab number GrN-12970) (Rollefson 1998a).

One control sample was extracted from the *in-situ* terra rossa clay underlying the archaeological deposits and two further control samples were taken from a nearby agricultural field and from the edge of the river system beyond the road beneath the site.

Laboratory and Statistical Methods

Phytolith Processing and Analysis

The majority of the phytolith samples were processed at Bournemouth University using the same method as was used for the ethnographic samples (Jenkins et al. 2017) with the exception that a 500 µm rather than a 400 µm mesh was used to remove the coarse sized particles. The 10 WF16 samples included in the pilot study were processed with the same method at the University of Reading.

Approximately 2 g of dried sediment was weighed out for sampling and screened through a 500 µm mesh to remove any coarse sized particle. The calcium carbonates were dissolved using a dilution of 10% hydrochloric acid and then washed in distilled water three times. Clay was removed using a settling procedure and sodium hexametaphosphate (Calgon) as a dispersant. Distilled water was added, and the

Table 1. Summary of the phytolith results by number, site and category, spilt into three comparison sections (1) monocotyledonous (monocots) and dicotyledonous (dicots) morphotypes; (2) taxonomical origins; and (3) plant part. Some categories had no sample available and are delineated by a n/a.

	WF16																		
	No of samples	Monocot vs. dicot		Taxo origin												Plant part			
Category		Monocot	Dicot	Poaceae	Pooideae	Hordeum	Triticum	Lolium	Avena	Panicoideae	Chloridoideae	Cyperaceae	Arundinoideae	Palmaceae	Dicotyledoneae	Leaf/ stem	Leaf	Husk	Stem
Control type 1	4	63.3%	36.7%	55.8%	6.3%	0.0%	0.0%	0.0%	0.0%	0.7%	0.3%	0.0%	0.2%	0.2%	36.7%	41.0%	54.4%	4.6%	0.0%
Control type 2	1	13.2%	86.8%	12.8%	0.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	86.8%	11.0%	89.0%	0.0%	0.0%
Control type 3	3	86.4%	13.6%	65.5%	1.5%	0.0%	5.2%	0.0%	0.0%	0.3%	0.3%	0.1%	11.2%	2.4%	13.6%	52.3%	28.3%	15.4%	4.0%
External fire installations and ashy deposits	5	79.0%	21.0%	70.6%	4.4%	0.7%	0.0%	0.4%	0.0%	0.1%	0.0%	0.0%	2.6%	0.0%	21.0%	47.5%	29.1%	23.1%	0.4%
External/Courtyard	8	15.4%	84.6%	14.0%	0.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.0%	0.0%	84.6%	11.4%	88.1%	0.5%	0.0%
Floors and surfaces	20	21.2%	78.8%	17.8%	0.8%	0.6%	0.0%	0.0%	0.0%	0.3%	0.0%	0.0%	1.7%	0.0%	78.9%	14.2%	84.1%	1.7%	0.1%
Hearth make-up	2	4.4%	95.6%	3.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.6%	0.0%	95.6%	3.1%	96.9%	0.0%	0.0%
Human occupation/accumulation	10	39.9%	60.1%	34.5%	2.4%	1.2%	0.0%	0.0%	0.0%	0.3%	0.0%	0.0%	1.5%	0.0%	60.1%	28.0%	67.6%	4.0%	0.4%
Internal fire installations and ashy deposits	5	29.0%	70.8%	27.3%	1.0%	0.0%	0.0%	0.0%	0.0%	0.8%	0.0%	0.0%	0.0%	0.0%	70.8%	25.5%	73.6%	0.9%	0.0%
Middens	8	27.6%	72.4%	23.7%	1.6%	0.8%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	1.4%	0.0%	72.4%	17.7%	76.7%	5.5%	0.1%
Pise walls	1	8.5%	91.5%	8.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	91.5%	8.0%	92.0%	0.0%	0.0%
Platforms and benches	6	14.4%	85.6%	13.9%	0.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	85.6%	12.3%	87.2%	0.6%	0.0%
Roofs and roofing material	2	10.8%	89.2%	10.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	89.2%	9.6%	90.4%	0.0%	0.0%
Storage features	6	12.3%	87.7%	11.2%	0.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	0.0%	87.7%	7.3%	91.8%	0.8%	0.0%

	Ain Ghazal																		
		Monocot vs. Dicot		Taxo origin												Plant part			
Category	No of Samples	Monocot	Dicot	Poaceae	Pooideae	Hordeum	Triticum	Lolium	Avena	Panicoideae	Chloridoideae	Cyperaceae	Arundinoideae	Palmaceae	Dicotyledoneae	Leaf/ stem	Leaf	Husk	Stem
Control type 1	1	48.1%	51.9%	47.4%	0.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	51.9%	47.0%	52.3%	0.0%	0.7%
Control type 2	1	99.3%	0.7%	87.3%	12.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.7%	76.9%	19.0%	4.0%	0.0%
Control type 3	1	97.7%	2.3%	89.6%	7.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.3%	0.0%	0.0%	0.0%	2.3%	79.4%	11.8%	8.1%	0.7%
External fire installations and ashy deposits	5	93.6%	6.4%	78.4%	9.6%	0.7%	1.2%	0.8%	0.0%	0.4%	0.1%	0.0%	2.4%	0.1%	6.4%	53.3%	17.9%	28.4%	0.4%
Floors and surfaces	25	94.7%	5.3%	80.6%	7.5%	2.5%	0.4%	0.3%	0.0%	1.5%	0.0%	0.0%	1.8%	0.0%	5.3%	58.6%	16.8%	23.5%	1.1%
Human occupation/accumulation	12	98.3%	1.7%	79.6%	9.7%	5.0%	1.1%	0.7%	0.0%	0.1%	0.3%	0.0%	1.8%	0.0%	1.7%	53.2%	15.9%	30.7%	0.3%
Internal fire installations and ashy deposits	1	99.6%	0.4%	87.4%	4.7%	0.0%	0.0%	1.5%	0.0%	0.0%	0.0%	0.0%	6.0%	0.0%	0.4%	63.2%	6.8%	24.9%	5.1%
Mortars	6	96.2%	3.8%	83.1%	8.7%	0.0%	1.3%	0.9%	0.0%	0.1%	0.1%	0.0%	2.0%	0.0%	3.8%	59.7%	18.4%	21.3%	0.6%
Plasters and clay features	7	94.6%	5.4%	81.6%	5.7%	5.0%	1.9%	0.0%	0.0%	0.2%	0.0%	0.1%	0.3%	0.0%	5.4%	66.2%	16.1%	17.6%	0.2%
Storage features	5	92.2%	7.8%	78.8%	9.6%	0.9%	0.3%	0.0%	0.0%	0.2%	0.1%	0.0%	2.4%	0.0%	7.8%	62.4%	21.7%	15.7%	0.1%

samples left for 75 minutes before pouring off the suspense. This was repeated at hourly intervals until the samples were clear. Samples were then transferred into crucibles and left to dry at a temperature of less than 50°C. After drying, samples were placed in a muffle furnace for two hours at 500°C to remove any organic matter present. Phytoliths were then separated from the remaining material using a heavy liquid calibrated at 2.3 specific gravity. Phytoliths were transferred to centrifuge tubes and washed three times in distilled water. They were then placed in small Pyrex beakers and left to dry. Approximately two milligrams of phytoliths per sample (where possible) were mounted onto microscope slides, using the mounting agent Entellan New (Merck) and covered in a 22 × 22 mm cover slip.

Slides with phytolith material were counted using a Meiji MT4300 microscope at magnification x400 except for the 10 samples from the pilot study that were counted on a Nikon Optiphot 2 microscope. Two-hundred and fifty individual phytoliths were counted per slide and where this figure could not be reached the whole slide was counted. Up to 50 conjoined phytoliths (multi-celled structures) were identified where possible and quantified, and each phytolith form in the conjoined form was added to the individual phytolith counts. If 50 conjoined or multi-celled had not been reached within the field of views represented by the 250 single cell count than further fields of view were scanned to enable this. This was done because multi-celled forms are useful for identifying phytoliths taxonomically in southwest Asia and can be used to identify potential domesticates such as cereals. The 10 samples from WF16 from the pilot study were counted similarly, with the exception that single phytoliths within the multi-celled phytoliths were not recorded. The number of burnt individual phytoliths per sample was counted following the assumption that the 'blackening' of phytoliths represents occluded carbon (Parr 2006; Dong et al. 2022; Figure 3a). Similarly, the number of corroded single celled forms in each sample were counted (Figure 3b). The term 'corroded' is used to refer to forms that display pitting, and degradation to their surfaces or edges that could result from a range of unknown pre and post-depositional taphonomic processes. A modern Jordanian plant reference collection was used for taxonomic identification. Standard identification criteria (Twiss, Suess, and Smith 1969; Brown 1984; Piperno 2006) aided the identification of morphotypes and taxa (see Jenkins et al. 2017 for other taxa references followed) and phytolith terminology followed the International Code for Phytolith Nomenclature 1 (Madella, Alexandre, and Ball 2005) following the approach we used in our ethnographic study (Jenkins et al. 2017).

pXRF Analysis

Multi-element analysis was conducted in the laboratory of the Council for British Research in the Levant, Amman Institute using a Niton Xl3t Goldd + handheld pXRF analyser in mining mode running for a total of 210 s (exposure times: main filter = 60 s, low filter = 40 s, high filter = 20 s, light filter = 90 s). The Helium purge was enabled to allow for better detection of lighter elements at the top of the periodic table. Nine millimetre plastic cups covered with polypropylene film were used to house the samples during analysis and these were analysed in a portable test stand.

