Out of Sight,
But Not Out of Mind

Exploring how phytolith and geochemical analysis can contribute to understanding social use of space during the Neolithic in the Levant through ethnographic comparison

Daniella Vos

Submitted in partial fulfilment of the requirements of Bournemouth University for the degree of Doctor of Philosophy

July 2016

Abstract

This research evaluates the potential of a geochemical and phytolith dual methodology for identifying activity areas at ephemeral sites, and adds to our understanding of the formation processes involved in the creation and preservation of soil signatures at ephemeral sites situated in dynamic environments. The work focuses on an investigation of the social use of space in temporary contexts using ethnographic and Neolithic case studies in Jordan. The background to this research involves the need for a better understanding of ancient activities at ephemeral sites during the Neolithic in the Near East. Despite the importance of this period, there are still many unanswered questions regarding the dramatic changes in subsistence and lifestyle that are associated with it. The structures built in this period, which in many ways embody the transition from hunter-gatherer societies to farming communities, are difficult to interpret due to their ephemeral nature and scarcity of organic remains. Nevertheless, although the motivation behind this research is achieving a better understanding of the Neolithic in the Near East, its outcomes are widely applicable to studies of ephemeral archaeological sites in various settings.

A dual geochemical and phytolith methodology was applied to seven Bedouin campsites at Wadi Faynan, Jordan, which constituted the ethnoarchaeological data. This was done in order to test the methodology in a controlled setting where knowledge of the use of space at the sites was at hand. The campsites were either occupied or abandoned for various lengths of time during sampling. This allowed for a consideration of taphonomic processes involved in the creation and preservation of soil signatures at these sites. The dual methodology was also applied to three of the Neolithic sites of Wadi el-Jilat, Jordan. This was done in order to test the dual methodology on archaeological case studies, assessing its efficacy in identifying activity areas through the soil signatures that were still available at these sites following an abandonment period of more than 8,000 years.

The geochemical and phytolith dual methodology was found to be successful in distinguishing activity areas at the ethnoarchaeological and archaeological sites, and carries much potential for future studies of the use of space in ephemeral structures. While previous studies have experimented with the use of multiple geoarchaeological methods for the study of spatial patterning at ethnographic and archaeological sites, this study is the first to address the use of statistical methods to combine the results from two different analysis techniques. The appropriate use of methods for data display and manipulation was found to be important for the successful application of multiple analysis techniques, allowing their results to aid archaeological interpretations of space.

This research has contributed to knowledge by establishing the value of a dual geochemical-phytolith methodology for interpreting the use of space at ephemeral sites. Through future applications of this dual methodology and the statistical tools explored in this study, a contribution can also be made to our understanding of the social use of space in sites and during periods which are difficult to interpret.

Contents

Acronyms

Cal. BP	Calibrated years Before Present
CBRL	Council for British Research in the Levant
IMPR	International Meeting on Phytolith Research
INEA	Identifying activity areas in Neolithic sites through Ethnographic Analysis of phytoliths and geochemical residues
JTS	Jouma's Tent Summer
JTW	Jouma's Tent Winter
LN	Late Neolithic
NIST	National Institute of Standards and Technology
NRA	The Natural Resources Authority
PCA	Principal Component Analysis
PDI	Phytolith Difference Index
PPL	Plane Polarised
PPM	Parts Per Million
PPNA	Pre-Pottery Neolithic A
PPNB	Pre-Pottery Neolithic B
P-XRF	Portable X-Ray Fluorescence
SPSS (IBM SPSS)	Statistical Package for the Social Sciences

SPT	Sodium Polytungstate
SRM	Standard Research Material
XPL	Cross Polarised
XRF	X-Ray Fluorescence
Uncal. BP	Uncalibrated years Before Present
WFLS	Wadi Faynan Landscape Survey
WD	Wadi Dana
WF	Wadi Faynan
WJ	Wadi el-Jilat

List of figures

Chapter 3

Chapter 4

Chapter 5

Chapter 6

Chapter 7

Chapter 8

Chapter 9

List of tables

Chapter 3

Chapter 5

Chapter 6

Chapter 8

Chapter 9

Acknowledgements

I would like to thank Andrew Garrard for providing advice on the background to the Wadi el-Jilat sites, and access to the soil samples and detailed descriptions of the fieldwork at these sites. I would also like to thank Carol Palmer and Helen Smith for allowing me to work on the soil samples collected during their ethnoarchaeological survey at Wadi Faynan and all of the advice and documentation they have provided. Carol was kind enough to take me to Wadi Faynan on different occasions, and helped me organise and collect new samples from campsites at Wadi Faynan during 2014. I am very grateful for her guidance on many aspects regarding the ethnoarchaeological work and material and Bedouin lifestyle in general. Many thanks to Rick Stafford for his guidance on the application of the statistical methods explored in this research, I wish I had more than brownies to offer in return.

I would also like to thank Jouma' 'Ali Zanoon and his lovely family for their great hospitality, not only were they wonderful and generous hosts, they taught me a lot about Bedouin life, often making me envious of this lifestyle. Jouma' was also very generous and helpful when it came to helping me collect soil samples in 2014.

My supervisors, Tim Darvill, Emma Jenkins and Kate Welham, provided guidance and support which facilitated not only my academic but also my personal development. I am very grateful for their supervision during my PhD trajectory. I would also like to thank the Arts and Humanities Research Council and Bournemouth University for their financial support which enabled this research.

Many thanks to my family and friends who provided support during a few dark moments, and to my sister for designing posters. Last but definitely not least, I would like to thank my partner, Bas Baaijens, who has offered support and has made many sacrifices to enable me to carry out this research. This thesis is dedicated to him.

1 Introduction

Within our homes we move habitually, unconsciously, from one room to another. Most of this movement will be guided by a functional transition from one space to another which is related to our needs during specific moments in time. We walk from the living room, where we are relaxing or entertaining guests, to the kitchen to get some food, and later on we take a shower in the bathroom and go to bed in our designated sleeping area – the bedroom. We interact with our spatial setting on different levels, it can dictate our movements and behaviour but is also influenced by our choices. It reflects our personalities and identities as much as our social status and specific requirements. This strong, and often static, association between activities and space in modern western societies might be a contributing factor to the interest archaeologists have in reconstructing the past use of space at archaeological sites. If we can understand this important aspect of the sites we study, perhaps we can gain insights into the social life, identity and daily habits of the past occupants of the exposed archaeological settlements. In the same way that we feel as though we know someone better by visiting their home, we try to get a better idea of past societies by reconstructing their use of space.

So far, most archaeological studies of spatial patterns have focused on a reconstruction of the location of activities based on the distribution of artefacts (see section 1.2.). There is, however, another level of evidence for the spatial patterning of activities which is likely 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 maybe 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. The aim of this research is to explore 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.

1.1. The need for a dual methodology to study ephemeral archaeological sites

It has been argued that the knowledge of soils has been around for about 11,000 years, having its origins, as many other modern aspects of human life, in the initial practice of agriculture. It was necessary for early farmers to know which soils were most appropriate for growing the desired crops, and how the earth should be treated (Brevik and Hartemink 2010). Ironically, this concern with soil was not shared by many of the archaeologists who excavated the remains of early farming communities in the Near East, who were more interested in the artefacts and macrobotanical residues distributed within archaeological deposits (Matthews 2003).

Soils are 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.

The dimension of space is a fundamental aspect of cultural soilscapes, yet one that has been often 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).

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 its ephemeral nature. 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 to 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.

1.2. Spatial analysis in archaeology

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. In order to do so, 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 legitimizes 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 (Clarke 1977).

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. According to the cultural element flow model, artefacts pass through a cultural system where they are affected by various processes constituting their life history:

procurement, manufacture, use, maintenance and discard (Schiffer 1995). The location of an object within a site can be linked to the phase in the artefact's life history: for example, a broken tool at its discard phase will likely be located among other refuse and one which is in the process of being manufactured will often be associated with a craft environment. In addition to the life history of an object, other factors need to be taken into account when reconstructing the spatial distribution of artefacts within a site, covered by Schiffer (1995) under two concepts: N-transforms and C-transforms. The first refer to natural formation processes such as erosion or animal disturbance, and the second to cultural forces such as clearing ash from a fireplace to a secondary location or digging a pit in earlier deposits within a site. The influence of all of these processes on the location of artefacts must be assessed in order to be able to create a plausible reconstruction of past use of the site, which provides a difficult task at the best of times.

With the rise of post-processual archaeology came other changes in approach and notions of space (Salisbury 2007). 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). One example of point pattern analysis is a study of the density of debris patterns at the Magdalenian site of Pincevent, France, by Leroi-Gourhan and Brézillon (1966). The excavators interpreted the presence of a past barrier catching material that had been swept or kicked towards it, inferring the boundaries of a hut or tent structure. They made use of red ochre stains alongside the chipping debris to reconstruct the limits of past activity. However, the results of visual examination are highly influenced by human bias and error and carry much uncertainty. Carr (1991) compared the interpretation of Leroi-Gourhan and Brézillon with a later interpretation of the same site by Binford, who suggested the traces of debris rather reflect drop and toss zones.

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 GIS analysis (Hodder and Orton 1979). The relationships between the 'points', but also between the artefacts or sites and various other attributes such as soil type or topography, could now be easily investigated. In addition, new questions could be incorporated into the analysis, such as the relation between topography and the location of Palaeolithic sites for example (Coinman et al. 1988). The use of a grid based analysis provided another approach to study distribution patterns, reducing the data to counts of debris, artefacts, or sites to each square of the grid. A Poisson distribution is assumed for the random dispersal of objects, and the mean density is measured for each quadrat (Orton 1980). Nevertheless, the problem with the grid-method is that the size of the quadrats can heavily influence the distribution patterns.

Although archaeological studies of spatial patterning cover a range of techniques to analyse spatial relationships, the methods outlined above were developed to be used on point-pattern and 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 prior- 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 2015). Micro-refuse studies are less affected by some of these issues, but the effort and time needed to perform these is substantial, not allowing for large-scale investigation (Hull 1987; Rosen 1986; Ullah 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). An overview of these studies is given in Chapter 2. 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.

1.3. Using a dual phytolith-geochemical methodology

Geochemistry and phytolith analysis are two techniques that have been recently put to use for spatial studies of activities at archaeological sites. While phytolith analysis has been previously used to answer more specific research questions regarding plant use at archaeological sites, geochemistry served as a method for prospection for a while (an overview of these techniques is provided in chapter 2). These soil signatures are considered to be less prone to effects of cultural or natural post-depositional disturbances that affect larger artefacts, and they generally reflect in situ activity (Canti and Huisman 2015). 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.

While recent studies have started utilising geochemistry and phytolith analyses for spatial reconstructions of activity areas within anthropogenic sites, in most cases generating fruitful results, very few have applied these two methods to the same data (see overview in chapter two). Testing a dual phytolith-geochemical methodology will enable us to explore the potential of these two promising methods for spatial analysis at ephemeral sites. 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 (see overview in chapter 2). 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.

1.4. Why delve into live archaeology? Considerations of an ethnoarchaeological approach

Ethnoarchaeology can be defined as the study of living cultures from an archaeological perspective with the aim of understanding the relationships of material culture to culture and human behaviour (David and Kramer 2001, 2). In practice, ethnoarchaeology may include the actual study of living communities in order to find links between artefacts and non-material aspects of cultures, or be seen as a broader framework used for the comparison of archaeological patterns with ethnographic cases (David and Kramer 2001). A definition of ethnoarchaeology given by Farid Khan (1994, 83) as the "study of modern (contemporary) and traditional processes which result in specific phenomena which might also be observable archaeologically", is more accurate in describing the focus of the ethnoarchaeological research presented in this dissertation, which is concerned with both method testing and taphonomic observation.

The use of ethnoarchaeology for direct analogy purposes has been highly debated in archaeology. Critique has focused on the application of functional models derived from ethnographic studies to archaeological data, challenging their failure to address indications of change and variation in the archaeological record, and overlooking agency and gender issues (Denbow 1986; Hall 1986; Lane 1998). The rise of the field of ethnoarchaeology as a product of processual archaeology, in particular its use of Middle Range Theory, created much resistance as part of more general post-processual critique in archaeology during the 1980s (Fewster 2006). Middle Range Theory, a term introduced by Binford (1977), proposed the objective testing of hypotheses about past behaviour in order to create general truths that apply to every human society, an approach which embodied the essence of the objectivity-aspiring, positivist framework of New Archaeology that was rejected by post-processualists. An attempt by Hodder (1982) to reinvent ethnoarchaeology as a field that will conform to post-processualist aims, renaming it 'anthropological archaeology', tried to distinguish between different types of analogies which could be used for different situations. Hodder argued that simple comparisons are pointless, However, despite his effort, ethnoarchaeology lost popularity over the following decades.

Supporters of ethnoarchaeology assert that all archaeologists use analogy to be able to interpret the archaeological record, drawing upon personal experiences and information they have gathered during their lifetime in search of possible analogies as they try to make sense of the fragmentary remains they discover (David and Kramer 2001, 1). Without a reference of known and expected human behaviour, and a basic assumption of uniformitarianism, archaeological interpretation would not be possible. Since our cultural range is too limited to provide analogous material for archaeological case studies, and ethnographic descriptions often provide a limited view of material culture, there is a need for targeted ethnoarchaeological studies (David and Kramer 2001, 1-2). It is perhaps for this reason that this field of research has not been entirely abandoned by post-processual archaeologists, some opting for ways of conducting ethnoarchaeological studies using different types of analogy in line with Hodder's approach (Fewster 2006).

The use of ethnoarchaeological analogy, however, has always been diverse. One of the first and most well-known ethnoarchaeological studies is the work of Karl Heider (1967), who confronted archaeologists with their inability to truly conceptualise the rich variety of human cultures, and revealed how misleading our common sense and imprinted assumptions can be. Others 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 relationship between the social and the material spheres of human cultures.

David Clarke was cited as once saying "I like to keep my archaeology dead", perhaps reflecting a desire shared among many archaeologists to keep their subject of study at a 'safe distance' (David and Kramer 2001, 31). 'Dead archaeology' enables us to bestow our own interpretation on the archaeological record, often with little constraints from the fragmentary material. Its living sibling, ethnoarchaeology, serves as a 'reality check', allowing us to test our assumptions about human behaviour and culture. As with every archaeological investigation, ethnoarchaeology uses analogy to interpret remains of past behaviour. And as with every type of archaeological analogy, one must be clear about how it is used. While it is undeniable that human societies are too variable to apply uniformitarian principles cross-culturally, some analogies can be drawn between the present and the past when the connection or relevance between the subject and source of the analogy has been established (Hodder 1982; Wylie 1985). When testing the potential of geoarchaeological techniques, ethnoarchaeological analogy becomes fundamental for our understanding of past processes. Though the application of uniformitarian principles to human cultures is largely debatable, they can generally be applied to chemistry, biology and soil formation processes. It is through these natural sciences, or N-transforms in Schiffer's terms, that the ethnoarchaeological analogy used in this research aims to connect between the present and the past.

1.4.1. Making sense of human settlements

The significant contribution that ethnoarchaeological studies have made to understanding patterns of activity at anthropogenic sites is irrefutable. 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. Here he links the location of objects within the domestic unit of a nuclear family to social context rather than function. !Kung campsites are formed as a ring of huts which enclose a communal area where ceremonial activities and meat distribution take place. Household activities are carried out within nuclear family areas, which include indoor and outdoor spaces, and messy activities such as skin drying take place in a second communal area outside the hut circle. Social space, as well as considerations such as messiness, or the time of day dictating the location of shade, were the 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 campsites would be no more useful in the interpretation of the spatial trends at these sites than abstract speculations (Yellen 1977).

A very different emphasis on the cause of spatial patterning is presented by Binford (1983), who published some of the most cited works on the subject of hunter-gatherer mobility and subsistence around the same time as Yellen's account of the !Kung. Binford's (1978) 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. These studies have been applied widely to the study of activity areas at Palaeolithic sites (Audouze 1988; Guan et al. 2011; Koetje 1984; 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 campsites 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 analysis of this case study has 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 (O'Connell 1987).

The different approaches to spatial analysis provided by the ethnoarchaeological works outlined above demonstrate the power of such studies in shaping ideas about human societies, and at the same time advising caution when interpreting archaeological remains. The same caution should be advised when relying on ethnographic analogy, which ought to open up avenues of interpretation rather than limit these to universal models. The examples provided above also suggest that spatial patterning at anthropogenic sites can reveal a lot about human life there, from subsistence and daily routines to social structures, ceremonial events and cultural preferences.

1.5. Research aims and objectives

Drawing on the background, the research presented in this thesis aims to establish the potential of a dual phytolith-geochemical methodology for distinguishing activity areas within ephemeral archaeological sites. By applying this methodology to sites that are difficult to interpret because of their short-lived nature, it is hoped to gain information 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 will be validated through an ethnoarchaeological study of Bedouin campsites at Wadi Faynan in Jordan, and then applied to the excavated Neolithic sites in Wadi el-Jilat, Jordan, in order to test its efficacy on archaeological material (see figure 1.1. for the location of the sites). While this is the first and main focus of this research, the secondary focal point is of importance to this and future geoarchaeological research, and involves the study of formation processes that give rise to phytolith assemblages and geochemical signatures in anthropogenic soils. This will be approached through the analysis of Bedouin campsites that had been abandoned for various lengths of time (from 6 months to approximately 15 years).

Finding and testing new approaches for studying the use of space in ephemeral sites is of particular importance to understanding the Neolithic communities of the Near

East. The Neolithic is a key phase in human history, well known for the socio-economic and cultural processes that characterise the transition from hunter-gatherers to sedentary farming communities. As human occupation is often ephemeral during this period, evaluating the use of signals of activity through phytolith and geochemical analyses will help us apprehend which methods are useful in studying such sites, how they can be applied to maximise information about social use of space during the Neolithic, and inform research agendas and sampling strategies for future work. In this sense, while this study is essentially a methodological one, it is applied and developed in the context of a specific archaeological problem, dealing with the transitory campsites that were used by the (semi-)mobile communities of the Neolithic in the Near East.

<u>The aims of this project are to:</u>

1) Evaluate the potential of a dual phytolith and geochemical methodology to identify activity areas in ephemeral ethnographic and Neolithic occupation areas. This aim includes the assessment of each of the analysis techniques and exploring statistical methods to combine the two sources of information in the most effective way.

The first aim will address the following research questions:

- Can activity areas at ephemeral anthropogenic sites be distinguished through the use of geochemical and phytolith analyses?
- How do the two methods compare in terms of their efficacy and type of information they provide?
- How can the two methods of soil analysis be combined in order to achieve the best understanding of the use of space at ephemeral sites?

2) Achieve a better understanding of how soil signatures are degraded through time in highly dynamic environments by examining taphonomic trends at ethnographic sites that have been abandoned for varying lengths of time, and through observations made about the preservation of soil signatures at the sampled Neolithic sites.

The second aim will address the following research questions:

- Do soil signatures of activities preserve in ephemeral sites well enough to enable the interpretation of activity areas?

- ❖ What observations about the taphonomic processes involved in element retention in soils can be made when the geochemical signatures of Bedouin campsites, which were abandoned for varying lengths of time, are compared?
- ❖ What can the analysis of the ethnographic and archaeological soil samples in this research inform us about sampling strategies for phytolith and geochemical spatial studies at ephemeral sites?

In order to achieve these aims a set of three objectives have been defined:

1) To analyse 90 soil samples from ethnographic sites for their geochemical and phytolith content. The samples were taken from various activity areas within seven Bedouin campsites at Wadi Faynan, Jordan, which were either occupied at the time of sampling or abandoned for different periods of time.

> This will be done in order to determine: a) if samples sharing similar phytolith and/or geochemical trends can be grouped according to specific anthropogenic activities; b) if the phytolith and geochemical signatures correspond to one another in relation to their context (*i.e.* kitchen assemblages have a typical geochemical *and* phytolith signature); c) how phytolith and geochemical assemblages are altered through time by taphonomy in anthropogenic soils. The latter will be aided by the variation in time since abandonment for each Bedouin campsite.

2) To analyse 70 soil samples from the Neolithic sites of Wadi el-Jilat, Jordan, for their geochemical and phytolith content.

> This will be done in order to test the efficacy of a dual phytolith and geochemical methodology to study Neolithic sites and achieve a better understanding of taphonomic issues related to phytolith and geochemical soil signatures.

3) To statistically explore the results of the dual methodology using boxplots, PCA scatterplots, discriminant analysis, decision trees and a Bayesian model.

> This will be done in order to find the best way to combine the information from both analysis techniques to achieve a better identification of activity areas in ephemeral sites.

1.6. Summary and layout of thesis structure

This introduction chapter has discussed the rationale behind exploring a dual phytolith-geochemical methodology to study the distribution of activity areas at ephemeral sites, and developed specific research aims and objectives for this thesis, which will be established through the application of the dual methodology to soil samples from ethnoarchaeological and archaeological sites. In the following chapter an overview is given of the two analysis methods used in this research, phytolith analysis and geochemistry, and their previous application for spatial analysis in archaeological studies. The third chapter introduces the ethnographic material, including descriptions of the Bedouin campsites at Wadi Faynan. In the fourth chapter the archaeological data is presented, which comprises three of the Neolithic sites of Wadi el-Jilat. The methodology of the analysis of the ethnographic and archaeological data is outlined in chapter 5, which is followed by the results of the phytolith analysis in chapter 6 and those of the geochemical analysis in chapter 7. Chapter 8 discusses the results of both analysis techniques for each context or activity area category, in order to assess how well the dual methodology works for every one of these. This is followed by a final discussion of the findings of this research in chapter 9, and the conclusions in chapter 10.

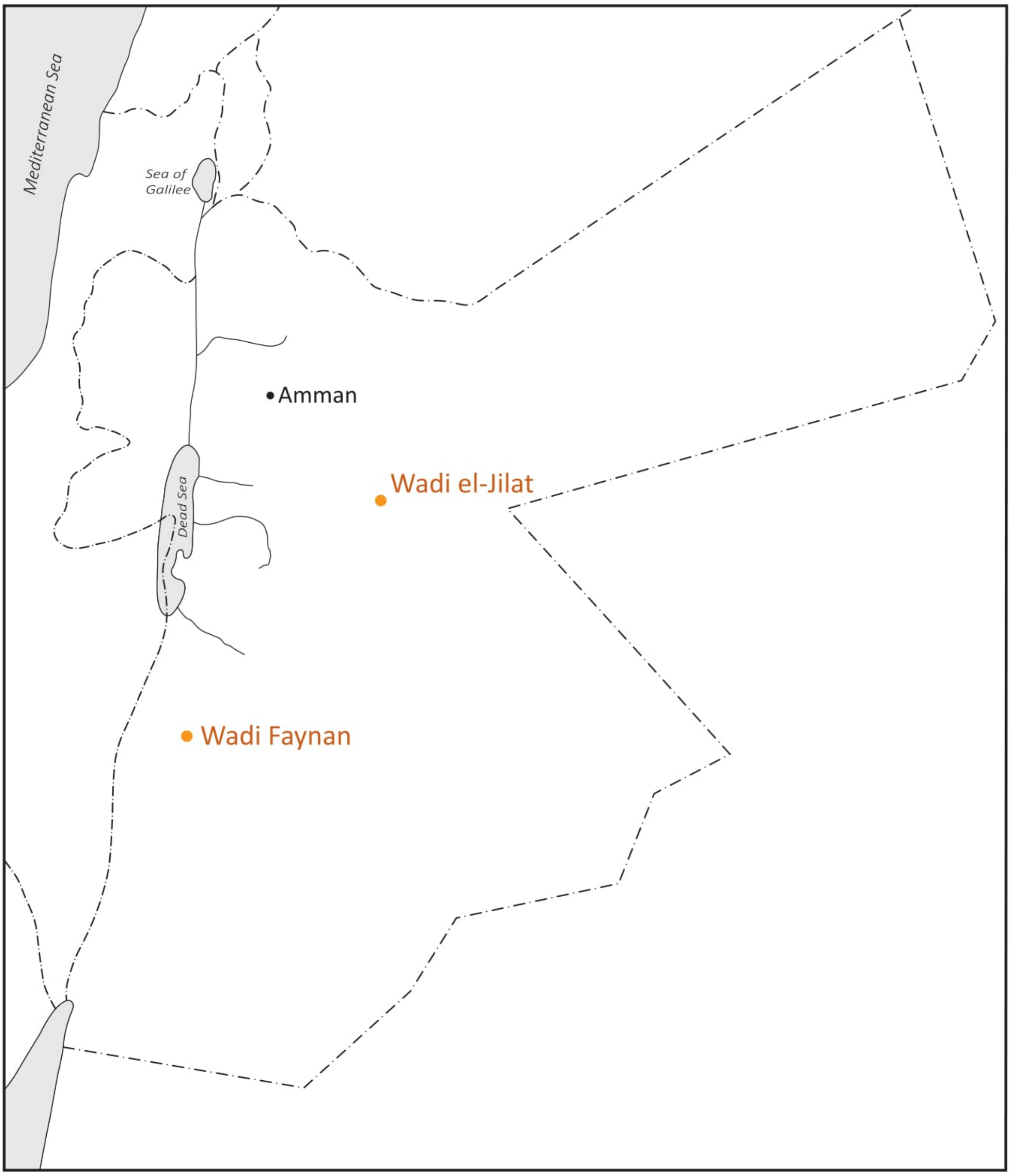


Figure 1.1. Map of Jordan showing the location of Wadi el-Jilat and Wadi Faynan (created by the author).

2 Phytolith and geochemical studies in archaeology

2.1. Introduction

This chapter will discuss the background to the methods used in this research, phytolith and geochemical analyses, and their application to interpret the use of space in archaeological case studies. A general overview of each method is given, followed by a summary of selected studies applying the technique to ethnoarchaeological or archaeological data in order to improve the applicability of these methods for reconstructing past patterns of activity areas and to achieve a better understanding of the studied sites. The last section will review the publications combining phytolith and geochemical analyses for spatial reconstructions to date, followed by a general discussion.

2.2. Phytolith analysis in archaeological studies

2.2.1. Introduction – phytolith creation within plants

The word phytolith is generally used to describe all mineral deposits within plants, however the term is used in archaeology predominantly to describe opal or amorphous silica representations of plant cell structures. The latter are formed when soluble silica from groundwater, monosilicic acid Si(OH)4, is absorbed by plants by either active or passive transport through their vascular system (Barber and Shone 1966; Jones and Handreck 1967). As monosilicic acid travels through the plant it becomes deposited in the solid form of silicon dioxide (SiO_2). The deposition occurs either within plant cells or in the spaces between the cells (Carnelli et al. 2001; Piperno 2006). Once silicon dioxide has been deposited in the plant, it forms a representation of the plant cell structures.

Different species vary in the amount of silica they absorb, and the areas of the plant where the monosilicic acid is deposited. The uptake and deposition of silica in plants can be controlled by genetic and physiological mechanisms. However, many external factors influence silica uptake in plants, such as environmental conditions, climate, soil type, age, plant taxa, and even irrigation, as water availability during plant growth can affect phytolith production (Hutton and Norrish 1974; Jones and Handreck 1967; Jones and Milne 1963; Madella et al. 2009). Both modes of phytolith creation may be active in different areas of a single plant simultaneously, and can influence the amount of phytoliths and even the number of different types produced (Piperno 2006; Rosen and Weiner 1994).

As silicon dioxide retains the shape of the structure in which it has been deposited, an identification of the original cell structure can be reached when phytolith are retrieved from the sediment. Studying phytoliths can provide much information regarding the family, genus, or in some cases even the species of the plant. In addition, because phytoliths are known to form in all parts of the plant, such as the leaves, stems and husks, these can also be identified as different areas are comprised of varying cell shapes (Piperno 1988).

2.2.2. Phytolith deposition and preservation within archaeological soils

The deposition of phytoliths into sediments can occur in a number of ways. The most common of these takes place when a plant decays, thereby releasing its phytoliths into the soil. Phytolith deposition might also occur following the burning of plant material, or through indirect carriers such as animal dung and windblown dust. While the latter provide instances in which phytoliths may be carried over a considerable distance, in most cases a local deposition is to be expected following *in situ* plant decay (Fredlund and Tieszen 1994; Piperno 2006).

In addition to the predominantly *in situ* accumulation of phytoliths, their good preservation in comparison to organic plant remains makes their analysis a valuable tool for archaeologists searching to answer a range of research questions. Due to their inorganic nature phytoliths do not require special conditions in order to survive in the archaeological record as is the case with other botanical remains, which must be charred, desiccated, mineralised or waterlogged (Van der Veen 2007). However, they can dissolve after being deposited in the soil when pH levels are higher than 9.0 (Piperno 2006). Other agents of destruction include bioturbation, wind, erosion, and compression (Madella 2000). A study by Cabanes et al. (2012) suggests that the initial amount of available silica and the depth of burial will have an impact on the chemical dissolution (diagenesis) of phytoliths in archaeological sites. Pitting and breakage patterns visible on phytoliths can be used to indicate their poor preservation, but severe dissolution will result in their absence (Cabanes et al. 2012; Madella 2000). In addition to the conditions of the depositional environment, characteristics of the phytoliths themselves contribute towards their preservation. The degree of silicification, shape, and surface area all influence durability, and there is evidence to suggest that phytolith dissolution rates vary among different plant taxa and even within a single plant (Bartoli and Wilding 1980; Piperno 2006; Wu et al. 2013).

In most settings however, phytoliths have a high rate of survival. The climatic conditions widespread in the Near East in particular provide a good environment for phytolith formation and preservation. This is due to the dry conditions in this area, leading to high rates of evaporation that contribute to silica consolidation in the plant cell and a lesser degree of loss of phytolith material in the soil through water seepage (Hillman 1984).

2.2.3. Phytolith identification

The phytolith identification process separates two general levels of classification: multi-celled or conjoined forms and single-celled phytolith forms. While the latter represent a single plant cell and can rarely lead to identification beyond the genus level, multi-celled phytoliths can be composed of several types of single phytoliths which are conjoined. These larger plant segments will often allow for the specific plant species to be recognized. Nevertheless, both forms contain useful information. Single-celled phytoliths can be classified according to their morphologies, which often link to different plant parts (for example husks or leaves) and can thereby indicate patterns of plant use (such as plant-processing). In addition, both multi- and single-celled phytoliths can distinguish between two groups of plants: monocotyledons (monocots) and dicotyledons (dicots). Monocots refer to flowering plants having a seed that contains one embryonic leaf and includes grasses and cereals, while the term dicots describes flowering plants whose seed holds two embryonic leaves and typically consists of more 'woody' plants such as shrubs and trees (Chase 2004; Cronquist 1981). Monocot plants produce more phytoliths than dicots, and generally produce more distinguishable phytolith forms which are more readily classified than dicot phytolith types. By adding up the information from a variety of phytolith forms and morphologies within a sample, a profile of plant use at a site can be created.

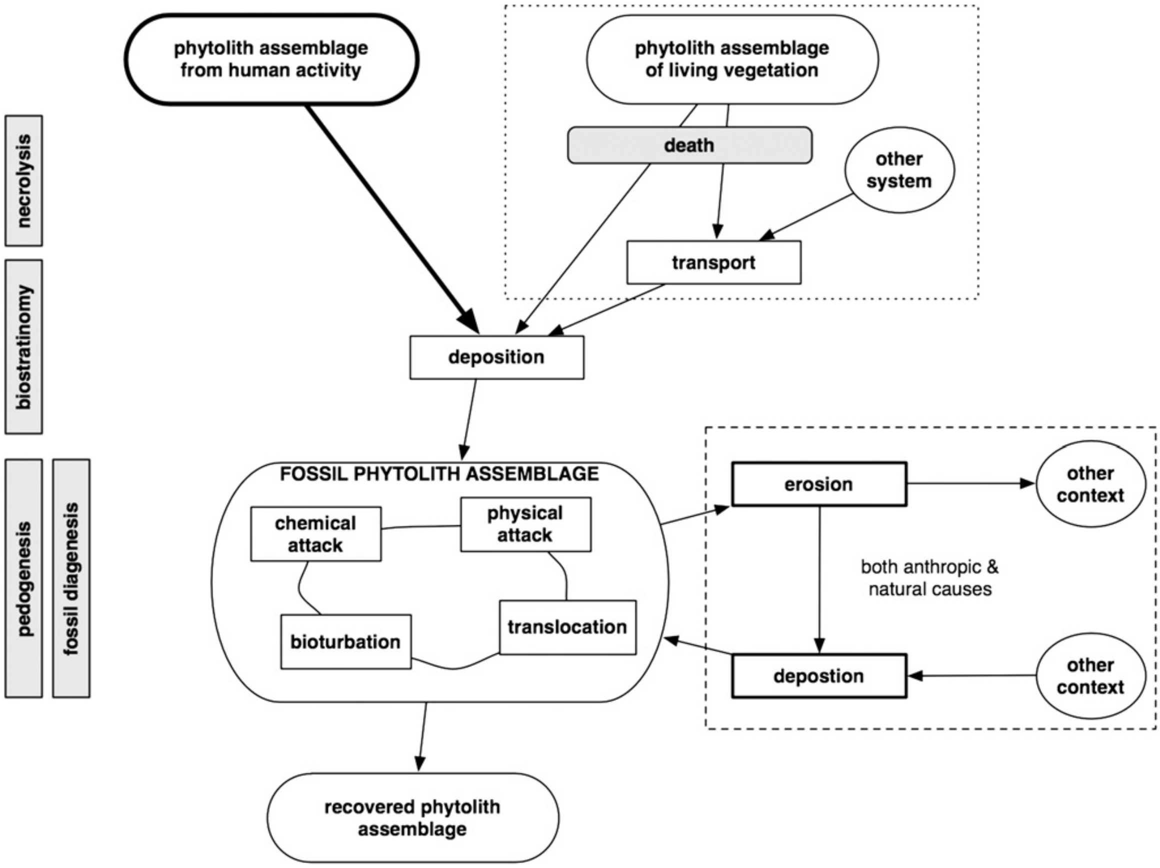


Figure 2.1. Theoretical diagram of the depositional and post-depositional processes of phytoliths in anthropic deposits (from Madella and Lancelotti 2012, 81).

2.2.3.1. Terminology

Phytolith terminology has been a topic of much discussion among specialists in recent years, as unlike other microfossils (such as pollen) phytoliths did not enjoy a universal system of classification until the publication of the International Code for Phytolith Nomenclature in 2005 (by Madella et al. 2005). Even now, more than a decade after the International Meeting on Phytolith Research (IMPR) in Brussels where the phytolith nomenclature was proposed, discussions surrounding the phytolith terminology are still the main focus at the IMPR meetings and the nomenclature is not used universally.

The differences in phytolith naming among institutions can cause confusion as the same name might be applied to different morphologies, or the same phytolith morphology could be given different names. It is for this reason that a pictorial overview of common phytoliths is often given. A pictorial overview of the phytolith morphologies used in this thesis is provided in Appendix 1.

2.2.4. Phytolith analysis in archaeological studies

In recent years, the use of phytoliths for spatial differentiation of archaeological activities has seen an increase in popularity, new methodologies and successful applications to ethnoarchaeological material having contributed to their applicability. Since many human activities at domestic sites are accompanied by the *in situ* deposition of certain kinds of plant material, studying the remains of these can reveal spatial activity patterns through the quantification and morphological identification of phytoliths morphotypes (Cabanes et al. 2010; Portillo et al. 2009; Tsartsidou et al. 2009).

