New techniques for tracing ephemeral occupation in arid, dynamic environments – case studies from Wadi Faynan and Wadi el-Jilat, Jordan

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New techniques for tracing ephemeral occupation in arid, dynamic environments: case studies from Wadi Faynan and Wadi al-Jilat, Jordan

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Abstract

Can we identify transitory, ephemeral camp sites in dynamic environments? How can we maximise the information gained from such sites, depicting mobile-pastoral subsistence, to enable a consideration of spatial patterns of activity? Ephemeral occupation is underrepresented within archaeological investigations, perhaps because short-lived sites are notoriously difficult to interpret due to the poor preservation of their remains. However, information about ancient modes of existence in peripheral areas carries much value for the interpretation of past ways of life that are currently understated within archaeological narratives. This paper will discuss recent methodological developments in geoarchaeology, which may enable us to maximise the information gained from ephemeral sites, even after a long period of abandonment. The value of reconstructing 'marginal' lifestyles for archaeological accounts will be discussed, addressing the visibility of subsistence strategies which have dominated many landscapes in the Near East since the Neolithic. The potential of the application of a dual methodology, using phytolith and geochemical soil analysis, to achieve a better understanding of the use of space at ephemeral archaeological sites will be explored by presenting two case studies from Jordan.

Keywords: geoarchaeology, phytolith analysis, soil analysis, ephemeral sites, Wadi Faynan, Wadi al-Jilat

Introduction

The completeness, and thereby representativeness, of the archaeological record is a re-occurring uncertainty within the investigation of past landscapes. Schiffer's influential consideration of processes leading to the preservation, state and location of artefacts (Schiffer 1988; 1995) might offer a way to address the effects of formation processes on the material record, but it does not model their influence on the visibility of entire sites and past activities. In order to assess how well past human activity is detectable across entire landscapes we must consider the durability of anthropogenic sites. While more substantial settlement forms may leave a clear mark in the landscape for thousands of years, ephemeral occupation is underrepresented in the landscape.

Though understated, ephemeral sites carry much value for the reconstruction of past lifestyles. Transient occupation is characteristic of many pastoral and hunter-gatherer societies, whose settlements reflects the demands of their highly mobile

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lifestyles. Entire landscapes and periods characterised by ephemeral occupation can be difficult to interpret due to the low intensity of occupation characterising them. The lack of durable structures and poor preservation of organic remains at these sites pose challenges for their identification and interpretation (Gifford 1977; Banning and Köhler-Rollefson 1983; Cribb 1991). Without being able to estimate what has been lost over time, it is difficult to distinguish between evidence of absence and absence of evidence in the archaeological record. And in order to properly consider pastoral nomadic ways of existence in the past, certain issues must be addressed: how durable are ephemeral traces of human activity? How fast do short-lived sites disappear in arid, dynamic environments? And how can archaeologists make the most of what is left for them to study?

In addition to their visibility, understanding the use of space in ephemeral structures is vital for their interpretation. This can shed light on past ways of life that are currently underrepresented within archaeological narratives. The division of space within human built environments can inform us about subsistence and daily activities, and can also reveal a great deal about notions of cleanliness, sacrality or gender, and relationships with animals or the natural environment (Douglas 1966; Bourdieu 1990; Parker Pearson and Richards 1994).

Until recently, most archaeological studies of spatial patterns have focused on a reconstruction of the location of activities based on the distribution of artefacts (Whallon 1973; Hodder and Orton 1979; Simek 1987; Hardy-Smith and Edwards 2004; Kuijt and Goodale 2009). There is, however, another level of evidence for the spatial patterning of activities which is more direct than the location of artefacts in abandoned sites: their sediments. These are often overlooked in spatial reconstructions, perhaps because they do not visually appear to contain evidence of activities, or perhaps because floors in modern western societies are not associated with soil but with hard surfaces of wood, stone and concrete. These are easily kept clean and are, in most cases at least, devoid of evidence of activities. Soils in archaeological sites, on the other hand, are central to the interpretation of past activities. They are both the carpet on which life takes place and the product of human endeavours.

Soils were often considered to be a product of natural processes but are increasingly seen as cultural products that should be studied as part of an investigation of social processes (Wagstaff 1987). As part of a shift in archaeology towards understanding past landscapes and environments as a whole rather than focusing on a single site, Wells (2006) offers the concept of cultural 'soilscape' as including a magnitude of materials reflecting both the use of resources and social frameworks by humans within their physical surroundings. Through the study of cultural soilscape the ways in which humans interact with their environment, both on the site level and beyond, can be understood within a framework of spatial activities. This is important because human environments are the physical manifestations of palimpsests of a range of behaviours and ideas. Although these records of human presence may be altered through time, they are tied to space.

Making sense of human space

The dimension of space is a fundamental aspect of cultural soilscapes, yet it has often been neglected in favour of a focus on time and history in western social sciences throughout most of the previous century (Soja 1989). When offered, discussions of the role that the material environment had on human well-being and consciousness mostly focused on two types of modern structures: dwellings and monuments. The majority of these, however, are characteristically different to the spaces that represent a wide range of functions and meanings at archaeological sites. Nevertheless, some approaches to space within the social sciences have provided important perspectives on the role of buildings, among others things: their part in allowing people to dwell in the metaphysical, spiritual and corporeal senses (Heidegger 1971); the agency of constructed space within a human belief system (Durkheim 1915); the instrumentality of the built space in the communication of power (Foucault 1982); the role of the material environment in articulating human consciousness (Husserl 1990); and the notion of *habitus* in regard to the built environment as a means to establish, express and sustain identities and social relationships (Bourdieu 1990).

The notion of correlations between spatial activity patterns and social structure has been put to the test in ethnographic studies of modern traditional societies. Yellen's (1977) study of the !Kung is one of the most well-known ethnoarchaeological recordings of the use of space in hunter-gatherer societies. In an examination of the use of household and communal areas, he links the location of objects within the domestic unit of a nuclear family to social context rather than function. Social space, as well as considerations such as messiness, or the time of day dictating the location of shade, were the main factors determining the location of activities and in turn that of the distribution of related artefacts in space. Yellen argues that straightforward, functional reconstruction of activities at the !Kung camp sites would be of no more use in the interpretation of the spatial trends at these sites than abstract speculations (*ibid.*).

A different emphasis on the cause of spatial patterning is presented by Binford (1978), whose account of a Nunamiut hunting stand in Alaska focused on the use of non-residential, ephemeral sites located away from main settlements, and the type of objects left behind there.

He argued that by studying a structure and the spatial organisation of activity areas within it, such as hearths and 'drop and toss zones', one can derive information about the number of participants and their activities. Relying on his own work on hunter-gatherer communities in Alaska, backed up by additional comparative studies, Binford developed influential models for understanding how activity areas in archaeological sites are shaped by the basic mechanics of the human body. His studies have been applied widely to the study of activity areas at various Palaeolithic sites (Audouze 1988; Guan *et al*. 2011; Koetje 1994; Simek 1987; Sørensen 2008).

Yet another consideration for the interpretation of the distribution of activity areas is provided by O'Connell (1987), who studied the occupation and abandonment of Alyawara camp sites in Australia. There he noticed that past a certain duration of occupation, the living areas would be swept, and large objects were removed to a secondary place of deposition, while small artefacts mostly remained *in situ*. This created a blurred spread of indicators of activity, according to which the location of activity areas would be difficult to discern. The outcomes of this case study have consequences for the interpretation of the spatial distribution of activity areas within sites, which could depend to a large degree on the duration and frequency of occupation. A site which has been revisited or cleaned, or in which the location of activities frequently changed, will be difficult to interpret (*ibid.*).

The different approaches to the correlation between the use of space and social and cultural domains provided by the ethnographic works outlined above demonstrate the power of such studies in shaping ideas about human societies. They suggest that spatial patterning at anthropogenic sites can reveal a lot about human lifestyles, from subsistence and daily routines to social structures, ceremonial events and cultural preferences. At the same time, they advise caution when interpreting archaeological remains. Ethnographic analogy ought to open up avenues of interpretation rather than limit these to universal models.

The work of Karl Heider (1967), who confronted archaeologists with their inability to truly conceptualise the rich variety of human cultures, revealed how misleading our common sense and imprinted assumptions can be. Other ethnographers enabled archaeologists to consider 'real life' scenarios for different archaeological patterns for the first time, such as what happens during the abandonment of structures (Cameron and Tomka 1993), the relationship between technology and social interaction (Gosselain 1998), or between material culture and inter-group relations (Hodder 1979). These studies opened room for discussion about the connection between the social and the material spheres of human cultures.

Spatial archaeology

It is up to the archaeologist to use all that remains of ancient occupation to reach a better understanding of the past use of the built environment and the role it played in different aspects of human life. This is not an easy task at the best of times. Even when studying ethnographic cases, where activities can be observed as they take place, the ambiguity and intricacy of human behaviour complicate interpretation. This task becomes more difficult when the material record of a site is very limited, whether because of poor preservation or the limited deposition of remains in the first place. In these instances the importance of a site's soilscape becomes clearer, as it enables us to reconstruct past behaviour *in situ*. The testing and application of methods of soil analysis to these sites is therefore vital if we want to understand their spatial use, which in turn can provide important insights into past behaviour. By establishing the value of soil analysis to the interpretation of ephemeral sites one also ascertains the potential to further explore periods characterised by ephemeral occupation, which are, as a result, poorly understood, such as the Neolithic of the Near East.

Theories of behavioural archaeology (Schiffer 1988) and spatial archaeology (Clarke 1977) have been used over the past four decades to link the spatial distribution of artefacts in archaeological sites with perceived past activities and behaviours of the groups that occupied them. To do this, the spatial patterns of artefact dispersal must be considered in relation to the cause of past human behaviour rather than a random scattering of objects. Spatial archaeology offers an approach that legitimises this idea by proposing that the spatial patterning of the remains of a site reflect behavioural patterns of the society that created them. Both social and functional interpretations are suggested based on the spatial distributions of artefacts, structures or activities (*ibid.*). Behavioural archaeology, as expanded by Schiffer (1988, 1995), extends the notion of spatial archaeology and provides a framework for culturally meaningful distribution patterns by describing the relationship between human action and the material record.