Data Treatments and Statistical Methods

Statistical analyses replicated those used in Jenkins et al. (2017). The geochemical data was characterised by several variables which had a high proportion of

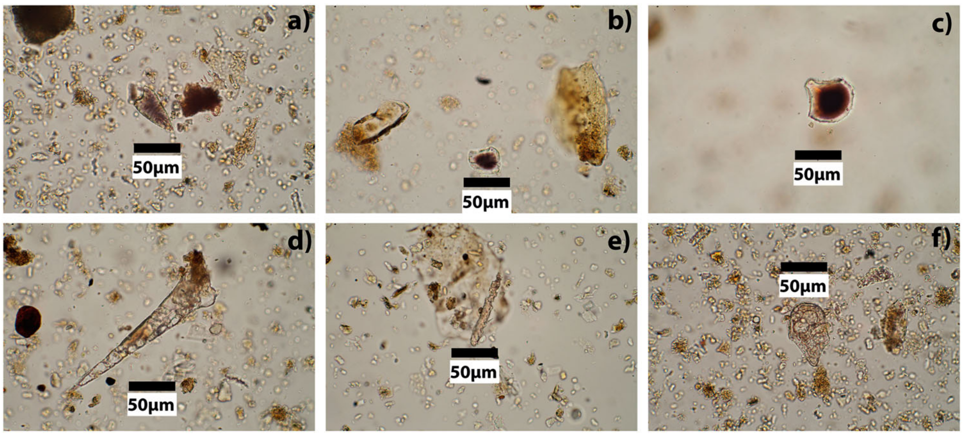

Figure 3. Burnt and corroded phytoliths: (A) trichome/hair phytolith with burning, Ain Ghazal, sample 39 6; (B) bulliform phytolith with burning and cracking, WF16, sample 2973; (C) keystone phytolith with burning, WF16, sample 6172; (D) macro hair phytolith with corrosion and pitting, WF16, sample 2973; (E) elongate smooth phytolith with corrosion, WF16, sample 6214; (F) keystone phytolith with pitting, Ain Ghazal, sample 39.

samples with values below the limits of detection (<LOD) and high (>10%) error readings and were not included in this study. In the case of elements which contain a lot of information pertaining to anthropogenic processes such as Mg, P and Cl (Holliday and Gartner 2007; Middleton and Price 1996; Reimann, Filzmoser, and Garrett 2002; Vranová, Marfo, and Rejšek 2015), and where only a small number of samples returned < LOD (<10%), these were set to their corresponding detection limit (as recommended by the instruments manufacture Niton) so that they could be used in the analyses (following Reimann and Filzmoser 2000; Reimann, Filzmoser, and Garrett 2002).

To be able to explore the retained elements using multivariate parametric statistics sensitive to outliers, cleaned and standardised data were used instead of raw data (Reimann and Filzmoser 2000). Outlying samples were cleaned using univariate and bivariate graphical approaches to jointly detect extreme and unusual outliers (Baxter and Heyworth 1989). Following outlier removal, variables were checked to see if they fitted a normal distribution and were centre log ratio transformed using CoDaPack v2 to ensure they approached normality and to overcome the problem of closed data (Aitchison 1986; Comas Cufí and Thió i Fernández de Henestrosa 2011). The transformed values were then standardised to a mean of 0 and standard deviation of 1 so that all variables could contribute equally to the analyses. The correlation structure of the data matrix was also studied so that elements of high correlation, with r-values above 0.75 and below −0.75, could be removed before Principal Components Analysis (PCA) was conducted because nearly-redundant variables can cause the PCA to over emphasise their contribution (Jolliffe 1972). Both the Spearman Rank coefficient and Pearson's Product coefficient were consulted and all but one co-varying variable was discarded.

Phytolith single-cell counts and multi-cell counts, were reduced following conversion into percentage data and variables containing less than 0.1% of the total count were removed due to the fact that they would offer little interpretative value to the statistical analyses (Gauch 1982; McCune and Grace 2002). Phytolith percentages were also checked for erroneous data, and visual outliers were discarded. Retained phytolith variables were then arcsine square root transformed in Microsoft Excel, to increase normality, reduce the influence of abundant morphotypes on rarer ones and to meet the assumptions of parametric testing (McCune and Grace 2002; McDonald 2014). The transformed phytolith data was standardised to a mean of 0 and standard deviation of 1. The weight percentage of phytoliths was calculated by taking the weight of the phytoliths extracted after processing and dividing by the weight of the dried sample, then multiplying by one hundred (Jenkins, Baker, and Elliott 2011).

To visualise and interpret the multivariate datasets, Principal Components Analyses (PCAs) were performed in a statistical software package PAST on the corrected data using correlation matrixes – using PAST's programme functions to maximise the variability between groups (Hammer, Harper, and Ryan 2001). PCA was further used as another data exploratory tool to examine the data for outliers (Baxter and Heyworth 1989).

Results

Phytolith Results

The raw data for all phytolith counts can be found in SM Tables 3–6. This includes both the counts of the single and the conjoined or multi-celled forms and details of how many fields of view and rows were counted on the microscope slide. The weight percent of phytoliths extracted from the original sediment indicates the proportion of phytoliths to original sediment and hence phytolith density. The weight percentages recorded for WF16 samples (Figure 4) are lower than those recorded for the 'Ain Ghazal samples with WF16 having an average weight percent of 0.5 and 'Ain Ghazal an average of 3.5, which is higher than the average weight percent found at al Ma'tan (see SM Table 7 for Standard Deviation). At both archaeological sites, there are categories which commonly have higher weight percentages compared with other categories, namely *external fire installations and ashy deposits*, *floors and surfaces*, and *human occupation/accumulation*.

The taphonomic analysis demonstrates that the percent of burnt forms is highest at Al Ma'tan with 50.9% of all forms being burnt and is highest in the *animal occupation* category. 'Ain Ghazal had the lowest level of overall burning with 1.4%. At both WF16 and 'Ain Ghazal the highest percent of burnt forms is found in the control samples. For the corroded forms it is evident that Al Ma'tan has the highest percent of corroded forms overall and WF16 has the lowest. At all three sites the control category has the highest percent (Table 2).

WF16 samples contained a greater number of dicot morphotypes with only 34.5% of all samples being monocot dominant. This is in comparison to the 'Ain Ghazal phytolith assemblage which is dominated by monocots (Table 1). Table 3 displays only three phytolith morphotypes: elongate dendriforms which come from grass husks, rondels which form in pooideae C3 grasses (Twiss 1992), and silica (or siliceous) aggregates which form in dicots (Amos 1952) with Collura and Neumann (2017) demonstrating that silica aggregates are most prolific in the bark rather than in the wood of West African woody plants. A similar reference

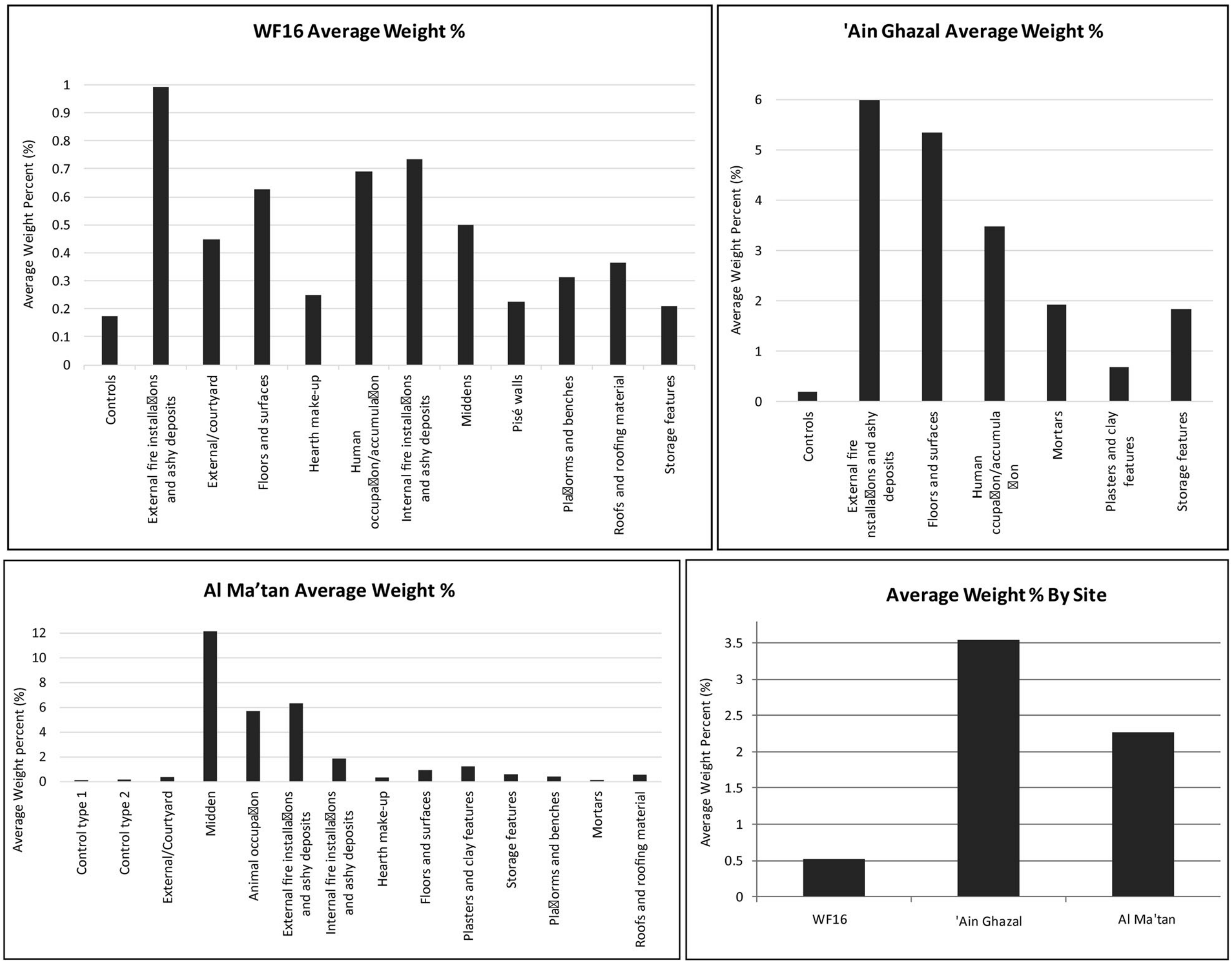

Figure 4. Bar charts showing the phytolith weight percentage values by category for WF16, 'Ain Ghazal and Al Ma'tan along with a chart showing the average weight percent for each site.