2.2.4.1. General phytolith studies

Initial phytolith studies within archaeology were mainly concerned with the following four areas of investigation: a) identification of cultivated grasses, b) economic use of plants, c) the function of pottery and stone tools, d) the reconstruction of near-site environments. Following the introduction of phytolith analysis to answering archaeological research questions in the 1970s, studies concentrated on cereal types that played a prominent role during plant domestication, mainly in the New World (Pearsall 1978; Piperno 1988). There, the phytoliths of maize crops and other cultivated grasses, tubers, seed plants and fruits were studies in order to identify the early use and domestication of plants. Phytoliths were mainly extracted from archaeological sediments, and their study was complemented by the exploration of starch grain from grinding stones. Phytolith research in the Neotropic ecozone provided an understanding of the history of human exploitation of crops such as maize, squash, manioc and arrowroot in this early center of domestication (Dickau 2005; Pearsall et al. 2004; Piperno 2006).

Work undertaken in another early center of domestication, southwest Asia, shares the same concern with early plant domesticates – mainly wheat and barley. Here emphasis was laid on structures of conjoined phytoliths, which enabled individual grass species to be recognized, because a combination of attributes can be found in these multi-celled "skeletons" that together provide a more secure identification (Rosen 1992). A study by Rosen and Weiner (1994) found that irrigation results in an increase in the amount of individual cells that are conjoined, which could mean that intentional farming of crops may be distinguished. However, taphonomic and other factors that can lead to the breakdown of conjoined forms need to be further explored through more experimental work, as suggested by a taphonomic study by Shillito (2011). Jenkins' (2009) duplicate processing of samples using three methodologies demonstrated that the extraction method can influence the presence and size of conjoined phytoliths, either by breakup or fusion of phytoliths during the process.

2.2.4.2. The use of phytolith analysis for spatial reconstructions

The use of phytolith material to reconstruct ancient spatial patterns of activity has several advantages above other proxies of organic material:

- Phytoliths often represent *in situ* deposition
- The preservation of phytolith material is usually better than organic remains, especially in areas of arid conditions
- Phytolith analysis enables distinctions to be made between different plant parts

As such, phytoliths are increasingly being used to inform archaeologists about ancient activities taking 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 recognized by using a suite of micromorphological, mineralogical and phytolith analyses. However, small gates and house floors could not be identified using these techniques. They suggest that together with information from features such as post-holes, artifact 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 spatial oriented phytolith analysis. Tsartsidou et al. (2008, 2009) conducted phytolith analyses on both ethnographic and archaeological material. The study of an agro-pastoral village in Greece, Sarakini, provided an indication that phytolith analysis may be a useful tool to distinguish activity areas at archaeological sites representing various subsistence strategies. Indoor and outdoor areas, including related features and construction materials, were sampled from four houses, three barns, a water mill and a smith's house. The team used an index of the amount of differentiation between phytolith morphotypes (which was named PDI) in each locality alongside the quantification of phytolith concentrations represented by the number of phytoliths per gram in each sample. This was later augmented by a detailed analysis of the phytolith types. The method has proven successful for the analysis of the village, allowing the researchers to differentiate between the dung of different animals and to identify animal enclosures, food storage areas and floors, although distinguishing between storage, processing and floor surfaces was occasionally made difficult by secondary use.

Phytolith analysis was also conducted at Makri, a Neolithic site in Greece, focused on various areas within the settlement including sampling floors, an open area and various constructions. The team found that phytolith diversity was lower at this site than at Sarakini, and attributed this to the scarcity of dicot leaf material. Indoor and outdoor spaces could not be separated based on their phytolith assemblage, indicating, according to the authors, that sediments from outdoor areas were used in the construction of the indoor floors. Only one series of floor surfaces contained phytoliths that may reflect *in situ* activities, probably food storage or processing. The interpretation of Makri was not made easy by the proposed subsistence at the site, which included wheat and barley cultivation used for both human and animal consumption. The presence of spherulites at several locations, however, did enable the researchers to distinguish dung related deposits, illustrating that a combination of methods might be the best approach to refining the results of spatial analyses.

A study of phytoliths and spherulites by Portillo et al. (2009) demonstrated that certain areas of the PPNB site Ayn Abū Nukhayla, Jordan, contained evidence of the processing of cereals, while others were used as animal pens. High concentrations of dung spherulites in the latter, and the large presence of inflorescent parts of festucoid grasses in areas where grinding stones were found, enabled the excavators to infer the locations of these two types of activities. A later study by Portillo et al. (2014) used the same methods, phytolith and spherulite analyses, to interpret the distribution of activity areas at Neolithic Tell Seker al-Aheimar, Syria. They complimented the archaeological investigation with ethnoarchaeological research into dung and agricultural remains from domestic structures nearby the site, which aided the interpretation of combustion and construction residues. The combination of phytolith and spherulite sources of information allowed the researchers to differentiate between plant material that was introduced into the building from dung and non-dung sources. They suggest that the distinguished areas may relate to domestic behaviors such as cereal exploitation, storage, cooking, crop-processing and food preparation activities.

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 later study at Tel Dor incorporating macro- and microarchaeological techniques enabled the authors to distinguish between roof, wall and floor materials within a destruction layer and provide a reconstruction of the sequence of this event (Namdar et al. 2011). These studies illustrate the importance of geoarchaeological methods in interpreting spatial patterns within archaeological sites.

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.

2.2.5. Summary

Archaeological applications of phytolith analysis have expanded in the past two decades. While at first research was focused on the identification of past environments and cultivated plants, today phytoliths are increasingly used as indicators of spatial activity patterns. Phytoliths are suitable for reconstructions of past spatial behavior because many human activities involve the use of plant material, such as construction, food preparation and storage, animal husbandry, and burning. Phytolith analysis can identify both plant types and parts, and the weight percent of extracted material and the number of phytoliths per gram of sediment are good indicators of the intensity of activities. This having been said, spatial reconstructions that are only based on phytolith material are rare and suffer from problems of equifinality. Phytolith characteristics of activities vary across sites due to the variation in the use of plant material which is affected by the available vegetation and human practices and preferences. In order to overcome issues of equifinality and ambiguity, phytolith analysis is often combined with other analyses such as spherulites, micromorphology, minerology, or artifact distributions.

2.3. Geochemical analysis of anthropogenic soils

2.3.1 Introduction – soil formation

The properties of soils are considered to be determined by five factors: parent material, topography, climate, biota and time (Dokuchaev 1898 cited in Jenny 1980, 203). A combination of these background conditions may trigger certain physical, chemical and biological soil formation processes such as additions, losses, transformations and translocations, which dictate the condition and attributes of the soil. Theoretically one could describe and quantify all of the factors influencing soil formation and predict the resulting soil profile. In reality, however, the complexity of soil formation processes inhibits such efforts, let alone attempts to reconstruct the history of factors and formation processes affecting a given soil profile (Van Breemen and Buurman 1998, 8).

The chemical properties of soils are affected by soil formation processes influenced by the five factors mentioned above. The physical property of the soil refers to the arrangement and proportions of mineral soil particles of different sizes, which are a result of the physical and chemical breakdown of rocks and minerals. The attributes of the soil particles are affected by the parent material of the bedrock, while topography and climate influence the weathering processes forming the particle size and arrangement such as erosion and deposition by water, ice or wind. Chemical weathering can continue the decomposition of rock fragments and change the chemical composition of the soil through processes such as hydrolysis, hydration, carbonation, solution and oxidation-reduction. The physical properties of the soil influence water movement and the sequestration of chemical elements in it (Gardiner and Miller 2004; Van Breemen and Buurman 1998). Biological activity in the soil is dependent on the physical, climatic and chemical conditions of the soil. The term soil biota includes flora, fauna, and microorganisms, which affect soils by different processes such as the addition and breakdown of organic matter, translocation of organic or inorganic material as a result of bioturbation, eventually changing the structure and porosity of the soil (Sylvia et al. 1998).

The attributes of the soil and the processes affecting it dictate the retention and loss of chemical elements. The changes resulting from soil formation processes are generally slow. However, exposure to certain climatic and physical conditions or anthropogenic impacts can speed up certain processes. Most rapid processes are not considered part of soil formation, and soil conditions may revert back to their original state depending on the nature of the processes involved (Mulder and Cresser 1994; Van Breemen and Buurman 1998, 7). The following section will introduce the study of geochemical anthropogenic anomalies in archaeology and discuss how researchers have tried to use these to reconstruct human past behaviour.

2.3.2. Geochemistry of anthropogenic soils

The archaeological perspective of soil chemistry can be defined as "the enrichment or depletion of certain elements in the soil through the act of human occupation" (Oonk et al. 2009a, 36). The accumulation of anthropogenic matter in human settlements leaves traces in the composition of soils, which are anomalous in comparison to natural soils (Oonk et al. 2009a). Human activities deplete the levels of macro plant nutrients such as N, P, K, Mg and Ca in soils and sub-sediments through the removal of vegetation, and the same elements are added to soils in habitation areas by the deposition of food, human and animal waste. Similarly, micronutrients such as Fe, Mn, Zn, Cu, B and Cl and trace amounts of metals and hydrocarbons can be added to soils through human activity, mainly those involved in processes of production and burning (Rapp and Hill 1998). These changes become fixed in the soil through various biogeochemical processes, such as adsorption, occlusion, coprecipitation, chelation and microbial fixation, and can be preserved in the anthropogenic sediments that form part of the archaeological record. As mentioned in the previous section, the extent and rate at which this occurs depends on various factors including the nature and condition of the parent material, climate, topography, vegetation soil fauna, and time (Haslam and Tibbett 2004; Rapp and Hill 1998).

The application of soil chemistry to archaeological sites is often used to locate and delineate settlements, refuse areas, graves, agricultural plots and production areas. It can also be applied on a site level to obtain a better understanding of stratigraphy and sedimentology, or help interpret the distribution of activity areas and features (Oonk et al. 2009a; Wilson et al. 2008). Recently, geochemical studies with the aim of identifying the functions of sub-areas within sites are becoming more popular (López Varela and Dore 2010; Vyncke et al. 2011). The simultaneous identification of geochemical elements in archaeological sites is easily achieved with modern analytical tools such as Inductively Coupled Plasma (ICP) or X-ray Fluorescence Spectrometer (XRF) instruments and is considered to reflect the complex interactions between a variety of human and natural factors, which form anthropogenic sediments (Middleton 2004).

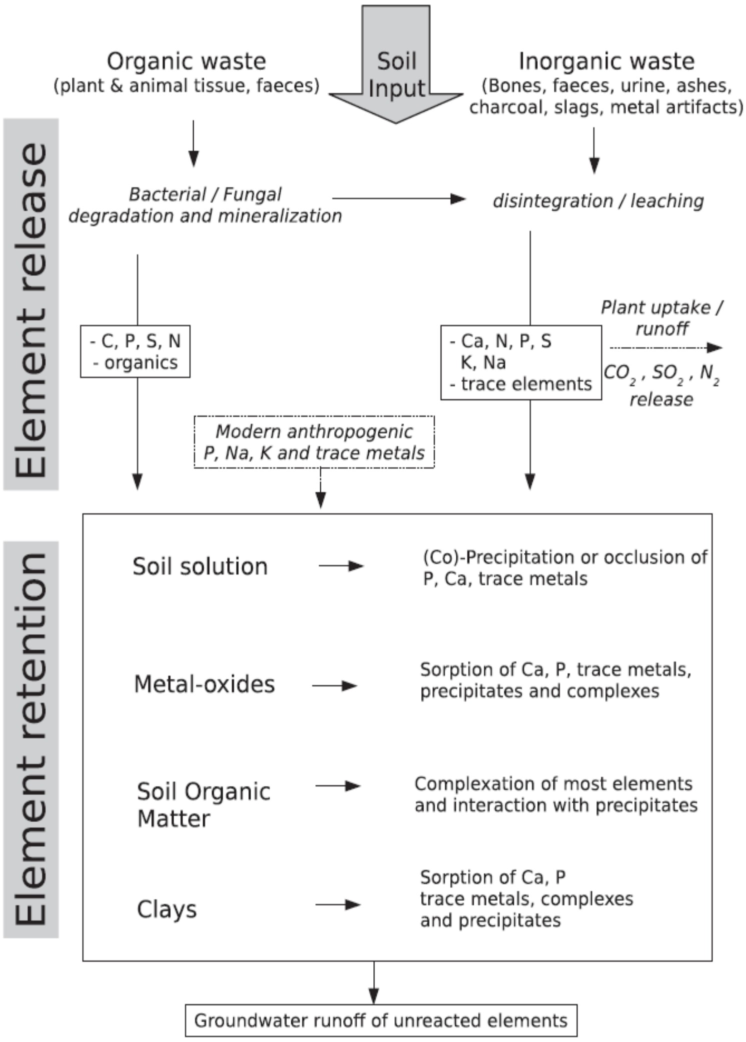


Figure 2.2. An overview of anthropogenic inputs and basal geochemical processes with respect to element release and retention in archaeological soils (from Oonk et al. 2009a, 39). This diagram illustrates the diversity of geochemical processes leading to the release and retention of chemical elements in soils altered through anthropogenic activity.

2.3.2.1. Concerns regarding the application of geochemistry to archaeological sites

Although geochemical analysis has a long history of use in archaeology (see section 2.3.3.), it has yet to gain a wider acceptance within the archaeological community (López Varela and Dore 2010). The main reasons for this are the unresolved issues regarding the correlation of the geochemical signatures to anthropogenic activities, problems regarding the 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. 2009a), and the process of the laboratory analysis itself which is relatively expensive and carries with it safety concerns (Frahm and Doonan 2013). While the introduction of new laboratory techniques and more affordable instruments (such as the portable XRF, which will be discussed in chapter 5) are expected to ease the incorporation of geochemical techniques in archaeological investigation in the future (Frahm and Doonan 2013), there are still many uncertainties involved in the interpretation of these complex soil signatures.

One of these issues is equifinality, where different processes may lead to the deposition of the same element(s) in the soil. For example, the presence of phosphorus can be correlated to the presence of various organic materials, such as bone, organic matter or ashes. In addition, similar practices may result in different outputs over time, if deposited under different circumstances. Another issue that can affect the interpretation of soil chemistry in archaeological studies is the influence of modern anthropogenic inputs on soils, which can be difficult to distinguish from ancient ones and obscure element concentrations. Beyond the intermixing of ancient and modern chemical inputs, farming activities can have a strong influence on soil chemistry through the input of heavy metals, and ancient and modern ploughing can affect element loadings (Oonk et al. 2009a).

Our knowledge of the processes behind the creation of archaeological soil signatures, and how these are influenced by taphonomic processes through time, is currently limited to differentiation into broad categories. Results of geochemical studies of archaeological soils often show great variation in their elemental composition, which may either be derived from the method used or represent a variation in environmental, geochemical or archaeological conditions (Oonk et al. 2009a). Nevertheless, geochemical investigations of archaeological sites can be a very useful, and sometimes necessary tool to understanding the past use of space. Although many occupational and production sites comprise features and artefacts that are indicative of their use, others, such as agricultural or ephemeral sites, are more difficult to interpret. The latter can benefit from the characterisation of their soil chemistry, which can add information about ancient practices and help define site perimeters (Middleton 2004).

2.3.3. Geochemical analysis in (ethno-) archaeological studies

The application of geochemistry to archaeological research questions goes as far back as the 1920s when Arrhenius correlated an elevation in P levels with prehistoric human occupation (Arrhenius 1929). Although elements such as Ca and Mg were experimented with throughout the twentieth century, until recently archaeological studies of soil chemistry have been mostly limited to the use of phosphorus, mainly for site prospection purposes (Middleton and Price 1996; Middleton 2004). The advantages of phosphorus are that it is a relatively stable soil component, and is correlated to the presence of organic tissues and bone, urine, ash and faeces, which makes it a key indicator of occupation deposits (Entwhistle and Abrahams 1997; Oonk et al. 2009a). However, when it comes to differentiating activity areas within sites, P alone is less helpful for the same reason it is used for prospection, as it is related to too many human activities. In addition, there is still uncertainty regarding the soil processes leading to P retention in different settings, and this element was found to be an unreliable indicator of anthropogenic activity in some cases (Entwistle et al. 1998, 2000).

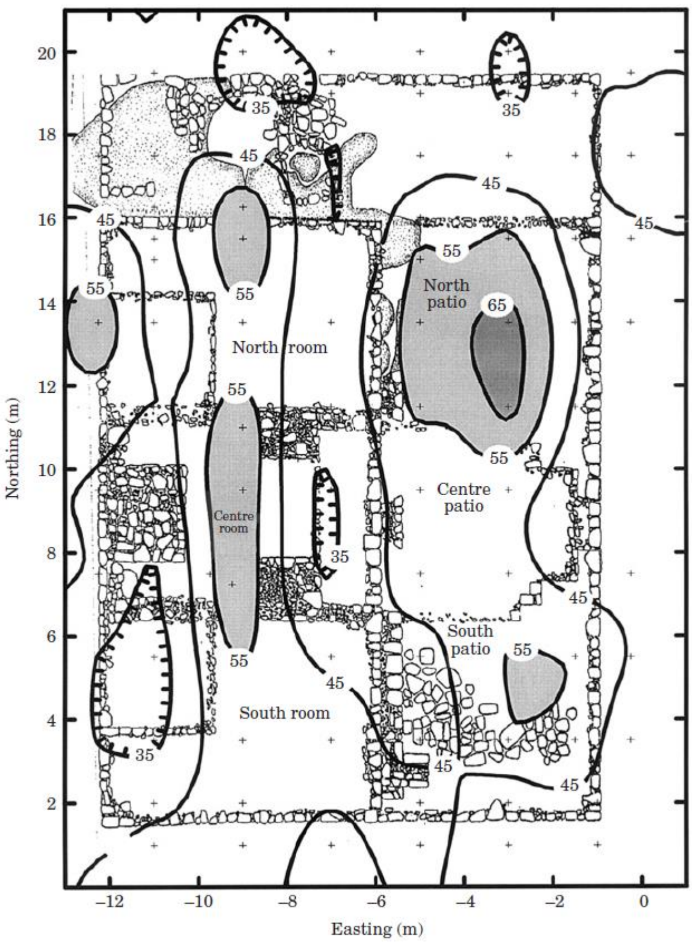


Figure 2.3. Concentrations of extractable phosphate for structure U-16 at Piedras Negras represented by isopleth lines (Parnell and Terry 2002, 386).

In order to solve these issues more recent geochemical studies aimed at identifying activity areas use combinations of several geochemical elements in addition to phosphorus, which can often be correlated to specific types of activities (Middleton and Price 1996; Oonk et al. 2009a; Parnell et al. 2006; 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 elements, and that household, production and even ceremonial practices can be distinguished. Wells et al. (2000), in a study of the Classical period Mayan centre of Piedras Negras, Guatemala, found that high P concentrations are a good indicator of kitchen middens while an abundance of heavy metals can represent a workshop or craft area, or ceremonial activities.

A later investigation at the same site (Parnell and Terry 2002) was able to indicate both areas of food preparation and craft production based on the patterns of extractable phosphate and trace and heavy metals distributions, which also revealed the outlines of the roofed area and evidence of sweeping patterns (figure 2.3.). These were not detectable by other means such as artefact distribution or architectural remains, and the geochemical analysis was able to refine the archaeological interpretation of the site, fine tuning patterns observed during excavation. At the same time however, it became clear that the interpretation of these element concentrations is more often than not equivocal, even when a suite of elements is tested.

2.3.3.1. Ethnoarchaeology comes to the rescue

One approach to 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 ethnographic analogies to our understanding of geochemical signatures and the activities that produce these (Fernandez et al. 2002, 488; King 2008, 1225; López Varela and Dore 2010). A geochemical study of a modern household in Oaxaca, Mexico, by Middleton and Price (1996) was able to distinguish floors and hearths from the natural ground surface in a modern house compound in Mexico. The kitchen area was characterized by elevations of K and Mg, derived from wood ash, and P. The higher levels of Ca, Na and Sr in other interior spaces though were

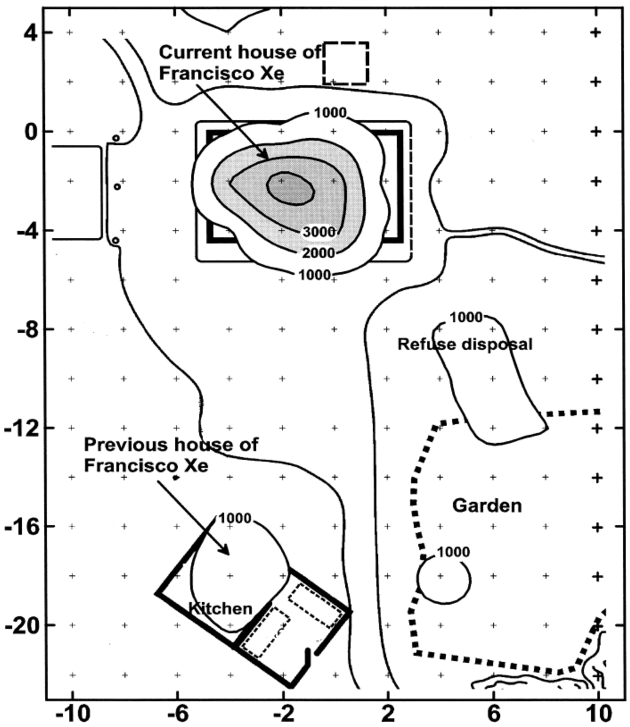


Figure 2.4. Potassium concentrations (mg/Kg) in Francisco Xe's house lot, represented by isopleth lines (Fernandez et al. 2002, 506). The highest enrichment was found in the contemporary residence.

unclear and thought to have derived from the use of lime in the preparation of a dough used for tortillas and tamales. Fernandez et al. (2002) studied the spatial distribution of chemical elements in soil samples from a house in Las Pozas, Guatemala, of which the authors possessed detailed information about its use. This allowed them to interpret the observed geochemical patterns to a high degree, and correlate these to patterns of behavior at the site. Elevated concentrations of K, Mg, Ca and Na in addition to high pH levels was correlated to cooking hearths and food preparation, and food consumption had enriched the living room floors with P, K and Mg while levels of pH remained low. An increase of P and Zn levels in certain localities correlated to refuse areas, and the pathways and patios were low in P and trace elements because they were swept and kept clean. Although detailed information was available for the studied buildings, some patterns remained enigmatic, such as the distribution of the heavy metals Cu, Hg and Pb. This suggests that ethnoarchaeological application alone might not be able to provide a conclusive base of knowledge for anthropogenic geochemistry.

A different approach by Wilson et al. (2008) provided a better understanding of how soil geochemistry can be understood across sites with a different geological background by evaluating previous studies and analysing soil samples from six farms in the UK that had been abandoned between the late 1800s and 1940. At each farm samples for multi-element analysis were taken from areas related to specific known activities such as hearths, byres, middens, gardens, fields, kitchens and off-site references, in addition to auger samples taken across one meter grids. They discovered that some elements were more influenced by site conditions, such as Ti, Ni and Fe, while others including Ca, Zn and P were only affected by them to a small degree. Certain generalized patterns of element enhancement did emerge from this study (figure 2.5.). It was observed that Ca concentrations were highest in the hearths and to a lesser degree in kitchens, and that byres contained the highest levels of P followed by hearths and kitchens. In addition, a combined stepwise discriminant analysis of four sites showed clear differentiations between activity areas that were not influenced by site conditions even though the background geology differs significantly among the studied farms. This suggests that certain elements are linked to certain types of human activity and are not affected to a large degree by the conditions of the parent material in most sites (Wilson et al. 2008).

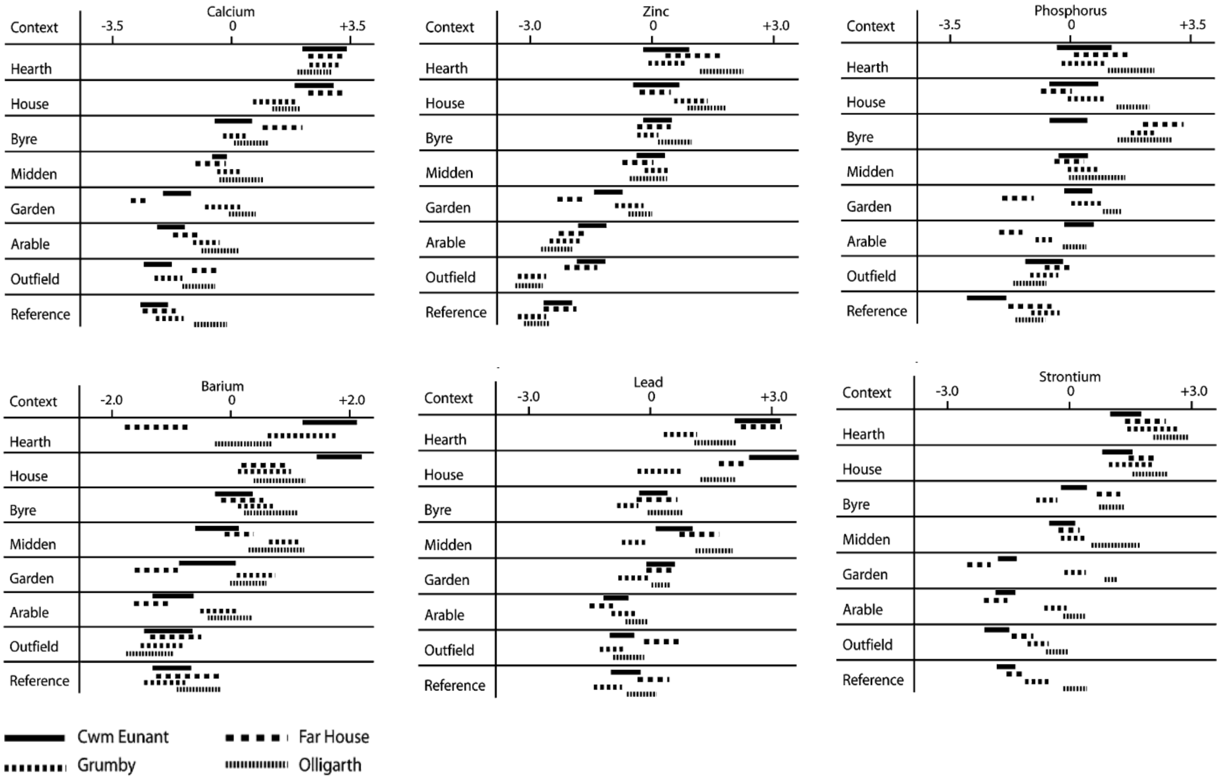


Figure 2.5. Comparisons of site and functional areas differences in a geochemical study of four abandoned farms in the UK (after Wilson et al. 2008, 417).

2.3.3.2. Geochemical studies incorporating ethnoarchaeological insights

The ethnoarchaeological observations discussed in the previous section 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 based on descriptions of these and other cases. Middleton (2004) 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.

Many of the sites examined through geochemical analysis were standing buildings with a clear division of space (Hutson and Terry 2006; King 2008; Milek and Roberts 2013; Terry et al. 2004). Some of these produced very comprehensive and convincing reconstructions, such as a study by Vyncke et al. (2011), who closely followed the work of Middleton (2004). They provided a division of a room in a Classical-Hellenistic at

Düzen Tepe, Turkey, into eight zones, each represented by a combination of measured elements. High values of K, Mg, Fe and P in one zone, which produced outliers within the PCA score for a first variable suggesting an external (anthropogenic) input, were explained as the result of *in situ* burning. The correlation of this signature with archaeological indications for the presence of a hearth in the same location provided additional support for this interpretation. They mention that several metals including Al, Zn and Ni were present in higher amounts in this zone because of their stability in basic sediments. Lower amounts of these in another zone which still enjoyed high levels of K, Mg and P, but included lower concentrations of Fe, suggested a secondary deposition of fire, characterized by a less basal character. In addition to these, elevations of P and Sr in a third zone were related to the remains of excrements, high levels of Ca, P and Sr in another zone to food preparation, and other zones which contained low or average concentrations of elements or ones that have no known correlation to human activity were interpreted as sleeping or high traffic areas.

2.3.3.3. Improving methodologies

As useful as ethnographic and experimental case studies are, the interpretation of many elements encountered in the process of the geochemical investigation of any site will remain equivocal (Canti and Huisman 2015). Each of the studies described in the previous sections, be they archaeological or ethnographic cases, reported chemical signatures that were incomprehensible. Oonk et al. (2009b) sought to improve the methodology used by archaeologists in an analysis of three Bronze Age and Roman sites in the Netherlands. They relied on off-site sampling, regional background comparisons, and used bivariate plots in order to improve the interpretation of the element concentrations across the sites. However, although this investigation managed to trace the anthropogenic versus natural enrichment and depletion patterns in the soils, the archaeological value of the geochemical patterns still relied on the known correlations achieved by previous ethnographic studies and carried the same limitations (for example the lack of anthropogenic source relating to Nd concentrations). The interpretation of these sites and the related soil processes influencing the geochemical patterns was improved by adding a suite of complementary tests, including mineralogical and microprobe analyses (Oonk et al. 2009).

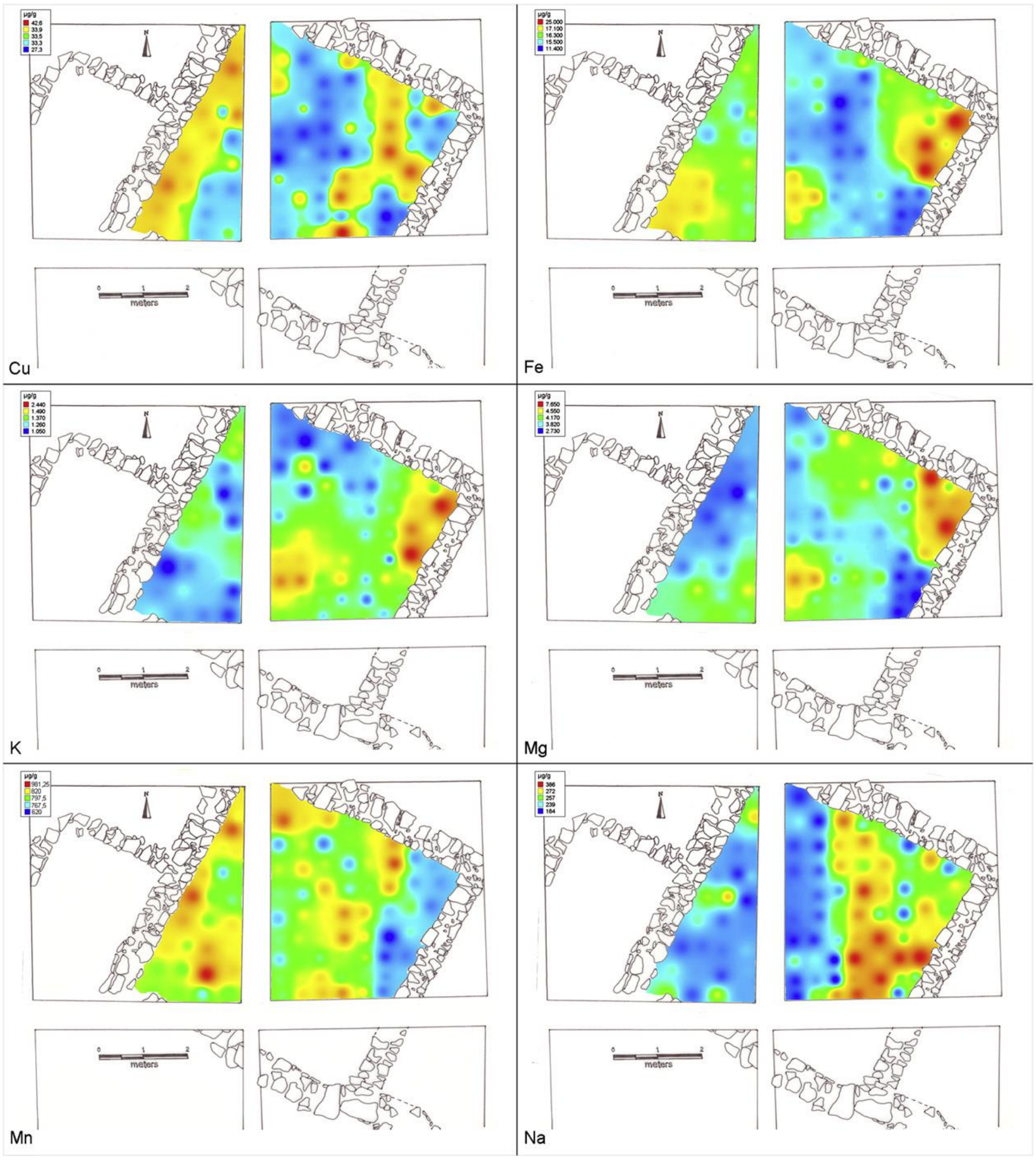


Figure 2.6. Visual representations of element concentrations in a room at Düzen Tepe (Vyncke et al. 2011, 2284).

The use of a combination of methods to interpret spatial activity patterns alongside multi-element mapping is becoming more widely used, and a multi-proxy approach is currently seen by some as essential to achieving fruitful results (Canti and Huisman 2015). The use of geochemistry in combination with micromorphology and pH and artefact distributions provided a powerful tool to interpret a Viking house in Iceland (Milek and Roberts 2013), multi-element site prospection in Sagalassos, Turkey, was aided by a geophysical and archaeological survey in order to identify the location of ceramic processing kilns (Dirix et al. 2013), lipid analysis was used to evaluate geochemical patterns in a reconstructed

Iron Age house in Leyre, Denmark (Hjulström and Isaksson 2009) and the importance of statistical analysis for spatial reconstructions is demonstrated by the use of geostatistics and spatial interpolations to refine the results of geochemical analysis at a modern household in India (Rondelli et al. 2014). Each particular case study might benefit from different aids to the geochemical interpretation, and ongoing experimentation with a range of techniques promise to achieve more refined reconstructions of the past use of space.

2.3.4. Summary

Soil chemistry is becoming a common tool with which archaeologists reconstruct the way in which ancient sites were used, allowing for *in situ* evidence of past activities to assist, and in some cases even guide, the interpretation of archaeological features and artefacts. While at first only distributions of P were explored, as techniques and equipment developed and ethnoarchaeological studies provided a better understanding of anthropogenic soil markers, multi-elemental analysis was increasingly relied upon. Nevertheless, geochemical analysis is still not widely used for archaeological purposes, and many issues regarding our limited knowledge of the correlation between chemical elements and human activities, soil processes influencing the retention of elements and problems of equifinality and equivocality must be dealt with in order to improve the application of this method.

Notwithstanding these issues, the studies discussed above demonstrate the value of geochemistry for our understanding of the use of space. Some of the problems regarding geochemical analysis of anthropogenic sediments can be resolved by increasing the amount of ethnoarchaeological and archaeological applications of this method, informing us about correlations between certain elements and human activities and exploring the taphonomic processes influencing observed patterns. Current efforts focus on the continuation of ethnographic and experimental investigations and finding new ways to incorporate a number of methods to refine the results of spatial analysis. In addition to further experimentation, the methodology involved in applying this technique can be improved. In what way can we best use the results of geochemical analysis? This research aims to address this issue alongside the application of the dual geochemical-phytolith methodology to anthropogenic sites.

2.4. Combined geochemical and phytolith spatial studies

2.4.1. Introduction

Experience from the documented cases above clearly shows that the use of multiple analyses to identify activity areas in archaeological sites has advantages over relying on a single method. It can fine-tune the results and allow for distinguishing between activities that produce similar patterns, such as the use of spherulites to distinguish input of vegetation associated with dung (Portillo et al. 2009). The following section will provide a brief overview of the use of a combination of geochemical and phytolith methods for spatial reconstructions of activity areas in archaeological sites.