With the rise of post-processual archaeology came other changes in approaches to, and notions of, space. Earlier functional interpretations were accompanied by phenomenological ones, seeing space an as active force both structured by and structuring human life and behaviour. Space became a social construct, a concept, perceived and determined by individual agents (Tilley 1994). The study of space within archaeology began to extend across multiple scales, from entire landscapes and regions to individual houses or areas (Salisbury 2007).

Following these theoretical changes came advances in methods and techniques, and space started to gain a cultural importance within archaeology. Careful visual examinations of the locations of individual artefacts, features or sites, an analysis technique called point patterns, had already been in use for a while (Bradley and Small 1985). The use of quantitative methods to investigate spatial correlations became more widespread during the 1970s, replacing the earlier visual examinations. These included different statistical tests such as nearest-neighbour, Thiessen polygons, and more recently also more extensive GIS analysis (Hodder and Orton 1979).

Geoarchaeological methods for the analysis of space

Although archaeological studies of spatial patterning cover a range of techniques to analyse spatial relationships, previous attempts concentrated on the distribution of artefacts rather than soils (Hardy-Smith and Edwards 2004; Hodder and Orton 1979; Kuijt and Goodale 2009; Simek 1987; Whallon 1973). These reconstructions of activity areas carry limitations in the form of both pre- and post-depositional taphonomic processes influencing the location of artefacts, and often portray problematic links between the location of artefacts and other contextual, functional or chronological evidence (Manzanilla and Barba 1990; Ullah *et al.* 2015).

The need for geoarchaeological approaches for the study of spatial activity patterns at archaeological sites has driven several research projects in the past two decades seeking to test and apply various microscopic techniques to the study of activity areas, such as micromorphology, geochemistry, phytolith analysis and mineralogy (Banerjea *et al.* 2015; Manzanilla and Barba 1990; Middleton and Price 1996; Shahack-Gross *et al.* 2004; Tsartsidou *et al.* 2009). Canti and Huisman (2015) provide an overview of the developments in the use of geoarchaeological techniques in archaeology during this time and emphasise the need for continued validation through experimentation and performing multi-proxy studies. While such studies were previously rare, they have now gained popularity to a degree that the term 'geo-ethnoarchaeology' has recently been coined (Friesem 2016). It is important to keep in mind however, that whether spatial analysis of archaeological sites relies on the distribution of artefacts, micro-refuse or soil analysis, it is always based on the premise that human occupation results in a non-random distribution of the remains of past activities.

This paper will focus on the use of phytolith analysis and geochemistry for spatial analysis in particular, though other geoarchaeological techniques should not be considered less or more valuable. Each particular situation, research question or site will call for the use of a specific geoarchaeological method or a combination of these.

The advantages of the use of phytolith analysis are that phytoliths often represent *in situ* deposition, usually preserve better than organic remains (especially in arid conditions), and enable us to distinguish between different plant parts. Nevertheless, phytoliths too may suffer from chemical dissolution depending on their depositional environment, and may not always be identifiable to the species or even genus level. Geochemical analysis benefits from a long history of use within archaeology, and the simultaneous identification of geochemical elements in archaeological sites is currently easily achieved with modern analytical tools such as Inductively Coupled Plasma (ICP) or X-ray Fluorescence Spectrometer (XRF) instruments. On the other hand, certain unresolved issues regarding the correlation of geochemical signatures to anthropogenic activities, understanding of the baseline geochemistry of the parent material and processes affecting elements in this (Matschullat *et al.* 2000), difficulties distinguishing the archaeological input from modern or geological ones (Oonk *et al.* 2009), and problems of equifinality must be considered prior to analysis.

In order to tackle some of these issues, recent geochemical studies of anthropogenic sites aimed at identifying activity areas use combinations of several geochemical elements, which can often be correlated to specific types of activities (Middleton and Price 1996; Oonk *et al.* 2009; Parnell and Terry 2002; Vyncke *et al.* 2011). During the past two decades, multi-elemental examinations of archaeological, historical and modern houses revealed that activity areas and different features can be correlated to certain (combinations of) elements, and that household, production and even ceremonial practices can be distinguished. Another approach for improving archaeological interpretations of geochemical signals is the testing of processes that influence the creation of anthropogenic soil signatures by studying ethnographic or experimental cases.

Many scholars stress the importance of such analogies to our understanding of geochemical signatures and the activities that produce these (Fernandez *et al.* 2002, 488; King 2008, 1225; Middleton and Price 1996; López Varela and Dore 2010; Wilson *et al.* 2008). Ethnoarchaeological observations laid the ground for better interpretations of general patterns of human input in soils, and later studies related a suite of elements to specific activities. Middleton (2004) for example, was able to distinguish activity areas in buildings at two sites, Çatalhöyük in Turkey and Ejutla in Oaxaca, Mexico. He managed to identify the chemical remains of burning (P, Na, Mn and K), food storage and preparation (P and Ca), plastered surfaces (by alkalinity), high traffic zones (lower reading of elements than off-site controls) and craft production (burning and high Fe). However, as with the case of even well informed ethnographic studies, some of the observed patterns in this analysis were left unexplained. Most of the sites examined through geochemical analysis so far were substantial buildings with a clear division of space, and some of these produced very comprehensive and convincing reconstructions (Hutson and Terry 2006; King 2008; Milek and Roberts 2013; Terry *et al.* 2004). While geochemical studies at ephemeral sites benefit from this knowledge, there is a need for additional targeted geoarchaeological studies of short-lived occupation.

In a similar way to geochemistry, phytoliths are increasingly being used to inform archaeologists about ancient activities which took place within and around ancient households, often in combination with other micro-techniques. Both quantitative and morphological studies of phytoliths are useful aids in identifying spatial activity patterns. A study of abandoned Maasai settlements by Shahack-Gross *et al.* (2004) demonstrated that ashy and trash deposits, livestock enclosures and even associated large gates could be recognised by using a suite of micromorphological, mineralogical and phytolith analyses. They suggest that together with information from features such as post holes, artefact and faunal and botanical studies, a comprehensive reconstruction of archaeological sites and ancient lifestyles can be achieved.

Following their study, other scholars started to explore the potential of phytolith analysis for spatial reconstructions. Tsartsidou *et al.* (2008; 2009) conducted phytolith analyses at both ethnographic and archaeological sites. Phytolith analysis was also used in combination with micromorphology in order to characterise outdoor activity areas at Çatalhöyük, Turkey (Shillito and Ryan 2013). The analysis was able to distinguish between episodes of construction, dumping, accumulation, exposure and trampling, demonstrating a dynamic use of these areas through time as middens, yards or traffic zones. The same techniques were able to achieve the same detailed level of interpretation at the Iron Age site of Tel Dor, Israel, revealing that deposits which were first considered to be plaster floors were in fact compressed layers of grasses and animal dung (Shahack-Gross *et al.* 2005). A study of phytoliths and faecal spherulites by Portillo *et al.* (2009) demonstrated that certain areas of the PPNB site Ayn Abu Nukhayla, Jordan, contained evidence of the processing of cereals, while others were used as animal pens. The combination of phytoliths and spherulites allowed the researchers to differentiate between plant material that was introduced into the building from dung sources and other origins.

Although these studies illustrate the usefulness of phytolith analysis for identifying activity areas in anthropogenic site, the nature of this type of information carries limitations which must be addressed. Since the use of plants varies across sites due to local availability of vegetation and human preferences, phytolith signatures from specific activities are not uniform across sites. When it comes to fire installation for example, Shahack-Gross *et al.* (2004) identified elevations in two types of phytoliths in hearth contexts from the Maasai compound in relation to other localities (one characteristic of grasses and the other of wood/bark), but no higher concentrations of other phytolith forms. They reported that the fuel type used in the settlement was wood. Portillo *et al.* (2014) found large amounts of grass phytoliths in the Neolithic fireplaces, which they associated with an abundance of faecal spherulites suggesting the use of dung for fuel. Tsartsidou *et al.* (2008) reported a high concentration of irregular phytoliths (comprising a high percentage of variable morphology phytoliths) in the hearth deposits of an ethnographic village in Greece, which they interpreted as the presence of wood ash. The same is true for phytolith evidence of dung deposits. Although high concentrations of phytoliths are a frequent characteristic of animal enclosures, the associated morphologies will vary according to fodder and the local availability of plant species grazed, and evidence of dung can be missing if it is removed for secondary use (Tsartsidou *et al.* 2008, 611). Phytolith evidence of specific activities is therefore site dependent and frequently ambiguous, it is often combined with other sources of information in order to cope with issues of equifinality.

Tracing pastoral lifestyles

The use of ethnoarchaeology to gain insights into ancient habitation is not new. Towards the end of the twentieth century, a growing interest in ephemeral and pastoral archaeological sites coincided with a revival of ethnoarchaeological studies in the Near East, within Bedouin groups in Jordan in particular. By establishing the nature of pastoral occupation during the recent past, and assessing the potential for identifying ancient pastoral activity following abandonment, they addressed our ability to interpret the archaeological pastoral landscape. What type of evidence of pastoral habitation is left in the landscape? Can we speak of evidence of absence, or merely absence of evidence? Although pastoral life would have undoubtedly changed through time, these studies recognise the need to establish a better understanding of different aspects of pastoral and nomadic activities across a varied landscape today (Palmer *et al.* 2007; Saidel 2009, 179).

Banning and Köhler-Rollefson (1983; 1986; 1992) were two of the pioneers of ethnoarchaeological studies in Jordan, who applied ideas about the relationship between spatial deposition patterns and the material record explored by earlier ethnoarchaeologists (Binford 1978; Gifford 1977; Yellen 1977) to the study of Bedouin camp sites in Jordan. They documented the remains of numerous abandoned pastoralist sites in the vicinity of Petra with the aim of contributing to the finding of archaeological pastoral sites and distinguishing them from those of settled agriculturalists. Their research focused on the material remains left behind after abandonment of such sites, and the identification of typical features indicating pastoral-nomadic occupation.

Figure 1. Map of Jordan showing the location of Wadi al-Jilat and Wadi Faynan.

Around the same time, Simms (1988) studied one of the camp sites of the Bedul Bedouin of Petra, Jordan, in order to compare the site's structure to those of hunter-gatherer sites that had been the subject of earlier ethnoarchaeological studies. The findings from this research represent a focus on functional explanations to the spatial distribution of activity remains, which can be used to understand cross-cultural patterns of the use of space at pastoral sites, and advise future excavation strategies. Findings made in this investigation include the location of refuse which was different from the location of activities, the cleaning of hearths which meant that their contents only represent their terminal use, and an indicator of animal domestication in the form of '*laban*' platforms for the processing of dairy products. The background to this study was the need for a better understanding of the processes leading to spatial distribution patterns in the archaeological record, especially after previous ethnoarchaeological studies questioned contemporary assumptions about the relationship between refuse and activities (Simms 1988; Yellen 1977; Kent 1984).