collection distinguishing between bark and wood phytoliths does not exist for southwest Asian species but it is reasonable to assume that this would also be the case for southwest Asian species. The table shows the importance of cereals, other types of grasses and wood plant material at each site. This more selective comparison of a few morphotypes demonstrates the dominance of woody/shrubby plant material at WF16, with *hearth make-up* and *roofs and roofing material* samples comprised of 100% silica aggregate. The percentage of elongate dendriforms at WF16 is generally low. Table 3 shows that silica aggregates were also recorded at 'Ain Ghazal for some categories and that the values for elongate dendriforms are comparatively high overall especially for *internal fire installations and ashy deposits* (Figure 5).

Table 2. Percent of phytolith forms in each context category affected by burning and corrosion for WF16, 'Ain Ghazal and Al Ma'tan.

	Burnt			Corroded		
Category	WF16	Ain Ghazal	Al Ma'tan	WF16	Ain Ghazal	Al Ma'tan
Control	4.69%	0.44%	5.86%	9.58%	14.88%	17.13%
Animal Occupation	N/A	N/A	19.82%	N/A	N/A	4.21%
External fire installations and ashy deposits	1.68%	0.22%	6.47%	5.08%	10.95%	15.29%
External/Courtyard	1.46%	N/A	0.45%	3.39%	N/A	9.05%
Floors and surfaces	2.25%	0.05%	2.13%	2.66%	2.96%	5.79%
Hearth make-up	0.04%	N/A	0.07%	0.04%	N/A	10.15%
Human occupation/accumulation	0.72%	0.15%	N/A	2.19%	4.17%	N/A
Internal fire installations and ashy deposits	0.22%	0.00%	4.68%	1.31%	0.00%	5.99%
Midden	0.33%	N/A	4.77%	0.77%	N/A	12.44%
Mortars	N/A	0.34%	2.14%	N/A	6.14%	14.39%
Pise walls	1.22%	N/A	N/A	3.91%	N/A	N/A
Plasters and clay features	N/A	0.11%	0.58%	N/A	3.63%	4.56%
Platforms and benches	1.63%	N/A	0.00%	2.03%	N/A	N/A
Roofs and roofing material	1.85%	N/A	1.46%	3.54%	N/A	6.07%
Storage feature	0.84%	0.09%	2.48%	2.42%	11.13%	4.64%

Table 3. Phytolith results from WF16 and 'Ain Ghazal based on three identified morphotypes only, elongate dendriforms (representing husked-grasses), short-celled rondels (representing pooideae C3 grasses) and silica aggregates (representing woody/shrubby dicot material).

	WF16		
Category	Elongate dendriform	Rondel	Silica aggregate
Control type 1	4.1%	9.7%	86.2%
Control type 2	0.0%	1.4%	98.6%
Control type 3	22.3%	8.3%	69.3%
External fire installations and ashy deposits	16.5%	6.0%	77.5%
External/courtyard	0.9%	0.8%	98.4%
Floors and surfaces	1.1%	1.1%	97.8%
Hearth make-up	0.0%	0.0%	100.0%
Human occupation/accumulation	0.6%	1.5%	97.9%
Internal fire installations and ashy deposits	0.3%	0.4%	99.3%
Middens	2.0%	1.1%	97.0%
Pisé walls	0.0%	0.0%	100.0%
Platforms and benches	0.6%	0.6%	98.8%
Roofs and roofing material	0.0%	0.0%	100.0%
Storage features	0.5%	0.7%	98.9%

	Ain Ghazal		
Category	Elongate dendriform	Rondel	Silica aggregate
Control type 1	0.0%	100.0%	0.0%
Control type 2	9.6%	28.7%	61.7%
Control type 3	15.3%	16.0%	68.8%
External fire installations and ashy deposits	11.7%	8.1%	80.2%
Floors and surfaces	3.9%	2.6%	93.6%
Human occupation/accumulation	9.6%	9.5%	80.9%
Internal fire installations and ashy deposits	37.1%	17.9%	45.0%
Mortars	15.9%	10.3%	73.8%
Plasters and clay features	5.6%	6.6%	87.8%
Storage features	18.1%	26.5%	55.4%

While conjoined phytolith forms were a small component of both phytolith assemblages, some samples contained phytoliths identifiable to genus. For both sites, *Hordeum* sp. (barley), *Lolium* sp. (ryegrass) (Rosen 1992, 142), and *Arundinoideae* (typically representing reeds *Phragmites* sp.) were identified, while *Triticum* sp. (wheat) was only present at 'Ain Ghazal (Figure 5).

At WF16, phytoliths related to grass inflorescences are strong drivers of the variability in the PCA (Figure 6) with *Hordeum* sp. and *Lolium* sp. mainly influencing samples at the positive end of PCA2 (group 3, Figure 6). *External fire installation and ashy deposits* samples, mostly, plot at the positive end of axis 2 and are associated with leaf phytoliths from *Phragmites* sp. A clear distinction can be seen between these samples and most of the other archaeological samples which have a strong association with platey and dicot phytoliths and *controls 1 & 3*, which plot by globular forms, *Triticum* sp. husks and bilobates which typically form in panicoid grasses (Twiss, Suess, and Smith 1969), although to note deviations from this pattern with bilobates forming in some pooid grasses in our own reference collection have been noted. Despite these issues it is largely the case that bilobates more commonly form in panicoid than in others grasses so we use them here as an indicator of panicoid grasses (Figure 5).

At 'Ain Ghazal, the PCA analysis (Figure 6) shows that samples do not cluster but can generally be divided into two groups of phytolith variability. *External fire installations and ashy deposits* (group 1) and *plasters and clay features*, *mortars,* and *human occupation/accumulation* (group 2). Typically, the *floors and surfaces* samples group towards positive axis 2 (group 1) but they have variable phytolith signatures and as with the geochemistry PCA can be separated into different PCA groups with different leading phytolith morphotypes (Figure 6). This will be discussed in more detail below.

Geochemistry Results

Of the 34 geochemical variable values obtained for both sites, only 11 variables were suitable for statistical examination from both sites: Magnesium (Mg), Silicon (Si), Potassium (K), Calcium (Ca), Phosphorous (P), Iron (Fe), Titanium (Ti), Aluminium (Al), Strontium (Sr), Sulphur (S) and Zirconium (Zr), with the addition of Chlorine (Cl) at WF16 and Zinc (Zn) at 'Ain Ghazal. The retained geochemical variables were plotted as average values per category (by activity and construction type) to summarise the overall patterning within the data; exact values have also been provided for reference in SM Table 8 and basic exploratory statistics in SM Table 9. The geochemical signatures at WF16 and 'Ain Ghazal are similar. For both sites, Ca and Si form a large component of the overall geochemical signature, as do the typically base elements of Fe, Al and K (SM Table 8). The lowest values are recorded for elements Sr and Zr. Higher S levels at WF16 compared to 'Ain Ghazal are evident, but the average figure is heavily influenced by only a few samples with high S readings.