2.4.2. Combined geochemical and phytolith reconstructions of activity areas

There have been very few published works dealing with research that integrates phytolith and geochemical analyses to reconstruct ancient spatial activity patterns, and the first combined studies relied on a limited range of chemical elements alongside the phytolith analysis. Sullivan and Kealhofer (2004) chose to combine phytolith and geochemical distribution patterns in order to explore the agricultural strategies in a seventeenth century Virginia house lot, assuming that the information from the two methods was needed in order to identify a full range of related activities. For the geochemical analysis they considered calcium and phosphorus to be sufficient indicators of farming activity. Six activity areas were distinguished, based on combinations of types of grasses represented by phytolith forms and elevations of Ca and P. Interestingly, the highest levels of P and a diverse combination of all phytolith patterns were found outside the eastern boundary of the compound, suggesting that off-site agro-pastoral activities that were invisible archaeologically can become highly visible when sediment analysis is performed. An earlier study of spatial activity distribution at a domestic compound at Oztoyahualco 15B:N6W3 applied a combination of geochemical, phytolith, pollen, botanical, faunal and artefact distribution analyses (Manzanilla 1996). Unfortunately, the report does not portray the results of the different analyses in a systematic manner, or addresses the value of the various methods used, but it seems that the rich macroscopic record did not need much support from the microscopic remains, which merely confirmed the observed archaeological patterns.

A recent application of a combined geochemical and phytolith methodology helped create a diversified spatial interpretation of activities that took place inside a Roman building at Győr-Ménfőcsanak, Hungary (Pető et al. 2015). The ancient house was sampled using a 50 by 50 cm grid, after which the samples underwent analysis to determine their total organic carbon, total phosphorus (PPM), pH, calcium carbonate, macro-botanical and phytolith content. The results allowed for the location of zones of high organic matter and concentrations of different plant features according to phytolith types, indicating the deposition of crop processing by-products and food remains. Although the visual assessment of the various indicators provided more focal points, the PCA analysis revealed only two main activity areas, representing a pathway or high-traffic section linking a possible entrance with the far corners of the building and an area with higher levels of organic matter and plant remains portraying more intense anthropogenic input. Although this study provided a detailed botanical account and a good indication of the spread of organic matter within the building, it might have benefited from applying a multi-element geochemical analysis to the data, adding information about a wider range of activities such as burning or construction. Another objective that could have presented some interesting results would have been to analyse samples from adjacent outdoor spaces in order to establish how unusual the indoor signals were, and what type of activities were potentially taking place just outside the house.

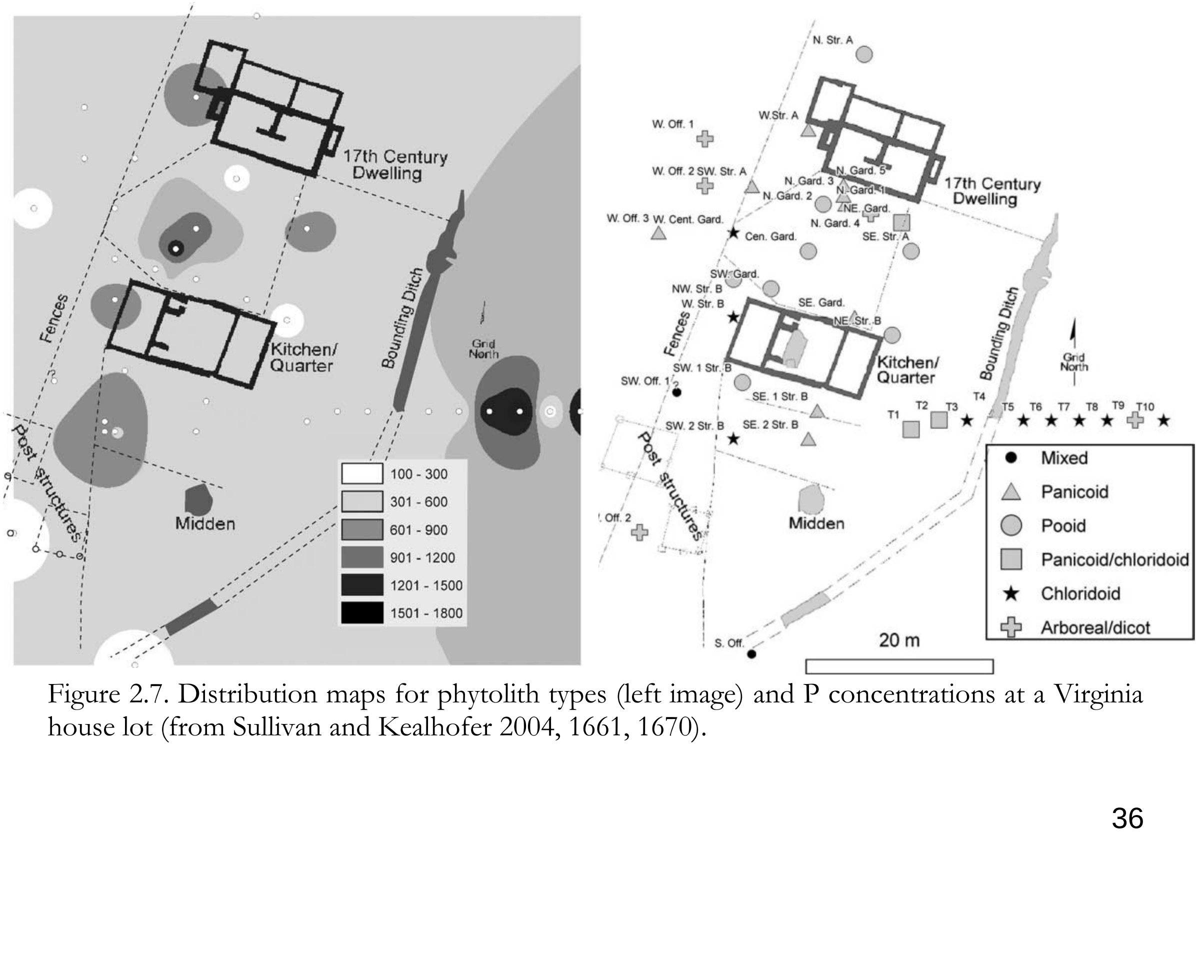


Figure 2.7. Distribution maps for phytolith types (left image) and P concentrations at a Virginia house lot (from Sullivan and Kealhofer 2004, 1661, 1670).

A combined approach using multi-element geochemistry, phytolith and micromorphology analyses at Songo Mnara, Tanzania, focused on a larger surface area and the characterisation of open areas and indoor spaces (Sulas and Madella 2012). The geochemical analysis revealed high levels of P, Mn and Sr in the open areas, while the phytolith analysis indicated the presence of grass leaves and culms, occasional woody morphotypes and the absence of inflorescence phytoliths in these areas. The authors suggest that the open areas could have been used for animal grazing, the phytoliths representing the remains of fodder. In addition, concentrations of metals were detected in the open areas, but their origin could not be explained. The thin section analysis might have been able to help determine the presence of stables or shed light on the presence of metals, but was unfortunately limited to the house deposits. As with the study of the Roman house outlined above, the indoor deposits were rich in organic matter mainly represented by grass leaves with a small number of non-grass morphotypes in the phytolith analysis, suggesting that unlike the Roman case crop processing byproducts were not introduced within the house. Two contexts, however, had a higher concentration of woody phytolith material. The results of the multi-element analysis also indicated high levels of organic matter by the elevations of P, Cr, Mn and Zn in the back room, while Ca and Sr indicated food storage or processing in the southwest room. The micromorphological analysis added detail to the investigation and allowed distinctions between deposits in different rooms to be made, and shed light on the production sequence of the plaster used for construction at this site. All in all, this analysis provided a good example to how the three methods can be combined to characterise indoor and outside deposits, but the interpretation could have been made more powerful by more comprehensive sampling and statistical analyses, which could have potentially been able to address additional spatial trends.

2.5. Discussion

The studies applying geochemical and phytolith analyses to reconstruct past spatial activity patterns discussed in this chapter illustrate the potential and limitations of each of these methods. Phytolith based spatial reconstructions were able to identify anthropogenic anomalies in certain activity areas, especially within hearths and dung contexts. The types of phytoliths associated with various activities, however, vary across sites. Geochemical signals of activity, on the other hand, seem to be universal, and associations between activities and certain (groups of) elements reoccur in different settings. Nonetheless, geochemical studies of anthropogenic spatial patterning require further development, and would benefit from additional understanding of the processes leading to element enrichment and retention in anthropogenic soils. While ethnoarchaeological and experimental studies have contributed a great deal to the improvement of phytolith and geochemical applications to the study of activity areas, even the most informed cases carry limitations for interpreting the output of the analyses, mainly due to problems of equifinality and equivocality.

A promising avenue of research for the development of geoarchaeological spatial interpretations of archaeological spaces which is capable of addressing these issues is the integration of two or more methods, allowing us to refine the results of each technique. In addition, although most studies focus on the development of laboratory procedures, the development of statistical analyses applied to the data could potentially help improve the effectiveness of these methods in distinguishing patterns and identifying different activity areas. While the studies presented in this chapter effortlessly analysed and displayed the results of single analysis methods, none of them address ways of combining the information from two or more analysis techniques, which are presented separately.

3 Background of ethnographic samples

3.1. Introduction

This chapter will provide an overview of the ethnographic material analysed in this study. The majority of ethnographic samples discussed in this research were collected as part of an extensive ethnoarchaeological survey of abandoned Bedouin campsites 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). In addition to this material, two campsites were sampled by Carol Palmer, Jouma' 'Aly and the author at Wadi Faynan during 2014, and an occupied tent at the contiguous Wadi Dana was sampled during 2009 by Emma Jenkins, Pascal Flohr and Sarah Elliott. 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 documented so that known activities can be correlated to the analysis results, the sites reflect a seasonal, ephemeral occupation in a dynamic and arid environment, and they represent a range of abandonment durations. The next section will provide a general introduction to Bedouin life at Wadi Faynan and the geography of the region, followed by an outline of the ethnoarchaeological survey at Wadi Faynan, and finally the sampling strategy and the individual campsites will be described.

3.2. The Bedouin of Wadi Faynan

The name 'Bedouin' is derived from the term for nomadic desert or steppe dwellers (*badawa*), and is used to refer to populations across the steppes and deserts of the Arab world who are associated with a nomadic-pastoral-tribal way of life (Saidel 2009, Na'amneh et al. 2008). They were romantically described by early travellers to the Near East in the nineteenth and early twentieth centuries, who saw them as the living representation of biblical nomadic folks. Bedouin were presented as camel breeders migrating far across the steppic landscape, their travels promoted by the invention of the camel saddle and, as a corollary, the black long tent (Bulliet 1975; Knauf 1992). They were portrayed as fierce, rugged and having warlike tendencies and a disdain for authority, but also as great hosts and honourable individuals with proud oral traditions. The notion of the 'true' Bedouins as camel breeding nomadic tribes venturing deep into the desert is also idealized in the Near East and among Bedouin tribes themselves (Palmer et al. 2007).

More recently, scholars present a more diversified idea of Bedouin existence, where people of the steppes in the Near East follow a range of subsistence strategies, and can be hunter gatherers as well as farmers, cattle raisers, sheep herders, outlaws, or any combination of these. The importance of the saddle is diminished in the account by Helms' (1990) of Bedouin reality, which sees Bedouin lifestyle more as a socioeconomic reaction and behaviour fostered by the steppic-desertic environment on its inhabitants, rather than a static package including a number of attributes (camels, the black tent, saddle) and existence (nomadic, pastoral). Jabbur (1995) talks of three types of Bedouin: one having a 'proper' nomadic existence, raising only camels and some horses; another consisting of sheep herders that have some contact with settlements in the area; and those belonging to the third type who maintain a migration that is restricted to the peripheries of villages and towns, where produce from animal husbandry can be sold. Bedouin ways of life at Wadi Faynan today include a variety of subsistence strategies, of which sheep and goat herding, cultivation and involvement in the local tourist industry are the most prominent. Subsistence strategies in the area both take advantage of, and need to adjust to a number of environmental, social, economic, political, and personal circumstances. As opportunities and restrictions arise, lifestyles change in order to make the most of them.

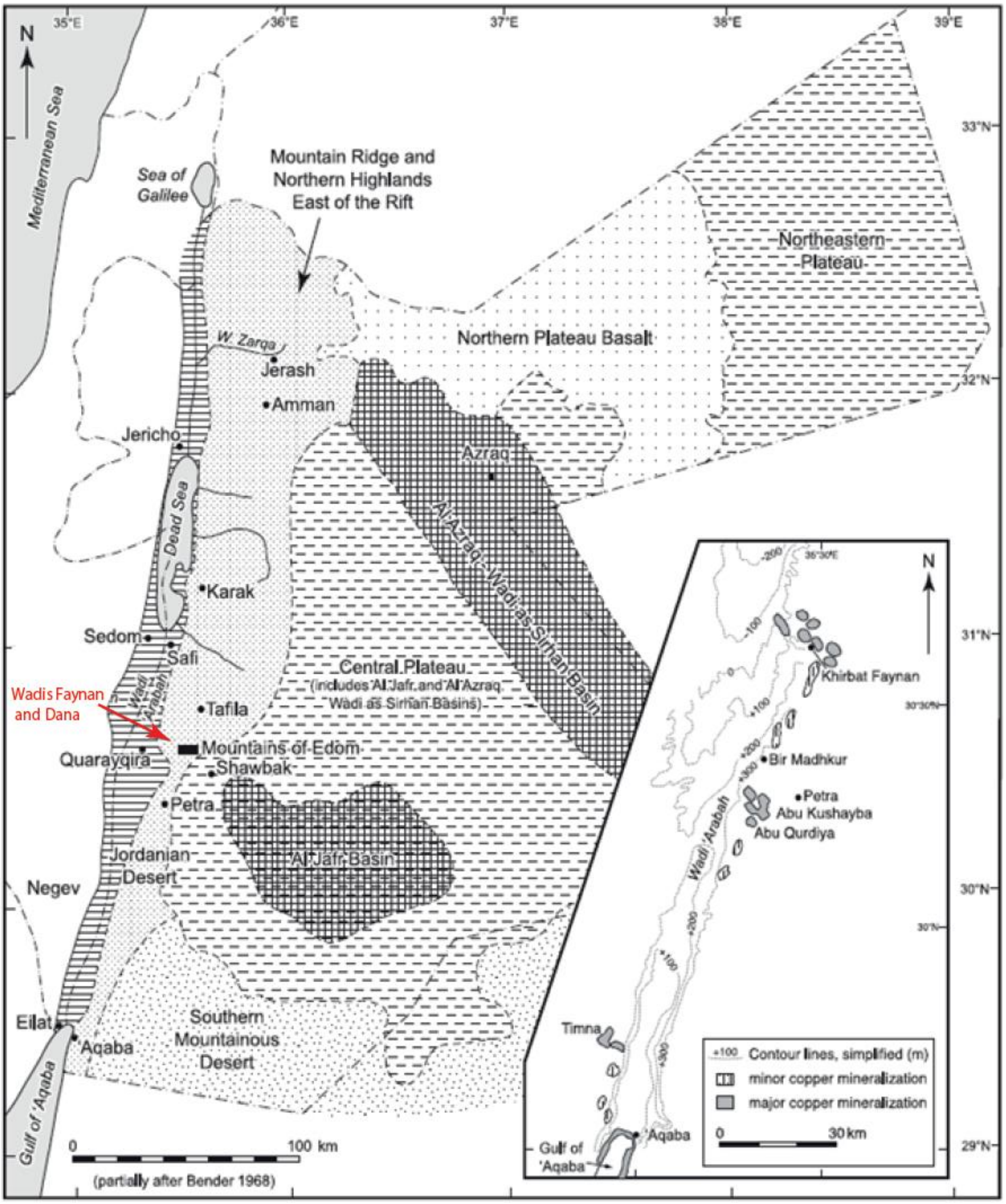


Figure 3.1. The location of Wadi Faynan and Wadi Dana in their regional context, landforms and topography (after Palmer et al. 2007, 26).

Figure 3.2. A picture taken by the author looking towards Wadi Faynan and the Dead Sea from the mountains of Edom.

Figure 3.3. The bottom of Wadi Faynan, picture taken by the author in April 2013.

The natural setting of Wadi Faynan is important for understanding patterns of mobility, as it allows its inhabitants to exploit different landscapes throughout the year. The Wadi is located in the Jordanian desert to the east of the Rift Valley south of the Dead Sea, and is bordered by the Wadi 'Arabah in its southern and western margins and by the Mountains of Edom and the Jordanian Tablelands to its east and north (figures 3.1., 3.2.). The lowest part of the wadi lies between 100 and 200 m above sea level, but the Jordanian Tablelands, only 15 km away, quickly rise to about 1,400 m above sea level (Palmer and Daly 2006). The Arabah rift structure in the Faynan area is characterised by an abundance of mineralized rocks, which have provided the inhabitants of the region with a source of copper for the past three millennia. Archaeological indications of copper mining at Wadi Faynan suggest that the mineral sources in this area were utilised at an industrial scale from at least 2900 BP to 1400 BP. During this time, copper industry at Wadi Faynan made part of the realms of various extensive kingdoms, including those of the Assyrian, Babylonian, Egyptian, Roman and Byzantine empires (Grattan et al. 2003; Hauptmann et al. 1992).

Seasonality is a chief aspect of the region's climate, with precipitation mainly restricted to the winter months December to March, and virtually absent between June and September. While the Wadi Faynan area only receives 63 mm annual rainfall, the higher grounds of the Jordanian Tablelands enjoy more than 200 mm of precipitation yearly (Bruins 2006). Summer is hot and dry, being influenced by the climate of the Saharo-Arabian desert to the southeast, with temperatures averaging at 29°C and occasionally reaching over 38°C in the Wadis. This having been said, the climate of Wadi Faynan, including the amount of rainfall, is highly variable and differs locally depending on altitude (Bolle 2003). Strong winds can occasionally sweep through the Wadi, which in combination with the aridity are a cause of deflation and the redistribution of dust and sand. Although the strongest storms usually take place during the winter months, windy episodes may occur all year round (Palmer et al. 2007).

Vegetation in the area reflects the complex relationships between topography, rainfall and geology between the Wadi 'Arabah and the Mountains of Edom, and as a whole Southern Jordan forms a meeting point for the Mediterranean, Irano-Turanian and Saharo-Arabian zones (Kurschner 1986). In areas of sufficient precipitation forestation will form, while low rainfall will result in steppe vegetation, or, where precipitation does not exceed 100 mm, a desert. However, flushes of vegetation may form following rain-storms, and the wadi bottoms and channels will be greener than their surroundings, with vegetation cover including *Anabasis*, *Salsola*, *Gymnocarpos* and occasional trees such as *Acacia*, *Moringa* and *Retama*. Wetter wadis will include *Phragmites*, *Nerium Populus* and *Salix*. In the steppe region a plant cover of grass and *Artemisia* can be seen in areas of stable soil, and the drier desert localities will include occasional short annual grasses in between shrubs and bare patches. Woodland in high altitudes is characterised by Mediterranean vegetation including species of *Quercus*, *Phoenix* and *Pistacia*, while woodland in lower altitudes is dominated by dwarf shrubbery including *Helianthemum*, *Artemisia*, *Salsola* and woody material such as *Juniperus* and *Pistacia* (Palmer et al. 2007).

	Desert-bush vegetation	**Extreme steppe desert**	**Steppe desert**	**Wooded steppe**	**Mediterranean evergreen woodland**	**Steppe woodland**
Dominant vegetation	*Haloxylon persicum*	*Acacia* *A. radiana* *Anabasis articulata* *Traganum nudatum*	*Anabasis* *Gymnocarpos* *Halogeton* *Salsola* *Zygophyllum*	*Juniperus* *Artemisia* *Helianthemum* *Salsola*	*Quercus* *Phoenix dactylifera*	*Pistacia*
Woody species	*Retama raetam* *Calligonum comosum*	*Ochradenus* *Retama raetam* *Ziziphus*	*Acacia* *Moringa* *Juniperus* *Retama* *Phoenix*	*Amygdalus* *A. korschinskii* *Atriplex halimus* *Pistacia* *Retama*	*Colutea* *Crataegus* *Daphne* *Pistacia*	*Crataegus*
Wadi vegetation	*Acacia* *Haloxylon persicum* (*Tamarix*) (*Retama*)	*Retama raetam* *Tamarix* *Ziziphus* *Acacia* (*Haloxylon*)	*Populus* *Salix* (*S. pseudosafsaf*)	*Salix* *S. pseudosafsaf* *Nerium* *Retama* (*Tamarix*)	(*S. pseudosafsaf*) (*Nerium*) (*Retama*) (*Tamarix*)	-

Figure 3.4. Summary of the vegetation zones in the Wadis Faynan and Dana and the Mountains of Edom (Palmer et al. 2007, 37).

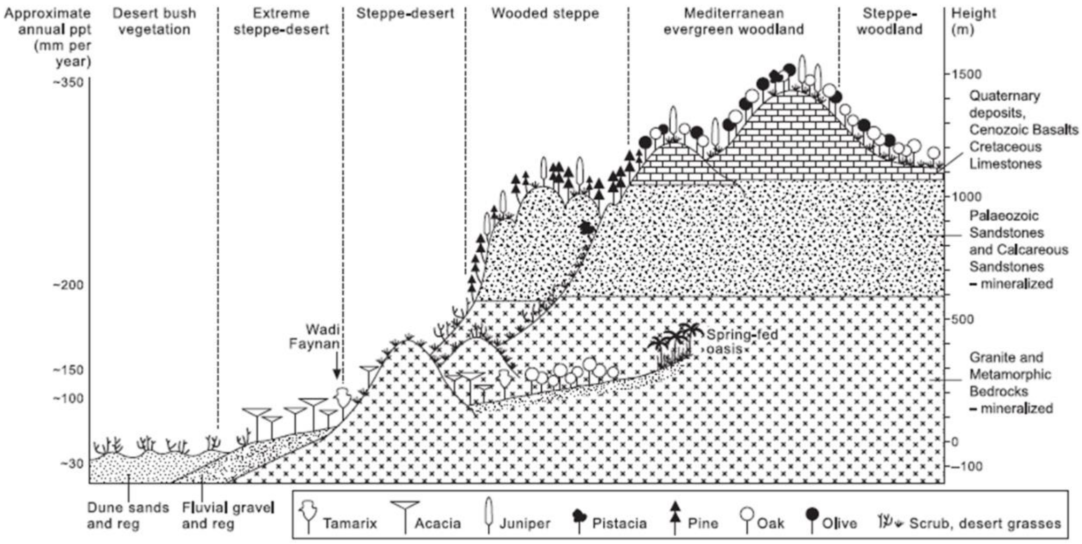


Figure 3.5. Summary vegetation transect throught the Wadi ‘Arabah and into the Mountains of Edom (from Palmer et al. 2007, 36).

The different micro-environments created by the area's topography and climate are well exploited through transhumance mobility. In practical terms at Wadi Faynan this translates to moving up to the highlands which are cooler than the lowlands during the hot summers, and then down into the Wadi over the winter, where the Wadi floor provides grazing and shelter throughout the cold rainy months. The extent to which this is done depends on the subsistence strategies chosen at any given moment. Previously, the tribes that visited Wadi Faynan were mostly semi-nomadic or semi-sedentary pastoralists, but all rural communities in the region were nomadic to some extent, depending on their involvement with agriculture and pastoralism. Today, permanent occupation of Wadi Faynan is common not only by villagers, but also with the four main local Bedouin tribes, and is facilitated by the use of supplementary fodder for the animals (Palmer and Daly 2006, 101).

Within a range of practices between pure pastoralism, referring to raising livestock on natural pasture, and agriculture, within the sense of crop cultivation, communities that rely heavily on pastoralism tend to be more mobile than the ones relying entirely on agriculture. In this context, nomadism can be defined as the regular mobility of households/home bases from place to place, but the duration of migration and settlement episodes may vary (Khazanov 1994; Palmer et al. 2007). In most cases migration will be seasonal with varying duration and distance, spending a certain amount of the year near a permanent dwelling, usually during winter. There is, nonetheless, a high level of variation in the reliance of households on livestock and the amount of mobility; some locations are occupied seasonally while others are occupied year-round (Noy-Meir 1975).

The simple correlation between pastoralism-nomadism and agriculture-settlement, however, do not provide a conclusive account of the mobility trends at Wadi Faynan. Mobility of Bedouin campsites has decreased over the past century due to external influences, and today herding practices range between transhumance and home-range (Saidel 2009, Palmer 2002). Changes in mobility patterns of modern Bedouin populations across the Arab world occurred in response to external influences that in most cases led to an increased rate of sedentarisation and modernisation (Na'amneh et al. 2008). In Jordan, sedentarisation policies have been in place from the Mandate period up until the 1970s, when more stable political forces enabled the control and integration of Bedouin tribes. When the newly independent Hashemite Kingdom of Transjordan was formed in the 1940s pressure for progress brought technological development for controlling the desert environment and the establishment of agricultural projects, which benefitted from the sedentarisation of the desert tribes (Bocco 2006). These governmental guidelines, in addition to widening markets, climatic conditions and internal decisions have changed the way many Bedouin communities live. The abandonment of their tent and thereby nomadic flexibility, their herding and agricultural activities in favour of a broader market economy, led to changes in other aspects of life such as diet and family structure (Na'amneh et al. 2008, Palmer and Daly 2006).

Some of the members of well-established tribes at Wadi Faynan served in the armed services of the Hashemite Kingdom following its formation, which resulted in a decline in the reliance on herding and crop cultivation by their families back in the Wadi. Large herds were no longer required once a salary was earned, and smaller herds for domestic needs could be kept. As smaller herds can be maintained by the use of crop by-products and fodder, and do not require as large a grazing range as more substantial herds would, mobility at Wadi Faynan had decreased in the 1940s and 1950s. In the following decades governmental guidelines and changes in taxation favoured individual farming to the collective-tribal based ownership of land, and the introduction of tractors and limitations on state-owned land reduced the availability of grazing. Bedouin settlements were established along the newly built Desert Highway, as part of the governmental settlement campaign.

The pace of progress in the area has increased from the 1980s onwards, when government and public sector employment opportunities, schools, road systems and health care became widespread (Palmer et al. 2007). The Natural Resources Authority (NRA) camp at Wadi Faynan became a base for archaeological fieldwork, providing employment opportunities for local individuals. The establishment of the Dana Nature Reserve in 1993 (which boarders with Wadi Faynan at its southern end) provided work prospects as well. Today the area enjoys a flourishing tourist industry including the Faynan Ecolodge, an environmental friendly hotel providing employment opportunities for many of the local Bedouin.

Bedouin subsistence at Wadi Faynan

Sedentarisation has a significant impact on Bedouin existence because of the important role pastoral food production, which each household manages autonomously, plays in their lifestyle. A combination of dairy and grain products forms the base of Bedouin diet. The dairy products are prepared from the milk of their sheep and goats, and wheat, which was traditionally cultivated and prepared, is now bought in the form of flour. *Shrak*, or *khubz al-saj*, is the traditional thin bread that is prepared by Bedouin women on a convex metal plate (*saj*) set above a fireplace. Milk from goats and sheep is largely processed before consumption to create yoghurt, butter and cheese that can be stored for a long period of time. The milking season, naturally limited to two to three months for sheep and four to five months for goats, takes place during spring. Using a limited range of basic ingredients, Bedouin women are able to prepare a wide variety of dishes that are served at various occasions (see Palmer 2002 for a full overview of wheat and milk products used in the past and today). As with other cultures, food preparation and consumption has a role beyond sheer survival, as it reinforces social bonds and helps define identity (Palmer 2002).

Bedouin social organisation

On a larger scale, Bedouin social organisation is 'tribal', though it has been debated to what extent this reflects an ideological form of social representation or a political reality (Bienkowski 2007; Nahedh 1989). A tribe will be composed of a large extended family descending from a common ancestor, from whom the name of the tribe will often be derived. There are different segments within the tribe that can be seen as political sections or as "genealogical braches of a clan" (Evans-Pritchard 1949, 12). Although connected by kinship and relationships, the concept of a tribe is not based on geography – family units do not need to camp in close proximity to each other and various tribes can occupy the same area. The majority of encampments will comprise a single or two tents, but there are often camps with three to four tents. Aside from the actual tents, campsites will often include animal pens, additional tents for storage or other purposes, and more recently a vehicle (Saidel 2009). A study of households carried out in the 1980s indicated that the average Bedouin tent will house approximately six people. This figure, however, should be treated with caution as the study only covered two districts in Jordan, and might now be outdated (Abu Jaber et al. 1987, 135).

Five tribes occupied Wadi Faynan at the start of the ethnoarchaeological survey, the 'Ammarin, 'Azazma, Sa'idiyyin, Rashaydah and Manaja' (Palmer and Daly 2006, 101). The 'Ammarin and the Sa'idiyyin have a long tradition of seasonal cultivation in the Wadi Fidan and Quarayqira areas (locations shown in figure 3.1.). The 'Ammarin have also been known to set camp at the foot of the Wadi Dana, while the Sa'idiyyin used to occupy territories on both sides of the Wadi 'Arabah, bordering on 'Azazma lands to the west, prior to the establishment of the modern national borders. Today these tribes are considered part of the Huwaytat, a large Transjordanian tribal confederation, but they seem to have both been independent groups in the nineteenth century. There are 'Ammarin and Sa'idiyyin settlements in the region, among others near Petra and at Quarayqira. The Manaja' are a section of the Huwaytat tribe that is currently the smallest group visiting Wadi Faynan. In the past they were involved in protecting long distance traders between Palestine and the Hijaz, and today they are included within the Quarayqira agricultural co-operative and hold strong links with the Sa'idiyyin (Palmer et al. 2007).

The Rashaydah have been perceived by themselves and others as 'true' Bedouin and as blood-brothers of the Huwaytat, and have held supremacy over villagers and other tribes in the past. They would set camp during winter at Wadi Faynan or nearby Ghuwayr, where Rashaydah members are told to have cultivated land in the beginning of the twentieth century, and moved up to their lands near Shawbak for the summer months. In the 1990s tomato cultivation by the Rashaydah met some resistance by people from Shawbak, as the agricultural development of land generally bestows ownership (Palmer et al. 2007). Within the last two decades most Rashaydah members have settled at Quarayqira. Lastly, the 'Azazma are the most numerous tribe camping in Wadi Faynan nowadays. They originally occupied lands in the Negev, and came to the area in 1948, following the establishment of the State of Israel. Most of the 'Azazma in the area had only received full legal status about three decades ago, which entitled them to acquire subsidized fodder and get access to other state facilities, such as certain types of employment. While mainly involved in livestock holding, they will supplement this by income from other activities and casual employment such as hiring themselves and their vehicles for rent, or conducting some mobile trade (Palmer et al. 2007). Although all of the Bedouin tribes discussed above occupy the same area and share many aspects of life, traditions and activities, they vary in their histories, subsistence strategies and interactions with the government, other groups, and the dynamic environment of Wadi Faynan.

Architecture and social use of space

Named *bayt al-Sha'r*, meaning 'house of hair', the Bedouin tent is largely created by the women, who set up the structure with parallel rows of centre poles (*wasat*) covered by a roof and walls made of woven goat hair strips (figure 3.6.). The number of centre poles defines the tent; in the Wadi Faynan area two- and three-pole tents are most common. A three-pole tent will have three rows, each containing five poles, about three to four m apart, typically measuring 15-16 m long and approximately four m wide. The tent outline will be marked, also after abandonment, by large stones used to secure tent eaves to the ground and cairns used to secure the ropes of the tent. These stones, especially the smaller ones used to secure tent eaves, will move around and start to disappear after abandonment, being reused by other households or moved by rainstorms (Na'amneh et al. 2008, 154; Palmer et al. 2007; Rosen and Saidel 2010). Variations to this basic tent layout can be seen as well, often a supplementary tent will only include one living area with a single hearth, or none (see description below).

One of the better known aspects of Bedouin life is a separation between two main spheres of life, the public and the private, this is reflected in the division of space within Bedouin tents. A separation between private and public areas is kept through a dividing screen, called a *mu'anad*. The screen separates the *mahram*, the women's section which is the private area, from the *shigg*, the men's public hospitality area (Na'amneh et al. 2008; Saidel 2009; Palmer et al. 2007). The *mahram* is the domain of women and young children, where household tasks such as cooking and weaving take place, but also where women entertain their friends. The *shigg* is used to receive guests, where tea, coffee, and meals are offered, and is the realm of the men. At night, the men stay in the *shigg*, while the women and young children sleep in the *mahram*. Both areas contain a hearth, which is a durable, key feature of the Bedouin tent. The *mahram* hearth is used for cooking, while the main purpose of the *shigg* hearth is making tea. The *Shigg* embodies another well-known, chief aspect of Bedouin life – hospitality. Serving coffee and tea is seen as a welcoming, generous act, which is a source of honour and respect.

In forming designated areas, the Bedouin home reflects the Bedouin sociocultural system through its spatial divisions, which help enforce a control of access based on gender roles (Ma'amneh et al. 2008). Control over privacy is important, as the honour and reputation of the entire family, and even tribe, is to a large extent dependent on women's honour. This does not mean that men and women never interact, but there are certain limitations to this interaction, depending on specific situations. Generally, young women will spend less time in the men's section than older individuals, who participate more often in welcoming guests. When there are no male visitors women and men spend time in the hospitality area together, where they also both sleep (Ma'amneh et al. 2008). In addition, although some spatial principles will be strictly adhered to at all times, the space within and around the tent can be used in a flexible manner to adjust to various scenario's (such as hospitality or day and night use). Mattresses and cushions used for sleeping are usually stored in the private area, for example, but are brought to the *shigg* when guests visit where they are laid out on three sides around the hearth (Na'amneh et al. 2008, 155; Palmer et al. 2007).

Figure 3.6. The Bedouin tent at JTW (image courtesy of Carol Palmer).

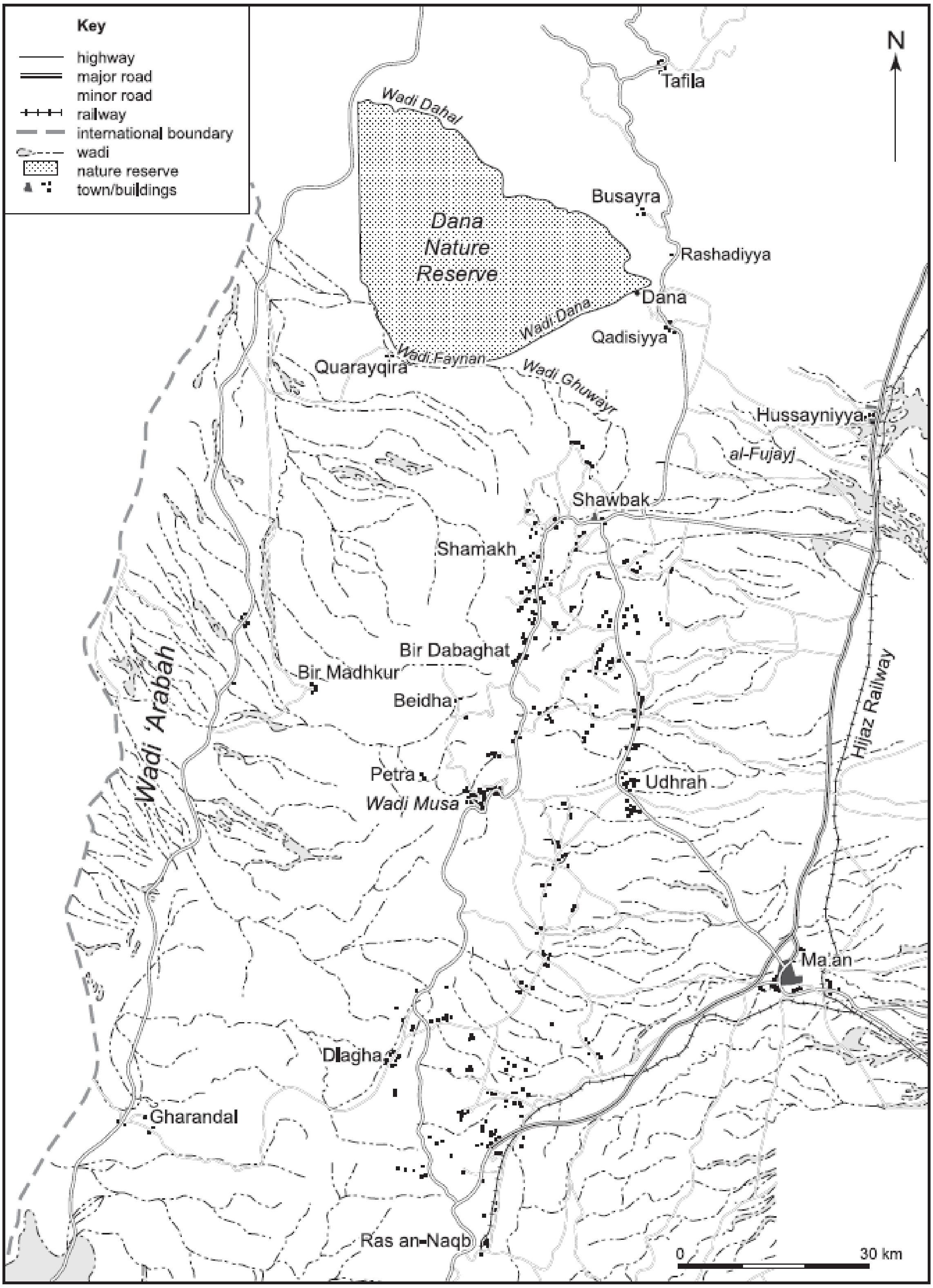


Figure 3.7. Principal locations and regions mentioned in the text in the area of Wadi Faynan (from Palmer et al. 2007, 40).