Later studies set out to expand both the methodologies used to study Bedouin camp sites, which focused on the identification and layout of the sites, and the area of Jordan where ethnoarchaeology took place – which at the time was limited to the Petra region. The Bedouin Ethnoarchaeological Survey Project, led by Saidel (2001), set out to position the studied Bedouin sites within a microenvironment with the aim of discovering correlations between local conditions and the size and spatial organisation of camp sites. Additional goals included establishing the patterns of artefact deposition within the camp sites, and the collection of soil samples for geoarchaeological analysis. The collection of geoarchaeological samples was likely inspired by an earlier micromorphological study of a Bedouin tent floor, which illustrated the potential of this technique to identify formation processes and evidence of human activities at nomadic-pastoral sites (Goldberg and Whitbread 1993).

The aims of ethnoarchaeological investigations of Bedouin camp sites in the 1990s and the beginning of the twenty-first century were not very different to those guiding research during the 1980s, including establishing cross-cultural functional explanations for the use of space at pastoral sites. However, the methodology for achieving them had changed to include more detailed studies of artefact distributions and the application of geoarchaeological analyses.

Case studies: Wadi Faynan and Wadi al-Jilat

The study described in this section sought to explore the potential of a dual phytolith-geochemical methodology for spatial analysis at ephemeral sites, particularly those located in the dynamic environments of the Near East. Analysing the data using two sources of information could potentially help combat issues of equifinality (*i.e.*, a state can be reached by multiple potential means) and equivocality (*i.e.*, a single process may result in several outcomes) that occur with the use of one technique. By verifying or contradicting the identification given by one method through additional information from the other, a more reliable and comprehensive account of the social use of space at a site can be reached. In addition, the combination of geochemical and phytolith analysis has the potential to capture signals from different types of activities, the phytoliths representing exploitation of plant material and the geochemistry reflecting other types of anthropogenic enrichment such as burning or craft production.

By applying this methodology to sites that are difficult to interpret because of their short-lived nature, information can be gained about the use of space that was previously unavailable because of the poor preservation of structures, artefacts and the limited incidence of organic remains. The dual methodology was first tested through an ethnoarchaeological study of Bedouin camp sites at Wadi Faynan in Jordan (Fig. 1). The Bedouin sites provide an excellent subject for the testing of the dual phytolith-geochemical methodology; the use of space by Bedouins at Wadi Faynan has been thoroughly documented so that known activities can be correlated to the analysis results. The sites reflect a seasonal, ephemeral occupation in a dynamic, arid environment, and they represent a range of abandonment periods. The same methodology was then applied to the excavated Neolithic sites in Wadi al-Jilat, Jordan, in order to test its efficacy on archaeological material (Fig. 1). The sites of Wadi al-Jilat provide an ideal case study to test the applicability of a dual phytolith-geochemical methodology for distinguishing activity areas in ephemeral occupation deposits as they represent seasonal occupation in an arid, dynamic environment and were completely excavated.

Methods

Laboratory methods

The geochemical analysis in this study focused on the following chemical elements, measured in PPM: magnesium (Mg), silicon (Si), potassium (K), calcium (Ca), phosphorus (P), iron (Fe), titanium (Ti), manganese (Mn), aluminium (Al), strontium (Sr), sulphur (S), chlorine (Cl), zinc (Zn), chromium (Cr) and zirconium (Zr). The analysis was performed using a Thermo Scientific Niton XL 3t Goldd+ (geometrically optimised large area drift detector) handheld XRF analyser (pXRF), with an Ag anode 50 kV, 200 μA tube. A helium purge was used to lower the detection limits for light elements. The samples were placed in 9 mm plastic cups, covered with a thin polypropylene film, and analysed using a mobile test stand. The pXRF machine was set to the 'mining Cu/Zn mode' and the exposure time for each of the ranges was adjusted to achieve the following settings: the main range was run for 40 seconds, the high and low ranges for 30 seconds each, and the light element range for 80 seconds to allow for reliable readings for elements on the edge of the detection limits of pXRF such as Mg and P. In total each reading took 180 seconds.

One silica (blank) standard and three National Institute of Standards and Technology (NIST) standards were analysed using the same setting as the soil samples during each analysis session; SRM 2711a (Montana II soil), SRM 2709 (San Joaquin Soil), and SRM 1646a (Estuarine Sediment). The measurements of the NIST standards confirmed the precision of the pXRF instruments (for details, see Vos *et al.* 2018).

Phytolith extraction was performed using the dry ashing method, where the soil sample is burnt in a muffle furnace in order to remove organic matter and isolate phytoliths (Rosen 1992). Slides containing the phytolith material were counted using a Meiji infinity polarising microscope at a magnification of x400, using a modern Jordanian phytolith reference collection prepared from plants collected in Jordan (housed at Bournemouth University and the CBRL British Institute in Amman). At least 250 phytoliths were counted per slide, and the entire slide was counted if this amount was not reached. The counted quantities of different phytolith types and (when relevant) taxa were documented on a tally recording sheet. The names of the phytolith types followed the International Code for Phytolith Nomenclature (Madella *et al.* 2005).

Statistical analysis

Separate databases for geochemical and phytolith data were created for each site, and a combination of sites, using IBM SPSS statistics version 23. The geochemical database included the readings of the chosen elements (see previous section) for each sample, which contained error readings of ≤3%. Other elements containing error readings (two-sigma precision) of ≥10% were excluded from the analysis. An exception to this rule was made for Mg, Mn and Zn, which contained error readings of 20%, 23% and 13% (respectively) but were kept in the analysis as they are valuable indicators of anthropogenic activities. The phytolith database included the morphological categories used in the counting sheets and additional variables calculated from the raw data: dicotyledon (dicot – here we use the term according to the pre-1990s definition to mean non-monocotyledon), monocotyledon (monocot), single-cell, multi-cell, Panicoideae, Pooideae, Chloridoideae, Arundinoideae, Palmaceae, Hordeum sp., Triticum sp., leaf, leaf/husk, leaf/stem, husk, awn, weight percent of extracted phytoliths (weight of phytoliths exctracted after processing divided by weight of the initial dried sample × 100), and number of phytoliths per gram of original sediment processed. As the total amount of counted phytoliths varied per slide, the data were transformed to percentages by dividing the number for each counted category by the number of phytoliths counted for the relevant slide, and then multiplied by 100. The number of phytoliths per gram of sediment was calculated using the following formula:

- no. per slide = (phytolith count / no. of counted fields) × total no. of fields on slide
- no. per gram = (no. per slide / mass of phytoliths mounted in mg) × (mass of phytoliths extracted in mg / total sediment weight in mg) ×1000

The data was explored using box plots and bar charts that were created for every variable and for related variables (such as plant parts or genus categories). When analysing the results, it became clear that several categories plotted very similarly, in most cases these were variations of floor surfaces. For example, samples collected from the edges of hearths did not differ from the general floor samples, and so were grouped under the floor category.

Principal component analysis (PCA) was run in SPSS using the correlation matrix, a method which standardises the variables. No rotation was applied to the analysis, and the components were extracted based on eigenvalues greater than 1, and saved as variables based on regression. Discriminant function analysis was carried out with the independents entered together and the prior probabilities computed from group size, including leave-one-out classification in the display option. A two-tailed Pearson correlation test was run with variables from both the geochemical and phytolith analyses in order to identify patterns that could influence the results of the PCA analysis.

Ethnographic case study: Wadi Faynan

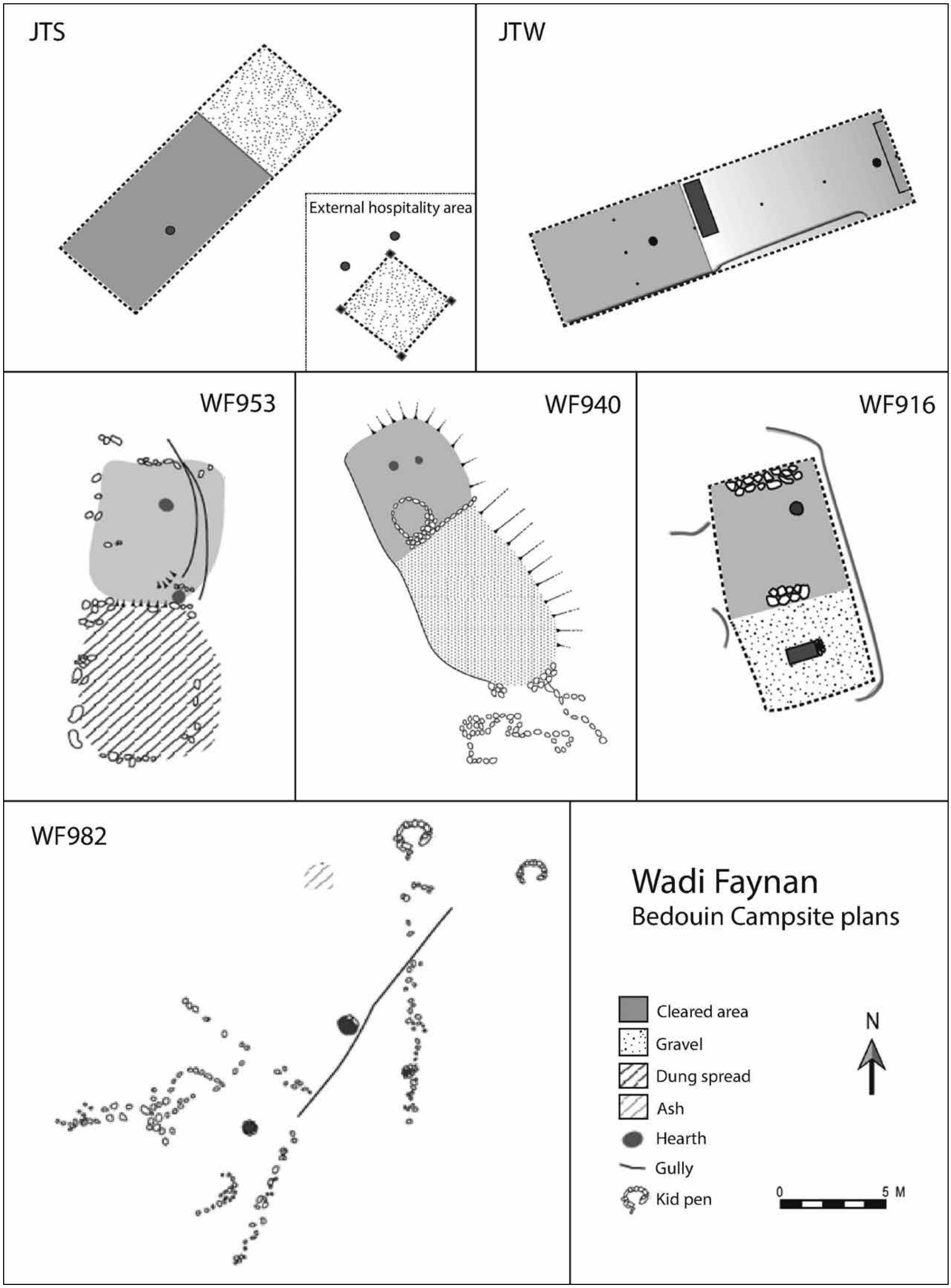
The majority of ethnographic samples discussed in this research were collected as part of an extensive ethnoarchaeological survey of abandoned Bedouin camp sites at Wadi Faynan during 1999 and 2000, led by Carol Palmer and Helen Smith as part of the Wadi Faynan Landscape Survey (WFLS) (Barker 2000). The aims of this survey were to explore the nature of pastoral activity in Wadi Faynan during the recent past and assess the potential for identifying ancient pastoral activity following abandonment. By doing so, the project intended to address our ability to interpret the archaeological pastoral landscape – what type of evidence of pastoral habitation is left in the landscape? And is there evidence of absence, or merely absence of evidence? Furthermore, the survey helped reveal practical and social aspects of Bedouin life, including use of space, and the changes in this through time and across seasonal and tribal variations (Palmer *et al.* 2007).