In terms of additions and depletions by category type for WF16, the results show relatively minor variations in geochemistry (SM Table 8; SM Figure 2) but some distinctions are evident (Figure 7). Similar samples do not discretely cluster, but they do form separate groups on the PCA bi-plot, with category type being a key discriminate – these groups are highlighted by three grey circles. There is, for instance, a stark difference between the samples classified as control (group 3) to those of anthropogenic origin (groups 1 & 2). Control samples are higher in Ca and Ti and lower in K, S and Cl than non-control samples. The background sediment signal, as evidenced in the various control samples, therefore plays only a negligible role in the anthropogenic signatures obtained. Other categories which can be differentiated are *external fire installations and ashy deposits* due to higher Ca and S values, and *hearth*

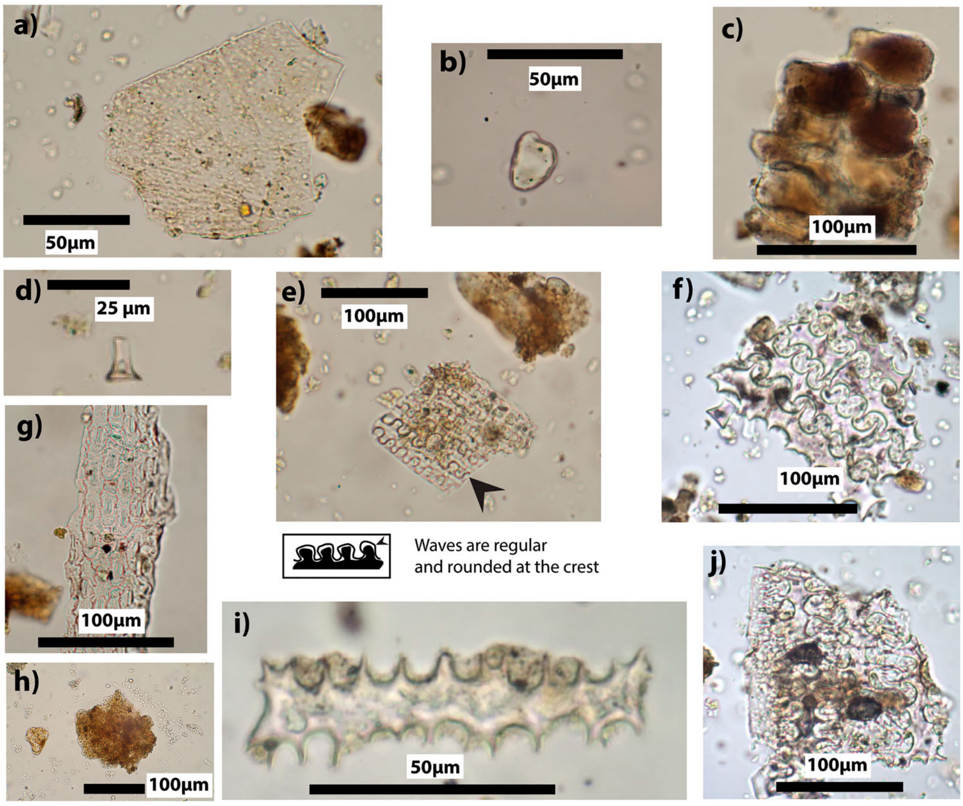

Figure 5. Selected images of phytolith material from WF16 and 'Ain Ghazal. (A) Dicotyledonous sheet phytolith, sample 2459, WF16; (B) Dicotyledonous platey phytolith, sample 6253, WF16; (C) Multi-celled stacked bulliform phytoliths from *Phragmites* sample 3853, WF16; (D) Single short cell rondel phytolith, sample 2970, WF16; (E) Multi-celled elongate crenates from *Lolium*, sample 2973, WF16; (below E, sketch of *Lolium* waves reproduced from (Rosen 1992); F) Multi-celled elongate dendriforms from *Hordeum*, sample 17, Ain Ghazal; (G) Multi-celled phytolith from *Phragmites* leaf, sample 6109, WF16; (H) Silica Aggregate, formed in woody dicots, sample 2459, WF16 (I) Single elongate dendriforms phytolith, sample 59, Ain Ghazal; (J) Multi-celled elongate dendriforms from *Triticum*, sample 55, Ain Ghazal.

make-up with the largest S values and the lowest *P* values (SM Table 8). The major difference in archaeological samples is a separation of samples with a fire origin, which are influenced more by the presence of P, but also S and Ca (Figure 7). Plotting adjacent to the fire origin samples are those categorised as *human occupation/accumulation* which likewise record higher S but are also markedly higher in Cl (Figure 7). The categories of *platforms and benches*, *floors and surfaces* and *storage features* plot by Cl and K, and the base elements, and are therefore geochemically different. Less definitive clustering is visible for *external/courtyard* and *middens* samples.

'Ain Ghazal control samples are higher in the base elements of Si, K, Fe, Ti and Al and lower in Ca and P, with the exception of *control type 3* which has more elevated levels of Ca and low levels of K and Mg (SM Table 8). *External fire installations and ashy deposit* samples, on average, contain the highest levels of P and S, and high Ca. *Mortars* have higher average values for Mg and S, as well as relatively raised levels of most elements, while *floors and surfaces* samples are distinct in having the highest Ca levels and reduced values for the base element components like Si.

PCA analysis for 'Ain Ghazal (Figure 7) shows that, like WF16, samples do not have definitive clusters, but that samples of the same type do plot in a similar area of the PCA plot and in some cases form indistinct collections. In the PCA (Figure 7), samples allocated as *plasters and clay features* and *storage features* are primarily influenced by Ti, Fe and K (grey circle, group 1). This is very similar to the pattern for *control types 1 & 2* suggesting that these samples may contain a marked proportion of these local sediments. *External fire installations and ashy deposits* samples plot oppositely on positive axis 1 with Ca and P, and in part with S (group 3). The similar average values for Ti, K and Fe for these opposing categories (Figure 7) suggest that it is the presence of higher Ca and P that creates this differentiation between groups. The one *internal fire installation and ashy deposits* sample sits alone in group 2 and has a very distinct signature associated with the presence of K and Mg, and reduced Ca compared to the other fire-classified samples (Figure 7). *Floors and surfaces* samples averagely plot near to *external fire installations and ashy deposits* samples and typically within group 3, but these samples have a very varied geochemical signature plotting across the PCA.

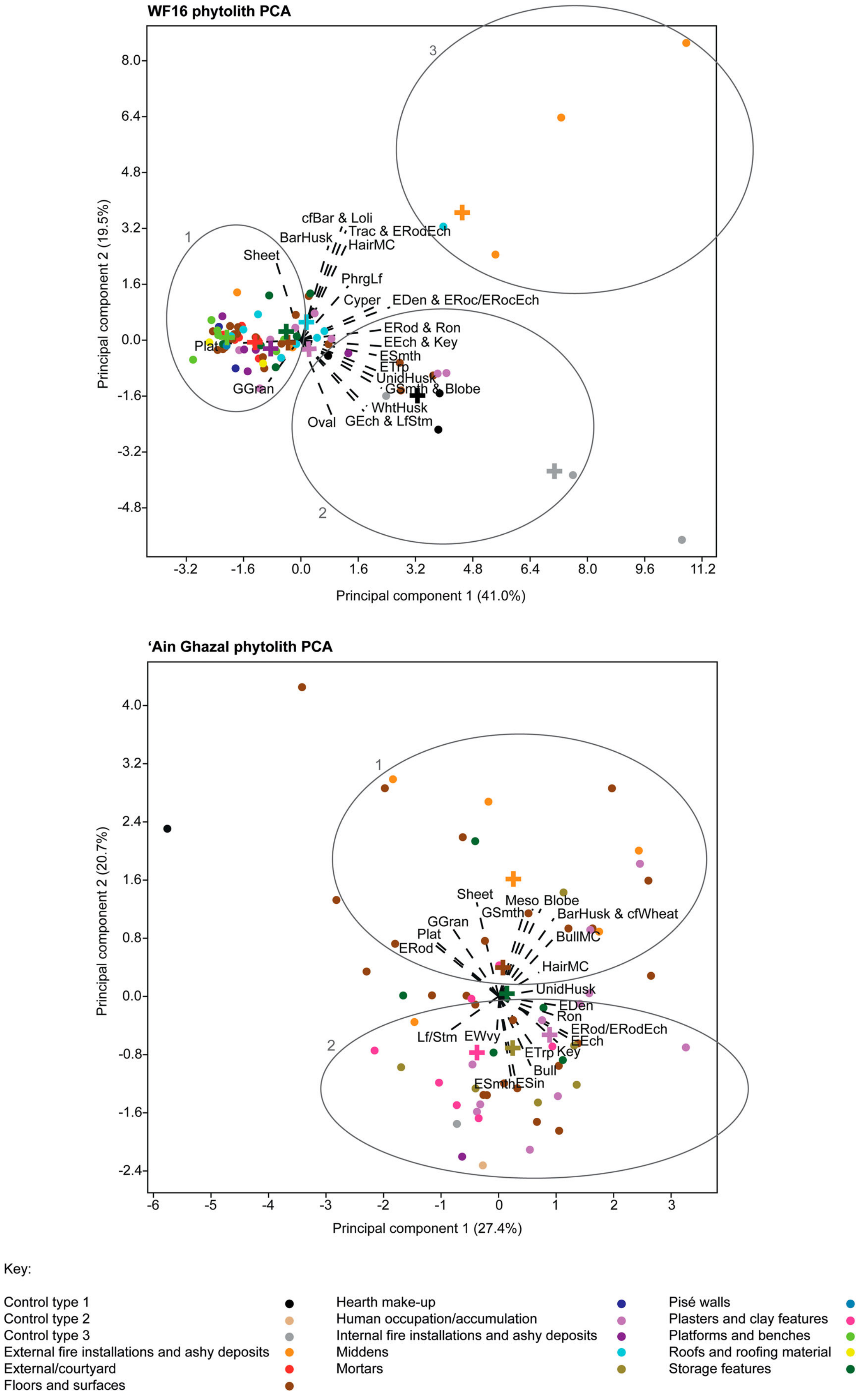

Figure 6. PCA bi-plots of the first two principal components (PCA1 vs. PCA2) for the WF16 and 'Ain Ghazal phytolith data. The PCAs were conducted on normalised values using a correlation matrix with between group distinctions optimised.