Previous ethnoarchaeological studies of Bedouin

Several ethnoarchaeological surveys of Bedouin tent-sites have been carried out in the Near East, studying all forms of material culture found at Bedouin campsite prior to and after abandonment (Banning and Köhler-Rollefson 1986, 1992; Bienkowski and Chlebik 1991; Saidel 2001; Simms 1988). The aims of these surveys involved establishing the nature of pastoral occupation and the assessment of the visibility of similar campsites in the archaeological record and their resemblance to the remains of ancient cultures found in the same area (Saidel 2009, 179). 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 and in the recent past in order to improve our understanding of archaeological pastoral communities.

Banning and Köhler-Rollefson (1983, 1986, 1992) were one 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 campsites 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.

Around the same time, Simms (1988) studied one of the campsites 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 campsites, 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 campsites. Additional goals included establishing the patterns of artefact deposition within the campsites, 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 campsites in the 1990s and the beginning of this century were not very different to those of the research performed during the 1980s, including the establishing of 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.

3.3. The ethnoarchaeological survey at Wadi Faynan

The study of Bedouin camps carried out by Carol Palmer and Helen Smith during the springs of 1999 and 2000 focused on sites that had been abandoned for various durations of time. 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? In addition, 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 approached by recording the material culture left behind during abandonment of modern Bedouin campsites at Wadi Faynan. 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 eighty-three 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 campsites 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 campsites 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 campsites were revisited and studied in greater detail, an artefact distribution study was undertaken and the soil samples used for this doctoral research were collected from chosen sites (Palmer and Daly 2006). During the recording of the campsites, they were divided into four types on the basis of their structure (table 3.1.).

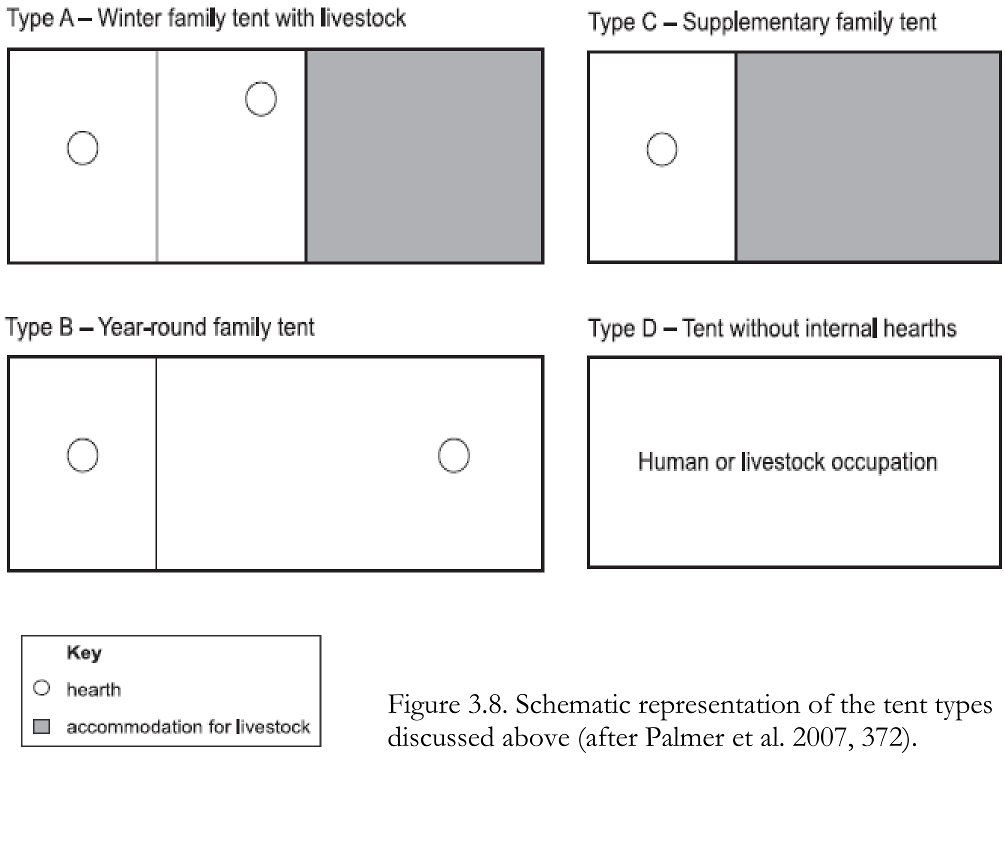


Figure 3.8. Schematic representation of the tent types discussed above (after Palmer et al. 2007, 372).

Campsite	Description
Type A	Winter family tent with livestock: used during cold and rainy periods and divided into a human occupation area and one for sheltering the livestock at night. The part occupied by the family is sub-divided into a public/male area (*shigg*) and a private/female section (*mahram*), each containing a hearth. As the dung build-up in the animal area tends to become unpleasant, these winter campsites are never occupied for long, and families will move two to three times during the winter period. The dung may be burnt off to hasten the decomposition process, before reoccupation of the site.
Type B	Year-round family tent: this form is mainly associated with larger tents and includes two hearths at the opposing ends of the tent, in the *shigg*/men's area and in the kitchen, which is located in the *mahram*/women's section. The latter is more extensive in this tent type, allowing for more differentiation between household related activity areas, such as cooking, churning, and sleeping areas.
Type C	Supplementary family tent: often used for housing additional wives, widows or recently married sons and will usually be smaller. It can be used for housing animals as well, and in that case will be divided accordingly. The human living space will be used as a private area, as this tent will always accompany a larger type A or B tent.
Type D	Tent without internal hearths: although these might be located outdoors. This type of tent is often used during summer, when more activities take place outside. The length of occupation is normally shorter with this type of tent, which is used for various purposes such as celebration or winter animal shelters.

Table 3.1. Overview of the four campsite layout types (after Palmer et al. 2007, 372).

All of the campsites studied in this research represent either type A or type B tents, and include the following features (after Palmer et al. 2007):

Hearths: As mentioned above, the tent sites examined in this doctoral study included two hearths, one located in the hospitality/men's area and the other in the kitchen/women's area. Their location within the tent creates a clear definition of spatial organisation, distinguishing the space around them as either the public or private domains. In addition to the hearths' typical locations within the tents, or instead of these, outdoor fireplaces can be used. This can be done either for special occasions, such as cooking the local feast dish (*mansaf*), or simply in order to keep indoor areas cool. Some summer campsites have an outdoor hospitality area (*muarash*), which is accompanied by a hearth. Ash from the hearths is cleared regularly, and disposed of either to the rear or to the back of the tent, often down a slope.

In both indoor and outdoor *shigg* areas, the hearth will be used for tea making, an important aspect of local hospitality (Layne 1987, 358). While these hearths can be simply structured, round shallow features, more elaborate, stone-lined rectangular versions can be found in the hospitality areas of more established groups in the area, especially in households more likely to receive large numbers of guests. The kitchen hearth, located in the *mahram*, will be circular and include three fire-blackened stones which are used for supporting a bread-baking tin, pan or a teapot.

Figure 3.9. Left image – the view from an entrance to one of Jouma's winter campsites at Wadi Faynan. Right image – entertaining guests in the hospitality area (images courtesy of Emma Jenkins).

Figure 3.10. An example of a substantial, rectangular stone-lined hospitality hearth (courtasy of Emma Jenkins).

Figure 3.11. Left image – hospitality hearth in use for tea preparation (a piece of dung is visible under the teapot). Right image – the remains of an outdoor hospitality hearth (images courtasy of Emma Jenkins).

Figure 3.12. Left image - bread (Shrak) being prepared above the kitchen hearth. One of the three supporting stones can be seen in front of the pan. Right image – tea being prepared above the same kitchen hearth. The kitchen storage area can be seen in the background (images courtasy of Emma Jenkins).

Floors: The surfaces of winter tents will often be cleared of stones, and in some cases levelling of the floors will take place as well. Summer tents or those occupied for short durations of time might not receive as much preparation. The various activities taking place within and outside the households will change living surfaces as well, mainly by cleaning processes which will usually involve sweeping an area that has been sprinkled with water. Over time, this will create a thin hard layer, which will be most evident in the kitchen area where food preparation necessitates frequent cleaning. Cleaning residues are then deposited beyond the edge of the tent, or swept into hearths. In some *shigg* areas, especially those decorated with an elaborate hospitality hearth, the floor is covered with small wadi stones, in which case the floor will not be regularly swept.

Gullies: Within winter tents, gullies are excavated along the perimeter of the tent in order to direct run-off water from adjacent slopes and the tent roof. Smaller interior gullies may be used in kitchen areas, formed by cooking and cleaning activities. Both types of gullies will fill up with sediment shortly after abandonment.

Sleeping areas: In the past, sleeping areas were distinguished by a platform made of a stone outline filled with sediment, and topped with soft vegetation – such as *Retama raetam* (white broom) or *Artemisia herba-alba* (white wormwood). On top of this, bedding would have been placed. Similarly, platforms for storing bedding, which are usually located next to the dividing screen between private and public areas, were made of an outline of large stones or slabs, with smaller stones in the centre. Sleeping and other platforms are not as common today however, with plastic and metal containers and frames enabling cheap and easy storage (Palmer et al. 2007). The location of the sleeping areas and bedding platforms has not changed, but plant material will not be used as often.

Animal pens: Unless livestock is kept within the tent, which is often the case with winter campsites, they are housed outdoors in a pen. The location of the pen will be moved according to dung build-up, and goats are separated from the sheep during breeding time to prevent interbreeding. Occasionally the surface of older pens will be burnt.

Kid pens: Between the age of a week and a month, young animals are separated from the older individuals and kept in kid pens at night during winter time. These circular structures are made of stone, with a roof made of wood or other materials (such as plastic or sacks). A layer of bedding is often placed inside, such as *Retama raetam* twigs, above an ashy layer used to soak up urine.

3.4. Descriptions of individual campsites

This section will introduce the campsites that were examined in this study. Three of the sites described below, WF953, WF940 and WF982 were studied for their material deposition post-abandonment, the results of which were published (Palmer et al. 2007). The information provided for each campsite includes the individuals sampling the campsite, the tent plan type (see description in section 3.3.), the duration of abandonment, the tribe whose members occupied the site, a short description and a plan of the site. The location of the campsites described below can be seen in figure 3.13.

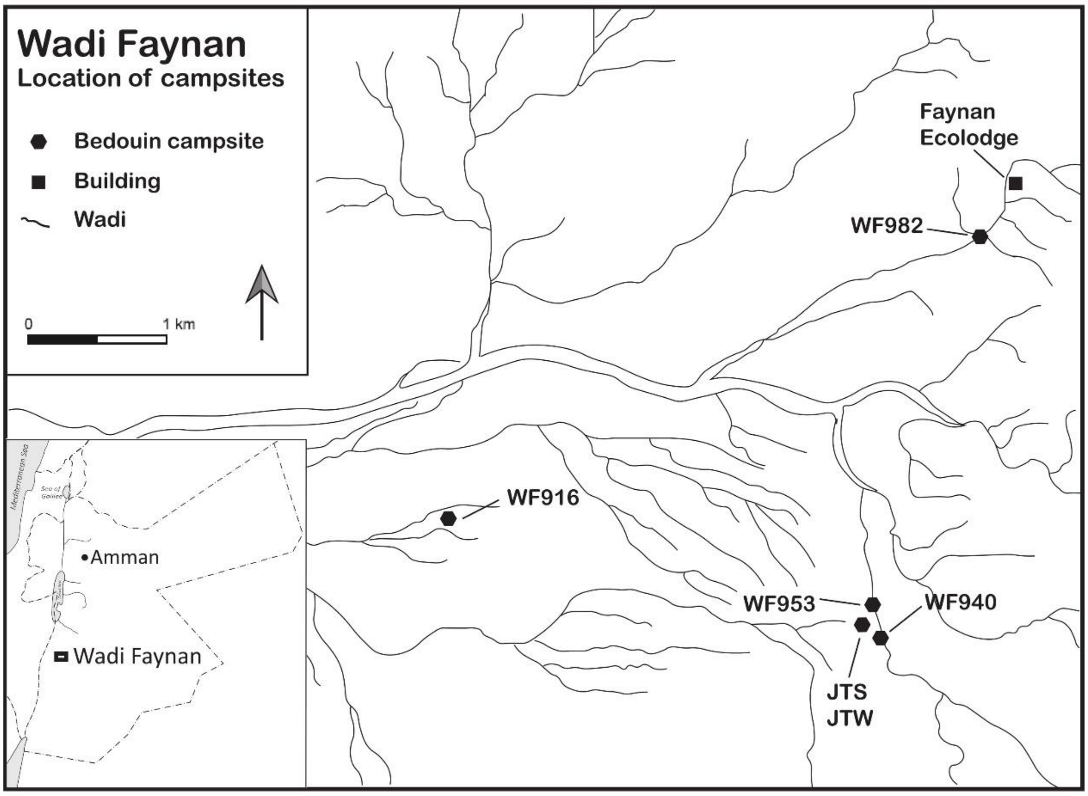


Figure 3.13. Location of Bedouin campsites at Wadi Faynan discussed in section 3.4. (created by the author).

Wadi Faynan 916 (WF916)

Sampled by: Helen Smith and Carol Palmer

Tent plan type: B

Duration of abandonment: three years

Occupied by members of: Rashaydah tribe

Description: This site is a good example of a B type tent form and was nine m long. There was a substantial stone lined rectangular hearth in the men's/hospitality area in the south end of the tent. At the centre of the tent was a stone platform, which was probably for bedding. There was another rectangular platform at the northern end and a small, round platform to the northwest which may have been used for milk processing. A gully had been constructed around the south-facing side of the tent that reached round to the circular platform beside the kitchen area. Associated with the site was a goat pen/spread of dung, two storage structures that reused archaeological features (ca. 1-1.5 m diameter), a mosque to the north - a cleared rectangular stone lined area with a niche to the southeast (al-gibla), and two ash dumps.

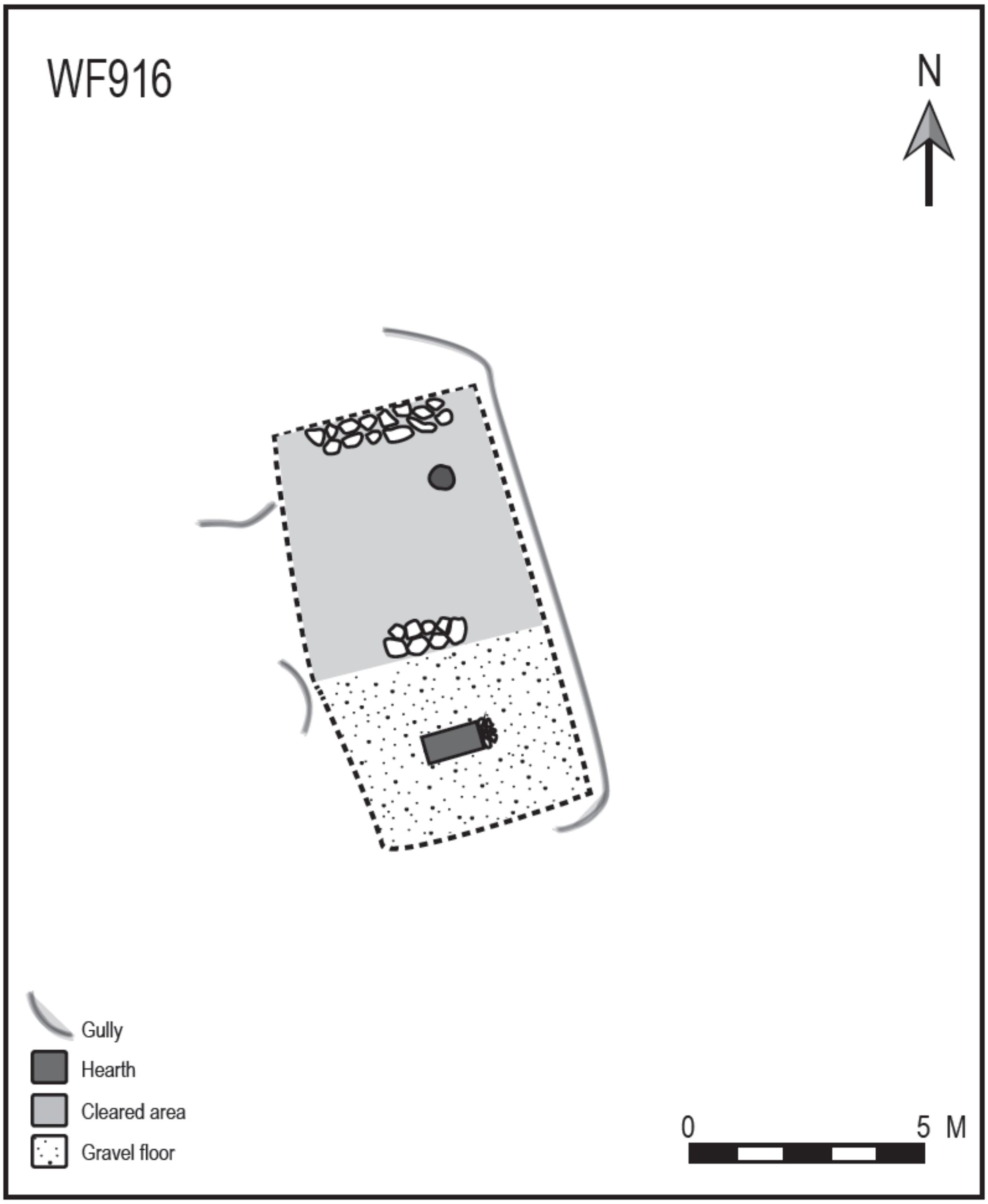


Figure 3.14. Plan of WF916 (created by the author based on schematic drawing by Carol Palmer and Helen Smith).

Wadi Faynan 940 (WF940)

Sampled by: Helen Smith and Carol Palmer

Tent plan type: C

Duration of abandonment: One year

Occupied by members of: 'Azazma tribe

Description: This tent site was left during the same year that the survey took place (1999) following a month's occupation. The abandoned area showed excellent preservation of features inside including a sleeping platform outlined in stones with the centre constructed of sandy silt. The tent area was well prepared, cleared of stones and levelled. There was no division between the hospitality and private areas. A single hearth in the northern end was the only one used, but the remains of a previously used hearth were still visible. There was an area of compacted dung at the southern end (where the animals were kept), a storage unit and a goat pen to the north. The walls of the latter were made from rubble and there was compacted dung inside and a dump of ash. There were two gullies along the west side of the tent, the furthest west of which was larger. This campsite was previously erroneously published as WF942, but it was originally documented and sampled under the number WF940 and was later confused with WF942, which represents the remains of an earlier campsite south of WF940.

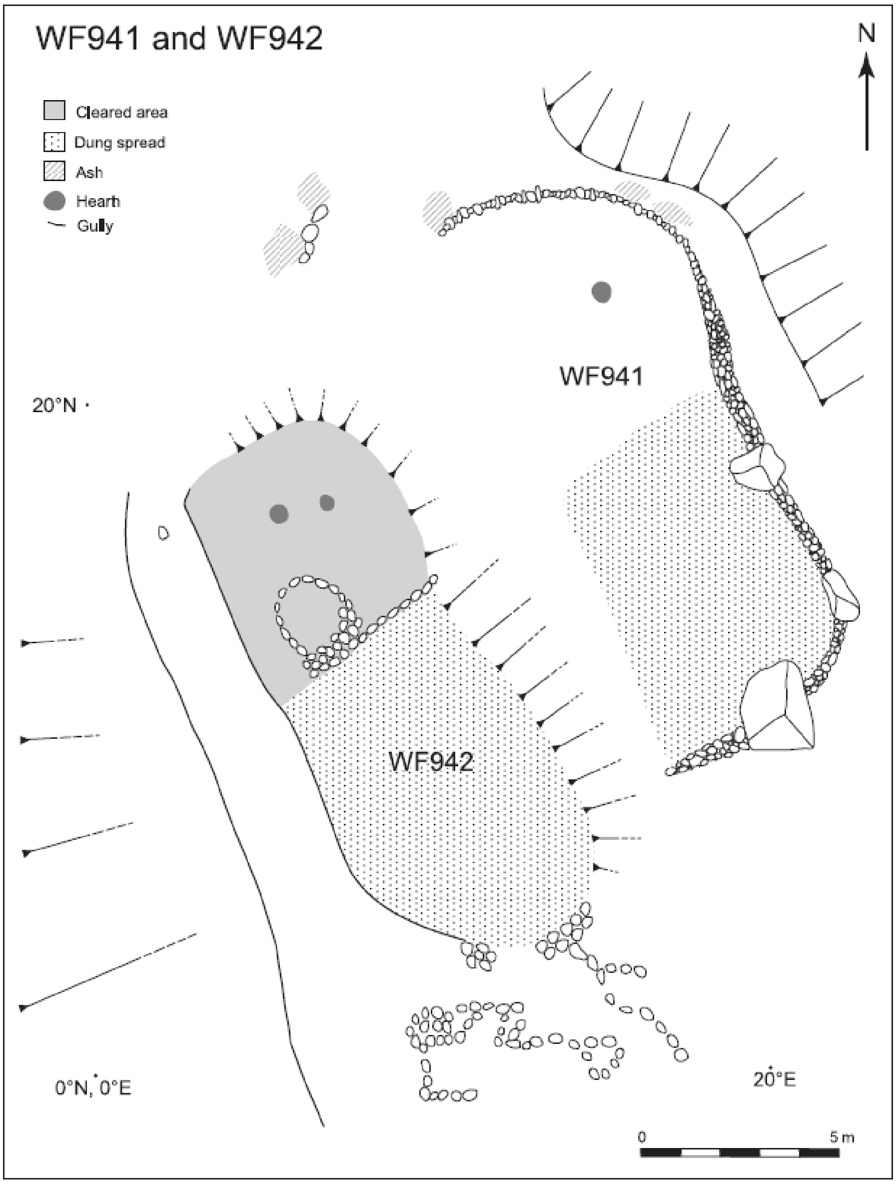


Figure 3.15. Plan of WF940, referred to as WF942 in earlier publications (from Palmer et al. 2007, 385).

<u>Wadi Faynan 953 (WF953)</u>

Sampled by: Helen Smith and Carol Palmer

Tent plan type: A

Duration of abandonment: one year, studied while occupied

Occupied by members of: ‘Azazma tribe

Description: This tent, which was occupied by Jouma' 'Ali, was 15 m by four m in size (three-pole type) and also housed livestock. The site was located on the rocky, eastern side of the Wadi terrace. The animal end of the tent was slightly higher than the human living quarters (due to a slope and a division wall), and could be easily observed after abandonment due to the formation of a dung layer. There were two hearths in the tent; the female hearth was off set and near to the tent opening (to the east). Stones marked a bedding platform (store of mattresses etc.) which was located behind a partition within the public area. There were two well defined gullies outside the human living quarters.

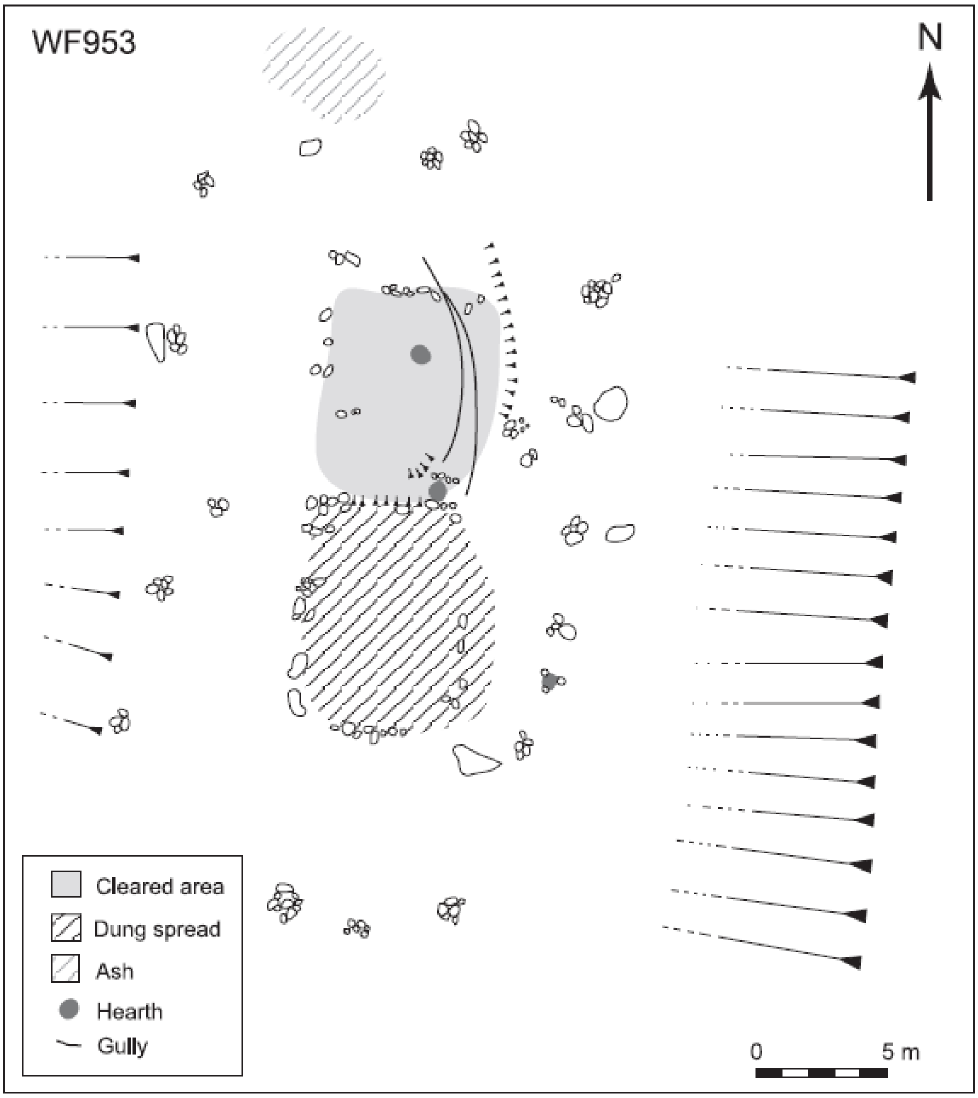


Figure 3.16. Plan of WF953 (from Palmer et al. 2007, 381).

Wadi Faynan 982 (WF982)

Sampled by: Helen Smith and Carol Palmer

Tent plan type: probably A

Duration of abandonment: approximately 15 years

Occupied by members of: Sa'idiyyin tribe

Description: Although it is likely that this site was occupied during a number of winters, the precise duration of occupation is unknown. The remains of two hearths (hospitality and kitchen) were located within the tent area, and kid pens and a small dung spread were found outside the outline of the tent. Among the samples of this campsite is one taken from a layer recognised as a concentration of *Retama raetam* (white broom) in the field.

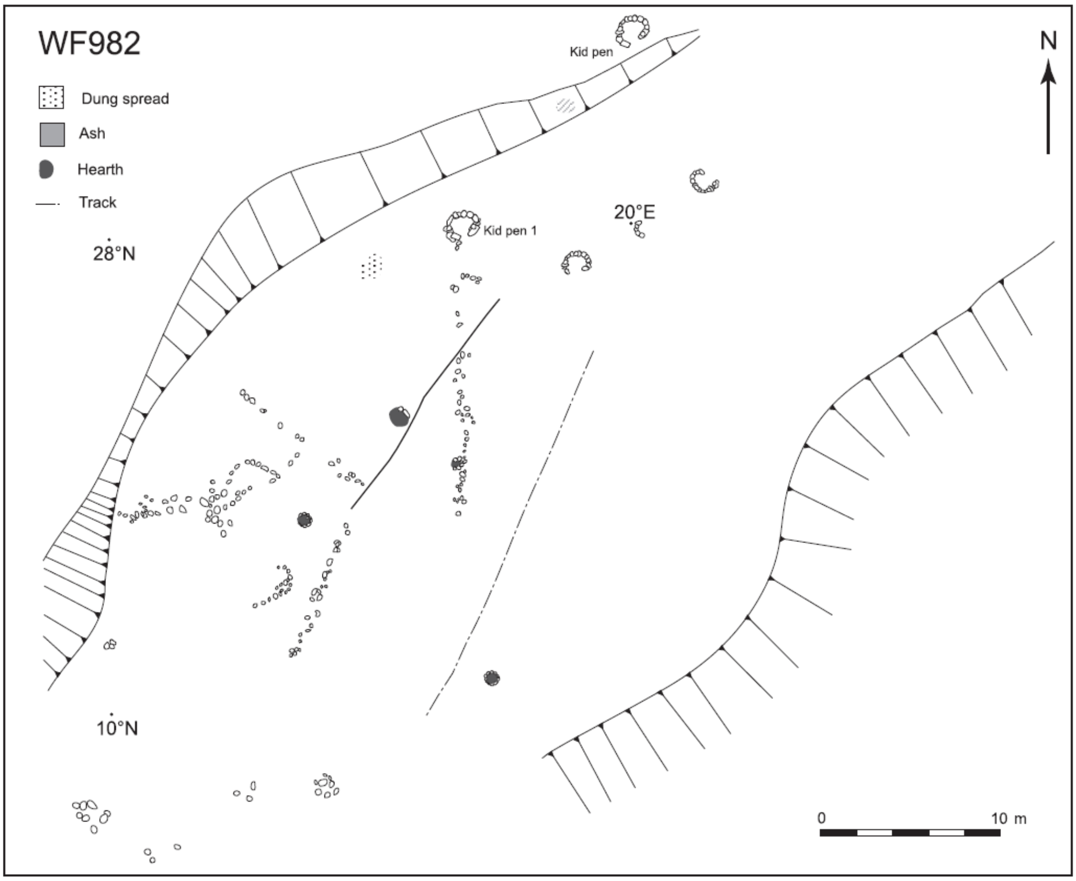


Figure 3.17. Plan of WF982 (from Palmer et al. 2007, 387).

Jouma's tent winter (JTW)

Sampled by: Jouma' 'Ali, Carol Palmer and the author

Tent plan type: B

Duration of abandonment: occupied

Occupied by members of: 'Azazma tribe

Description: Jouma's occupied winter tent which was located at the foot of a hill. It was sampled in 2014 at a point in time when the family was about to move to the summer site which was located up an adjacent hill. The family living there included Jouma' 'Ali, his wife Um Ibrahim, their nine-year old daughter, 11 year-old son and their two older brothers. Um Ibrahim milks the goats in the morning, makes bread on the kitchen hearth, then attends to other household activities such as making dairy products and preparing tea for visitors. The children leave to go to school or work in the morning and return in the afternoon.

The plan of the living area inside the tent included a kitchen area, adjacent women's activity area, women's sleeping area, and the separated *shigg* (hospitality area). Outside were goat and sheep pens, one combined, and two remains of pens separately housing sheep in one, and goats in the other. Two storage tents and an animal feeding station were not sampled as these categories differ from those sampled from the other campsites in this study. There were two entrances to the tent, one directly into the kitchen, which was located in the *mahram*, used for cooking and contained a storage area. The kitchen floor was uncovered and had become compact during use. Further into the tent was the women's activity area, which is used for a variety of household activities, churning took place during this visit. The adjacent sleeping area, where mattresses are stored during the day, was located within the *mahram* against the divide from the *shigg*. The latter contained the second entrance and three mattresses arranged in a U form – the floor was covered by plastic matting except in the centre of the mattress area (where the hearth was located), which had become hardened through use.

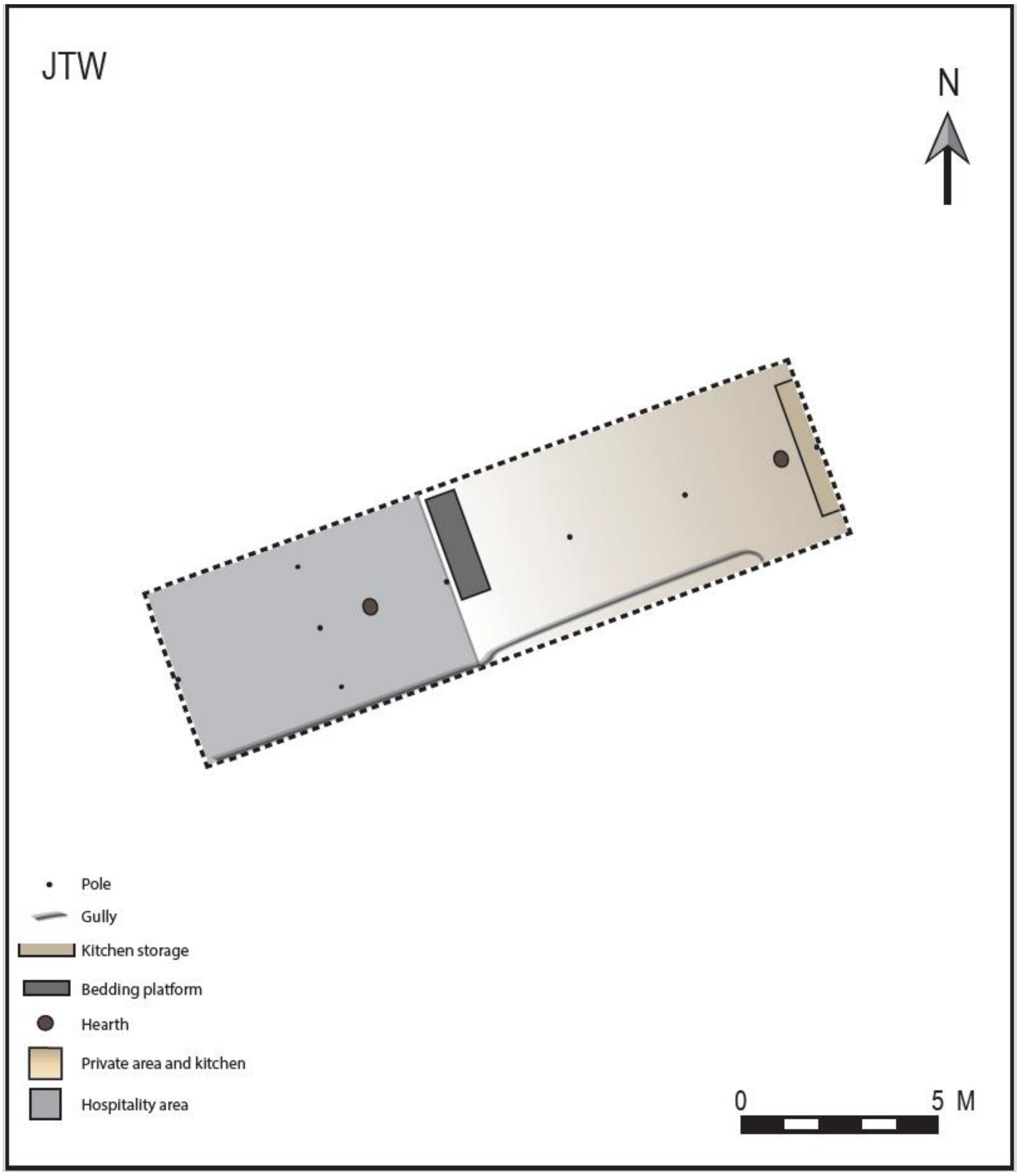


Figure 3.18. Plan of JTW (created by the author based on measurements and drawing made in the field).