The research questions stated above were addressed by recording the material culture left behind during abandonment of modern Bedouin camp sites at Wadi Faynan. The study focused on sites that had been abandoned for various durations of time in order to evaluate the influence of taphonomic processes on the presence of material remains during different stages of abandonment.

An initial survey during April 1999 documented the locations and main architectural characteristics (both durable and perishable) of Bedouin tents in the landscape; in total 83 sites were visited. During the visits several physical attributes were recorded, including tent size, orientation, position, spatial arrangement and both common and supplementary features such as storage facilities or outdoor hearths. These data were accompanied by the accounts of the occupants of the area, who provided information about the abandoned camp sites and the activities that took place at these. The team conversed with the tent inhabitants in order to get a better understanding of the use of space at these camp sites and where possible, about the individuals that were living there and the animals owned by them. An accompanying local informant, Jouma' 'Aly of the 'Azazma tribe, enabled a good flow of conversation with the interviewees and a deeper understanding of local lifestyles and use of space to be achieved (Palmer *et al.* 2007).

During 2000, the same camp sites were revisited and studied in greater detail, an artefact distribution study was undertaken, and the soil samples used for the research presented in this paper were collected from chosen sites (Palmer and Daly 2006). In addition to the sites that were

Figure 2 (right). Plans of the Bedouin camp sites at Wadi Faynan (plans of WF953, WF940 and WF982 after Palmer *et al.* 2007, 381-387. Plans of WF916, JTS and JTW created by Daniella Vos, based on schematic drawings made in the field).


JTS
External hospitality area
JTW
WF953
WF940
WF916
WF982
Wadi Faynan
Bedouin Campsite plans
Cleared area
Gravel
Dung spread
Ash
Hearth
Gully
Kid pen
N
0
5 M

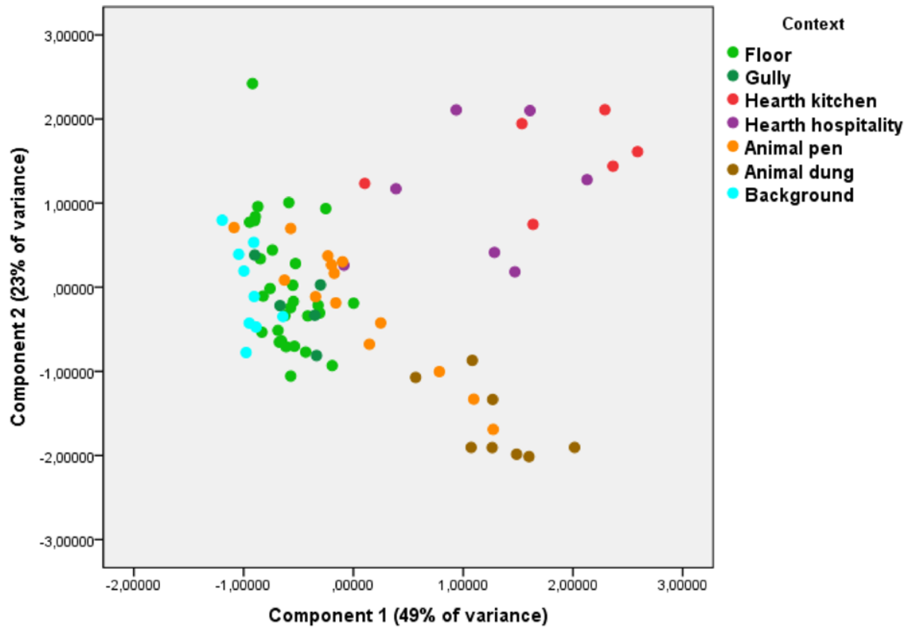


Figure 3. PCA biplot for all Wadi Faynan sites. The first component is driven by P, K, Zn and negatively by Si, Al, Ti and Zr. The second component is driven by Ca, Mn and Mg.

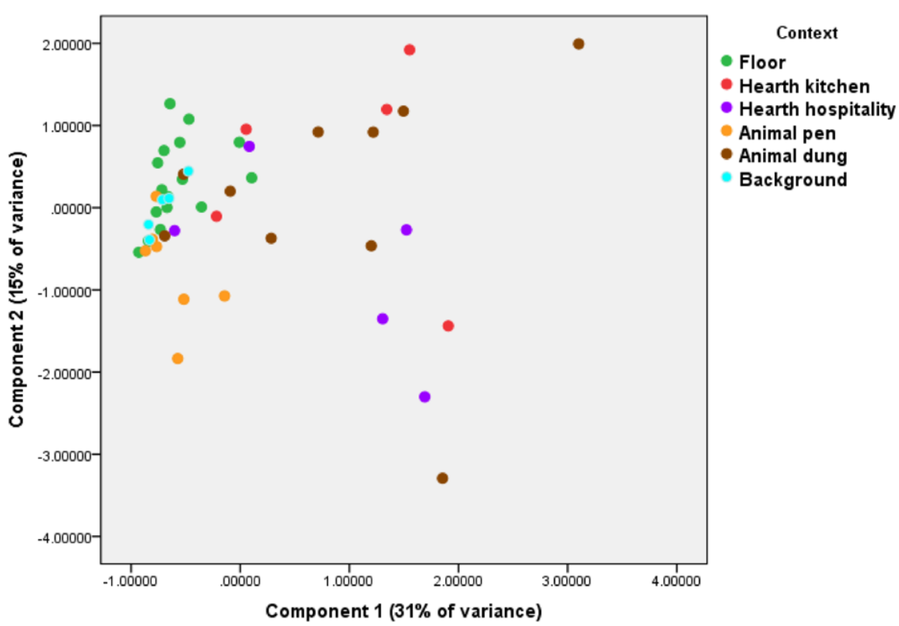


Figure 4. Combined PCA biplot for the sites JTS, JTW, WF916 and WF953. The first component is driven by monocots vs. dicots, multi-celled vs. single-celled phytoliths, husk material and Pooideae. The second component is driven by unidentified phytoliths, leaf, negatively by no. per gram, weight percent and *Triticum* sp.

sampled in 1999 and 2000, two additional camp sites were later sampled by Carol Palmer, Jouma' 'Aly and the author at Wadi Faynan in 2014. The ethnographic soil samples discussed here were collected from one occupied and five abandoned sites at Wadi Faynan (Fig. 2) (Vos *et al.* 2018).

The seasonally occupied ephemeral Bedouin camp sites at Wadi Faynan were chosen as a case study for testing the efficacy of geochemistry and phytolith analysis to identify activity areas because much is known about the use of space in Bedouin tents. Generally, the tents are divided into public-male areas (*shigg*) and private-female (*mahram*) areas. The public area is used for hospitality; coffee, tea or food are served to honoured guests here, and the central hearth can be used for preparing coffee and sometimes tea, though tea is usually prepared in the *mahram* and brought to guests. Various household activities take place within the private area, which includes a kitchen with a hearth which is used for cooking. The use of space within Bedouin households at Wadi Faynan has both static and dynamic aspects. While activities take place within designated areas, each section of the tent can change its function throughout the day. For example, the private area can be used for activities such as weaving, churning butter or entertaining female guests, and will be used for sleeping at night. And when guests are not present, the public area is used by all members of the household.

The use of space at the Bedouin camp sites of Wadi Faynan is in many ways fixed and guided by cultural principles, but some flexibility is maintained through the dynamic use of spaces for different purposes at various points in time throughout the day. The types of camp sites analysed in this research all include a private area which contains a kitchen, and all but one include a hospitality area, animal pens, and in some cases internal animal sleeping areas. All but one camp sites (WF940) contain two hearths, one used for food preparation in the kitchen and another for coffee making in the hospitality area.

Results

The traditional use of space at the Wadi Faynan Bedouin camp sites resulted in relative fixed locations of activity. These leave clear traces of burning and animal husbandry, even after post-abandonment exposure to the elements in this dynamic environment. Activity areas with a strong anthropogenic input were clearly distinguishable from the background and floor related samples through both means of analysis: the hearths, dung sediments, and, to a lesser degree, the animal pen floors (Vos *et al.* 2018).