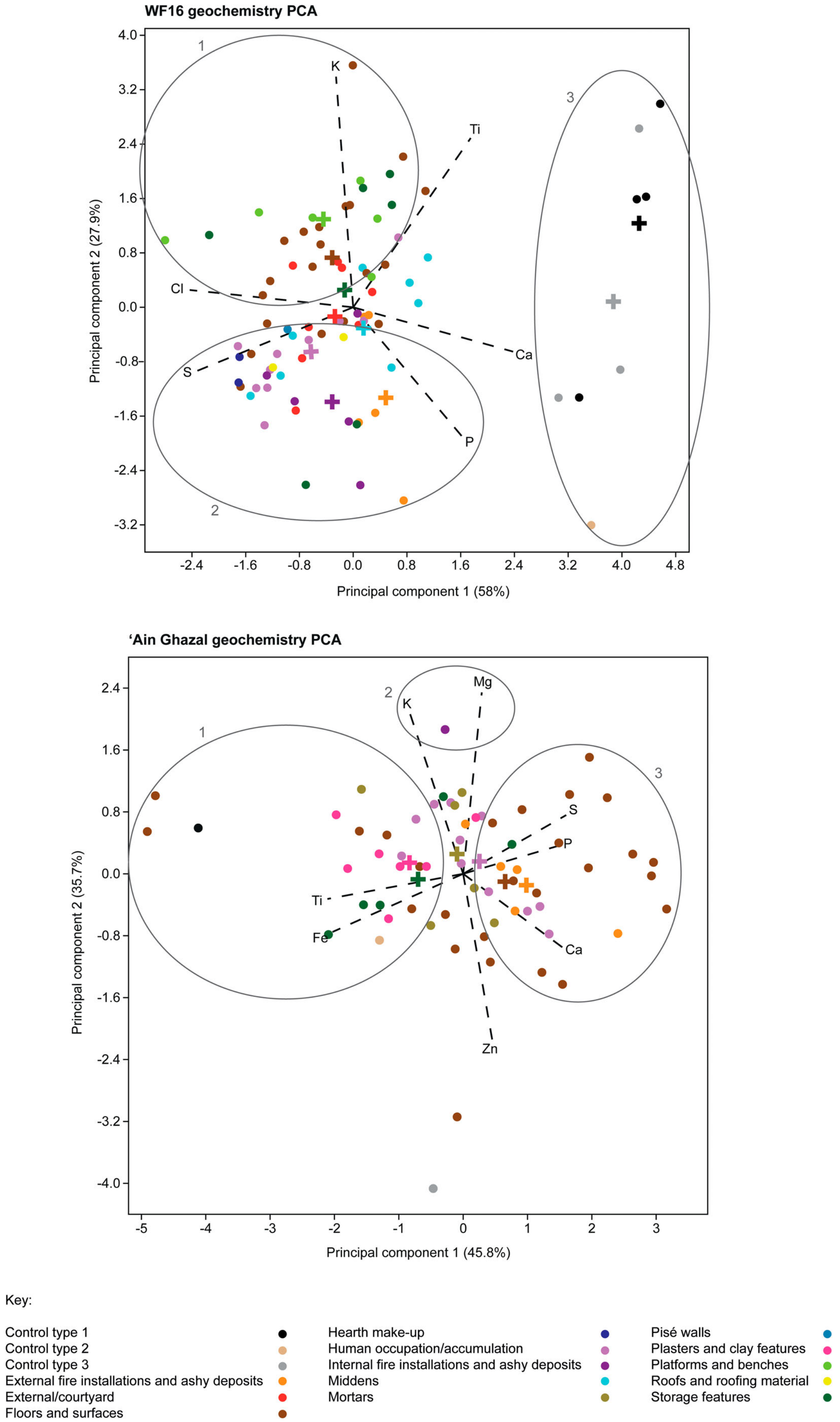

Figure 7. PCA bi-plots of the first two principal components (PCA1 vs. PCA2) for the WF16 and 'Ain Ghazal geochemical data.

When the ʻAin Ghazal *floors and surfaces* samples are plotted in isolation from other context categories, it is apparent that there are four distinct groups, delineated by circles in Figure 8. As stated above, Ca is the key element in these, but samples also associate with Ti and Fe (groups 1 and 2), Zn (group 3) and P and S (group 4). These differences are not seen at the earlier site of WF16 due to differences in construction hence why Figure 8 only includes ʻAin Ghazal.

Comparison of Results

The phytolith and geochemical patterns identified from the tabulated data and PCA visual explorations help us to consider shared archaeological activity signatures for each category context, and why these distinctions occur, which we can compare with those from the ethnographic site of Al Ma'tan (Jenkins et al. 2017). Comparisons are made of the geochemical and phytolith signatures across all three sites where applicable (Table 4).

The phytolith weight percentages reflect key intersite differences with the earlier dated deposits at WF16 having fewer phytoliths overall than the later deposits at ʻAin Ghazal, and the ethnographic site of Al Ma'tan (Figure 3). It is also clear from Figure 4 that at WF16 and Ain Ghazal the control samples have the lowest phytolith weight percent while at Al Ma'tan they have the second lowest after the mortars. This increase in phytolith density on site is in accord with results from research conducted at the Iron Age site of Izbet Sartah which demonstrated that the number of phytoliths per one gram of sediment was 100 times higher in the samples taken on site than those taken off site (Cabanes et al. 2012). There are a range of reasons for this difference. Firstly, the increase in the use of cereals from the PPNB onwards afforded more chances for plant material to be brought onto and used on-site. Secondly, a relative abundance of dicot plant material compared to monocot plant material at WF16 disproportionately reduces phytolith quantities at WF16 in comparison with ʻAin Ghazal because monocots are more prolific producers of phytoliths (Tsartsidou et al. 2007). Lastly, local environmental differences between the sites will have led to a different array of plants being available for collection, which may also partially account for variances in the assemblages and the different background phytolith signatures in the natural sediments. Today *Hordeum spontaneum* is common around ʻAin Ghazal but is not found growing in the wild around WF16 (Palmer pers. observ.). While wild barley may have been brought to Wadi Faynan during the PPNA it is not found in significant quantities in Wadi Faynan until the domesticated form appears at the adjacent PPNB site of Ghuwayr 1 (Jenkins and Rosen 2007; Jenkins, Baker, and Elliott 2011; Simmons and Najjar 1998).

The two fire-related categories at WF16 and ʻAin Ghazal show similar phytolith and geochemical signatures, with *external fire installations and ashy deposits* samples being the most alike, distinguishable by elevated Ca, P and S, and monocot phytoliths. Geochemically, the signatures are consistent with burnt ash signatures, especially wood ash (Braadbaart et al. 2017; Canti 2003; Hammes et al. 2006; Sanderson and Hunter 1981). The presence of monocot grasses, mainly of Poaceae origin, suggests their use as an additional fuel source (Canti 2003; Lancelotti 2010). Dung fuel as a source of the monocot signature is unlikely at WF16 given the lack of evidence for managed animals and while we cannot completely rule out that wild animal dung could have been collected (Miller 1996; Stiner et al. 2014), we have no evidence for dung in the micromorphological analysis (Roe 2007; Elliott pers. observ.). Dung as a fuel choice cannot be ignored for ʻAin Ghazal; nor can the influence of grasses from adjacent food processing activities at both sites. Again, the significance of monocots in the fire signatures could be amplified due to the disproportionate nature of phytolith production between monocots and dicots (Metcalfe 1960; Parry and Smithson 1964).

The fire installations do not have the highest percent of burnt forms at either of the archaeological sites nor from the ethnographic site. Instead, at Al Ma'tan the highest percent of burnt forms comes from the *animal occupation* category while at WF16 and ʻAin Ghazal the highest percent comes from the *control* samples. It is possible that some of the penning deposits sampled at Al Ma'tan were deliberately burned post depositionally as a cleaning exercise (e.g. Alonso-Eguíluz, Fernández-Eraso, and Albert 2017; Burguet-Coca et al. 2020). At Al Ma'tan, a small test pit was excavated and a micromorphological sample taken c. 1 cm down from the contemporary floor surface from the upper penning deposits. While most of the dung layers represented fresh compacted dung material with high numbers of faecal spherulites (15–80%), phytoliths (20–50%) and high organic content (20–60%), the uppermost unit also contained ash and burnt occluded carbon phytoliths. The high levels of burnt forms in the *contro*l samples could suggest that there was a high level of natural burning occurring at this time.