Figure 3.19. Jouma's occupied winter campsite, JTW. A white storage tent can be seen behind the main black tent. The animal feeding station is located left of the tree. In the front the animal pens can be seen, one of them covered (image courtesy of Carol Palmer).

Figure 3.20. The author attempting to churn butter in the private area, JTW. The floors are covered with plastic matting in many areas. The kitchen hearth and the gully can be seen in the background (image courtesy of Carol Palmer).

Jouma's tent summer (JTS)

Sampled by: Jouma' 'Ali, Carol Palmer and the author

Tent plan type: B

Duration of abandonment: half a year

Occupied by members of: 'Azazma tribe

Description: This location up on a hill had been used seasonally for the past three years as the summer campsite, while the location down the hill was used for the winter campsite (JTW). The area covered by the tent included a kitchen area, which was the only one showing evidence of a floor – a hard surface was left behind, which was cleared of stones. Next to it was the women's activity area. About 38 m to the southwest of the tent was the outdoor living area (*muarash*), and approximately 15 m west of the tent were the remains of a series of goat and sheep pens. At first the two species were kept together, but later on they were separated.

Figure 3.21. The abandoned summer camp, JTS. The kitchen hearth can be seen on the left within the kitchen area, which had been cleared of stones. The outdoor hospitality area, marked by four poles, can be seen in the background (photograph taken by the author).

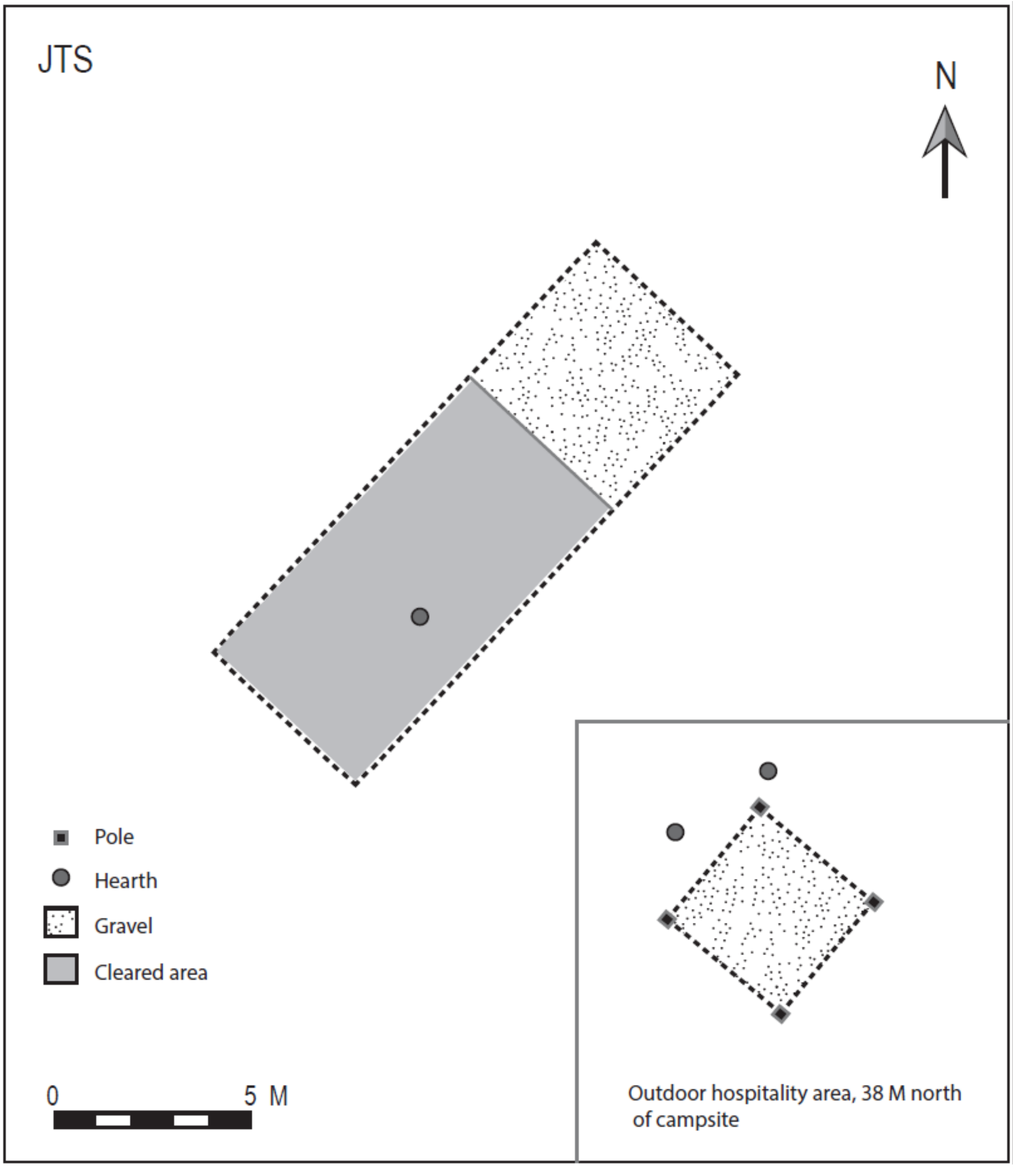


Figure 3.22. Plan of JTS (created by the author based on measurements and drawing made in the field).

Figure 3.23. Left image - the kitchen hearth at JTS. Right image – Jouma' holding up a piece of dung taken from an animal pen at JTS during sampling (images courtesy of Carol Palmer).

Wadi Dana (WD)

Sampled by: Emma Jenkins, Pascal Flohr and Sarah Elliott

Tent plan type: A

Duration of abandonment: occupied

Description: Jouma's winter tent is not the only occupied site included in this study. During 2009 a tent in the adjacent wadi, Wadi Dana, was sampled. The tent had been occupied every winter for twenty years, and living there at the time of sampling were an elderly couple. It included a *shigg*, a mahram including a sleeping area, activity area and the kitchen, and an adjacent goat sleeping area (figure 3.24.). Outside were two goat pens and an outdoor hospitality area (*muarash*). The state of this campsite was described as messy at the time of sampling.

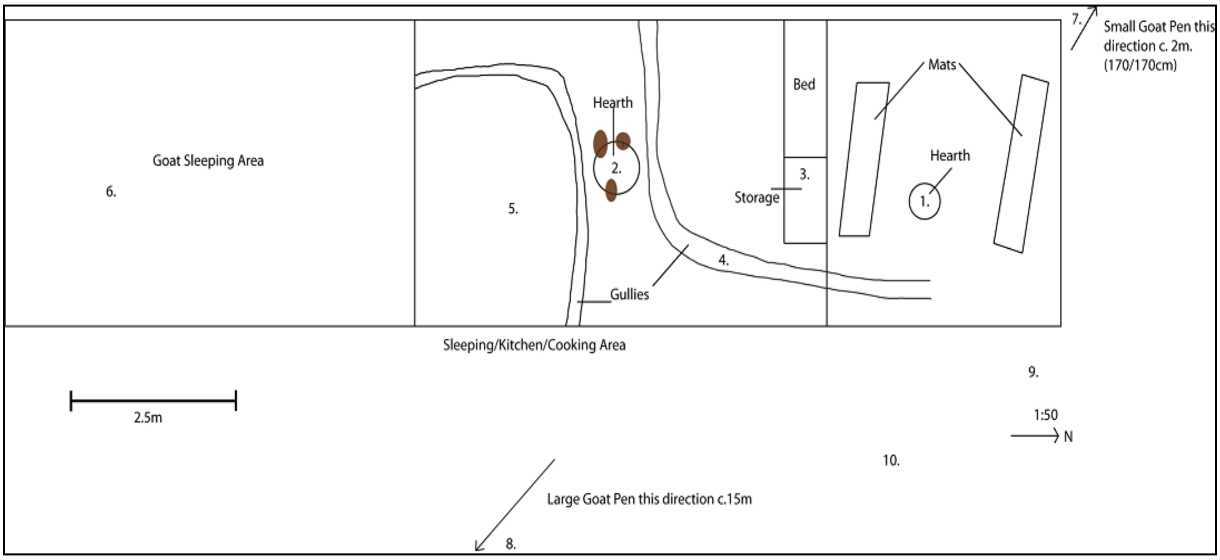


Figure 3.24. Plan of the occupied Bedouin tent at Wadi Dana (courtesy of Emma Jenkins).

3.5. Summary

This chapter provided an overview of Bedouin life at Wadi Faynan, and introduced the Bedouin campsites that will be examined in this research through geochemical and phytolith analysis of their soil samples. The use of space at the Bedouin campsites 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 campsites 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 campsites, WF940, contain two hearths, one used for food preparation in the kitchen, and another for tea making in the hospitality area. The knowledge of the use of space at these sites enables us to correlate observed patterns of activity to the soil signatures that will be discussed in the results chapters.

4 Background of archaeological samples

4.1. Introduction

This chapter will provide the archaeological background for this study. Soil samples from three Neolithic sites at Wadi el-Jilat form the archaeological data: Wadi el-Jilat 7 (WJ7), Wadi el-Jilat 13 (WJ13) and Wadi el-Jilat 26 (WJ26). Fieldwork at these sites 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 early stages of sedentism, agriculture and pastoralism (Garrard et al. 1988). The sites of Wadi el-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. In the following sections an introduction to the Neolithic of the Near East will be given followed by an outline of the geographic, environmental and archaeological setting of Wadi el-Jilat. Lastly the individual sites will be presented.

4.2. Background for the Wadi el-Jilat Neolithic sites

4.2.1. The Neolithic of the Levant

The Neolithic of the Near East, dated to roughly 10,000-5,500 cal. BC (figure 4.1.), encompasses gradual yet substantial changes in lifestyle that have dramatically altered modes of human life. While the greatest part of human existence consisted of mobile hunter-gatherer groups that followed the movement of large herbivores, during the Neolithic period a subsistence of agriculture and herding, and the establishment of early sedentary farming settlements became more widespread. Previously termed the "Neolithic Revolution", a term coined by Gordon Childe (1936), the transition from hunter-gatherer lifestyles to sedentary farming ones has fascinated researchers both within and outside the field of archaeology for almost a century. In the past two decades it has become increasingly clear that the dramatic changes in subsistence have deep roots in preceding periods and that these processes are much more gradual than was first recognised.

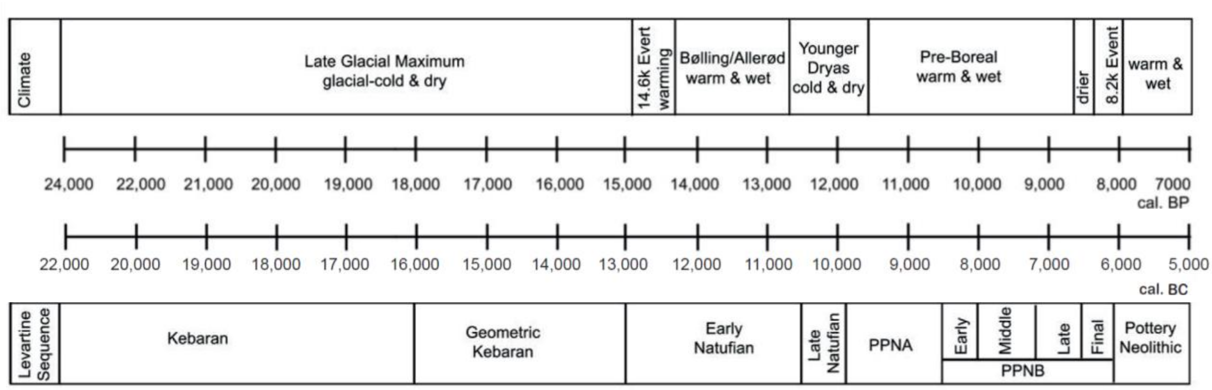


Figure 4.1. Timeline of Levantine chronology and climatic conditions in cal. BP and cal. BC years (after Zeder 2011, 223).

Early signs of transition

The first signs of this transition can be found in the Epipalaeolithic societies of the Levant, dated to roughly 24,000-10,000 cal. BC. Although the earliest secure evidence for wheat and barley domestication is considered to be dated to the Pre-Pottery Neolithic B (PPNB) period, roughly 8,500 cal. BC (Zeder 2011), a recent paper suggests that small scale trial cultivation took place as far back as 23,000 (Snir et al. 2015). The excavation of Ohalo II, a hunter-gatherer sedentary campsite in Israel, produced an extensive archaeobotanical assemblage which included the presence of "proto-weeds" alongside seeds of wild cereals that would later on appear in the archaeological record in their domesticated form, such as barley (*Hordeum spontaneum*) and emmer wheat (*Triticum dicoccoides*). Excavations at Kharaneh IV, a 20,000-year-old hunter-gatherer settlement in Jordan, exposed dense and extensive occupation deposits of hut structures, suggesting that our ideas about the Epipalaeolithic as a period associated with small mobile hunter-gatherer groups need to be reconsidered (Maher et al. 2012). During the Epipalaeolithic a shift towards increased sedentism, social complexity, and an intensification in food procurement started to take form (Bar-Oz 2004; Bar-Yosef 2002; Boyd 2006; Goring-Morris et al. 2010; Richter et al. 2011).

During the late Epipalaeolithic, 12,800-10,000 cal. BC, Natufian communities tended to occupy sites for longer periods of time, and constructed more permanent architecture (Bar-Yosef and Valla 2013). Although subsistence at these sites is still considered to be based mainly on hunting and gathering locally available food sources, this now focused on a broader range of species in proximity to these early settlements, which were more intensively exploited (Munro 2009; Stutz et al. 2009). The Younger Dryas, a cold climatic event dated to 11,500-9,800 cal. BC, is considered to be of importance for the development of domestication in this and the following period. Before the Younger Dryas, during the Early Natufian, climatic conditions were favourable which contributed to the extensive settlement patterns during this period, mainly in the Mediterranean zone. The architecture is characterised by spatially segregated circular and D-shaped structures measuring ca. 7-15 m in diameter. Early Natufian buildings are more durable than those of the previous Epipalaeolithic settlements, and often include circular arrangements of postholes suggesting the support of substantial roofs (Goring-Morris and Belfer-Cohen 2008).

During the Younger Dryas most sites were abandoned, and according to some certain groups resorted to cultivation as a result of changing climatic conditions (Bar-Yosef 1998, 2003; Byrd 2005). Most of the architectural remains of the Late Natufian are considered less substantial, and even more opportunistic, than those of the Early Natufian. The structures are smaller and interchangeable through time, and in the drier peripheral region of the Negev seasonal campsites can be found alongside clusters of small structures (Goring-Morris and Belfer-Cohen 2008). Nevertheless, the finer details of cultivation and settlement practices during this period are not well known. The site of Nahal Ein Gev II, for example, maintained a substantial and likely sedentary occupation during the Late Neolithic (LN), suggesting that not all Natufian populations reverted back to a nomadic lifestyle (Grosman et al. 2016).

And so, although a trend towards agro-pastoralist village life can be seen throughout the Neolithic, it is important to note that this was not a linear and inclusive change that affected all human societies in the Near East. Rather, a mosaic of human cultures and modes of subsistence would be a more suitable description of the situation during this period. The Levant is known for its high variety in precipitation and vegetation zones across a relatively small area, and local conditions dictated for a great deal the scope and pace of the Neolithization processes in each specific environmental zone. These regional differences correlate to a greater degree of variation among archaeological cultures or entities during the Natufian, and to a diversity in the subsistence strategies chosen by different groups. While some Natufian groups were more sedentary, others practiced seasonal residential mobility (Goring-Morris and Belfer-Cohen 2011).

The following period, the PPNA (10,000-8,700 cal. BC), saw settled communities re-emerging in the area, and many of them appear to have practiced pre-domestication cultivation of crops while hunting wild game. The archaeobotanical remains at PPNA sites portray a diverse diet, with a focus on barley and wheat consumption which correlates with a shift from pounding instruments to grinding tools more suitable for cereal processing (Boyd 2005; Fuller 2007). PPNA settlements were larger than Natufian ones, measuring up to 2.5 hectares. While those in the southern Levant generally show continuity from the Natufian, later sites from the northern Levant generally do not. Domestic buildings were semi-subterranean, oval structures, often made from mudbrick with stone foundations. They were more standardised in form and size than the previous period and often contained silos for grain storage. In addition to domestic and storage structures, buildings with a communal function started to emerge towards the end of the PPNA. Alongside small-scale 'villages' such as Jericho and Gilgal, smaller and more ephemeral sites such as Dhra and Iraq ed-Dubb were spread out across the landscape (Boyd 2005; Goring-Morris and Belfer-Cohen 2008; Kuijt and Goring-Morris 2002).

Based on the study of the distribution patterns of lithic artefacts, it has been suggested that a shift in the organisation of space occurred during the PPNA in comparison with previous periods. While Epipalaeolithic hunter-gatherer groups carried out activities in space in a relatively non-delineated manner, PPNA occupation portray the use of designated activity areas. These changes are assumed to be correlated to mobility patterns, and have been proposed to reflect notions of 'home' In any case, it seems that people started to develop more structured and formalised uses of space during the Early Neolithic (Kuijt and Goodale 2009).

The Pre-Pottery Neolithic B and Late Neolithic

The earliest secure evidence of the domestication of both plants and animals is dated to the beginning of the Pre-Pottery Neolithic B (PPNB) period in the Levant, dated to 8,700-

6,400 cal. BC, although long phases of plant cultivation and animal husbandry pre-dated their domestication (Zeder 2011). The emergence of more substantial village societies, and an increase in population size, led to greater social complexity and broad cultural interactions during this period. The PPNB 'koine' included permanent villages as well as mobile foraging groups and pastoral communities. The proximity of various local geographic zones, each encompassing different climatic and environmental conditions, meant that a range of human adaptations to local settings co-existed within the Levant. The shift to the PPNB, and the timing and degree of adoption of aspects of the agricultural, sedentary lifestyles associated with it, varied across the Near East (Goring-Morris et al. 2009; Goring-Morris and Belfer-Cohen 2011).

In addition, an elaboration of the symbolic and ritual realms of life can be witnessed throughout the PPNB, including the so called 'skull cult' that involved the removal, plastering and display of skulls from burials (Belfer-Cohen and Goring-Morris 2011). Population growth and the introduction of domesticated herd animals during the PPNB led to a shift in settlement patterns, embodied by the rise of larger settlements that reached a size of up to 12 hectares, referred to as "megasites" (Belfer-Cohen and Goring-Morris 2011; Kuijt and Finlayson 2009). A change can also be seen in architectural traditions, with internally divided quadrilateral buildings replacing the circular structures typical of earlier periods. Construction was mainly based on mudbrick and stone foundations, and in the southern Levant lime-plaster was widely used for floors and walls. Unlike earlier sites, within the large settlements of the PPNB trash was disposed of at open areas or abandoned structures, forming middens. Smaller PPNB sites can be found in the drier peripheries of the southern Levant, some of them characterised by 'beehive' like structures constructed of waist-high circular stones once forming foundations for organic superstructures. The varying thickness of their walls and location within the landscapes reflects their seasonal use (Goring-Morris and Belfer-Cohen 2008).

Together with developments in human subsistence and settlement during the Neolithic, came changes in other aspects of human life. Archaeological sites reflect an intensification of material culture, which was enabled by the decrease in mobility. Occupying a site for longer durations of time and relying more heavily on grain food sources, meant that people could invest more in storage facilities for example (Kuijt and Finlayson 2009). Architecture became more elaborate, buildings that are interpreted as having a communal function appeared in the archaeological record during the PPNA and became more extensive throughout the PPNB, and trade networks became more extensive. Studies on the effect that the increase in material culture and group sizes had on social interaction suggest that the size of social networks has expanded in size yet decreased in density as a result of changes during the Neolithic, leading to the development of additional levels within the hierarchy of social relationships (Coward 2013, 251-255). These changes in social interaction, with new emerging economic systems, are seen by many as the groundwork for ambitious or successful family units to gain leadership (Byrd 2005).

At the end of the PPNB and beginning of the following period, the Late Neolithic (6,300-5,200 cal. BC), changes in animal husbandry led to the secondary exploitation of ovicaprids. While it is presumed that up until about 6,500 cal. BC animals were only kept for meat consumption purposes, evidence from lipid residues in the now available pottery vessels suggests that dairy production became more common after this date (Evershed et al. 2008). The increased reliance on animal products, pressure on farmland and pastures due to the rise in population size and exploitation of local resources, and drop in annual precipitation in the southern Levant at the end of the PPNB, corresponded with occupation patterns continuing into the LN (Rollefson et al. 2014).

The LN is characterised by architecture and settlement layouts which show more variety and were less substantial than the PPNB ones, with a mix of circular and different types of rectangular structures. Specialised ritual spaces have not been identified for sites from this period, and the few examples of burial practices recovered for the LN represent a great deal of variation in the treatment of the bodies of the deceased, their burial locations, and associated grave goods (Gopher and Orelle 1995; Twiss 2007). Largely still poorly understood, the LN has long been thought of as a period of decline in population and PPNB cultural traditions, though evidence of continued social complexity and an intricate regional interaction sphere contradict the idea of a 'systems collapse' during this period (Banning et al. 1994; Gibbs 2013; Twiss 2007). It has been suggested that populations inhabiting some of the PPNB megasites relocated to other areas, possibly into landscapes which were unsuitable for agriculture but agreed with a pastoral nomadic, hunter-herder, existence (Köhler-Rollefson 1992; Rollefson et al. 2014). Other scenarios involve the adoption of pastoral subsistence by local hunter-gatherer populations already inhabiting these areas (Byrd 1992; Martin 1999). Whether any of these hypotheses, or both of them, are true, by the end of the Neolithic human socio-economic existence in the Levant relied heavily on the management of animal and plant domesticates, and the landscapes of the LN were scattered with a diversity of adaptations in habitation, food production, architecture, and ritual (Twiss 2007).

When considering the shift towards increased sedentism throughout the Neolithic, it is important to keep in mind that the nature of occupation in early sedentary sites is both debatable and variable. There are ethnographic examples in the Near East of settlements with storage facilities that are occupied by nomadic populations only a certain period of each year that suggest that the use of the word "sedentary" is not straightforward (Bar-Yosef and Belfer-Cohen 1989). Broadly speaking however, while early Epipalaeolithic settlements were probably not occupied throughout the year, the later and more substantial Neolithic settlements in the Levant represent more permanent dwellings (Bar-Yosef and Belfer-Cohen 1989, Byrd 2005, Goring-Morris and Belfer-Cohen 2011). Goring-Morris and Belfer-Cohen (2008) identify four general types of occupation that represent a trend toward increased diachronic site densities throughout the Neolithic: a) mobile hunter-gatherer band occupations during the Palaeolithic; b) initial sedentary communities during the Natufian and PPNA; c) large PPNB 'villages' or 'megasites'; and d) dispersed hamlets of the Late Neolithic. At the same time, Goring-Morris and Belfer-Cohen recognise regional variation in occupation trends and the site densities and levels of sedentism they represent. Settlement features were related to many different factors such as community size and scalar stress, modes of subsistence, environmental conditions, and social structures and ideologies, rather than merely adhering to a chronological plan devised by archaeologists thousands of years later.

4.2.2. The need for a better understanding of the use of space during the Neolithic

While the general developments in subsistence and mobility, architectural and mortuary trends, and even to some degree social processes that took place during the transition from hunter-gatherer lifestyles to sedentary farming communities in the Levant have been recognised, we are yet to reach a detailed level of interpretation for these early sites. The latter are difficult to interpret due to their shallow deposits and poor preservation of the organic remains they comprise (Banning and Köhler-Rollefson 1983; Cribb 1991; Gifford 1978). Nevertheless, as has been discussed in Chapter 1, understanding the use of space in any structure is vital to their interpretation. 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 (Bourdieu 1990; Bourdieu 1992; Douglas 1966; Parker Pearson and Richards 1994). Understanding the use of space at ephemeral sites which are typical of many types of habitation during the Neolithic can shed light on past ways of life that are currently underrepresented within archaeological narratives. Identifying the location and nature of activity areas within Neolithic habitation is the first step in addressing the social use of space at these important sites.

As mentioned in the previous section, alongside the 'megasites' of the PPNB, which consisted of permanent architecture, other sites such as Wadi el-Jilat show a more ephemeral occupation during the PPNB and do not fall under the description of the typical Neolithic agricultural 'village'. At these ephemeral sites a mixture of subsistence activities seems to have taken place, and a reliance on gazelle and hare hunting continued into the Late Neolithic (Garrard et al. 1994). In order to truly understand human life during the PPNB it is not enough to focus our attention on the larger and more substantial sites that display the full suite of 'Neolithization'. It is as important to understand communities who have adopted other lifestyles, and present more ephemeral occupation, as all of the subsistence strategies and settlement types during this period form a whole. By emphasizing this variety and finding ways to better comprehend sites that are difficult to interpret one can begin to truly explore social conditions and lifestyles during the Neolithic, and how these led to the development and adoption of agriculture and sedentism by some communities while others chose to rely on a mixture of subsistence and habitation strategies. The following section will discuss the environmental setting of Wadi el-Jilat, which is important for understanding the subsistence strategies people in this region chose to rely upon.

4.2.3. Environmental setting of Wadi el-Jilat

Wadi el-Jilat is a tributary of the Wadi ed-Dabi in the south-west of the Azraq Basin, located approximately 55 km southwest of the town of Azraq. The latter forms an endorheic drainage basin with a drainage catchment of 12,800 square km in north-central Jordan, within the dry steppe and desert areas of the eastern plateau. While the central playa (Qa Azraq) is only 500 m above sea level, the relief of the outer drainage divides increases to over 900 m in the southwest, more than 1000 m in the northeast and about

1800 m across the Syrian border, at Jebel Druze. The area encompasses a surface lithology characterised by a complex of limestones, chalks and marls in the south and volcanic basalts and tuff in the north.

Wadi el-Jilat lies in a transition area between steppe and desert, receiving approx. 100 mm precipitation yearly, and cuts into late Cretaceous and early Tertiary limestones, chalks and marls which contain a large concentration of flint beds. The gorge on which the sites lie cuts through an aggradation consisting of two units, the lower unit comprised of a sequence of gravel bodies, scour and fill structures and silty overbank deposits, and the upper unit including epsilon cross-bedded gravels, greenish silty channel fill deposits and extensive overbank flood loessic silts containing the Epipalaeolithic and Neolithic sites. The latter suggests the existence of a localised marshy area with a meandering perennial stream. The Neolithic sites lie in close proximity to each other across the edges of the gorge where they form superficial mounds, the seasonal water supply providing a natural incentive for settlement (figure 4.2., 4.4.) (Garrard et al. 1994).

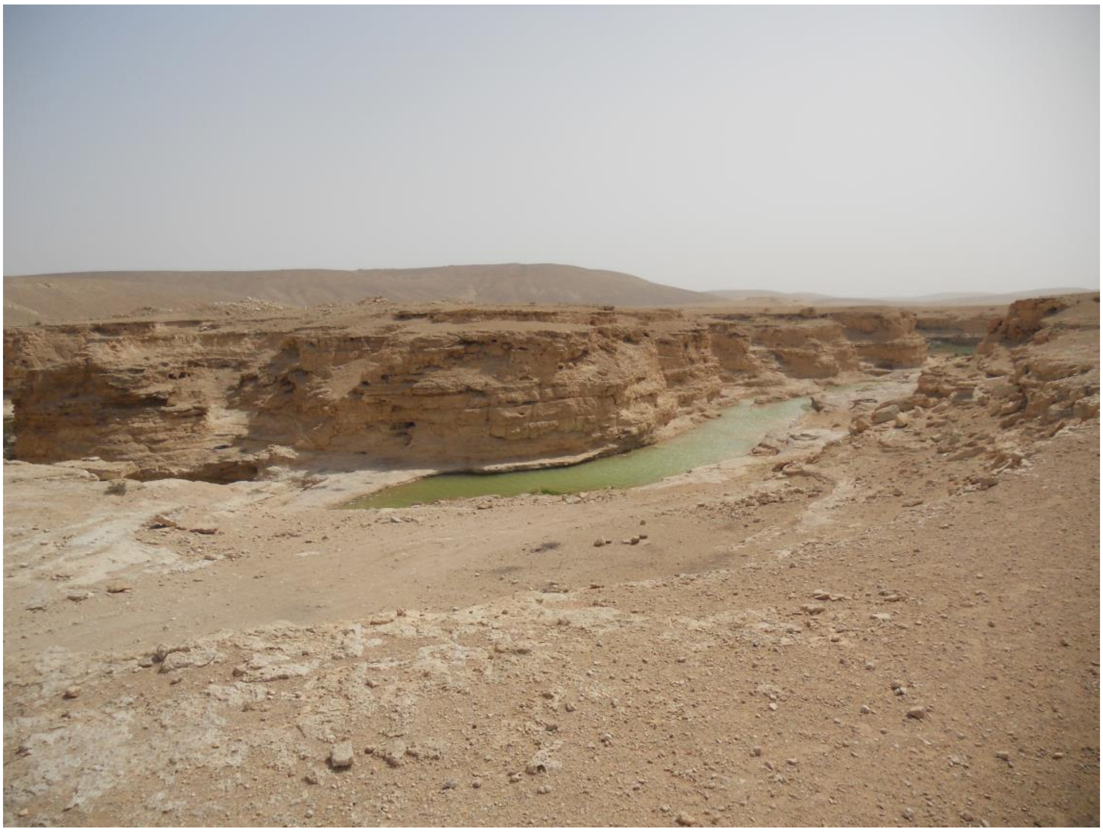


Figure 4.2. View of the Wadi el-Jilat gorge, picture taken by the author in April 2013.

Figure 4.3. A view towards Wadi el-Jilat gorge and sites Wadi el-Jilat 6 and Wadi el-Jilat 7 (image courtesy of Andrew Garrard).

The climate in the Azraq Basin is variable across the different areas and altitudes, with rainfall exceeding 200 mm in the north and along the western margins, and less than 50 mm in the south. In addition, precipitation will also fluctuate yearly, and can be very localized, only affecting small areas. Precipitation is almost entirely limited to the winter months, November until April. Temperatures are variable as well in the region, ranging between an absolute maximum of 42 and absolute minimum of minus 4 degrees Celsius, with frosts possible between November and April. Drainage in the basin is well-developed in the limestone, chalk and marl hills in the western, central and eastern areas, with a dendritic system of wadis feeding into a braided channel structure towards the low-lying areas of the central part of the basin. Several springs in the area have fed wetland zones until recently, which attracted migratory birds (Nelson 1973, Hemsley and George 1966).

Vegetation in the region is dependent on the local climate and precipitation, and soil conditions. Along the western rim there are calcareous or basaltic steppe soils and more rainfall than other areas, translating into higher levels of vegetation. Until recent times, when large-scale pumping of water to Amman and Irbid began, springs near Azraq fed extensive wetlands. These housed a wide range of plants, including *Arundo donax*, *Typha angustata*, *Scirpus litoralis*, *Juncus acutus*, and *Tamarix jordanix* was available in seasonally flooded depressions. Playas with highly water-resistant soils form mudflats supporting almost no vegetation, while others might have a cover of small halophytic shrubs and herbs. Around the major playas silt dunes are common, characterised by a *Nitraria retusa-Tamarix macrocarpa* shrub association. The many wadi systems running through the basin provide the largest concentration woody plants, housing dwarf shrubs such as R*etama raetam*, *Artemisia herba-alba*, *Achillea fragrantissima*, and chenopods such as *Atriplex halimus*, *Seidlitzia rosmarinus*, *Salsola tetrandra* and *Anabasis articulata*. In the past, trees such as *Pistacia atlantica* could have been more common in the western wadis, and are today only found in Wadi Aseimir.

Within the more arid regions, the limestone steppe, located about 40 to 50 km west of Azraq, comprises loessic silts that are held in place by grasses such as *Poa sinaica* and *Carex stenophylla*, and include shrubs such as *Anabasis syriaca*, *Noaea mucronata*, and *Allenia lancifolia*. The limestone desert has a rather sparse plant cover, though dwarf shrubs and herbs may occur in silty depressions, including among others the shrub *Artemisia herba-alba*, the chenopods *Anabasis articulata*, *Haloxylon salicornicum*, and the grasses *Stipa capensis* and *Schismus arabicus*. The basalt desert shares some of the limestone desert's vegetation, but has some species more specific to it such as the *Seidlitzia rosmarinus*, *Anabasis articulata* and *Lycium depressum*. Dwarf shrubs such as *Achillea fragrantissima*, *Artemisia herba-alba*, *Capparis spinosa* and *Salsola vermiculata* are characteristic of the larger, siltier depressions.

4.2.4. Wadi el-Jilat during the Neolithic

The dynamic environment which Wadi el-Jilat makes part of is not unlike that of Wadi Faynan, described in the previous chapter. 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 el-Jilat using a range of subsistence strategies, each of which might have been appropriate 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.

The vast majority of Neolithic buildings at Wadi el-Jilat are circular or oval semi-subterranean constructions, with upright slabs forming the fragile external walls. Many of them had internal divisions, hearths and other features such as benches or storage bins (Montague et al. 1988, 40-1). Nevertheless, unlike contemporary sites in moister regions of the Levant, which present substantial architectural remains, the Neolithic settlement at Wadi el-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). 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 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 wadi el-Jilat 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 suggest 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. 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. The botanical assemblage at WJ13 is similar to that of WJ7 (see detailed descriptions below). Interestingly, Colledge mentions that species diversity was larger at the WJ7 and WJ13 compared to 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 el-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 el-Jilat than the perhaps more specialised cultivation taking place during the Neolithic at Wadi Fidan and Beidha.

Combining the information from the botanical and zooarchaeological analysis, it appears that the sites of Wadi el-Jilat were occupied during late winter to late spring. This is based on the seeds of species found at the site which are known to flower in autumn while others flower during spring, the proximity of migrating herds to WJ13 during spring, together with evidence from the cull patterns at WJ7 suggesting that hunting took place between February and June. All in all, it seems that the people occupying the Wadi el-Jilat sites used a variety of subsistence strategies during the Neolithic, the most visible ones archaeologically being hunting, pastoralism, low-intensity cultivation and foraging. Due to the lack of written sources during this period we cannot address a range of factors, such as possible political, religious or market considerations which could have played a role in lifestyle choices, and we are probably far from providing a full account of all subsistence strategies practiced at Wadi el-Jilat during the Neolithic. However, we can suggest that as in the case of Wadi Faynan, patterns of mobility and subsistence have probably changed through time in relation to varying circumstances, and that the use of the ephemeral architecture at these sites corresponded with these.