The hearths are clearly visible within the ethnographic data. They have the largest enrichment of Mg, Ca, Sr, and in some of the sites also S and Zn. The evidence from the phytolith analysis is less straightforward. Elevations of monocots and multi-celled phytoliths, and in some cases Panicoideae grasses, were found in most hearths. An increase in phytoliths that were indicative of various plant parts is correlated to the large amount of monocots identified within the hearth context. The kitchen hearth samples at some of the sites contained higher levels of husk material, but so did many of the dung samples. This might reflect the preference for dung cake fuel in the kitchen hearth (Vos *et al.* 2018). While the PCA biplot created for the geochemistry results shows that the two hearth types form a cluster (Fig. 3), the PCA biplot based on the phytolith analysis displays less clustering and differentiation between the hearths and the animal dung samples (Fig. 4). Interestingly, the two groups of kitchen and hospitality hearths plot separately in the PCA biplot based on the phytolith results. This suggests that the difference between the two types of hearths is better observed through the phytolith data (*ibid.*).

Dung deposits at Wadi Faynan were rich in grass phytoliths, and contained high proportions of conjoined phytolith material. However, the dung samples did not contain higher phytolith concentrations with the exception of the samples from WF916. This could be due to the use of dung cakes in the other sites, which might have caused a reduction of dung within the animal enclosures (Vos *et al.* 2018). The same trend can be seen within some of the elements chosen for the geochemical analysis. P levels are elevated in all dung samples, but are higher still within the hearths of all of the sites apart from WF916. In addition to these, concentrations of K and Cl are highest in dung samples, and S and Zn are slightly elevated in relation to the background samples (*ibid.*).

Floors and gullies display similar patterns to each other and to the background samples in all of the Wadi Faynan sites, and plotted similarly to these in the PCA scatterplot (Figs. 3-4). They contain no elevations in the anthropogenic chemical markers mentioned above, such as Mg, P, K, Mn, Sr, Ca, or the phytolith categories related to anthropogenic input such as high levels of monocots and multi-cells, although slight Cl enrichments can be seen in floor and gully samples from the majority of sites. Unlike floor areas that have been described as high traffic zones (Middleton 2004, 56), the floors and gullies at Wadi Faynan do not show signs of a depletion in concentrations of chemical elements. They plot similarly to the background samples, which suggests that signatures of activity remained local and did not spread out across the floor surfaces.

Archaeological case study: Wadi al-Jilat

The Neolithic of the Levant is characterised by very gradual changes in lifestyle, leading to a transition from hunter-gatherer societies to early sedentary farming communities. This transition, however, is not a linear and inclusive change that affected all human societies in the Levant. Rather, a mosaic of human cultures and modes of subsistence would be a more suitable description of the situation during the Neolithic. Alongside the so-called mega-sites of the Pre-Pottery Neolithic B (PPNB) period, which consisted of permanent architecture, other sites such as Wadi al-Jilat show a more ephemeral occupation during the Neolithic (Goring-Morris *et al.* 2009; Goring-Morris and Belfer-Cohen 2008; 2011). At these ephemeral sites, a mixture of subsistence activities seems to have taken place, and the occupation of the Wadi al-Jilat structures appears to have been seasonal. Ephemeral habitation has been studied at less depth than more substantial settlements during the Neolithic, and the difficulty of interpreting the use of space at these sites limits our view of lifestyles during the Neolithic.

Is was therefore important to explore new ways to study the use of space at such sites. To this end, 36 soil samples from the Neolithic site of Wadi al-Jilat 13 (WJ13) and 17 from Wadi al-Jilat 7 (WJ7) were analysed in this study. Fieldwork at Wadi al-Jilat was part of a series of excavations at the Azraq Basin during the 1980s under direction of Dr Andrew Garrard. The project aimed to provide new insights into settlement and subsistence in the steppe and desert regions of the Levant during the

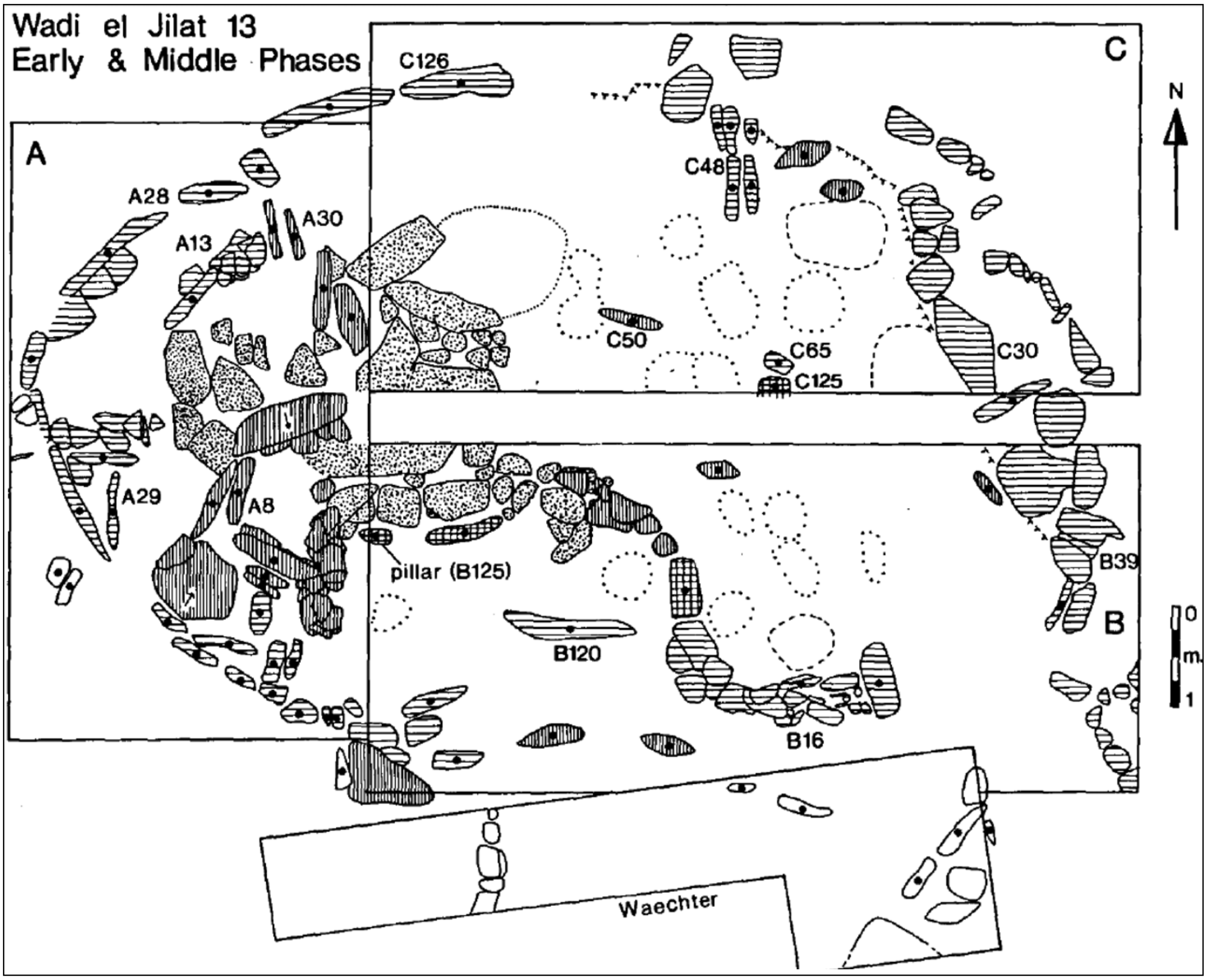


Figure 5. A plan of early and middle phases at WJ13 (from Garrard *et al*. 1994, 80).

early stages of sedentism, agriculture and pastoralism (Garrard *et al.* 1988). The great advantage of using the Neolithic sites at Wadi al-Jilat is that complete structures have been excavated and a soil sample from each context (including hearths and other internal features) was collected. This meant that a full sequence of occupation at these sites was available to choose from, and the detailed records for each context make a reconstruction of the occupation history a straightforward task.

Wadi al-Jilat is situated on the banks of the Jilat gorge, a tributary of the Wadi al-Dabi in the south-west of the Azraq basin and located approximately 55 km south-west of the modern town of Azraq in Jordan. The site lies in a transition area between steppe and desert, receiving approximately 100 mm precipitation yearly, and cuts into late Cretaceous and early Tertiary limestones, chalks and marls which contain a large concentration of flint beds (Garrard *et al*. 1994). The dynamic environment which Wadi al-Jilat makes part of is not unlike that of Wadi Faynan (for an overview, see Vos 2017). The availability of a nearby seasonal water source and presence of diverse ecological zones formed by the topography of the region, together with the restraints set by the arid and variable climatic conditions, could have been exploited by the Neolithic inhabitants of Wadi al-Jilat using a range of subsistence strategies. Each of these strategies might have been preferred under different circumstances. It is in this aspect that the two types of data analysed in this research, ethnographic and archaeological, may show the most similarity. If patterns of mobility during the Neolithic reflect communities' negotiation with frequently changing environmental, socio-economic and internal factors in the same way that mobility patterns at Wadi Faynan did in the recent past, it is not surprising that we find ephemeral patterns of settlement at both. These would allow for the flexibility needed when interacting with a highly dynamic, arid environment.

Description of the sites

The vast majority of Neolithic buildings at Wadi al-Jilat are circular or oval semi-subterranean constructions, with upright slabs forming the fragile external walls, which often enclosed shallow deposits. Many of these structures had internal divisions, hearths and other features such as benches or storage bins (Garrard *et al*. 1988, 40-41). Nevertheless, unlike contemporary sites in moister regions of the Levant, which present substantial architectural remains, the Neolithic settlement at Wadi al-Jilat left traces of somewhat flimsy structures. These, according to the excavators, hint towards a seasonal occupation, as is the case with many ephemeral structures used today by modern nomadic populations (Garrard 1994; Köhler-Rollefson 1992).

WJ13 is comprised of one (relatively large) oval structure measuring 10 x 6.5 m that has been fully excavated, with the exception of a single baulk. The structure takes advantage of a natural crescent shaped gully in the bedrock and follows this natural line, along which the western and north-western walls were erected from upright stone slabs. No clear wall was found bordering its southern end, but some features and stone slabs along the southern boundary could have been part of a wall in the past. Several bedrock post holes in the centre of the gully could have provided support for a superstructure. The excavation surface was divided into three areas, A, B and C (Fig. 5). The building was dated to the final PPNB according to four radiocarbon dates, ranging between 6840 ± 150 and 6739 ± 152 cal BC.[1] The four dates are similar to each other, which might suggest that this site was in use for only a short duration of time. Nevertheless, during its occupation history the sites was prone to substantial remodelling, resulting in a complex stratigraphic sequence and probably significant changes in the use of space.