External fire installations and ashy deposits and *internal fire installations and ashy deposits* from WF16 plot together on the PCA (Figure 7) but are marginally different because of reduced Ca and S levels in the *internal fire* samples and the significance of husk material from mainly barley (*Hordeum*) but also ryegrass (*Lolium*) in the *external fire* samples (Figure 6). Differences in Ca values can relate to the amount of wood fuel used, wood fuel and ash being higher in Ca than fuel and ash from grasses (Canti

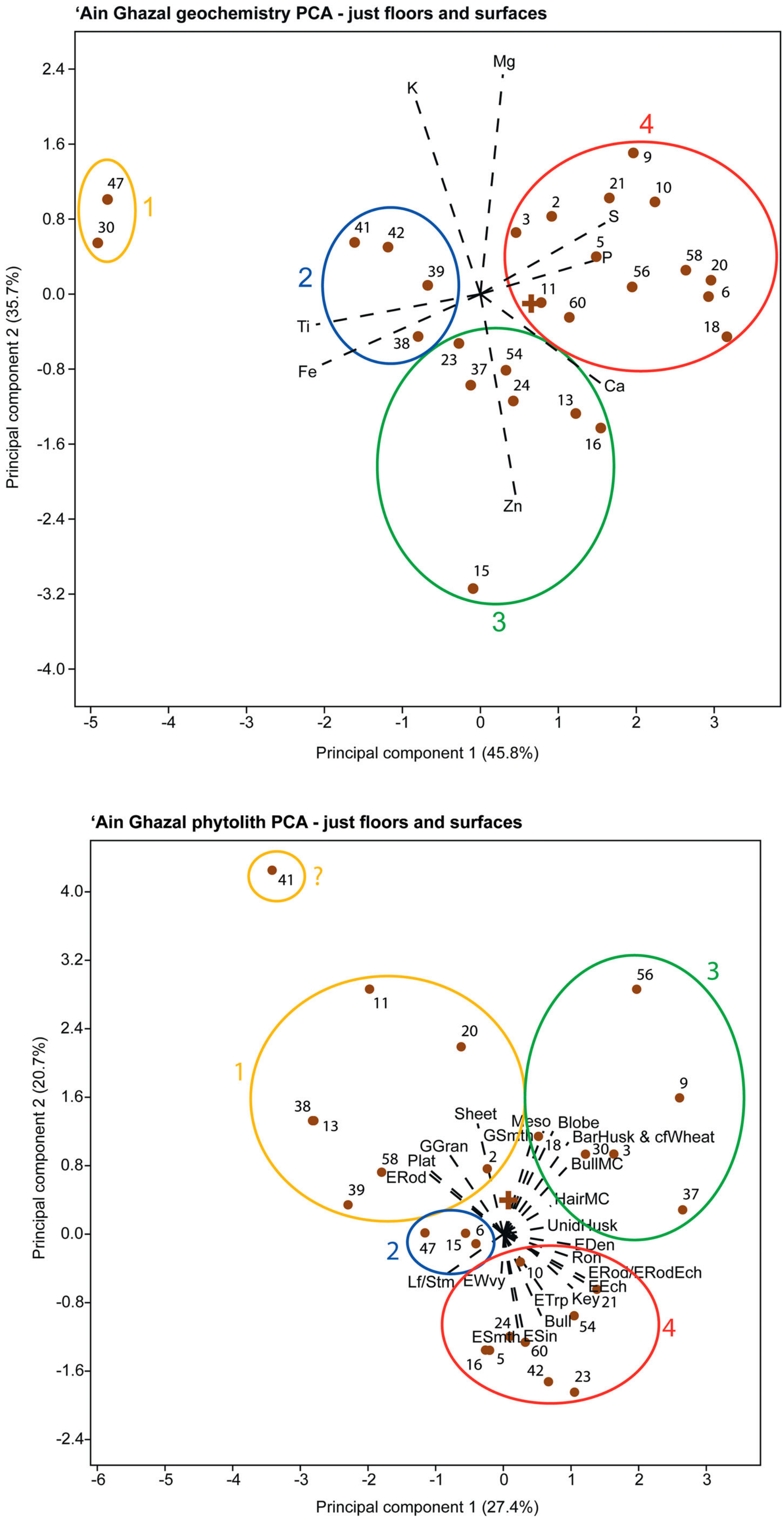

Figure 8. PCA bi-plots of the first two principal components (PCA1 vs. PCA2) for the 'Ain Ghazal geochemical and phytolith data for *floors and surfaces* samples only. Numbers represent sample numbers. Four distinct sample clusters are circled and numbered.

Table 4. A comparison of the two archaeological sites WF16 and 'Ain Ghazal with the ethnographic comparison site of Al Ma'tan. Comparing the main geochemical and phytolith signatures by category; e = elevated and d = depleted.

		Al Ma'tan				WF16				Ain Ghazal			
		Geochemistry	Phytoliths			Geochemistry	Phytoliths			Geochemistry	Phytoliths		
	Category	Dominant elements	Weight %	Monoco vs Dicot	Dominant morphotypes	Dominant elements	Weight %	Monocot vs Dicot	Dominant morphotypes	Dominant elements	Weight %	Monocot vs Dicot	Dominant morphotypes
Comparable all sites	Control/background	Ti, Ca, Mg	Low (<0.5%)	Monocots (e dicots)	Dicots, *Phragmites*	Ca, Ti & P (d, K, S & Cl)	Low (<0.5%)	Monocots	Grass inflorescence, bilobes, globulars	Si, K, Fe, Ti, Al	Low (<0.5%)	Monocot	Grass leaf/stem elongates
	storage feature	Ca, Cl	Low (<1%)	Monocots	Grass leaf/stem elongates, rondels	K, Ti, Cl	Low (<0.5%)	Dicots	Dicots, *Phragmites*	Si, Ca, Fe, Ti & Al	Low (<2%)	Monocot	Rondels, *Hordeum*, *Phragmites*
	Floors and surfaces	Ca, Cl	Low (<2%)	Monocots	Grass leaf/stem elongates, rondels	K, Cl	Low (<1%)	Dicots	Dicots, *Phragmites*	Ca	High (>5%)	Monocot	Silica aggregates, *Phragmites*
	External fire installations and ashy deposits	P, S	High (>6%)	Monocots	Grass inflorescence, hair bases	P, S, Ca	Low (<1%)	Monocots	Grass inflorescence, *Phragmites*, *Hordeum*	P, S, Ca	High (>5%)	Monocot	Grass inflorescence elongates
	Internal fire installations and ashy deposits	S, K, P	Low (<2%)	Monocots (e dicots)	Dicots, *Phragmites*	P, S	Low (<1%)	Dicots (e monocots)	Grass leaf/stem elongates	K	n/a	Monocot	Grass inflorescence elongates, silica aggregates
Comparable across two sites	Midden	P, S	High (>12%)	Monocots	Grass inflorescence, hair bases	Ca, Ti, P	Low (<1%)	Dicots (e monocots)	Grass leaf/stem elongates, *Hordeum*, *Phragmites*	n/a	n/a	n/a	n/a
	Mortar	Ti, Ca, Mg	Low (<0.5%)	Monocots (e dicots)	Dicots, *Phragmites*	n/a	n/a	n/a	n/a	Ca, S	Low (<2%)	Monocot	Grass leaf/stem/ inflorescence elongates, *Phragmites*
	Hearth make-up	Ti, Ca, Mg	Low (<0.5%)	Monocots (e dicots)	Dicots, *Phragmites*	P, S	Low (<0.5%)	Dicots	Dicots, silica aggregates, stacked bulliforms	n/a	n/a	n/a	n/a
	Human occupation/ accumulation	n/a	n/a	n/a	n/a	P, S	Low (<1%)	Dicots (e monocots)	Grass leaf/stem elongates, *Phragmites*, *Hordeum*	K, Mg, S, P & Ca	High (>3%)	Monocot	Grass leaf/stem/ inflorescence elongates, *Horduem*, *Phragmites*
	Plasters and clay features	Ca, Cl	Low (<2%)	Monocots	Grass leaf/stem elongates, rondels	n/a	n/a	n/a	n/a	Si, Ca, Fe, Ti & Al	Low (<1%)	Monocot	Grass leaf/stem elongates, *Hordeum*, *Triticum*
	Platforms and benches	Ca, Cl	Low (<0.5%)	Monocots	Grass leaf/stem elongates, rondels	K, Ti, Cl	Low (<0.5%)	Dicots	Dicots	n/a	n/a	n/a	n/a
	Roof and roofing material	Zr, Ca, Sr	Low (<1%)	Monocots	*Phragmites*	P & S (e Mg, Si, K, Fe, Ti, Al)	Low (<0.5%)	Dicots	Dicots, silica aggregates	n/a	n/a	n/a	n/a
One site	Pise walls	n/a	n/a	n/a	n/a	Cl	Low (<0.5%)	Dicots	Dicots	n/a	n/a	n/a	n/a
	Animal occupation	P, S	High (>5%)	Monocots	Grass inflorescence, hair bases	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

2003). The presence of more monocot phytolith forms, mainly of poaceae origin, in the external fire areas at WF16 further supports the interpretation that these differences in Ca levels could be due to grasses being burnt with the fire installations. As noted above, at later archaeological sites the presence of more monocot forms could suggest the use of dung fuel but due to the lack of evidence for managed animals at WF16 it is likely the increased amount of monocot grasses is more likely from their use as a form of bio-fuel (Lancelotti 2010), or may represent spillage from what was being cooked on the hearth if improperly processed. Certainly, cereal husk material is a key component of the *external fire installations and ashy deposits* samples, as they distinctly cluster by positive PCA1 and PCA2 where *Hordeum* sp. and *Lolium* sp. drive the axes variation. This could suggest that barley was being cooked on, and potentially partly processed next to, the external fires, a hypothesis supported by the fact that barley phytoliths were relatively absent in other categories at WF16 and by the presence of the genus *Lolium* which is comprised of species that are common field weeds particularly of cereal weeds (Izquierdo et al. 2003). Alternatively, *Lolium* could have been gathered as a wild food source in its own right (Whitlam et al. 2018).

However, the suggestion that wild barley was being cultivated aligns with the finding of mortars and grinding stones at WF16 which could have been used for processing barley, and the excavation of a granary at the nearby PPNA site of ʻDhra which contained high numbers of barley phytoliths with nearly twice as many coming from the husks as the leaves and stems suggesting some off-site processing (Kujit and Finlayson 2009; Jenkins pers. observ.). At ʻDhra it was suggested that the barley found was in a transitional state between wild and domesticated form suggesting intentional cultivation (Colledge et al. 2018).