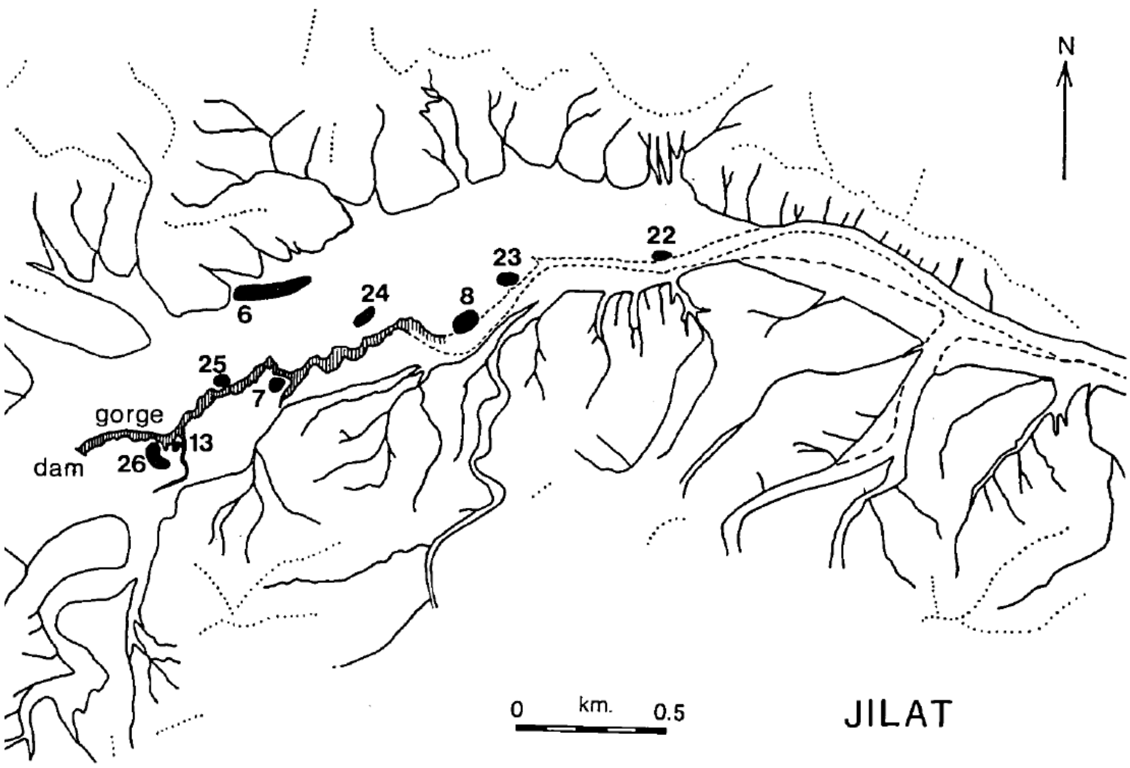


Figure 4.4. Map of Wadi el-Jilat showing the location of the excavated Epipalaeolithic and Neolithic sites (from Garrard et al. 1994, 73).

4.3. Description of individual sites

The individual sites chosen for analysis are described below. The selection of these case studies aimed at representing a range of activity areas and building forms represented at Wadi el-Jilat during the Neolithic. The majority of structures in this area are circular or oval, semi-subterranean, and contain shallow deposits. External walls and in some cases internal partitions were constructed from upright stone slabs of local limestone or travertine. Features within the buildings included hearths, which were often stone-lined, stone pavements, benches or working surfaces, and round bedrock features. The only two areas of Neolithic occupation excavated at Wadi el-Jilat which were not chosen for this analysis have not been presented in the section below. Wadi el-Jilat 25 was not chosen as it was partially excavated, and area B in the site of Wadi el-Jilat 26 covered a limited area, and so the similar yet more extensive area E was selected instead.

Wadi el-Jilat 7 (WJ7)

The occupation of this site took place during the Early and Middle PPNB period, two radiocarbon samples from the building provided the dates of 7,942 ± 197 and 7,571 ± 106 cal. BC (all dates in this section were taken from Garrard et al. 1994 and calibrated through www.calpal-online.de). It is located on the southern bank of the Wadi, about 700 m downstream from the historic dam of Wadi el-Jilat, forming a low mound that extends approximately 30 m in diameter (figures 4.4., 4.5.). Two small soundings were opened in 1984, exposing three main phases of construction which contained several circular structures and sub-structures. Interpretation of the series of occupation in these structures however was complicated by the collapse, revamping and possible robbing of stone from some features.

The areas were extended into three larger trenches during the 1987 and 1988 field seasons, dividing the site into areas A, B and C (figures 4.6. - 4.9.). Area A contained a series of inter-connecting walls, forming larger and smaller circular spaces. One of the walls in the north-eastern part of area A continued into area C, creating the eastern, southern and western borders of a rectangular area containing eleven circular bedrock features, which could have been used as postholes or mortars. The initial deposit on the bedrock in the two areas 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, including the wall described above. During the later phases, dated to the Middle 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 the south-west corner of area A. A curvilinear wall and small compartments made from upright slabs were then filled with sand and silt deposits.

In area B the outline of a single building was exposed, which was remodelled throughout the three stages of occupation. The initial phase, dated to the Middle PPNB, included the preparation of the bedrock by cutting a pit into it, leaving a bedrock shelf in the north-western end. Upright stone slabs were used to frame the oval building and create a partition along its southern edge. 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. In the later phases, dated to the Middle PPNB and Middle or Late PPNB, a pavement and upright slabs were added to a sub-compartment in the northwest 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 remains found at WJ7 are similar to those from the earlier Wadi el-Jilat Epipalaeolithic sites, containing high concentrations of gazelle with smaller numbers of hare and tortoise, but differing from them in lacking any equid bones and having a wider range of carnivore and bird species (Montague et al. 1988, 47). Evidence of caprines is absent at this site, suggesting that wild sheep and goat were not present in this area (Garrard et al. 1994, 97). Carbonised plant remains were present in WJ7, but the preservation of specimens was poor, with many of the distinguishing morphological features in the grains obscured or absent. Nevertheless, a number of identifiable cereals was obtained. Einkorn wheat (*Triticum monococcum*) and cultivated two-row barley (*Hordeum sativum*), and probably also wild barley (*Hordeum spontaneum*) are the three species of cereals that could be identified. It is unclear if these were cultivated nearby the site or imported. In addition to grasses, fruits of *Ficus* sp. and *Pistacia* sp., legumes such as *Cicer* sp. And *Lens* sp., and chenopods were recognised in the analysis (Montague et al. 1988, 47; Garrard et al. 1994, 104-5). Charcoal concentrations were highest in WJ7 and WJ13 (described below), which 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 el-Jilat sites contained relatively low amounts of charcoal in comparison to the occupation fills.

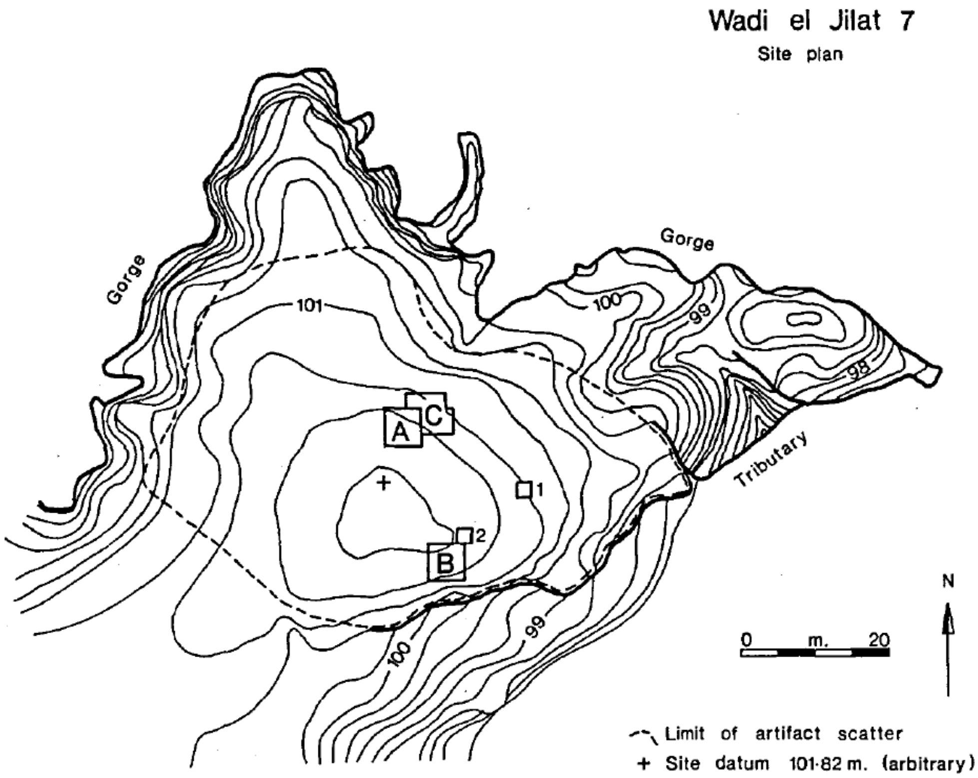


Figure 4.5. Site plan of Wadi el-Jilat 7 showing the location of areas A, B and C (from Garrard et al. 1994, 74).

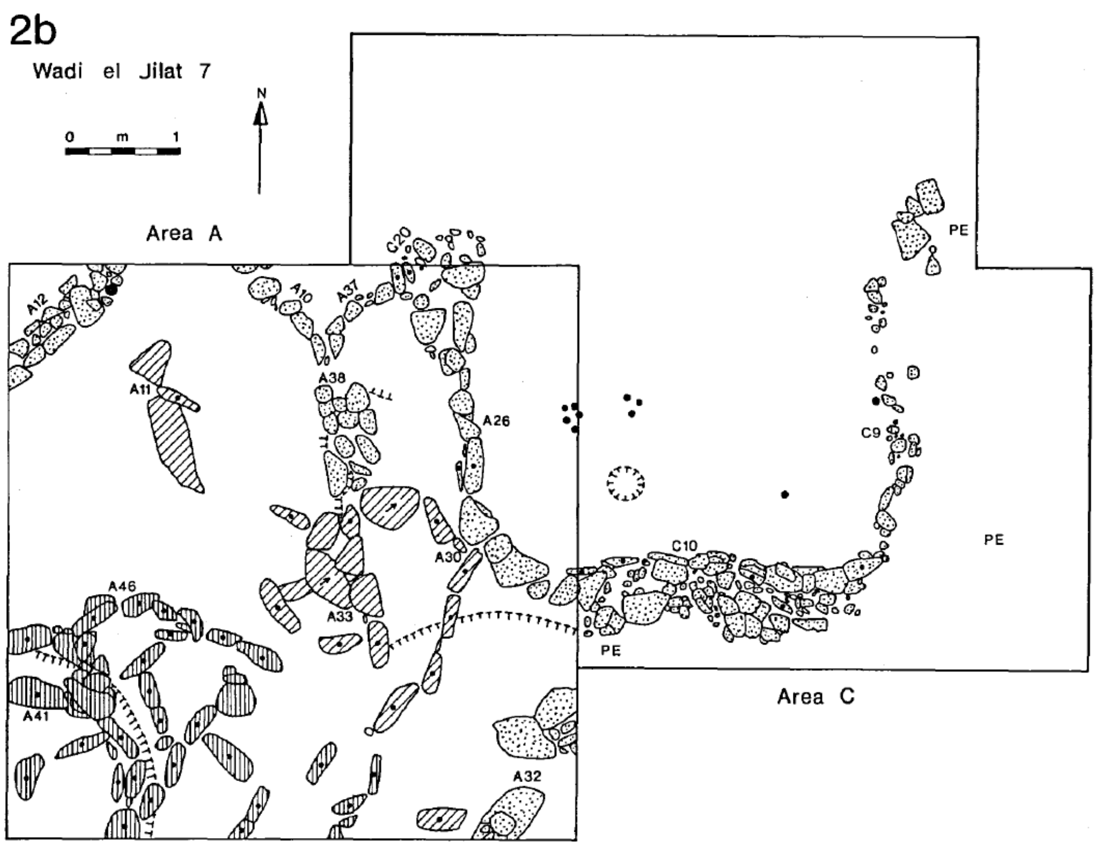


Figure 4.6. Plan of areas A and C, Wadi el-Jilat 7 (from Garrard et al. 1994, 74).

Figure 4.7. View of Wadi el-Jilat 7 areas A and C (image courtesy of Andrew Garrard).

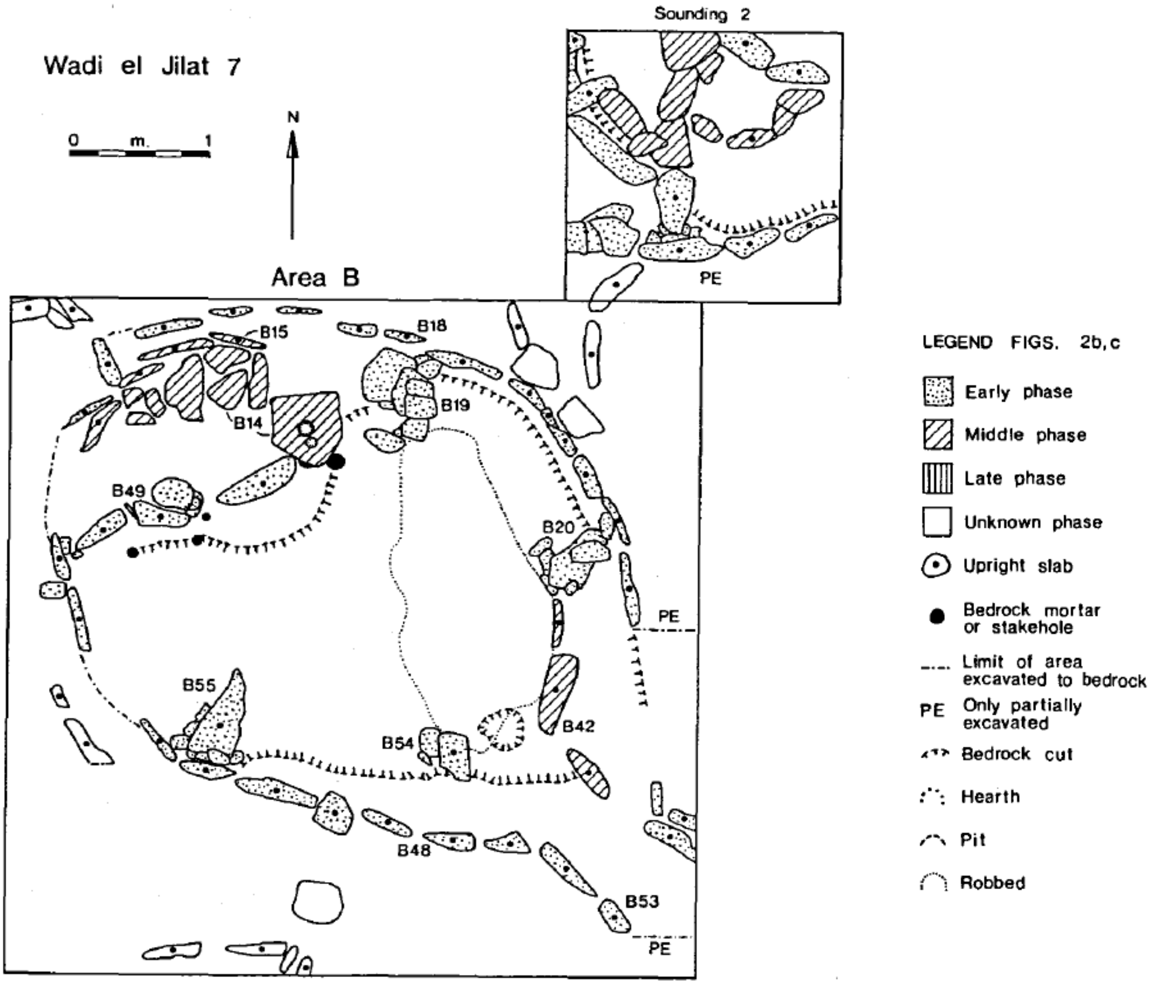


Figure 4.8. Plan of area B, Wadi el-Jilat 7 (from Garrard et al. 1994, 74).

Figure 4.9. Wadi el-Jilat 7 area B, view from above (image courtesy of Andrew Garrard).

Wadi el-Jilat 13 (WJ13)

This site is located immediately east of WJ26, on the southern bank of the Jilat gorge. It 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 postholes 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 (figures 4.10., 4.11.) (Garrard et al. 1994).

The building was dated to the Final PPNB and displayed three phases of occupation, 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. Two C14 dates were available for this stage of occupation, 6,840 ± 150 and 6,796 ± 161 cal. BC.

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. Three stone upright slabs from the middle phase of occupation protruded through the pavement, and a large horizontal limestone slab lay near the partition wall, which appeared to have been roughened for grinding in one area. West of the partition, two statues were found lying on their sides. Cutting through the north-eastern section of the pavement, several stone-lined hearths were found. These produced two C14 dates, 6,828 ± 142 and 6,739 ± 152 cal. BC. These dates are similar to the ones established from the initial phase of occupation, which might suggest that this site was in use for only a short duration of time.

The faunal assemblage at the site is dominated by sheep, goat and gazelle bones, and hare remains make up a quarter of the material. The remains of large herbivores such as equids and bovines are present, but rare. Small numbers of small to medium carnivores, reptiles and birds were also recorded. The botanical analysis of WJ13 provided similar results to WJ7, with large amounts of carbonised plant remains and poor preservation of the specimens. Wild and domestic einkorn wheat (*T. boeoticum* and *T. monococcum*), domestic emmer (*T. dicoccum*) and cultivated and wild barley (*Hordeum spontaneum* and *Hordeum sativum*) were identified at this site, similarly to WJ7, and in addition one grain of naked barley was tentatively identified. As is the case with the PPNB material, the question of local cultivation is unclear. Fruits of *Ficus* sp. and *Pistacia* sp., legumes such as *Cicer* sp. And *Lens* sp., and chenopods were also found in WJ13 (Montague et al. 1988, 47; Garrard et al. 1994, 104-5).

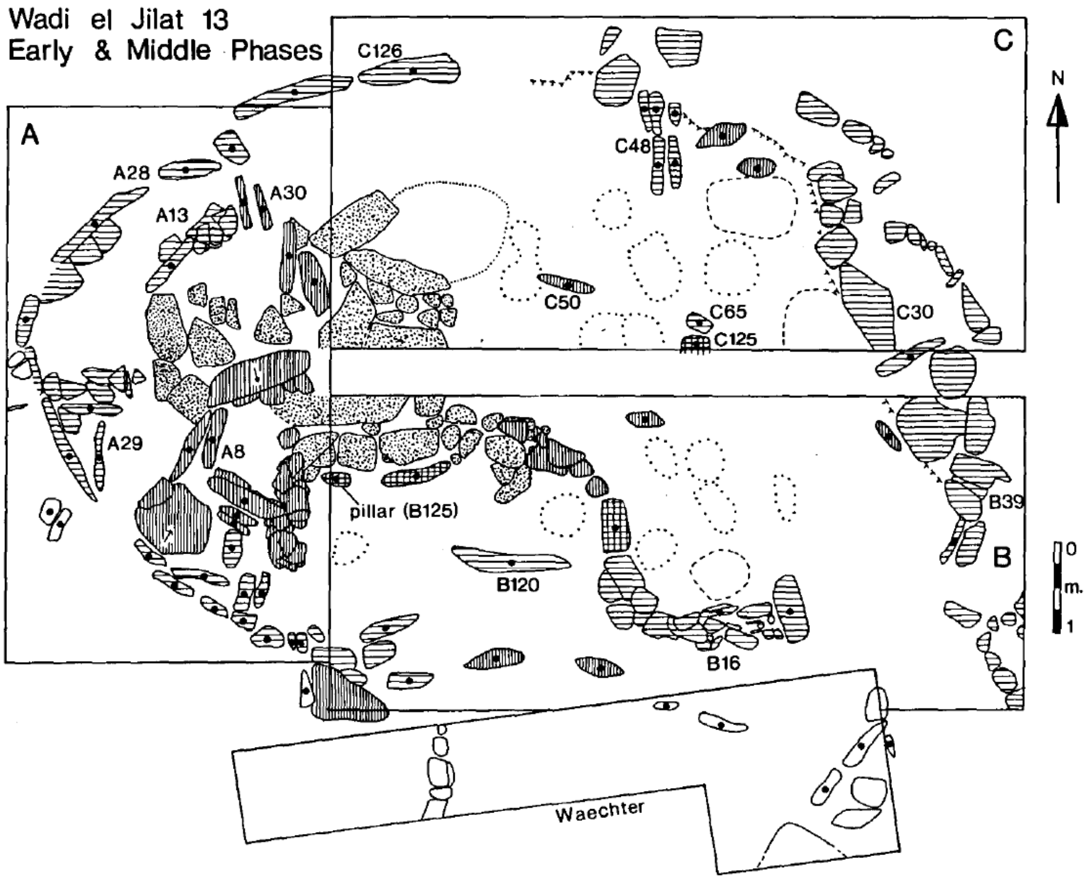


Figure 4.10. A plan of early and middle phases at Wadi el-Jilat 13 (from Garrard et al. 1994, 80).

Figure 4.11. Wadi el-Jilat 13, view from above (image courtesy of Andrew Garrard).

Wadi el-Jilat 26 (WJ26)

The excavated area in WJ26 was comprised of two main structures (one circular and the other rectangular), and an area containing circular units (some of which are interpreted as hearths). The deposits in the different areas of WJ26 were shallower than the previous sites, reaching an average depth of 50 cm while WJ7 and WJ13 contained deposits as deep as 80 cm. The site is located on the southern back of the gorge, approximately 200 m downstream from the dam, forming a semi-circular spread of buildings and finds around the western and southern sides of an erosional gully draining into the main ravine (figure 4.12.). There are approximately 20 main sub-structural buildings within this arc, mostly circular, all seem to have had entrances towards the inner part of the semi-circle, away from prevailing westerly winds. Following an initial sounding, four areas were excavated during the 1987 and 1988 seasons, areas A, B, C and E.

Area A comprises one of the only two rectangular structures at the southern end of the WJ26 alignment, and was chosen for excavation in order to understand the nature and date of these buildings (figures 4.13., 4.16.). It was built during the Middle PPNB and was quadrangular in shape, the northern and eastern walls being 5 m long and the western and southern walls measuring 4 m. It was cut into the bedrock in some areas and into pre-construction sediments in other parts, and the walls were made from upright stone slabs. Features made from upright stone slabs with silt and rubble packing in the centre of the unit could have served as low benches or alternatively formed foundations for a superstructure. The early phase of use of this building is not associated with any hearths. In the late phase, also dated to the Middle PPNB, various stone pavements were added in various areas of the building, which were associated with single stone uprights in each of the four quadrants of the building. In addition, an annex was built to the north of the structure, made from double course walls instead of the commonly used upright slabs. It is possible that this structure was in use around the same time the circular building from area C, described below, was. This is based on the similarities in lithic assemblages (Garrard et al. 1994).

Area C was chosen for excavation as it contained a well preserved circular building within the WJ26 arc of structures (figures 4.14., 4.16.). It has two parallel rows of upright slabs with silt and rubble packing in between, the external diameter was 5 m, and the internal one measured 3.5 m. The 80 cm wide band could have been used as a shelf or bench, and it is possible that the outer line of slabs provided foundations for a superstructure while the inner slabs could have supported internal partitions or other features. This type of construction seems to have been used for the adjacent circular structures as well. The early phase of occupation is dated to the Middle PPNB, when the structure was cut through pre-constructional sediments into the bedrock. Two radiocarbon dates gave a date of 7822 ± 161 and 7798 ± 159 cal. BC for this early phase of occupation. A circular hole of 25 cm dimeter and 20 cm deep was found in the building, which could have served as a mortar, hearth or roof support. A stone lined hearth was found within the primary fill, in a central position within the building. During two later phases of occupation, dated to the Middle PPNB, additional features were constructed within the structure. Two parallel rows of stones were added at the northern end, and two large horizontal slabs were placed on a rubble foundation at the western part. Lastly, a stone blocking was positioned in the entrance and further sedimentation occurred within the building.

Area E is located in a sheltered space east of area C at the gully edge (figures 4.15., 4.17.), and was excavated in order to get a better idea of outdoor activities. The presence of the latter were indicated by stone-lined hearths and some bedrock features that were visible at the surface prior to excavation. Two walls run through the area, meeting just off its centre, and two upright stone slabs were placed parallel to the walls. They seem to enclose the bedrock features that had been exposed prior to excavation, which may have been used as mortars, or alternatively represent the remains of a structure. A sequence of stone-lined hearths was exposed in the southwestern corner of area E, ranging from 0.5 to 1 m in diameter. One of the hearths provided a C14 date of 7,871 ± 196 cal. BC, making a plausible case for the use of this area being at least partially contemporary to that of the structure in area C.

Remarkably, the amount of faunal remains retrieved from all areas of WJ26 was much smaller than the quantities found in the other sites, WJ7, WJ13 and WJ25. Only 12 bone fragments were recorded for all areas and phases, while the number of faunal remains retrieved from WJ7 and WJ13 are in the thousands. This discrepancy does not seem to correlate to the influence of natural factors and appears to indicate the lack of deposition of these within the structures and open areas of WJ26. Similarly, the various areas in this site were not rich in botanical material either, the samples contained some wood charcoal but no specimens were reported.

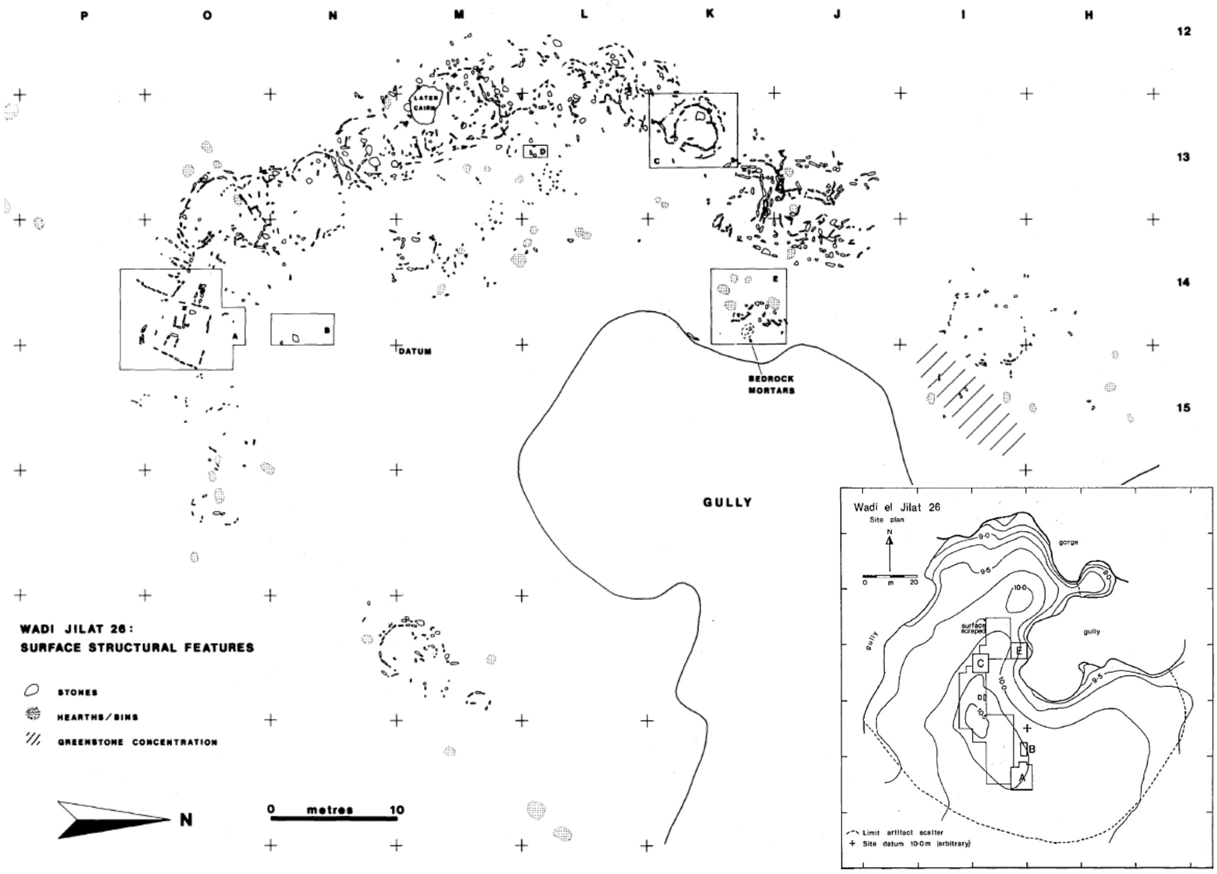


Figure 4.12. Overview of Wadi el-Jilat 26 and related surface structural features. Inserted image provides plan of excavated areas in Wadi el-Jilat 26 (from Garrard et al. 1994, 76, 78).

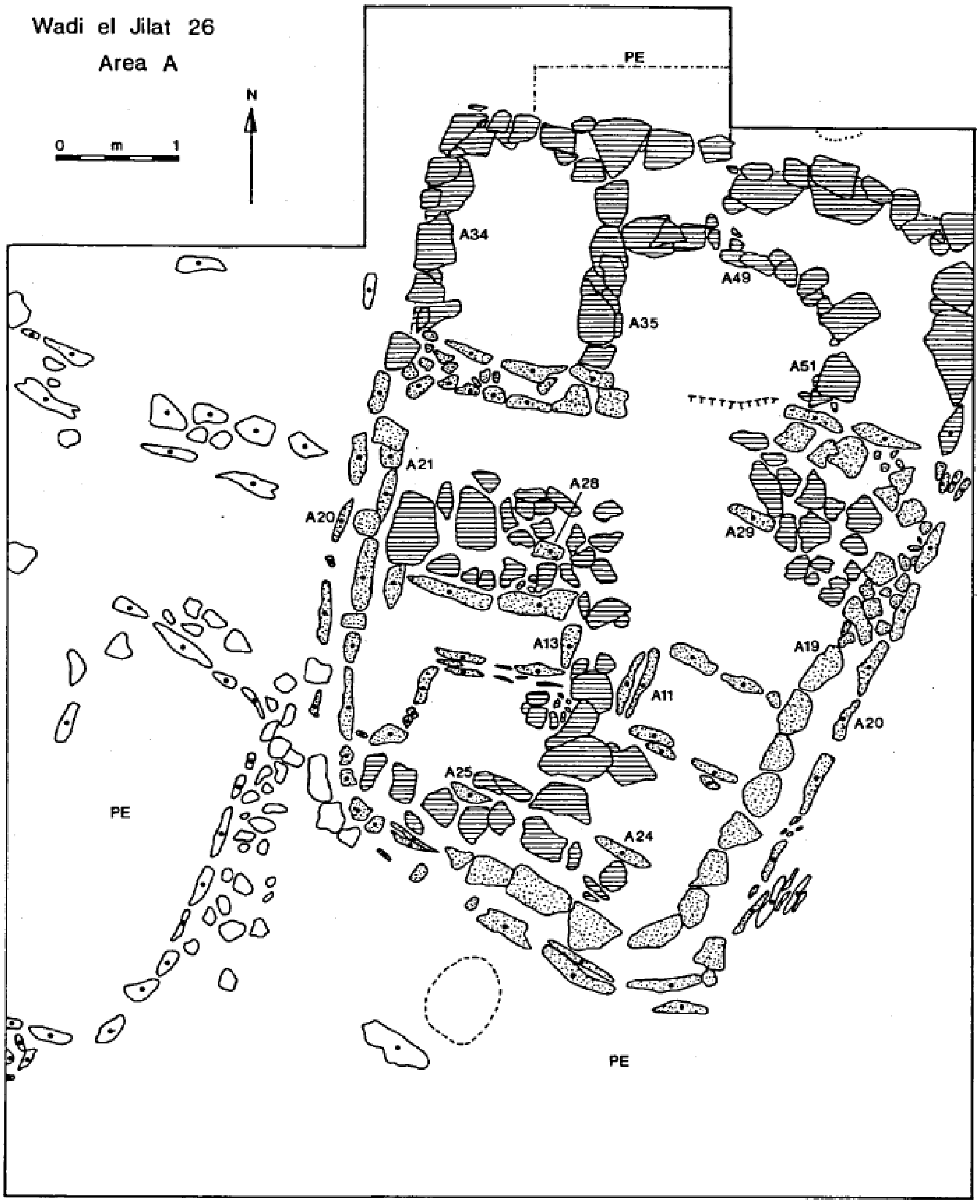


Figure 4.13. Plan of Wadi el-Jilat 26 area A (from Garrard et al. 1994, 78).

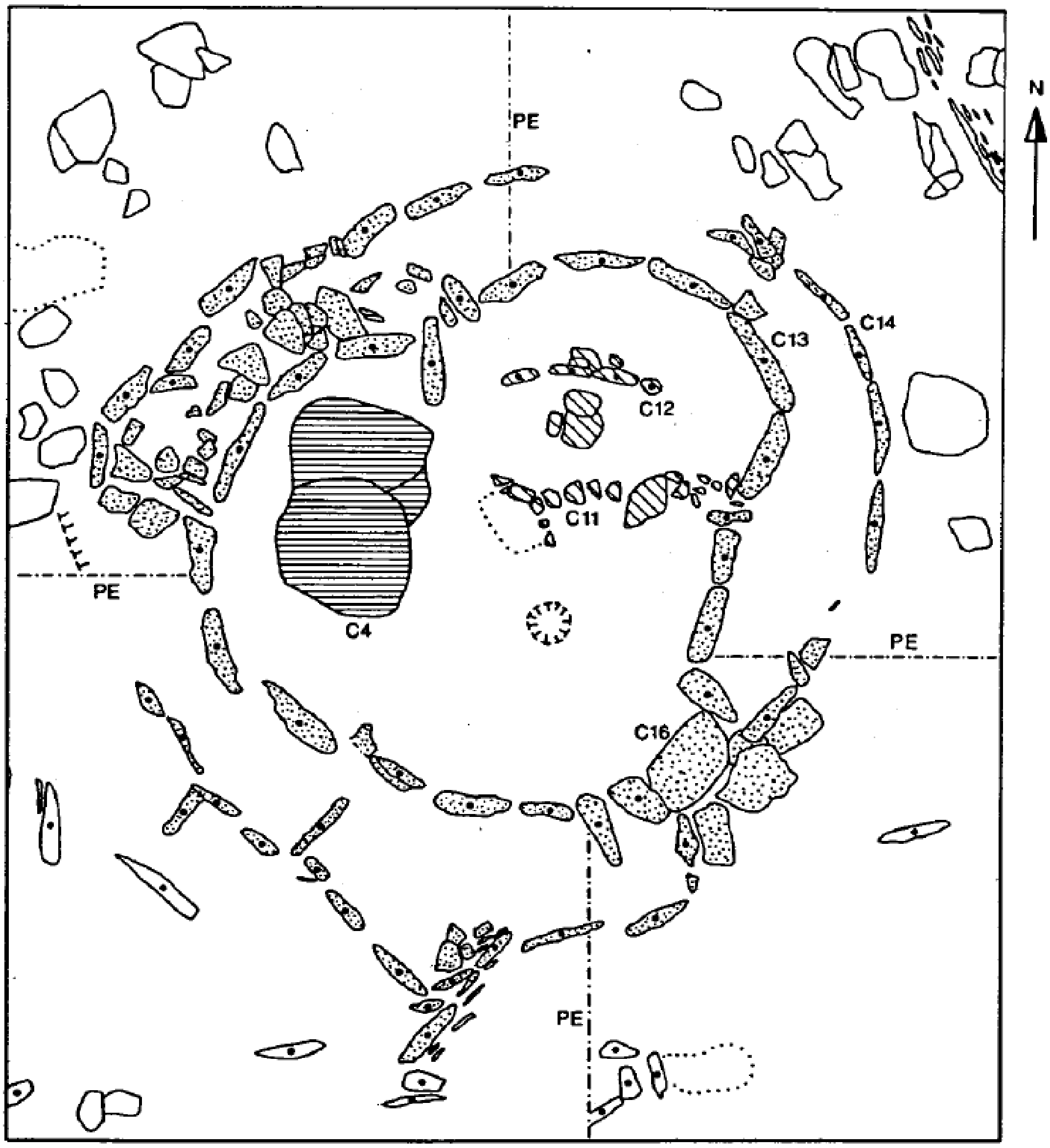


Figure 4.14. Plan of Wadi el-Jilat 26 area C (from Garrard et al. 1994, 78).