Three phases of occupation were recognised, during each of these the interior of the structure had been divided up by platforms and partition walls (in the form of lying or upright stone slabs). During the initial phase, following the construction of the building, a series of occupation fills was deposited within the structure, and a pavement of stone slabs was laid on top of these at the western end. Within the primary deposits in the southern and eastern sections several stone-lined hearths were used. The middle phase of occupation included the construction of a partition wall separating the western part of the structure, above the previous pavement. A niche or sub-compartment was added as part of this wall, and in the eastern sector two pits and a number of stone-lined hearths were created. Isolated upright slabs were erected within the structure, the function of which is unclear. The last phase of occupation at WJ13 saw the placement of a stone-slab pavement on top of a rubble foundation, extending from the entrance in the south-east to the partition wall at the western end.

The occupation of WJ7 took place during the Early and Middle PPNB period, and two radiocarbon samples from the building provided the dates of 7942 ± 197 and 7571 ± 106 cal BC. The site was divided into areas A, B and C (Figs. 6-7). The initial deposit on the bedrock in areas A and C was a layer of compact ashy material dated to the Early PPNB, which covered most of the excavated surface. Several sub-structures and walls were set into or overlay this primary deposit. In area B a silty layer covered the bedrock, not including much archaeological material, and above it a series of ashy midden deposits and two unlined hearths were found. During the later phases, dated to the Middle or Late PPNB, a number of stone alignments were built in the centre of area A, and a pit was cut through earlier deposits and the bedrock in its south-west corner. In area B, a pavement and upright slabs were added to a sub-compartment in the north-west area. Above the pavement a compact occupational deposit was excavated. After this phase, the building seems to have fallen into disuse (Garrard *et al*. 1994).

The faunal assemblages found at these sites show a reliance on wild populations of gazelle and hare during the PPNB, and the introduction of caprines into the area by humans during the early Late Neolithic (LN), when hunting seems to have decreased but was still significant. While 78% of the faunal assemblage at PPNB WJ7 consisted of hare and gazelle, within the faunal remains at LN WJ13 hare and gazelle represent 42% of the assemblage and caprines make up 20% of the assemblage (Garrard *et al*. 1994; Baird *et al*. 1992). The faunal remains at the sites have been interpreted as representing a range of subsistence strategies, including hunting, trapping and, from the early LN onwards, also sheep and goat herding (Martin 1999).

The results of the faunal analysis tie in well with those of the botanical examination, which likewise suggests a broad use of subsistence strategies including foraging and crop cultivation. Colledge (2001) found domestic glume wheats and barley in early PPNB levels at WJ7, and tentatively identified einkorn. It is unclear if these were cultivated nearby the site or imported. While only opportunistic cultivation takes place in the Jilat area today, cereals could have been grown there in the past if rainfall was sufficient during the Neolithic. Legumes, chenopods, fruits and seeds were also identified (Garrard *et al*. 1988, 47; 1994, 104-105). The botanical assemblages at WJ13 and WJ7 are similar, with large amounts of carbonised plant remains and poor preservation of the specimens.

Interestingly, Colledge mentions that species diversity was larger at WJ7 and WJ13 compared to

1 All dates in this section were taken from Garrard *et al*. 1994, and calibrated through www.calpal-online.de.

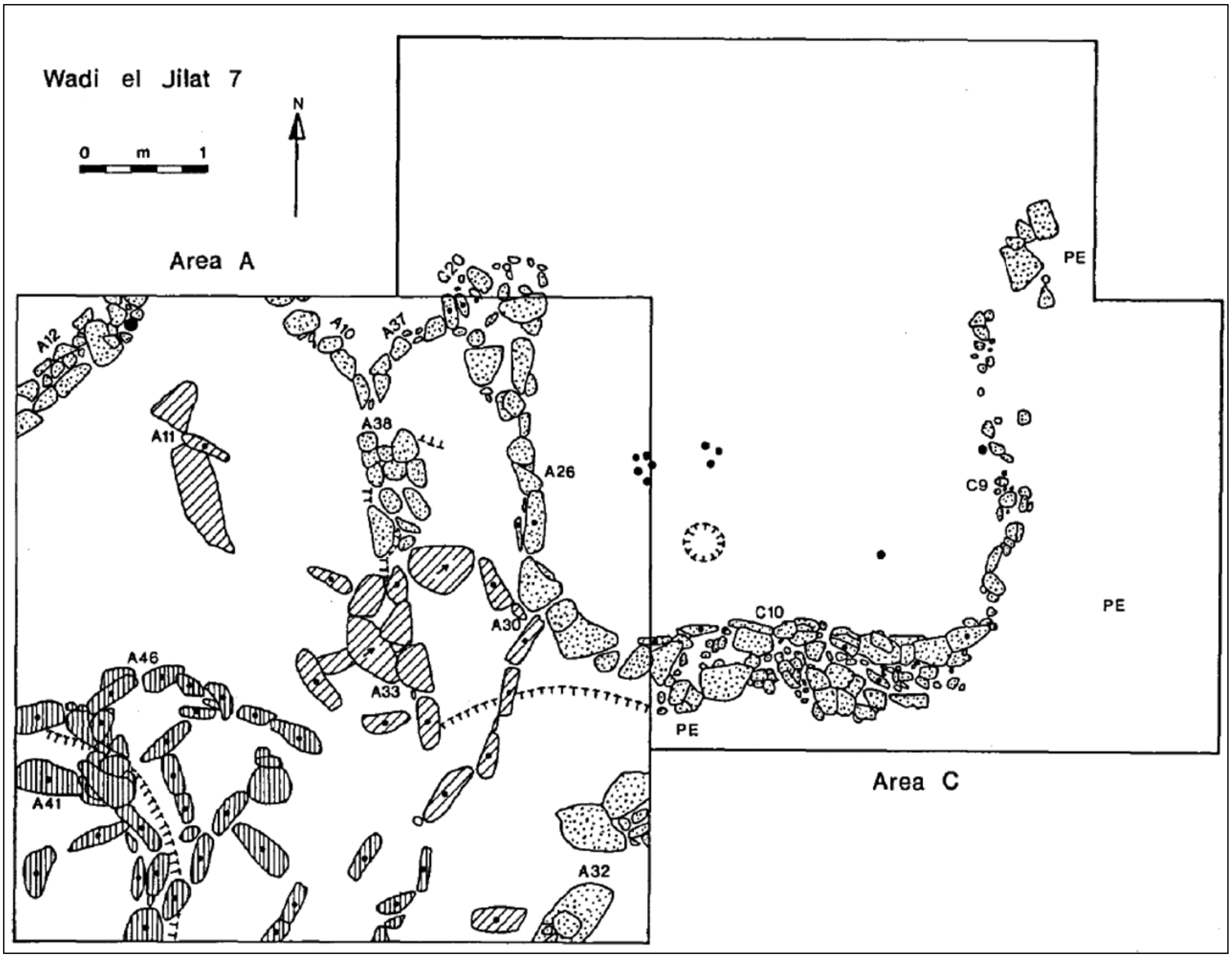


Figure 6. Plan of areas A and C at WJ7 (from Garrard *et al*. 1994, 74).

Wadi Fidan and Beidha, which are located in the Mediterranean woodland region and seem to have relied more heavily on cereals. The latter sites also contained higher levels of charcoal residue then the Wadi al-Jilat sites (Colledge 2001). Although this could be the result of excavation or collection biases, this observation could also reflect a reliance on a wider range of plant species at Wadi al-Jilat than the perhaps more specialised cultivation taking place during the Neolithic at Wadi Fidan and Beidha. Charcoal concentrations were higher in WJ7 and WJ13 than the other Wadi al-Jilat sites, these are also the two sites with the deepest stratigraphies. This trend could either relate directly to the extent of burning activities at the sites, or reflect taphonomic processes. It is worth noting that hearth features at the Wadi al-Jilat sites contained relatively low amounts of charcoal in comparison to the occupation fills.

The two sites of Wadi al-Jilat encompass various structures that were occupied, probably seasonally, between around 8000 and 6000 cal BC. It is likely that the extensive time span separating between the occupation of the various areas at this site encompassed differences in subsistence strategies, cultural practices and other aspects of life. On the other hand, the inhabitants of Wadi al-Jilat across the Neolithic are connected by sharing the same terrain, and probably similar environmental conditions. In this respect, they share similarities with the ephemeral sites at Wadi Faynan, where patterns of mobility and subsistence changed through time in relation to varying circumstances (Vos 2017). The use of the ephemeral architecture at these sites corresponded with these. These changes might be better understood through the incorporation of new techniques for gaining information about the spatial use of such structures. At the same time, the range of purposes and uses which might be represented at the Wadi al-Jilat sites must be kept in mind when analysing the phytolith and geochemical soil signature at these sites, as they affect the ability to juxtapose the results of such analysis.