In comparison, at ʻAin Ghazal the *external fire* samples and *internal fire* sample do not closely group on the PCAs because of a greater amount of husk plant material (Figure 6), and lower Ca and raised K in the *internal fire* samples (Figure 7). More husk material suggests either grasses were prepared or discarded in the *internal fire* setting, or that they entered as part of a supplementary fuel source, for example as a form of bio-fuel (Lancelotti 2010) or perhaps derived from dung used for fuel (Miller 1996). Waste material from crop processing, such as cereal husks (see Harvey and Fuller 2005) could have been foddered to animals, and therefore end up in dung used as fuel (see Miller and Smart 1984). At Al Ma'tan, cereal husks were identified in the *external fire* deposits which were known to be fuelled by animal dung and dung was confirmed through the identification of calcareous faecal spherulites (Canti 1997; 1998; 1999) in micromorphology samples from the midden and external hearth deposits (Elliott pers. observ.). The ethnographic information collected about the animal diets showed that they were both grazed and foddered; the fodder consisting of a mix of old bread, grass leaf/culms, cereal grains and cereal husks. The addition of grass as an interchangeable fuel or an additional fuel is confirmed by the geochemical results which showed lower levels of Ca which is typically lower in plant-fuelled rather than wood-fuelled ashes (Canti 2003).

More can be inferred from the geochemical differences between the *internal fire* samples and *external fire* samples at ʻAin Ghazal. The *internal fire* sample consists mainly of *in-situ* charcoal fragments, this represents a very concentrated anthropogenic residue that might have left behind a strong and localised burning signature. We know that more concentrated areas of burnt wood remains contain high Ca but also K and Mg and would be characteristically different from areas of more scattered wood ash or an undisturbed surface (Middleton and Price 1996 and references therein). A clear point in this comparison is therefore the context in which the remains were formed, the distinction driven perhaps by external ash dumps versus repeated use of a single internal hearth with high charcoal content. Nevertheless, it is important to question the role of structures and enclosed spaces in this variability. The difference in elemental signatures found between the one internal and the external fire samples could be due to weathering processes affecting the external fire installations leading to reduced readings for K and Mg.

The influence of fuel choice in determining fire activity signatures is evident in the Al Ma'tan study, where the use of dung fuel in *external fires* and not in *internal fires* resulted in a different phytolith signature, the latter containing very few grass inflorescence phytoliths and elevated dicot plant material (Jenkins et al. 2017). Geochemically, both fire contexts at Al Ma'tan recorded elevated levels of P and S, and K, and are clearly distinct from other categories, as at WF16 and ʻAin Ghazal. The phytolith and geochemical signatures for fire activities are heavily influenced by context and fuel choice yet form distinct patterns. At Al Ma'tan, *external fire installations and ashy deposits* as a category was directly related to *middens*, both recording high phytolith percentages, mainly monocot phytolith remains and raised levels of P. *Middens* at WF16 are geochemically more diverse than the fire categories. Typically, they have raised levels of P and are dominated by dicot phytoliths (Table 4). This is because middens at WF16 appear to be derived from refuse dumping from a range of *in-situ* activities as identified during excavation (Mithen et al. 2018) thus the greater diversity of signatures comes from all the different depositional pathways for these contexts. *Middens* and *hearth make-up* samples were not analysed for ʻAin Ghazal because these contexts were unavailable for sampling. At WF16 *hearth make-up* samples do not plot directly with the other fire type samples. This is because this category records the hearth structure which is typically made of clay and pisé and not the hearth content. Comparatively with Al Ma'tan, there is no clear activity signature for the phytoliths or geochemistry, but low phytolith percentages and elevated dicot morphotypes are shared characteristics (Table 4).

Phytolith and geochemical signatures are comparable for the *human occupation/accumulation* category between WF16 and ʻAin Ghazal with elevated levels of P and S, elevated monocots and predominantly elongate phytolith forms with some *Hordeum* sp. (Table 4). Moderate similarities also exist between all three sites for *storage features* with raised Ca and Cl, and low phytolith percentages, however, specific variations between the sites were also found for this category.

Samples from storage features could represent a range of past activities from the initial construction of the feature through to their actual storage function. As well, the use in this study of averaged phytolith and geochemical data from specific sample spots from the storage features means the information obtainable is limited by the sampling approach. At WF16, dicot phytoliths are significant identifiers of *storage features* with reed being found in one sample from context (887). At ʻAin Ghazal, reed and *Hordeum* sp. were both found in *storage features*. Reeds in storage contexts could have been present as stored material or used as a lining material, as has been observed in other southwest Asian Neolithic contexts, for example Çatalhöyük (Jenkins, Rosen, and Otsaku 2012). The storage features at Al Ma'tan contained grass stem elongate phytoliths which originated from the use of '*tibn*', chopped barley straw to line the features (Jenkins et al. 2017). It is possible that the barley phytoliths identified at ʻAin Ghazal could also have been used as a lining material rather being direct evidence for the stored material.

Floors and surfaces samples do not have common signatures, each site documenting different driving elements and phytolith morphotypes (Table 4). Chemical readings for domestic floors are the result of diverse element residues left by a wide range of activities and use including, food preparation, burning, and the activities that took place in the enclosed spaces and living areas. Furthermore, activities are not conducted uniformly across occupation surfaces leading to differences in element distribution (Middleton and Price 1996; Negre and Munoz 2016) and floor deposits can be affected by movement of residues on the soles of feet (Shillito 2017), spreading once defined activities away from their original location, such as ash from hearths (e.g. Regev et al. 2015). Heavy foot traffic can even cause wear to sediment layers depleting chemical contents (Manzanilla and Barba 1990). Certain areas may represent a paucity of activity, such as in corners and the walls of houses, particularly internal divisions which affect the distribution of chemical elements across a structure (Negre and Munoz 2016). Concave areas or depressions within a floor can also create pooling of residues.

Intra-site variability was most important at ʻAin Ghazal where four different groups of samples were apparent in the PCAs (Figure 8). At ʻAin Ghazal, floor deposits were made using localised silicified limestone outcrops, high in soft limestone and chalk members (Banning and Byrd 1987; Batayneh 2009; Rollefson, Quintero, and Wilke 2007; Sawariah and Barjous 1993). Limestone and chalk contain much Ca and this largely explains why the *floors and surfaces* samples have elevated levels and plot predominately within groups 3 and 4 (Figure 8) where Ca is the key elemental driver of sample variance. However, Ca is not the only distinguishing feature of ʻAin Ghazal floor deposits with group differentiations on the PCA strongly reflecting the construction materials used during different occupational phases. The same was true at Al Ma'tan as variability was a key feature of the *floors and surfaces* samples (Jenkins et al. 2017). Ethnographically, as stated above, phytolith variations occasionally reflected some specific on-floor activities but the geochemical signatures were a strong reflection of the floor construction materials – particularly the samaga clay matrix and gypsum plaster covering (Jenkins et al. 2017).

Group 1 samples (Figure 8) at ʻAin Ghazal plot together because they are sediment deposits from under the same basin feature (AG30 and AG47, section TRIII.I) and likely show a discrete geochemical signature because they are both clay rich, burnt and stratigraphically related. Their stratigraphic proximity just above the terra rossa soil likely accounts for their dominant Fe signature because sediment of this type contains high iron oxide concentrations which give it its red colour. Whilst not clear in the section stratigraphy, it is assumed these surface samples were below or part of a hearth feature because of the scorching evident to the base of the storage feature on top of the surface, and this would account for the specific elevation of K and Mg.

Group 2 (Figure 8; AG38, AG39, AG41 & AG42, also from TR III.I) contains samples which date to the PPNC. These samples likewise group because of their stratigraphic relationship. These samples come from recognised 'huwwar' floors which were made from a crushed and reconstituted chalk mixed with water and local muds (Rollefson and Kafafi 1996).

This enhanced 'mud plaster' was a cheap form of improvement, being a simple modification that required no firing and was characteristic of later periods of occupation (Rollefson 1996). For a floor composed of two main components (1) ground chalk and (2) sediment mix we would have expected to see signatures for both Ca for the chalk and Fe/Al/K etc. for the sediment. This is true of the raw pXRF values (SM Table 8), but the group is geochemically aligned with the latter of these components in the PCA (Figure 8). Therefore, despite its white colour, the floor plaster appears more 'mud plaster' than 'huwwar' in its geochemical patterning. The 'mud' component was probably not too dissimilar to *control type 1*, a contemporary deposit high in Fe, Al and Si, with lower Ca.

High Ca, however, does characterise sample groups three and four (Figure 8), though they are partially discernible by higher Zn, and P and S respectively. Whilst the samples in each group were retrieved from a range of archaeological contexts (specifically from sections 3070, 3071, 3071, TRIII.I and TRIII.II (SM Figure 1)), most samples in the group 3 are from lower MPPNB stratigraphic levels and samples in the group 4 are from upper MPPNB and LPPNB stratigraphic levels, except for two PPNC samples (37 and 54) in group 3. Thus, the age of the floor constructions is reflected in their geochemical signatures. We know from excavations that MPPNB floors at 'Ain Ghazal are made from a hardened lime plaster, in contrast to the 'huwwar' floors of the later PPNC. Lime plaster production involves a complex mix of additives (Rollefson 1996) and can be costly in terms of time but also ecologically in terms of wood fuel used in the heating process. Adding 'fillers' to the mix reduced the amount of slaked lime required to form the plaster and therefore less fuel and time (Rollefson pers. observ). If, over time, the distance to wood resources increased due to unsustainable management by the inhabitants at 'Ain Ghazal, then the effort afforded to make the lime plaster might have forced people to use more additives to bulk out the plaster mix. This reasoning perhaps explains why there are subtle geochemical differences between groups three and four. The differences may alternatively or additionally result from the presence of red ochre pigment which is unique to group four. Red ochre is known to be largely composed of ferric oxides mixed with sand and clay, and whilst it would be expected that ochres have strong Fe geochemical signatures, which this group does not, Fe concentrations as low as 0.1% can be sufficient to provide the red colour of the pigment (Cornell and Schwertmann 2003).