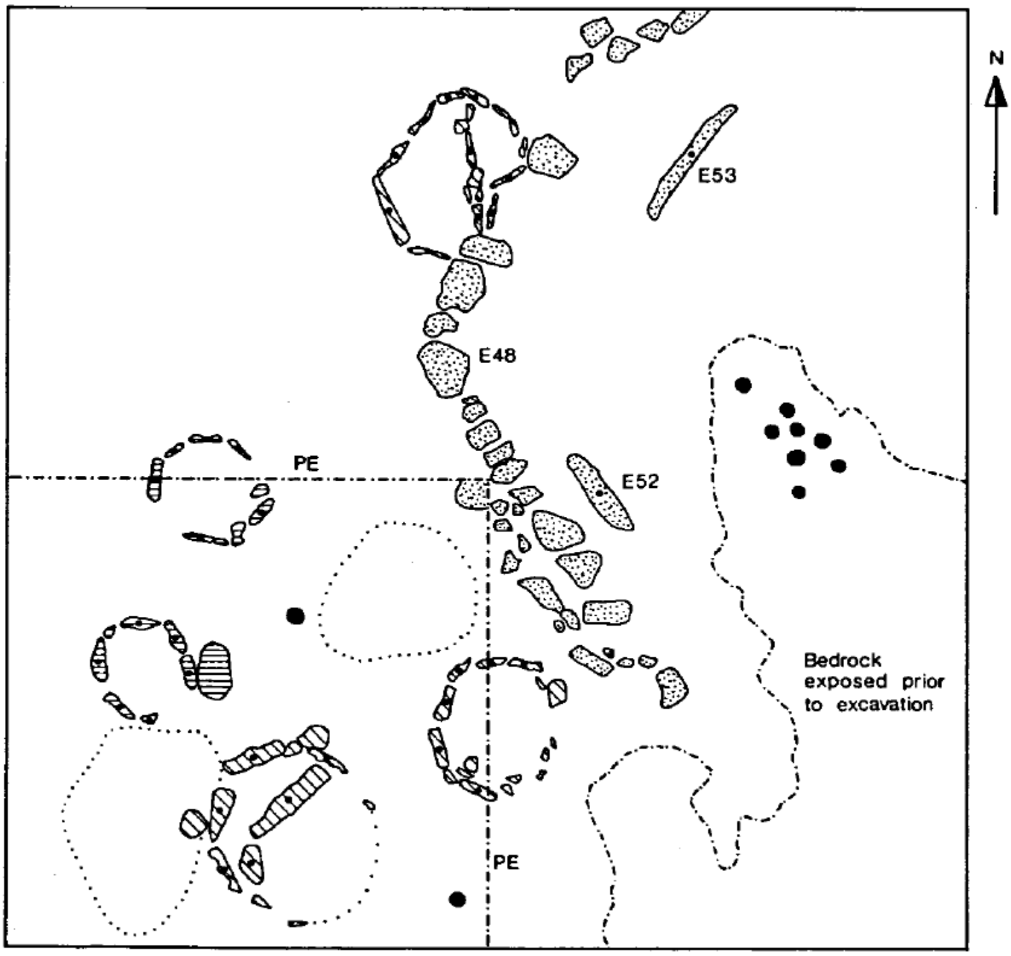


Figure 4.15. Plan of Wadi el-Jilat 26 area E (from Garrard et al. 1994, 78).

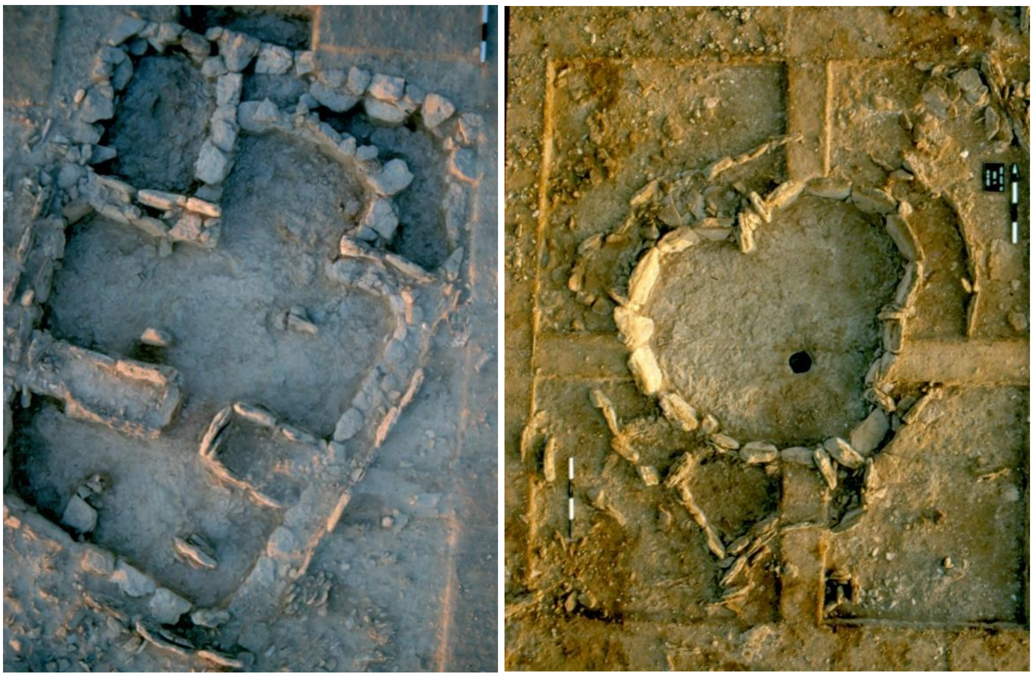


Figure 4.16. Wadi el-Jilat 26 areas A and C, view from above (image courtesy of Andrew Garrard).

Figure 4.17. Wadi el-Jilat 26 area E (image courtesy of Andrew Garrard).

4.3.1. Interpretation of the structures

The use of the Neolithic structures of Wadi el-Jilat described above is difficult to interpret according to the architectural, faunal, botanical and stone artefact remains unearthed at the sites. The buildings' external walls are described as flimsy in the report of the '87 and '88 seasons, and the lack of evidence for stone superstructures suggests that, if they existed, they were made from organic materials which have since then perished (Garrard et al. 1994). The two rectilinear structures at WJ26, one of which was excavated and is described above (WJ26, area A), seem to be contemporary to the semi-circle structures in WJ26, such as the one found in area C. It is likely that the difference in form is related to the use of these buildings, perhaps representing domestic versus communal functions, but without clear evidence for the spatial use of these sites we can only speculate.

What is clear, is that space in the earlier buildings of WJ7 and WJ26 was confined in size and by internal divisions of partitions and buttresses. The later sites were much larger, and it was suggested that WJ13 had a non-domestic use based on the presence of figurines and potentially statuary, a buried cache of four flint implements, and pavements which were carefully laid out. In addition, an occupation of the series of semi-circular structures by one or two extended families, and the later sites of WJ13 and WJ25 by several individuals, was proposed (Garrard et al. 1994). The excavation of the Neolithic structures at Wadi el-Jilat provided information about the date, seasonality and related modes of subsistence for the Neolithic occupation along the gorge, but also raised questions about the purpose of their construction and the use of the buildings. If we can develop ways to address the use of space at such ephemeral sites, we may be able to provide a better understanding of their ancient occupants' lifestyles. Were these spaces used by extended families, a large group, or perhaps even by part of a community during seasonal expeditions? Did these structures have a domestic purpose, a communal or craft function, or were they storage facilities? Did their function change through time? What does the difference in form relate to? Finding methods to increase the information gained from ephemeral sites can illuminate aspects of ancient life, such as social structure and subsistence, during the Neolithic.

4.4. Summary

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 megasites of the PPNB, which consisted of permanent architecture, other sites such as Wadi el-Jilat show a more ephemeral occupation during the Neolithic. At these ephemeral sites a mixture of subsistence activities seems to have taken place, and the occupation of the Wadi el-Jilat structures appears to have been seasonal. Ephemeral habitation has been explored 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.

The three sites of Wadi el-Jilat encompass various structures that were occupied, probably seasonally, between 8,000 and 6,700 cal. BC. This extensive time span separating between the occupation of the different areas at these sites undoubtedly corresponds with differences in subsistence strategies, cultural traits and other aspects of life. On the other hand, the inhabitants of Wadi el-Jilat across the Neolithic are connected by sharing the same terrain and probably similar environmental conditions. The faunal and botanical analysis of the findings at WJ7, WJ13 and WJ26 suggest that a wide range of species were exploited at these sites, but at the same time a gradual shift towards a greater reliance on domesticates can be seen through time. The nature of the occupation of these structures is not entirely clear, were they domestic? Did craft activities take place within some of them? Were others used as communal spaces, or for storage? The sites of Wadi el-Jilat might be comparable when it comes to their environmental settings, but differ in their period of occupation, the size and form of their structures, and possibly in the nature of their occupation. These differences 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 el-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.

5 Methodology

This chapter will describe the procedures for the geochemical, phytolith and statistical analyses applied in this research to analyse the samples from Wadi Faynan and Wadi el-Jilat and to the results of the soil analysis. This was done in order to establish the soil signatures characterising each context and to assess the value of the dual methodology for interpreting the social use of space at ephemeral sites. The following section will discuss the sampling strategies for obtaining the ethnographic and Neolithic soil samples. Sections 5.2. and 5.3. outline the procedure for the phytolith and geochemical analysis, respectively. In the last section the methodology for the statistical analysis is described.

5.1. Sampling

There are currently no established protocols for geoarchaeological sampling. The locations from which material is removed, the amount of soil taken and how it is kept depend on the site, its excavators, and on the research questions addressed through soil analysis. In the case of the ethnoarchaeological survey at Wadi Faynan, the focus of sampling was to study abandonment processes in key features of Bedouin occupation. A targeted sampling strategy therefore concentrated on observed units of activity such as hearths, animal pens, but also kitchen floors and sleeping areas. The sampling strategy at Wadi el-Jilat was not guided by a clear soil analysis purpose, and sediment samples were kept for each excavated context in forethought for future analysis needs. The following sections describe the sampling procedures in the ethnoarchaeological and Neolithic sites.

5.1.1. Ethnoarchaeological material

At each of the Bedouin campsites in Wadi Faynan sampled by Carol Palmer and Helen Smith as part of the ethnoarchaeological survey in 2000 (see chapter 4) soil samples were taken from each of the different activity areas, including the two hearths, the sleeping area, animal pens, and floors in the hospitality area, women's activity area and kitchen (the locations of these can be seen in the campsite plans in Chapter 3). In addition to these, three background samples were taken for each site from areas considered to reflect low human presence within approximately 40 m from its perimeter. The number of samples varied according to the available features at the sites, ranging from seven to thirty-four. The soil was collected using a clean trowel and bagged in plastic sample bags by Helen Smith and Carol Palmer for the sites WF916, WF940, WF953 and WF982. The amount of soil varied for each sample, some of the dung and hearth samples containing around 15 gr of material, while others weighing approximately 40 gr. The type of occupation and a schematic site plan were recorded for each campsite, including the available features (such as hearths and animal pens).

Additional sampling at Wadi Faynan during 2014

Supplementary sampling at Wadi Faynan took place during May 2014 by Carol Palmer, Jouma' 'Aly Zanoon, and the author, where soil samples were collected from an occupied winter tent (Jouma's Tent Winter – JTW) and an adjacent summer campsite (Jouma's Tent Summer – JTS) that had been abandoned in the previous six months. The aim of this fieldwork was to retrieve samples from an occupied Bedouin campsite, in addition to samples from a freshly abandoned camp, in order to have a reference point to relate observed abandonment processes to. The sample collection strategy followed that of the ethnoarchaeological survey as closely as possible, and the same context categories were used (described in section 5.5.2.). As the tents were occupied or very recently abandoned during sampling, understanding how different localities were used was straightforward, and samples taken from the animal pens could be described in detail. The sampling took place in two tent sites that belonged to Jouma' 'Aly Zanoon and his family, from the 'Azazma tribe. A winter campsite previously occupied by this family was part of the ethnoarchaeology survey at Wadi Faynan, and is part of the analysis in this project – WF953. The sites were described in a form and a schematic plan of the sites was drawn (an example of both is provided as Appendix 2).

5.1.2. Neolithic material

The great advantage of using the Neolithic sites at Wadi el-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. The samples analysed for this project were chosen according to the following criteria:

- The samples were chosen to reflect specific archaeological contexts – hearths, floors, bins, fills and bedrock features.

- Expected quality of preservation – this was based on the assumption that deeper sediments would contain better preserved phytoliths. An initial test of several samples that originated from sediments at different depths revealed that depth did not play a major role in phytolith preservation, but the top layers were still largely avoided as deeper layers would probably suffer less from modern contamination.

- Where possible, a group of samples was taken which represents a single habitation phase within a building so that a comparison of different activity areas that were used simultaneously could be achieved.

Although these considerations guided the choice of samples, when it came to collecting the selected bags from the storage area at the CBRL (Council for British Research in the Levant) British Institute in Amman, it became apparent that the physical availability of the samples set limitations on the selection process. During the three decades that had passed since the samples went into storage a few boxes and some of the samples in the available boxes seem to have disappeared. The absence of between a quarter and a third of sample material, depending on the site, meant that the aim to study contemporaneous samples could not be fully achieved, and the focus shifted towards analysing samples that represented a variety of features and activities (the location of analysed samples can be seen in Appendix 3). Fortunately, the soil samples that were available for analysis had all been well bagged, having been first wrapped in aluminium foil and then double-bagged. Due to this packing procedure virtually no sediment was lost from individual samples, which contained homogenous fine sandy-silty material with the occasional presence of small stones and lithic material.

Another issue that affected the choice of material for this study is the extent of the excavated surfaces. Although entire structures were exposed, the adjacent outdoor spaces were not studied in depth, and so potential activities taking place directly outside buildings are not fully represented in this analysis. The excavation and sampling of area E of WJ26 however, which appears to have encompassed various outdoor activities, provided this research with an opportunity to study an open area which is considered to have been used contemporarily with one of the adjacent studied buildings – WJ26 C (see description of WJ26 in chapter 4).

The two background samples were collected from two locations, one near WJ7 and one in the vicinity of WJ13. As is always the case with background sampling, it was difficult to identify layers that were contemporaneous with the Neolithic sites and to be sure that they do not contain any anthropogenic intrusions. The background sample for WJ13 contained small lithic pieces, which are scattered across the area today. This might mean that this sample is less "natural" than would have been hoped. The background sample for WJ7 did not contain any lithic material. The background samples will be used as a baseline to which the on-site samples can be compared in order to establish patterns of anthropogenic enrichment in relation to the natural soil composition.

5.2. Description of phytolith analysis procedure

140 soil samples were treated using the dry ashing method. This technique is an established protocol widely used for phytolith extraction, and was preferred in this analysis as it is considered to cause less breakdown of conjoined phytoliths than the acid extraction method (Rosen 1992). The phytolith slides were then counted and identified morphologically. The soil samples were processed in batches of six to twelve samples. All batches followed the processing order described above, except for one batch of twelve dung samples which is described at the end of this section. The laboratory procedure included the following six stages, which are described in more detail below:

Stage 1: Sample preparation

Stage 2: Removal of carbonates

Stage 3: Clay removal

Stage 4: Organic matter removal

Stage 5: Heavy liquid separation

Stage 6: Mounting of phytolith material

1. Sample preparation – the samples were dried in a drying oven at 50° C for two days and sieved through a 400 µm mesh on shiny magazine paper, after which 800 mg or 1 gram of the sediment was weighed using an analytical balance and placed into 50 ml test tubes (an increase of the original sample material weight from 800 mg to 1 gram was necessary in order to be able to extract enough phytolith material for mounting with the ethnographic samples).

2. Removal of carbonates – 15 ml of 10% HCl was added to the 50 ml test tubes containing the samples in three runs, pausing each time after pouring 5 ml in order to allow the samples to effervesce. Once the reaction was over distilled water was added up to the 40 ml mark, and the tubes were centrifuged at 2000 rpm for 5 minutes, after which the supernatant was discarded. This process was repeated three times.

3. Clay removal – the samples were transferred into tall 400 ml beakers, and allowed to sink. After pipetting off any excess water, 20 ml of 5% Sodium hexametaphosphate was added to each beaker, which was then stirred well. Distilled water was then added up to 8 cm followed by another vigorous stir, and the samples were left to sediment for 70 minutes. The floating suspend was then carefully poured to keep the sediment material that had settled at the bottom. The beakers were then refilled with distilled water up to the 8 cm mark, after 60 minutes the supernatant was poured off. This last step was repeated for each beaker until the water turned completely clear. After letting the sample sediment in order to pipette off any excess water, the sample material left at the bottom

of the beakers was transported into crucibles using a pipette and a washing bottle filled with distilled water. The crucibles were left to dry in a drying oven overnight at 50° C.

4. Organic matter removal – the dry samples were put in a muffle furnace for 2 hours and 30 minutes at 500°C. After cooling to room temperature, the samples were lightly crushed within the crucibles using a small spatula. The samples were then carefully transferred into 15 ml test tubes.

5. Heavy liquid separation – 3 ml of Sodium polytungstate (SPT) calibrated at 2.3 Specific Gravity was added to each of the 15 ml test tubes containing the samples. These were then centrifuged at 800 rpm for 10 minutes after shaking each tube in order to spread the material evenly. The supernatant (containing the phytolith material) was poured into a new 15 ml test tube, which was used to wash off the SPT by adding water until the 10 ml mark, shaking the tubes, and centrifuging the test tubes at 2000 rpm for 5 minutes. The supernatant, containing the SPT, was then poured off. This process was repeated three times.

6. Mounting of phytolith material – the samples were transferred into 10 ml beakers of a known weight using a pipette and some distilled water. The beakers were placed in a drying oven at 50° C. Once the samples were dry the beakers were weighed again to obtain the weight of the extracted phytoliths.

Between 0.0019 and 0.0021 grams of the phytolith material was placed onto a 3 x 1 inch slide. Approximately 8 drops of Entellan were added to the slide, and then spread out while distributing the phytolith material evenly, using a toothpick. A 22 x 22 mm cover slip was placed on top of the mounted material, and the slides were left to dry in a fume cupboard for three days.

Due to the high organic content of a group of 12 dung samples, the organic matter removal stage was the first to be performed so that larger organic particles were not lost during the sieving process. For this batch the process started with placing a large amount of the sample in a crucible, weighing it and extracting the crucible weight to get that of the sample, next followed the organic matter removal stage, after which the samples were sieved. Then part of the samples was extracted to be the equivalent of an original, pre-furnace sample weight of 1 gram. This has the disadvantage of creating a discrepancy between the weight of the original material and the sieved material. However, as the dung samples contained mainly organic material and few stones or clay lumps, this discrepancy is considered small by the author and is nevertheless smaller than the bias that would have been created by sieving out the larger organic particles. Following these stages, the samples were treated in the same way as the others, starting with the carbonate removal stage, and excluding a further organic material removal stage.

5.2.1. Counting

The slides containing the phytolith material were counted using a Meiji infinity polarising microscope with an XY mechanical stage for holding and moving the slides at fixed intervals. The slides were examined under plane polarised (PPL) and cross polarised (XPL) transmitted light in order to differentiate between phytoliths and minerals. A magnification of x400 was used during the counting of 250 to 300 phytoliths per slide (the entire slide was counted if this amount was not reached). Albert et al. (2000) argue that counting 194 phytoliths produced a 23% error margin, while counting 265 phytoliths reduced the error margin to 12%. The counted quantities of different phytolith types and (when relevant) species were documented on a tally recording sheet. The names of the phytolith types were later adjusted according to the International Code for Phytolith Nomenclature (Madella et al. 2005). An example of the counting sheet and a table presenting the adjustments made to the names are provided as Appendix 4. The identification of phytoliths to species, genus or family level was aided by comparing specimens with examples in a phytolith reference collection prepared by the INEA project at Bournemouth University from plant samples collected in Jordan by the author. Observer bias can always pose issues when dealing with count data, but this is considered to be minimal within this study as all of the counting was done by the author, and the results would still allow for comparisons between context categories to be made.

The counts of the various phytolith types were later translated to a number of categories which relate to taxonomic identification and information about preservation, plant part and concentration of the associated vegetation. The table below presents the associated taxonomic and plant part information for each phytolith type (table 5.1.). As mentioned above, in most cases multi-cell or conjoined phytoliths are necessary for

Phytolith type	Plant part	Taxa
Single-cells		
Bilobate short cell	Leaf/husk	Panicoideae/monocot
Parallepipedal bulliform cell	Leaf	Poaceae/monocot
Cuneiform bulliform cell	Leaf	*Phragmites* and *Oryza*/monocot
Ovate crenate	Leaf/stem	Poaceae/monocot
Cross	Leaf	Panicoideae/monocot
Globular echinate	Leaf	Palmaceae/monocot
Globular granulate	-	Dicot
Globular psilate	-	Dicot
Hair base	-	Poaceae/monocot
Hair cells	-	Poaceae/monocot
Elongate dendritic	Husk	Poaceae/monocot
Elongate psilate tenis	Leaf/stem	Poaceae/monocot
Elongate sinuate	Leaf/stem	Poaceae/monocot
Trapeziform psilate	Leaf/stem	Poaceae/monocot
Papillae cell	Husk	Poaceae/monocot
Tabular irregular	-	Dicot
Polyhedral granulate	-	Cyperaceae/monocot
Polyhedral plain	-	Dicot
Rondel	Leaf	Pooideae/monocot
Saddle	Leaf	Chloridoideae/Arundinoideae/monocot
Scalloped	-	Dicot
Rectangle tabular	-	Dicot
Cylindric sulcate tracheid	-	Dicot
Silica aggregate	Tree bark?	Dicot
Multi-cells		
Wheat husk	Husk	*Triticum*/monocot
Barley husk	Husk	*Hordeum*/monocot
Unidentifiable husk	Husk	Poaceae/monocot
Unidentifiable conjoined	-	-
Phragmites stem	stem	Arundinoideae/monocot
Phragmites leaf	leaf	Arundinoideae/monocot
Bulliforms	Leaf	Arundinoideae/monocot
Leaf-stem	Leaf/stem	Poaceae/monocot
Cyperaceae psilate tenis	Leaf/stem	Cyperaceae/monocot
Jigsaw puzzle	-	Dicot

Table 5.1. Associated plant type and taxonomic affiliation for the phytolith types identified in this study (information courtesy of Emma Jenkins).

producing an identification to genus or species level, yet all single phytoliths can be divided into the general monocot and dicot categories. In addition, most can also provide information about the part of the plant the phytolith is derived from. Alongside the phytolith types, counts were also made for unidentifiable, burnt, degraded and poorly silicified phytoliths, diatoms and silica aggregate material. The latter category refers to lumps of silica of varying size, which are considered to derive from woody plants, mainly present in the bark. Individual silica aggregates are counted, but this count is considered to be a rough estimate since they do not reflect individual cells but an agglomerate of siliceous material of varying shapes and sizes.

5.3. Description of geochemical analysis procedure

5.3.1. Introduction

The samples were analysed for the following chemical elements: aluminium (Al), calcium (Ca), iron (Fe), potassium (K), magnesium (Mg), chlorine (Cl), manganese (Mn), phosphorus (P), strontium (Sr), titanium (Ti), sulphur (S), zinc (Zn), chromium (Cr) and zirconium (Zr). These elements are considered to be influenced by human occupation of sites and are commonly tested for in archaeological geochemical studies of spatial patterns (an overview of previous geochemical analysis at archaeological sites is given in section 2.3.2. and a summary of associations found between chemical elements and human activities in this and previous studies can be found in tables 9.1. and 9.2.).

The analysis was performed using a Thermo Scientific Niton XL 3t Goldd+ (geometrically optimised large area drift detector) handheld XRF analyser (henceforth P-XRF), which provides a quick determination of the elemental composition of a range of elements. The machine measures the elemental composition of soil samples by exciting them with high-energy, shot wavelength X-ray radiation. This energy frees a tightly held inner shell electron, which makes the atom become unstable, and an outer shell electron replaces the missing inner shell electron. The P-XRF measures the energy that is released during this event, which is termed fluorescent radiation (fluorescence in short). As the differences between electron shells are known and fixed, the machine can measure the fluorescent X-rays through electronic detectors and provide a reading for the abundances of elements present in the sample (Shackley 2010).

The use of P-XRF instruments for the analysis of archaeological soils is a recent development (Frahm and Doonan 2013), and there are currently no established protocols for this type of analysis. The following sections will therefore discuss the reasons for carrying out the geochemical analysis according to the procedure described in section 5.3.4. The rationale for each decision made throughout the analysis is based on the few studies that have addressed analysis using a P-XRF so far.

5.3.2. Rationale for using a portable X-ray Fluorescence analyser

The use of portable XRF instruments by untrained archaeologists has been criticised for ignoring protocols that were in use for the laboratory-based XRF, which lead to inappropriate use of the machine (Frahm and Doonan 2013; Shackley 2010). However, evidence that results of portable and laboratory XRF instruments provide similar results (Speakman and Shackley 2013, 1436, see figure 5.1.) and the potential of P-XRF to enable high resolution studies of occupation areas and the use of space due to its availability and ease of use (Frahm and Doonan 2013) suggest that the archaeological applications of this apparatus will become more popular in the future.

This dissertation will not try to contribute to the heated debate surrounding the use of the P-XRF for archaeological research, but address its use within the investigation outlined in this study. The evaluation of the application of P-XRF to the studied material can only be done in regard to the research question. The main aim of this research is to establish the potential of a dual phytolith and geochemical method to distinguish activity areas in ephemeral sites. The review of geochemical case studies in section 2.3. has illustrated the difficulty in correlating accurate, universal measurements of specific elements to individual human activities. Although certain (combinations of) elements have been repeatedly found to correlate to certain types of human activities in both the ethnographic and the archaeological record, across sites with varying soil conditions, these are merely trends and not specific inputs or reading of elements. Hence, the elevations or depletions of elements are evaluated in respect to other localities within a site, and there are no universal values for these elements in relation to specific activities. Seeing as the P-XRF has been shown to carry out precise measurements (Lin 2009; Kalnicky and Singhvi 2001), even if the values of the elements measured are not accurate the machine will still provide results that can be compared on a site basis as they are consistent. The data produced will also enable us to establish general trends of elevations and depletions across the sites.

In addition, one must consider the nature of archaeological and ethnographic data. When applying scientific methods to the anthropogenic record the aim is often to create more tangible, accurate results and a more solid interpretation of human behaviour. Nevertheless, the actual archaeological and ethnographic data do not change even when scientific methods are applied, and remains subject to shortcomings and ambiguity due to the variable nature of human behaviour and the incompleteness of the archaeological (and to a certain degree ethnographic) record. The type of data at hand and the accuracy that can be achieved by analysing it need to be taken into account, and if the record is compromised and ambiguous there is little merit in trying to pin down the most minute trends. Instead, the focus should be on archaeological and anthropogenic signals that are "loud" and clear enough to provide a solid interpretation. Having established that precision, rather than accuracy, is the key requirement of the apparatus for this analysis, the P-XRF was found to be a suitable tool for the geochemical analysis in this research.

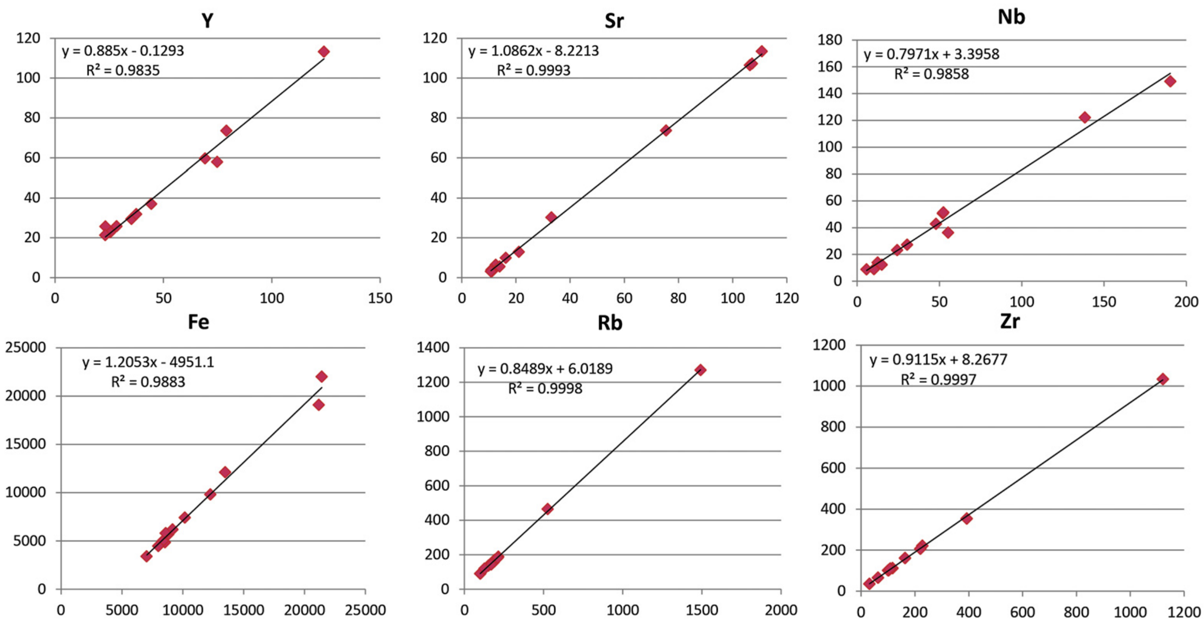


Figure 5.1. Comparison of values (in PPM) for 12 soil samples using a P-XRF (x axis) and laboratory based XRF (y axis) (from Speakman and Shackley 2013, 1437). The diagrams show a strong correlation between values obtained through the two different instruments, suggesting that the performance of the P-XRF can be as reliable as that of the laboratory XRF.

5.3.3. Rationale for sample preparation, machine settings and use of accessories

Unlike phytolith analysis, which is associated with a limited number of published extraction procedures that are broadly used, the geochemical analysis of soil samples for archaeological purposes using a P-XRF has not been standardised and does not follow known procedures. This section will provide the rationale for the decisions made regarding the analysis procedure guiding the use of a P-XRF within this study, before outlining the analysis stages in the following section.

5.3.3.1. Samples preparation

The moisture content in soil samples can influence the interpretation of the results because it is not a constant factor. Tests performed comparing the outcomes of P-XRF analysis on soil samples found that the accuracy of the results can be affected when the samples contain even low levels of moisture, suggesting that drying the samples prior to analysis may improve the analysis results (Hays 2013; Kalnicky and Singhvi 2001). A postgraduate study testing the effect of particle size, matrix, moisture and organic matter content on the precision of P-XRF measurements found that rather than these attributes, exposure time had affected precision in some elements (Lin 2009). Therefore, although the organic content of the soil samples can influence the readings as well through dilution of the soil, it was decided not to ash the samples prior to the analysis as the effect was found to be minor in comparison to moisture content, and it was estimated that the organic content of the soils was generally low.

5.3.3.2. Use of accessories

Since the samples had been collected and were available for analysis in the laboratory, they were analysed using a stand holding plastic cups filled with soil. This meant that the conditions of the analysis were better than a direct scan of the in situ sediment because of the reduction of moisture and higher level of homogeneity. However, the same conditions could easily be achieved in the field by removing and drying the studied sediments before using them in a stand. The samples were analysed using two types of films that are commonly used for the analysis of soil samples while held in cups, made of polypropylene and Mylar. The difference between the results of the two films seems to lie mainly in the readings for lighter elements. As the Mylar film contains phosphorus, all readings for this element were elevated by approximately 2000 PPM, and as P lies on the limits of detection this could significantly change the results. Because the polypropylene film is thinner, it performed better for P and other lighter elements such as Mg. Although the two films presented differences in absolute readings for many of the elements, comparatively they produced similar patterns of enrichment and depletion across the different context categories. As polypropylene films allowed for finer detail when analysing the lighter elements, it is preferred in this analysis and the results presented in Chapter 7 are based on the readings obtained using this film type. All of the instrumentation and materials used for the geochemical analysis were supplied by Niton UK.

5.3.3.3. Machine setting and use of standards

The P-XRF was used in the 'mining Cu/Zn mode', which produces better measurements for lighter elements and has been used in previous P-XRF geochemical studies of archaeological sites (Hays 2013; Gauss 2013). The other option for analysis, the soils mode, assumes a porous and inhomogeneous sample, allowing for changes in moisture and compaction. Seeing as the analysis took place under laboratory conditions after sample preparation, and considering the fine and homogenous nature of the sample material, the mining mode was preferred as it performs well with light elements. The mining mode includes four cycles of filters, each focusing on a different excitation filter providing a suite of element ranges: main, high, low and light. The main range was run for 40 seconds, the high and low ranges were given 30 seconds each, and the light element range was allowed 80 seconds in order to achieve reliable readings for elements on the edge of the detection limit such as Mg and P. In total each reading took 180 seconds to measure. In addition to the long running time given to the light element range, a helium purge was used in order to enhance the detection of the lighter elements.

During each session three National Institute of Standards and Technology (henceforth NIST) and one Silica (blank) standards were scanned in order to detect any shifts in the machine's readings. The NIST standards used were: Standard Reference Material (SRM) 2711a (Montana II soil), SRM 2709 (San Joaquin Soil) and SRM 1646a (Estuarine Sediment). These three standards were selected because they cover a wide range of elements, including all of the elements tested for in this research. The readings of the NIST standards did not show inconsistencies with any of the elements (Appendix

5). The P-XRF instrument and its output were not calibrated to provide more accurate results for reasons described in section 5.3.2., especially the need for internally consistent results in this study rather than accuracy.

5.3.4. Analysis procedure

Based on the rationale outlined above, the following stages took place as part of the geochemical soil analysis:

Stage 1: Sample preparation

Stage 2: Preparation of instrument and sample cups

Stage 3: Analysis

Stage 4: Obtaining the results

1. Sample preparation – prior to being analysed, the samples were dried in a drying oven at 50°C for two days in order to diminish the amount of moisture in the soil.

2. Preparation of instrument and sample cups – the samples were placed in 9 mm plastic cups, which were tapped in order to lightly compact the soil. The cups were covered by a thin plastic film, which were placed in a stand individually. The helium purge and a laptop containing Niton analysis software was connected to the machine. Care was taken to make sure that the analysis window on the machine remained clean at all times. If the window became dusty it was gently cleaned using a camera lens cleaning cloth or replaced entirely if necessary.

3. Analysis – the P-XRF 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 were given 30 seconds each, and the light element range was allowed 80 seconds. The helium was allowed to flow into the machine approximately ten minutes before the first samples were run. Each sample was analysed

for 180 seconds, and the NIST and Si standards were analysed using the same setting as the soil samples every day the machine was used.