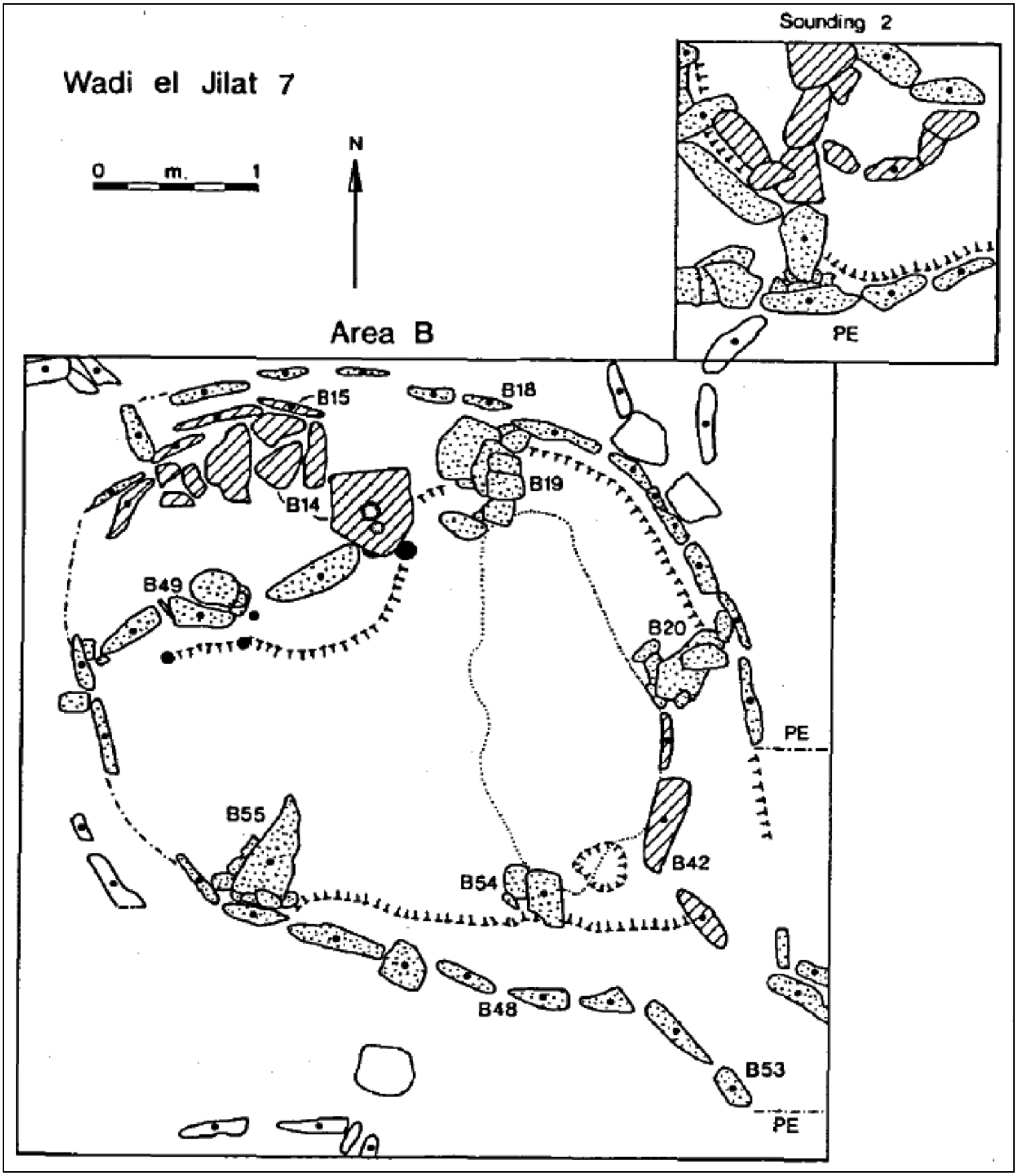


Figure 7. Plan of area B at WJ7 (from Garrard *et al*. 1994, 74).

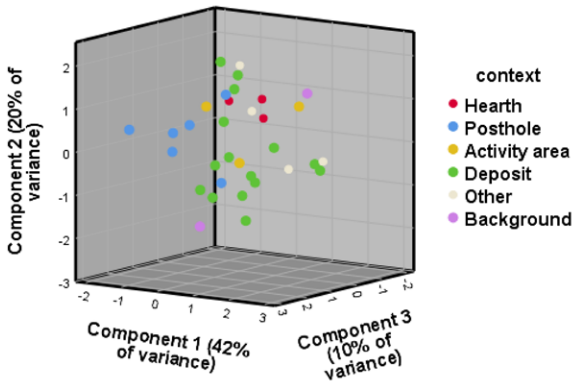


Figure 8. 3D PCA biplot, WJ13. The first component is driven by Ti, Si, Fe, K, Al, Zr and Nb. The second component is driven by Mg, Ba, Sr and Ca. The third component is driven by Cr, P, Rb, Cl and negatively by V.

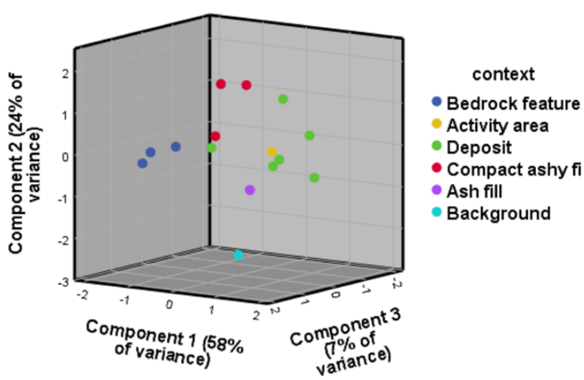


Figure 9. 3D PCA biplot, WJ7. The first component is driven by Mg, Si, Ti, Fe, S, Zr, K and P, and the second component by Ca, Sr and Rb.

Results

At first sight, the results of the geochemical analysis at Wadi al-Jilat do not appear to show clear trends of anthropogenic anomalies when it comes to individual chemical elements, and are not as straightforward as those obtained for Wadi Faynan. The geochemical variables that drive most of the variance within the PCA analysis of the Neolithic sites do not correspond well with the elements that were found to indicate anthropogenic input in the analysis of the Wadi Faynan sites or in earlier studies. In addition, WJ7 and WJ13 portray more differences then the Wadi Faynan sites, where most trends were representative of all sites.

The largest variance within the geochemical results of WJ13 is driven by background elements such as Ti, Fe, Al and Si, represented in the first component (Fig. 8). However, the anthropogenic input is better represented by the second, third and fourth components. Scatterplots combining the first three factors show a clustering of the bedrock features, hearths, and to a certain degree also the deposits and activity areas (Figs. 9-10). The main elements that drive the second, third and fourth components are P, Mg, Cl, Mn, Zn, Ca, Ba, Cr, Sr and S negatively. The first six elements are also important indicators of anthropogenic activity in the Wadi Faynan sites, which might indicate that the signal of human activity might still be similar to other sites after all.

The PCA scatterplot created for the first, second and third components of the geochemical results of WJ7 provided a better result than the one representing the first two components for WJ13, explaining 82% of variance (Fig. 9). These were driven by both chemical elements associated with anthropogenic activity such as Mg and Sr, and those related to the natural background such as Si and Ti. However, although the overall trends at this site enable us to distinguish between context categories based on geochemical variables considered to reflect anthropogenic activity, the individual elements do not appear to show remarkable trends or share similarities with findings in previous studies. This, however, was the case with the site of WJ13, where trends of specific elements provide interesting insights. P levels are increased in all anthropogenic contexts in comparison to the background samples, noticeably mostly in the posthole samples (Fig. 10). This could be explained by leaching of P downwards, but then one would expect to see a similar pattern in the other Wadi al-Jilat sites, which is not the case. Interestingly, there is a slight elevation of K and Mg in the hearths, and of Mn in activity areas (Fig. 10). These trends are similar to the observations at Wadi Faynan.

Generally, the context category that stands out in relation to the rest is postholes, as was the case in WJ13. However, it varies from the other contexts for different reasons, and seems similar to the background sample in some respects. Bedrock features at WJ7 had the lowest levels of Mg, K and P, yet the highest amount of S. Deposits generally contained high levels of most elements, but low levels of S, which was higher in the background and compact ashy deposits in addition to the bedrock features. Nevertheless, the PCA scatterplot above (Fig. 9) reveals that overall, samples in the same context category do cluster and that all categories vary significantly from the background sample.

The results of the phytolith analysis at Wadi al-Jilat revealed only very subtle patterns of differentiation between activity areas within the sites, while the background samples were clearly different to the on-site material. A high monocot to dicot ratio, the abundance of grass husks and the high weight percent and number of phytoliths per gram all appear to be associated with anthropogenic activity at the Neolithic sites. The bedrock features at WJ13 contained very low counts of phytoliths

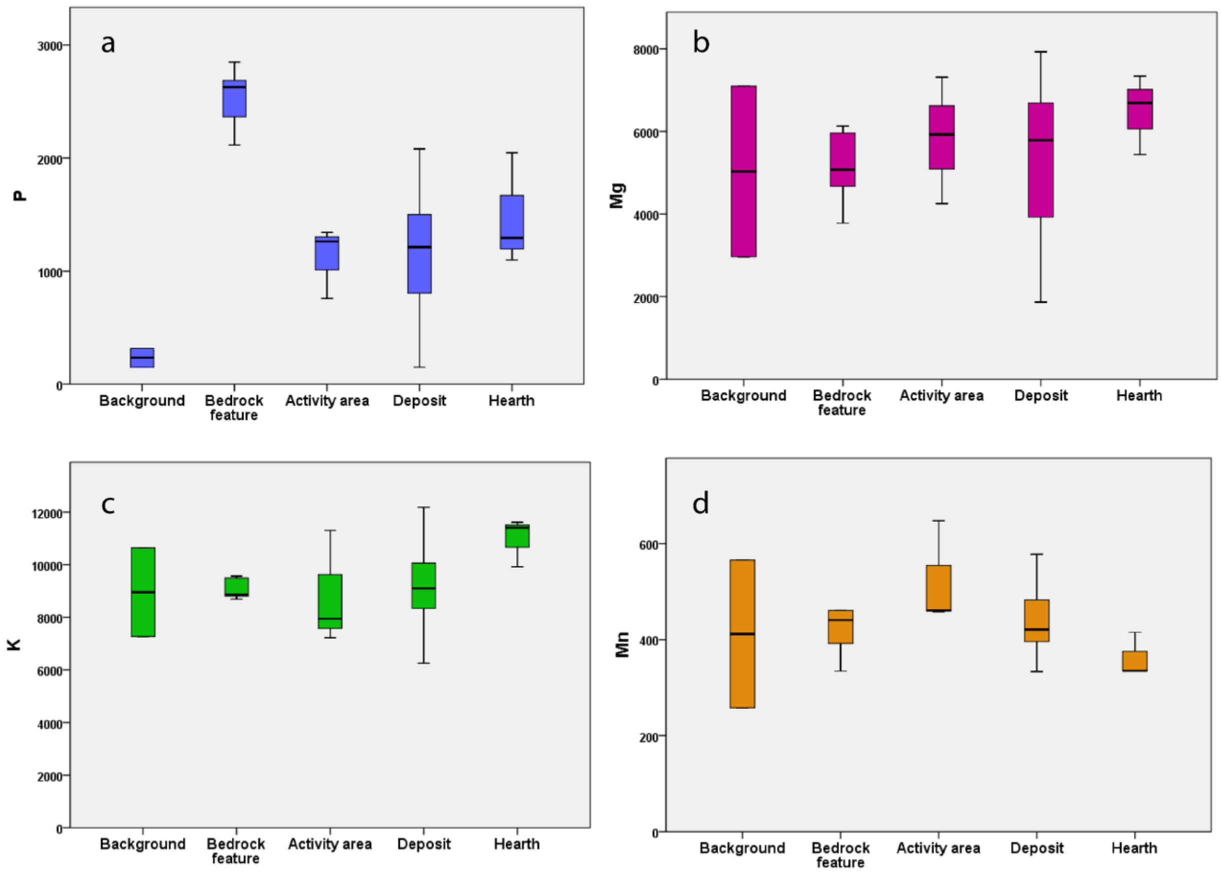


Figure 10. Average measurements in PPM for WJ13 per context category for the following chemical elements: (a) P, (b) Mg, (c) K, (d) Mn.