The importance of the sediment matrix in delineating samples is most evident with *floors and surfaces* samples 23 and 24, and 37 and 54. They plot together on the PCA bi-plot (Figure 8) despite including samples comprised of both MPPNB plaster, and PPNC 'huwwar' respectively because of similarities in their levels of Fe and Ti, and Zn. If we consider that both sets of samples could be more 'mud' than plaster or huwwar than it might explain why they show similar geochemical characteristics.

The other categories where we can compare across at least two sites, *plasters and clay features*, *platforms and benches*, and *roof and roofing material* have virtually no similar signatures and low phytolith numbers. The samples from these categories reflect the materials used in construction, rather than associated activities. There is little commonality in signatures when different construction methods are used.

WF16 did not contain *mortar* because the walls were made of pise, while at 'Ain Ghazal the mortars were characterised by low phytolith weight percentages; *Phragmites* sp. phytoliths; and higher Ca, which is like the results from Al Ma'tan (Table 4). At Al Ma'tan the mortars were composed from local muds mixed with water, with no additional plant material added beside those remains accumulated in the mud matrix from the spring source (Jenkins et al. 2017). It is feasible that a similar activity of mud collection and use was completed at 'Ain Ghazal for making mortars, with riverine muds being in proximity (Rollefson, Simmons, and Kafafi 1992).

Using a Combined pXRF and Phytolith Approach to Further our Understanding of Construction and Activities in Archaeology

The results from the two archaeological sites show that that for some context categories, there are consistent patterns that can be interpreted as an activity signature, for example in the *external fire installations and ashy deposits* category; fire contexts generally had the most distinctive signatures. Overall, using phytolith and geochemical data to determine a space signature was difficult because most of the contexts were variably used providing variable phytolith and geochemical assemblages such as middens which can be multipurpose or used in different ways. The same applies to the floors and surfaces because these are areas which seem to have been used for different activities over time and subsequently been subjected to different taphonomic processes. Chemical readings for domestic floors are the result of diverse element residues left by a wide range of activities and use including, food preparation, burning, and the activities that took place in the enclosed spaces and living areas. Furthermore, activities are not conducted uniformly across occupation surfaces leading to differences in element distribution (Middleton and Price 1996; Negre and Munoz 2016) and, as previously stated, floor deposits can be affected by movement of residues on the soles of feet (Shillito 2017), spreading once defined activities away from their original location, such as ash from hearths (e.g. Regev et al. 2015). Heavy foot traffic can even cause wear to sediment layers depleting chemical contents (Manzanilla and Barba 1990). Certain areas may represent a paucity of activity, such as in corners and the walls of houses, particularly internal divisions which affect the distribution of chemical elements across a structure (Negre and Munoz 2016). Concave areas or depressions within a floor can also create pooling of residues, and depressions which may be filled with materials such as ash (Milek and Roberts 2013).

At ʻAin Ghazal, our results suggest that the use of indoor space was not controlled by strict rules or have been segregated by activity. At this site, the geochemistry proved the most sensitive indicator of variation in floors and surfaces samples, indicating stratigraphic variation in construction practices.

The efficacy of the geochemistry in identifying an activity type was much greater than that for the phytoliths. Geochemical patterns were more consistent between samples and categories, which was likely aided by comparing only one parameter. The phytolith data in contrast was complex to understand because of the different standard methods used in classifying phytoliths – phytolith counts, taxonomic origins, weight percentages, and morphotypes found. These multiple ways of viewing the data meant that there was greater variance and detail in the phytolith results obtained, providing less comparability and a reduced chance of finding similarities within and/or between contexts. This lack of comparability in phytolith results was also an issue in a similar study conducted on Jordanian ephemeral sites by Vos, Jenkins, and Palmer (2018). As with Vos, Jenkins, and Palmer (2018), we found though that geochemistry alone was not enough to be able to explain context differences and that the added strength of the phytoliths was that they often provided the explanation for category separations e.g. between *internal* and *external fires* at ʻAin Ghazal, with fuel choice being a key discriminator.

In contrast, the dominance of platey phytoliths at WF16 (a dicot form) and elongate phytoliths at ʻAin Ghazal (a monocot form) meant that the use of phytoliths as a distinguishing activity indicator was often problematic. It was only in particular situations where phytolith variability helped provide better separation. From the Al Ma'tan study we know that the common use of the same plant material in the plasters of roofs, walls and features made the signatures for all these categories similar. But where dung fuel instead of wood fuel was used in the *external fires*, the higher proportions of grass inflorescence phytoliths and reduced dicot plant material helped in determining a clear signature for this fire activity.

Category separation and understanding these archaeologically was also hampered by the low number of phytolith remains and restricted morphotypes at WF16 compared to ʻAin Ghazal which had many more morphotypes and higher phytolith numbers. The early date (PPNA) of WF16 probably partly accounts for this difference with no current evidence for full cereal domestication during this period, in contrast to the PPNB/C/Yarmoukian (ʻAin Ghazal) which has domesticated cereals.

The role of off-site natural material in influencing signatures is also noteworthy. The use of local material in the formation and use of a context will inevitably include a measure of its geochemical and phytolith component in the signature of the context. At WF16, phytoliths were found which were probably from naturally occurring plant material within the local muds used for building, while at Ain' Ghazal, sediments which formed through similar pedogenic and geological processes were commonly used in floor constructions. Finding significant enrichments beyond the background material was therefore difficult and anthropogenic alterations often remained hidden, especially when minimal. Only where there were large anthropogenic enrichments were we able to see this influence in the activity signal, and primarily in the geochemistry results.

Our ethnographic results equally showed that caution must be given when interpreting the geochemical and phytolith assemblages from sites that have a high proportion of clay in their construction. The results from Al Ma'tan demonstrated that much of the dicot material found in the plastered features did not result from their use but instead from naturally occurring vegetation that was incorporated into the sediment used for construction (Jenkins et al. 2017). A lack of understanding of past vegetation and landscape could lead to an over-interpretation of the importance of different taxa to the economy of a site largely constructed of clay.

One way to ensure that we best understand the associations between geochemistry, phytoliths and activities is to ensure that all archaeological specialists work concurrently and plan their sampling strategies together to optimise the information that can be gained from the micro-proxy data (e.g. geochemistry, phytoliths, macrobotanical and artefactual remains etc). This has been the case at some sites where the archaeological methodological approach and the funding has allowed for this to happen e.g. Çatalhöyük, although even in these instances integrating the various forms of evidence is not without difficulty (Shillito 2017). In addition, even when specialists do work concurrently on the various archaeological evidence, finding ways to undertake and interpret the statistical analyses of the various datasets to integrate them in a meaningful way can be problematic (Jenkins et al. 2017).

For the sites we focused on in this study, it was not possible to concurrently sample and analyse the various forms of evidence. In the case of WF16, for example, the phytolith and geochemical study occurred before the study of many of the macro remains such as the macro-botanical and the zooarchaeological assemblage while for ʿAin Ghazal it happened after other analyses.

What this research has shown, however, is in that in southwest Asian sites, phytolith and geochemical analyses can enhance our understanding of context categories and should be used alongside the macro remains to help refine interpretation. For example, while the fire installations at the sites we studied were identified as such during excavation, the information gained from the phytolith and elemental analyses provided more specific information with regards to what fuel may have been used and what kinds of food processed. At WF16, in *external fire installations,* we found that monocot phytolith forms dominated the phytolith assemblages (79% monocot/21% dicot) with both barley and reed being found in these samples. While, as previously, stated monocots are more prolific producers of phytoliths than dicots, this still does suggest that reeds were used as a source of kindling or fuel and potentially indicates that barley was being cooked in these external hearths at WF16. The discovery of *Lolium* sp. a typical cereal crop weed, may suggest that barley was being cultivated.

Conclusion

In summary, we suggest that phytolith and geochemical remains can provide useful data to supplement interpretations derived from archaeological excavation, but that site and context specificity must be considered in analysis and interpretation. Phytoliths and geochemistry provided distinguishable signatures for some context categories in this study, primarily the fire categories, but generally intra and inter-site differences meant that activity-related signatures were hard to differentiate. Basically, for contexts which had more variable uses or were multi-use, there was a more variable phytolith and/or geochemical signature. This was largely true for *floors and surfaces* because although these are areas which at one time might have been associated with a primary function, this function may have varied over time, and they also may have been subjected to different taphonomic processes. At ʿAin Ghazal, the geochemistry proved the most sensitive indicator of variation in *floors and surfaces* samples, but signatures were closely aligned to the different construction practices used in each phase. There is, therefore, no one size fits all with regards to phytolith and multi-element analyses, but the study of these micro-proxies can be enhanced by understanding specific contextual and archaeological features; particularly if enhanced with information from other forms of archaeological evidence.

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