and most of them were associated with large amounts of silica aggregate material (which is considered to be an indicator of woody material by Schiegl *et al.* 1994). In addition, the weight percent of this context category was much higher than the other activity areas (calculations of phytolith number per gram would not suffice as silica aggregate does not fall within the phytolith counts). The background samples clearly vary from all the on-site ones, having lower amounts of weight percent and number of phytoliths per gram, and a lower monocot to dicot ratio. The phytolith analysis results at WJ7, which provided the best results for the geochemical analysis, demonstrate the most variability in context categories. While all contexts show an increase of monocots in relation to the background samples, the categories 'activity area' and 'compact ashy fill' (which probably reflect hearths) contained the highest concentrations of these. These two categories show resemblance when it comes to plant parts, containing the largest amounts of husk material in relation to the other context categories.

The anthropogenic enrichment within these two context categories at WJ7 appears to reflect high activity, strengthening the association between the mentioned variables and human occupation. In addition, enrichment of silica aggregate material in combination with low phytolith counts at the bedrock features of WJ13 might indicate a high anthropogenic input, albeit of a different kind. Interestingly, the background sample is devoid of husks, but contains larger amounts of silica aggregates.

The PCA scatterplots created for the phytolith results at these sites portray some clustering. As with the results of the geochemical analysis, the second and third components represent less of the overall variance but demonstrate better clustering of context categories than the scatterplots created for the first two components (Figs. 11-12). All in all, a high monocot to dicot ratio, the abundance of grass husks and the high weight percent and number of phytoliths per gram all appear to be associated with anthropogenic activity at the Neolithic sites.

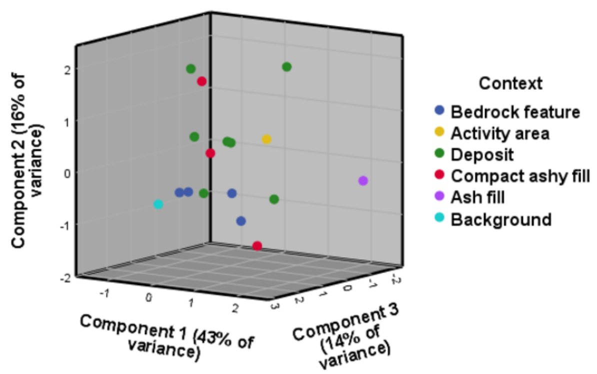


Figure 11. 3D PCA biplot, WJ7. The first component is driven by monocots, unidentified and degraded phytoliths, leaf, leaf/stem, Pooideae and single-cell phytoliths. The second component is driven by weight percent, Chloridoideae and negatively by burnt phytoliths. The third component is driven by Panicoideae, leaf/husk and weight percent.

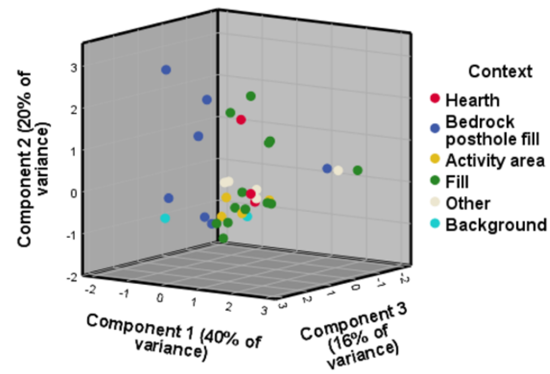


Figure 12. 3D PCA biplot, WJ13. The first component is driven by the variables monocots, leaf and leaf/stem, the second is negatively driven by dicots and single-cell phytoliths. The third component is driven by number of phytoliths per gram and multi-cell phytoliths.

Discussion

The results of the geo-ethnoarchaeological analysis suggest that the geochemical and phytolith analyses provide useful methods for studying activity areas at the Bedouin camp sites at Wadi Faynan. Activity areas with a strong anthropogenic input were clearly distinguishable from the background and floor related samples through both means of analysis. Individual trends within the geochemical and phytolith analysis were found to correspond with the known context categories within the areas of high anthropogenic activity. These findings support observations made in previous geo-ethnoarchaeological studies, indicating that specific (groups of) chemical elements are correlated to certain human activities and that anthropogenic anomalies can also be observed through phytolith analysis, though the latter trends will be more site specific.

The analysis of the Neolithic sites suggests that there is great potential in identifying, or at least distinguishing between categories of activity areas at ephemeral archaeological sites. Although WJ13 and WJ7 share the same environmental and historical setting and are adjacent to one another, the dual geochemical-phytolith approach worked differently with each site. WJ7 exhibits distinguishable context categories when examined through PCA scatterplots (mainly due to the geochemical input), while the geochemical and phytolith analysis of WJ13 demonstrate subtle trends within individual variables.

The geochemical variables that represent most of the variance between context categories in the Neolithic sites are not always the same ones that were found in the analysis of the Wadi Faynan sites or earlier studies. The PCA scatterplots exhibited far better clustering of context categories when plotted according to the second and third components, which did include variables more similar to the ones found to represent anthropogenic input. This might indicate that the signal of human activity might be comparable to other sites after all but has been diluted, and could be found at such sites once anthropogenic traces are filtered from other chemical 'background noise'. Additional studies are needed to establish the effects of long term abandonment of ephemeral sites on the presence (and relative abundance) of specific chemical elements in more detail.

Within the phytolith analysis results, it appears that the same variables indicate a strong anthropogenic input at the Wadi al-Jilat sites as the ones identified for Wadi Faynan, although the signals of activity within the archaeological data are weaker than for the ethnographic data. These results are encouraging especially considering the general sampling strategy (soil samples were collected from the general area of each context rather than targeting smaller, specific zones), the ephemeral and shallow nature of the Neolithic sites and the long duration since abandonment, which made the deposits prone to mixing, dissolution, and various other taphonomic disturbances.

It is therefore likely that the length of time since abandonment and perhaps the remodelling activities that took place within the buildings have affected the ability to identify activity specific soil signatures in these samples. One of the issues that complicates the interpretation of activity areas at Wadi al-Jilat is the difference in period of occupation and perhaps also in use between the two sites, which is responsible for some of the variation between the context categories. While the Bedouin camp sites were used contemporarily and in the same manner (domestic occupation) and therefore portray similar soil signatures, WJ7 and WJ13 could have had been used for different purposes which would have affected their geochemical and phytolith characteristics. After all, even within the ethnographic sites at Wadi Faynan, there were differences between the results of WF916 and the other camp sites due to the limited use of dung cakes at this site (Vos *et al.* 2018).

The geochemical and phytolith analyses at WJ13 portray a less straightforward clustering into the predefined context categories than is the case with WJ7, even though it is a more substantial site. This, however, might have contributed to the complexity of its interpretation. WJ13 had a long sequence of occupation and re-use, which could have caused mixing of material within the building. In addition, it was excavated in three parts, and a baulk was left between areas B and C which might have added difficulty to the systematic excavation of its three areas. WJ7 enjoyed a less extensive occupation then WJ13 and contained shallow deposits, and although it was also excavated in three parts it portrayed a simpler stratigraphic sequence than WJ13. It could be that the short-lived nature and relative simplicity of the occupation sequence at WJ7 actually contributed to the ease of its interpretation.

These findings support the observations made by O'Connell (1987) during his study of occupation and abandonment patterns at the Alyawara camp sites. The longer a site is in use, the more prone it is to cleaning activities which can affect the distribution of signals of activity. In addition, a long sequence of occupation including episodes of reconstruction can cause a shift in activity areas and evidence of these within the site, making the spatial patterns more difficult to interpret. In this respect one could propose that ephemeral archaeological sites with a straightforward stratigraphic sequence and a fixed, structured, spatial use of activity areas can benefit from geoarchaeological analysis techniques to a greater degree than sites with a complex stratigraphy which have been regularly modified.

Conclusions

This article discussed the value of (ethno-) geoarchaeological studies to aid the interpretation of ephemeral anthropogenic sites. The results of the two case studies support earlier reports and suggest that geochemistry and phytolith analysis carry much potential for the spatial reconstruction of activity areas within ephemeral sites situated in the dynamic, arid environments of the Near East. Such sites may retain signs of anthropogenic enrichment over thousands of years, though the anthropogenic signals might be diluted and thus more difficult to identify.

The successful application of the dual phytolith-geochemical methodology was more site dependent at Wadi al-Jilat than at Wadi Faynan. While the identification of activity areas at WJ13 was fruitful to a limited degree, the application of the dual methodology to WJ7 provided clear differentiation of activity signals and a profound clustering of context categories within the PCA scatterplots. It is likely that the individual buildings at Wadi al-Jilat were used in a different way, or for different purposes, which did not always comply with the predefined context categories. It was therefore not possible to study the sites together, or in comparison to each other. An investigation into spatial patterning is therefore best restricted to an individual, contemporary site context, which contains a large enough sample size to establish general trends for each context category.

The interpretation of ephemeral archaeological sites can greatly benefit from the use of geoarchaeological techniques. These have so far mostly been applied to substantial sites, where repetitive activities in fixed locations often leave clearer traces in the soil. However, shallow and straightforward sequences of occupation in ephemeral sites used in a 'habitual' manner, where activities had fixed locations, may prove to be as promising candidates for spatial analysis as more substantial ones. This might be a consequence of the limited cleaning and change in location of activity areas that take place at a site which is only occupied for a short time. Additional studies should be encouraged to fully explore the potential of geoarchaeology in contributing to our understanding of the use of space at sites which are less visible, and therefore underrepresented in the archaeological record.

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