4. Obtaining the results – the readings were downloaded from the machine using the provided Niton software, which created excel sheets providing the time, duration of analysis, and the readings and errors for each element.

5.4. Description of statistical analysis procedure

This section will outline the procedure for the statistical analysis presented in this dissertation. The different tests and visualisation methods described below were applied to the results of the geochemical and phytolith analyses in order to establish the presence of patterns in the data which relate to human activity areas and achieve a better understanding of the elements driving the variation within the data. In addition to these statistical methods, a model based on Bayesian belief networks was tested in Chapter 8, the procedure for this analysis is described in section 8.7.

5.4.1. Database construction and initial data manipulation

5.4.1.1. Phytolith data

The counting sheets that were used for recording phytoliths were converted to individual Microsoft Excel worksheets for each site, including the categories used in the counting sheets and additional variables calculated from the raw data: dicots, monocots, single-cell, multi-cell, Panicoideae, Pooideae, Chloridoideae, Arundinoideae, Palmaceae, *Hordeum*, *Triticum*, leaf, leaf/husk, leaf/stem, husk, awn, weight percent of extracted phytoliths, and number of phytoliths per gram. 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 the 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:

$$\text{№ per slide} = \frac{\text{Phytolith count}}{\text{Number of counted fields}} \times \text{Total number of fields on slide*}$$

* This number was adjusted in cases when bubbles appeared under the coverslip, or if the mounting agent spread beyond the limits of the coverslip.

$$\text{№ per gram} = \frac{\text{Number per slide}}{\text{Mass of phytoliths mounted (mg)}} \times \frac{\text{Mass of phytoliths extracted (mg)}}{\text{Total sediment weight (mg)}} \times 1000$$

5.4.1.2. Geochemical data

The readings were downloaded from the P-XRF machine using Niton software which produced Excel spreadsheets. Elements containing error readings (two-sigma precision) of ≥10% were excluded from the analysis with the exception of Mn, Zn for the ethnographic data and Mn, Mg, P, Cr and Zn for the archaeological data which were retained because of their relevance in interpreting anthropogenic input. A few elements contained readings under the limits of detection, these were replaced with their corresponding lower limit of detection as provided by Niton.

5.4.2. Exploratory statistics

Separate databases for geochemical and phytolith data were created for each site using IBM SPSS statistics version 23. The data was explored using bar charts that were created for every variable and for related variables (such as plant parts or genus categories) using SPSS. When analysing the ethnographic results, it became clear that several categories plot very similarly, in most cases these were variations of floor surfaces. The tables below (tables 5.2., 5.3.) show which categories were combined due to likeliness in the results of their geochemical and phytolith analysis.

5.4.3. Investigating context groupings and characteristics

In order to be able to assess the potential of the geochemical and phytolith methods to distinguish between activity areas within sites the division into context categories was tested in light of the values obtained for each method and a combination of the two. In addition, it was important to understand which variables were the key determinants driving the variation within the data, and how well the soil signatures could be divided into the context categories that were believed to reflect human activity areas. The statistical analyses used to explore groupings in the data are described below.

Categories used during sampling:	Categories used in this study:
Floor - kitchen	Floor
Floor – women area	Floor
Floor – men area	Floor
Sleeping area	Floor
Gully	Floor
Edge of hearth	Floor
Hearth – kitchen	Kitchen hearth
Hearth – hospitality/men area	Hospitality hearth
Animal sleeping area (indoor)	Animal pen/animal dung – depending on description
Animal pen	Animal pen
Kid pen	Kid pen
Animal dung	Animal dung
Background	Background

Table 5.2. Categories used during the ethnographic sampling and the equivalent categories used in this study.

Categories used during sampling:	Categories used in this study:
Fill	Deposit
Occupation deposit	Deposit
Compact ashy fill	Deposit
Activity area	Activity area
Compact silt with lithic material	Activity area
Compact silt, rich occupational material	Activity area
Hearth	Hearth
Ash fill	Hearth
Posthole fill	Bedrock feature
Bedrock mortar fill	Bedrock feature
Bedrock posthole fill	Bedrock feature
Pit lining/rubble/bin	Other
Background	Background

Table 5.3. Categories used during archaeological sampling and the equivalent categories used in this study.

5.4.3.1. Principal component analysis and discriminant analysis

Principal component analysis (PCA) and discriminant analysis are both statistical tools that can be used to reduce the dimensions of a dataset in order to get a better understanding of what variables drive the data. The difference between the two methods is that PCA ignores class labels (in our case these are the context categories) when calculating the best components to explain variance in the data, while discriminant analysis uses the assigned categories in order to calculate the best discriminating components for the pre-defined groups. SPSS was used to carry out both analyses. The PCA was run using the correlation matrix, a method which standardises the variables. No rotation was used, and the extraction was based on Eigenvalue. The discriminant 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 type of cross-validation used for estimating the generalisation performance of a model generated by a particular procedure).

5.4.3.2. Classification trees

In order to understand and visualise how well the data is categorised into activity areas, and which variables are important within this classification, decision trees were applied to the geochemical readings, phytolith counts, and to a database combining variables from both methods. Decision trees predict how data will behave based on the current observations. The data is split into the chosen subsets (in our case the context categories) according to each attribute with the aim of creating the most homogenously split groups, and the splitting variable which is closest to achieving this goal is kept. The process is continued until the highest purity of subsets is reached (all elements in the subsets belong to the same class). The numbers within each subset (or tree node) represent the amount of instances that are found within the subset. In cases where two numbers appear within the tree node, the first number indicates the 'correct' instances and the second reflects the 'incorrect' instances falling within the subset (i.e. samples having categories which agree or disagree with the category represented in the node). The numbers appearing between the tree nodes and the variables represent the splitting point, i.e. the value that split the instances according to those containing values of this variable that are smaller, larger or are equal to this number. The analysis was performed in Weka version 3.6.13 software, using the standard settings for classifier J48. The analysis provides a classification tree which can be visualised and reports the amount of instances which were 'correctly' and 'incorrectly' classified according to the set parameters (figures 5.2., 5.3.).

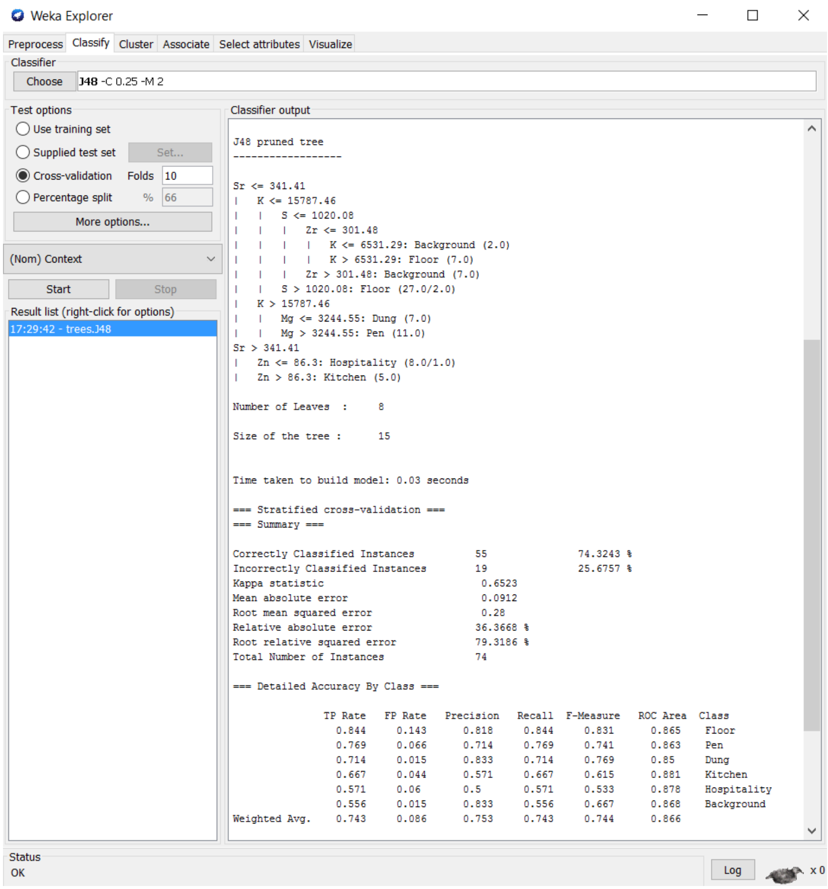


Figure 5.2. Example of Weka classification tree output.

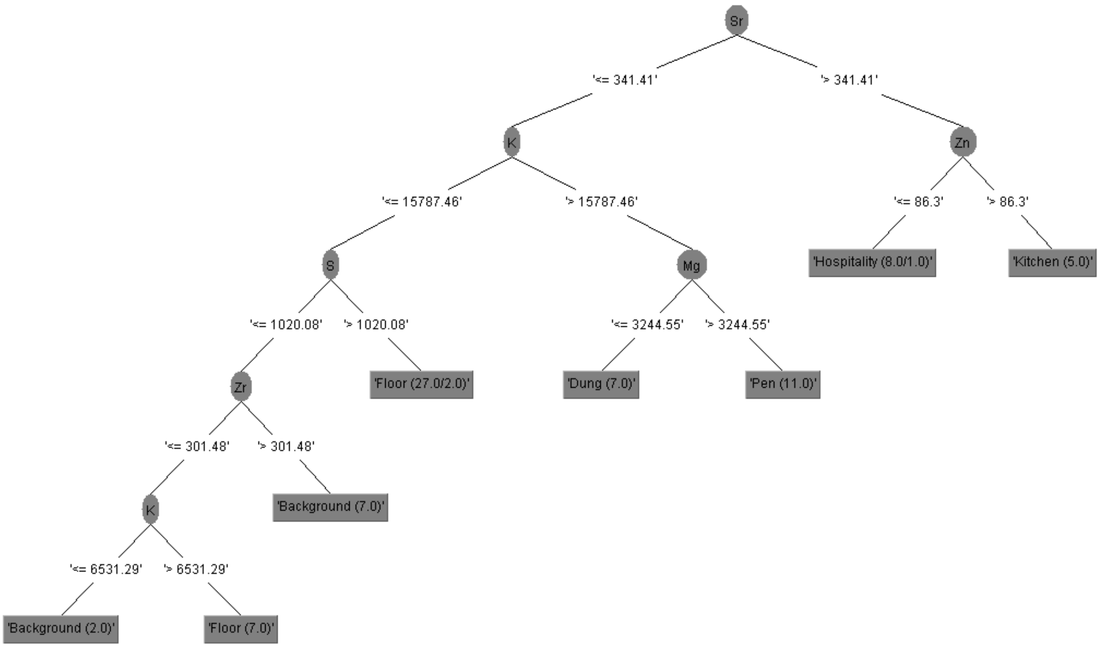


Figure 5.3. Example of Weka classification tree visualisation.

5.5. Summary

This chapter discussed the sampling strategies used for collecting the soil samples for the ethnoarchaeological and Neolithic sites, including issues concerning these, and presented the methodologies for the phytolith, geochemical and statistical analyses used in this research. The procedure chosen for phytolith extraction is the dry ashing method, which is described in section 5.2. It was chosen for this analysis since it is considered to cause less breakdown of conjoined phytoliths than the acid extraction method, and is safer because it does not necessitate the use of nitric acid as does the wet ashing method. The rationale behind the methodology of the geochmical analysis and choice of the P-XRF instrument are discussed in section 5.3.. The P-XRF was found suitable for the aims of this research with its focus on internally consistent results rather than accuracy. The previous section, 5.4., provided an outline of the statistical methods used in this study. These were chosen in order to bring to light various aspects of the results of the phytolith and geochemical analyses.

6 Results of phytolith analysis

6.1. Introduction

This chapter will present the results of the phytolith analysis of 141 samples, 73 from the ethnographic campsites and 68 from the Neolithic sites, which are introduced in this order (the methodology of the phytolith analysis is described in chapter 5). The data are displayed through PCA scatterplots and bar graphs for both individual and combinations of variables. This is done in order to explore both individual trends within each of the sites and more general patterns within the data which enable us to distinguish between different context categories. The phytolith counts can be divided into larger categories than the individual phytolith forms based on their taxonomic nature, which can relate to different levels of identification such as genus or the more general monocot and dicot categories, or according to their former location within the plant. Additional information about the phytolith assemblage can be gained from related aspects such as the concentration of the phytolith material in the soil, or the count of silica aggregate material (see descriptions of these characteristics and the methods used of recording them in sections 2.2.3., 5.2.1. and 5.4.1.2.). The different aspects of phytolith analysis are more diverse than the geochemical analysis presented in the next chapter, which compares measurements in parts per million (PPM) for a range of elements. Here the ratios between related variables, such as taphonomic aspects or single vs. conjoined phytoliths, are investigated alongside counts and estimations of taxonomic data or the amount of silica aggregate material.

It is also important to keep in mind that the context categories that were identified in the field for the sites of Wadi el-Jilat are different to the activity areas sampled for the Bedouin campsites at Wadi Faynan (see overview of sampling strategy and context categories in chapter 5). While the archaeological interpretation of activity areas might not always reflect the actual use of space in the past, the knowledge of the locations of activities at the Bedouin campsites in Wadi Faynan allowed for an informed sampling and therefore a reliable identification of the context of each sample. This having been said, two of the sites that had been abandoned for a long duration of time, Wadi Faynan 940 and Wadi Faynan 982, hold more uncertainty regarding the sampled context categories, a distinction between kitchen and hospitality hearths at these sites could not be made for example. One background sample was analysed for each ethnographic and archaeological site with the exception of the Bedouin campsite at Wadi Dana, the sampling of which did not include the parent soil material.

Before the results of the analysis are presented for each site, a summary of the frequency and abundance of phytolith types identified in this study is given below. Table 6.1. provides this information for the ethnographic data, and table 6.2. for the Neolithic data. Information about the taxonomic and plant part identification for each phytolith type can be found in section 5.3.1. The most abundant types within both data are tabular irregular (platey) phytoliths and silica aggregates, which dominate the samples. Both types form in dicots, and the second is considered to be derived from wood (mainly the bark). Parallepipedal bulliform cells, elongate dendritic and elongate psilate are common as well, while ovate crenate and rectangle tabular are common within the Neolithic assemblage.

Type	***Frequency in samples***	***Abundance within samples***
Bilobate short cell	****	****
Parallepipedal bulliform cell	******	****
Cuneiform bulliform cell	****	***
Ovate crenate	***	**
Cross	**	**
Globular echinate	**	**
Globular granulate	*	*
Globular psilate	**	****
Hair base	*	**
Unciform hair cell	*****	***
Elongate dendriform/dendritic	*****	*****
Elongate psilate tenis	*	***
Elongate sinuate	***	***
Elongate psilate	******	****
Trapeziform psilate	****	***
Papillae cell	**	**
Tabular irregular	*******	******
Polyhedral plain	**	**
Rondel	*****	*****
Saddle	***	****
Scalloped	*	**
Rectangle tabular	*****	****
Cylindric sulcate tracheid	*	*
Silica aggregate	*******	******

*Frequency in samples: * 1-9 ** 10-19 ***20-29 **** 30-39 ***** 40-48 ****** 49-59 ******* 60-69*

*Abundance within samples, mean for all counts: * ≤1 ** >1-2 *** ≥2-3 **** 3-7 ***** 15-20 ******>60*

Table 6.1. Overview of the frequency and abundance of phytolith types within the ethnographic data.

Type	*Frequency in samples*	*Abundance within samples*
Bilobate short cell	*****	**
Parallepipedal bulliform cell	******	***
Cuneiform bulliform cell	*****	*
Ovate crenate	******	***
Globular smooth	*****	***
Globular granulate	*	*
Hair base	*	*
Unciform hair cell	*****	**
Elongate dendriform/dendritic	******	***
Elongate psilate tenis	*****	*
Elongate sinuate	*****	**
Elongate psilate	******	****
Trapeziform psilate	****	***
Papillae cell	*	**
Tabular irregular	*******	*****
Polyhedral plain	**	**
Polyhedral granulate	*	**
Rondel	*****	****
Saddle	**	**
Scalloped	*	**
Rectangle tabular	******	****
Cylindric sulcate tracheid	*	*
Silica aggregate	*******	*****

*Frequency in samples: * 1-9 ** 10-19 ***20-29 **** 30-39 ***** 40-49 ****** 50-59 ******* 60-69*

*Abundance within samples, mean for all counts: * ≤1 ** >1-2 *** ≥2-3 **** 3-7 ***** >200*

Table 6.2. Overview of the frequency and abundance of phytolith types within the archaeological data.

6.2. Results of analysis of ethnographic sites

6.2.1. Wadi Faynan 916 (WF916)

Three years after the abandonment of this campsite, a distinguishable pattern of spatial activity could still be observed. The main outlier within the assemblage is the sample taken directly from the goat dung, which only contained monocots and is significantly different to the other context. The floor under the dung layer comprised higher levels of monocots compared to other localities, and so did the two hearths but to a lesser degree. The monocot to dicot ratio in the sample taken from the kid pen seemed similar to the background sample, as is the floor related contexts (figure 6.2.). Within the phytoliths identified as monocots however, the two hearths stand out as they contained phytoliths that are related to the Pooideae and Panicoideae subfamilies, which are absent in other samples. Although it would appear that the sample taken from the kid pen only contained Panicoideae grasses, this identification is based on a single phytolith, and the sample is further devoid of monocots (figure 6.3.). The goat dung sample proved different to other contexts in other aspects, having the highest weight percent and largest number of phytoliths per gram, and hardly containing any silica aggregate material (figures 6.4., 6.5.).

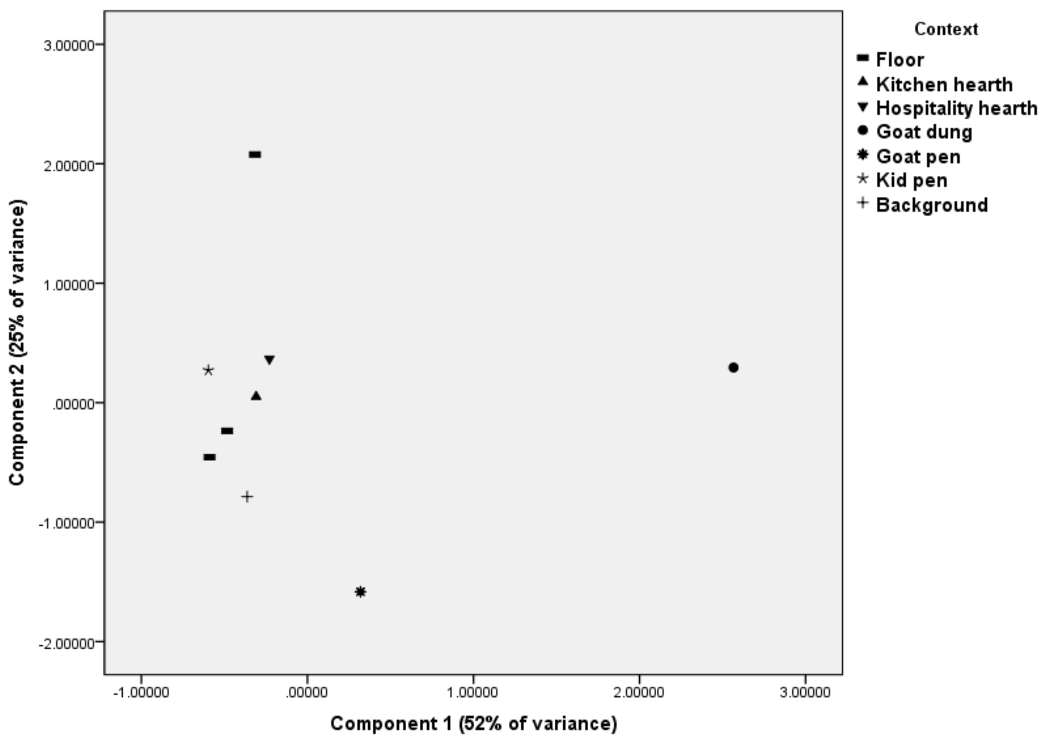


Figure 6.1. PCA scatterplot, WF916. The first component is driven by the ratios multicell to single phytoliths and monocots to dicots, Poaceae, *Triticum* sp., Pooideae, awn and husk phytoliths. The second component is driven by Panicoideae, leaf/husk phytoliths, Cyperaceae, leaf phytoliths, and negatively by silica aggregate material.

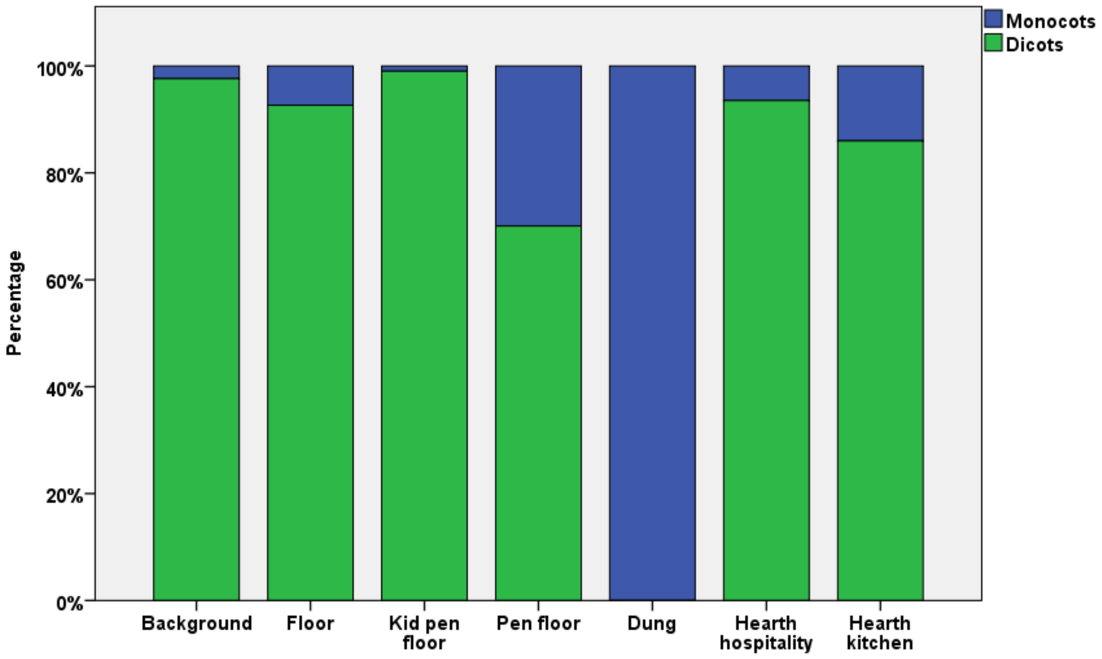


Figure 6.2. Monocot vs. dicot ratios per context, WF916.

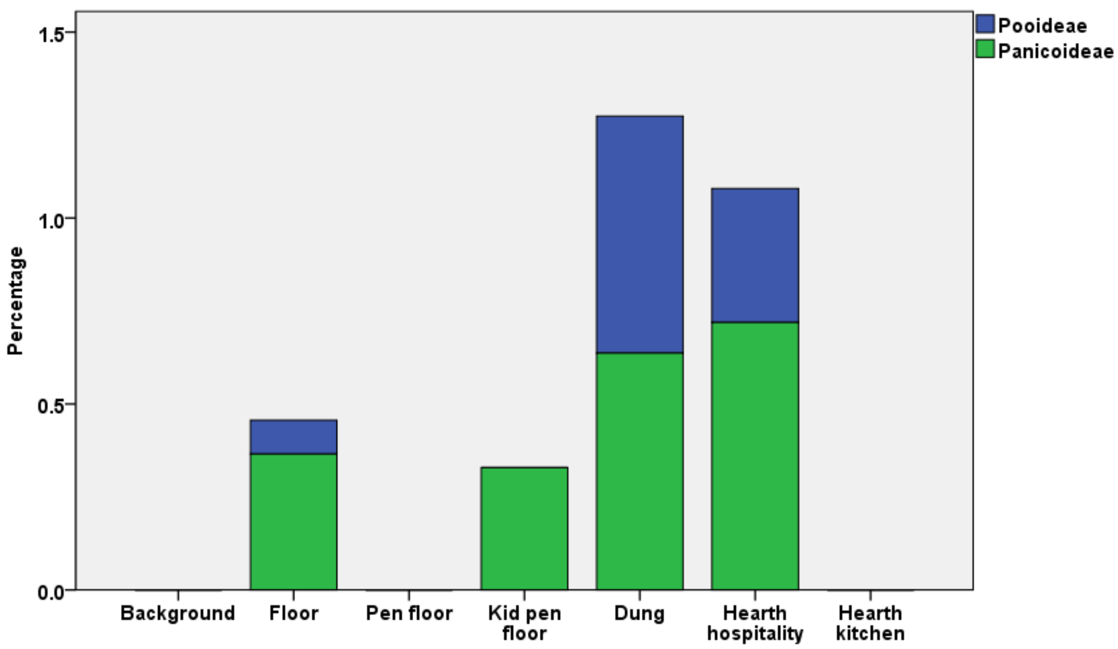


Figure 6.3. Phytoliths identified to sub-family level per context, WF916.

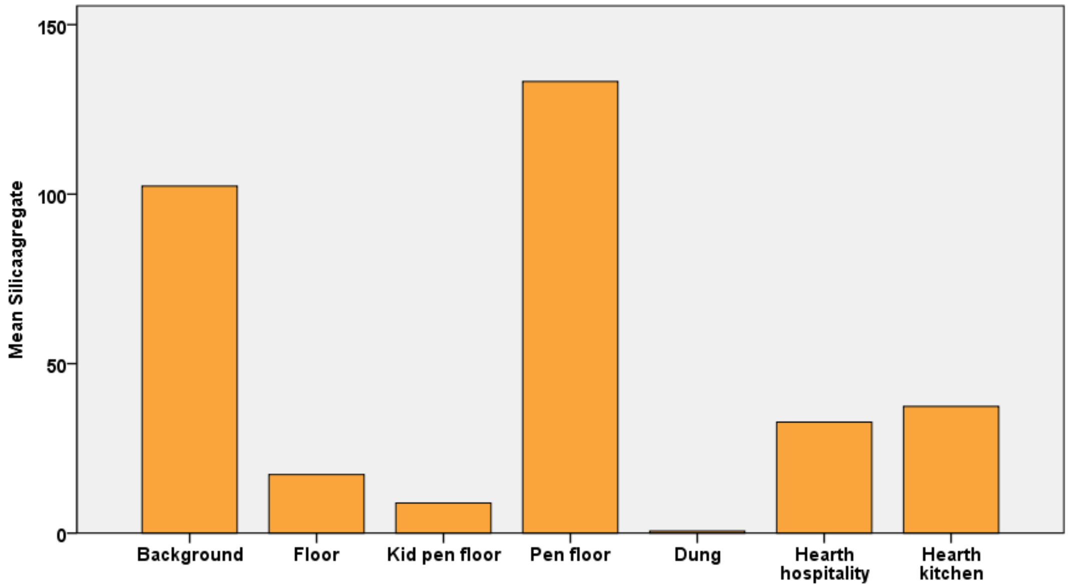


Figure 6.4. Counts of silica aggregate per context, WF916

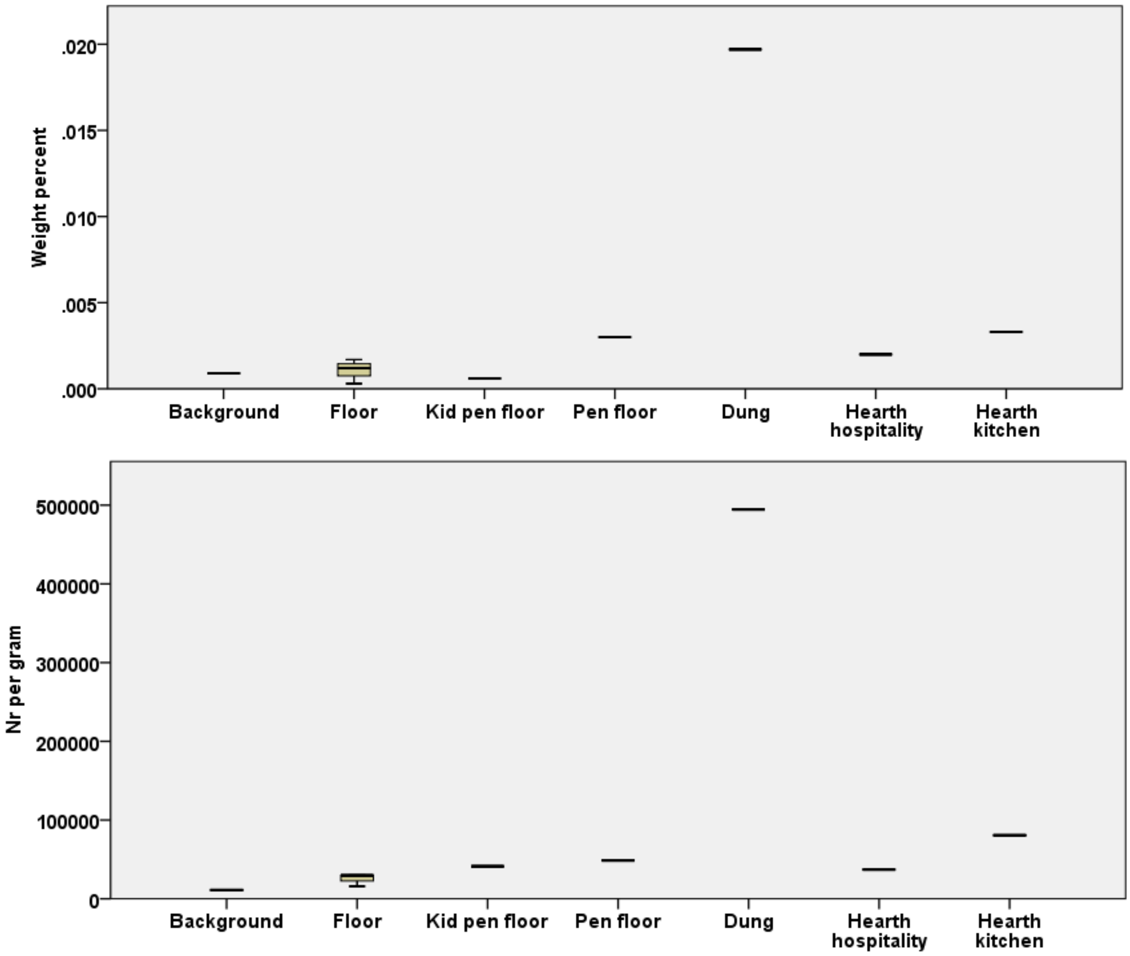


Figure 6.5. Weight percent and number of phytoliths per gram in each context, WF916.

6.2.3. Wadi Faynan 953 (WF953)

The results of the phytolith analysis in the different localities of this tent site, which had been abandoned for approximately one year prior to sampling, show some indications of activity areas. The contexts could be grouped into two clusters, falling either under the group that is similar to the background sample and includes floors and related contexts (such as gullies), and a group that shows more anthropogenic input comprising a layer of animal dung and the two hearths. This can be seen in the ratio of monocots to dicots, in the type of subfamilies that could be identified within the grasses, and in the presence of reed and wheat material that could be identified to genus level (figures 6.7. – 6.9.).

Within the contexts that contained phytoliths identified to genus level, it is interesting to see that although all three contexts contain reed material, the hearth kitchen alone has a great amount of wheat, making it a distinguishable sample. As for the distribution of plant parts across the sampling locations, the animal dung and kitchen hearth plot similarly and are rich in husk material, while the other contexts are more comparable to the background sample (apart from the animal floor, which only contains leaf material). These trends are displayed in the PCA scatterplot below (figure 6.6.), showing the similarity of the two hearth and dung samples in most aspects (represented by the first component) yet divergence in others (represented by the second component). The other contexts plot similarly to the background sample along the first component, but are still different to it.

Nevertheless, these patterns do not apply to all aspects of the analysis. When considering the weight percent of extracted phytoliths per context, the differences between contexts with high anthropogenic input (hearths and dung) and lower anthropogenic input (floors, background sample) are less clear. The number of phytoliths per gram, on the other hand, does show clear elevations within the hearth contexts, especially the kitchen hearth (figure 6.12.). The discrepancies between extracted weight and amount of phytoliths per gram could be due to the varying sizes and weights of different phytolith morphologies, laboratory procedures, and/or materials being extracted but not counted as phytoliths such as minerals or silica aggregates, which are tallied as a separate category (figure 6.11.). The high amount of phytoliths per gram in the kitchen hearth could also be explained by the enrichment of wheat in comparison to other contexts (figure 6.9.).

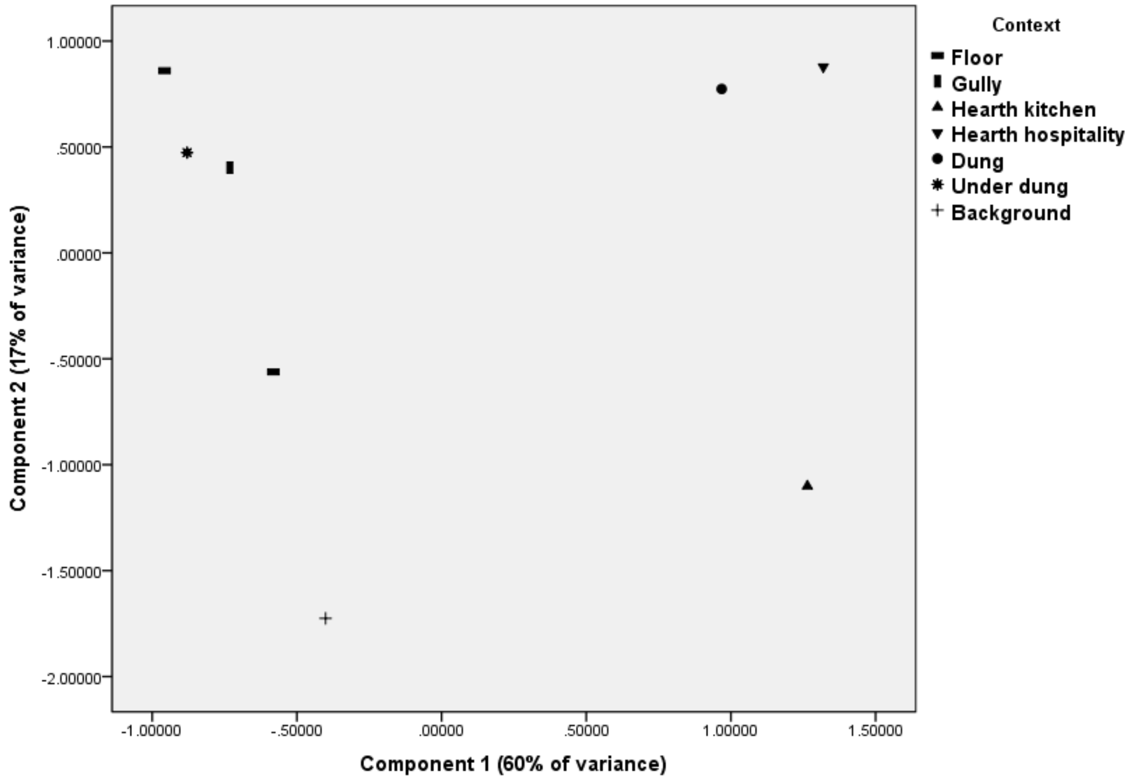


Figure 6.6. PCA scatterplot, WF953. The first component is driven by the categories monocots, multi-cells, leaf/husk, leaf, Pooideae and Panicoideae, and the second component by single phytoliths, silica aggregate and dicots.

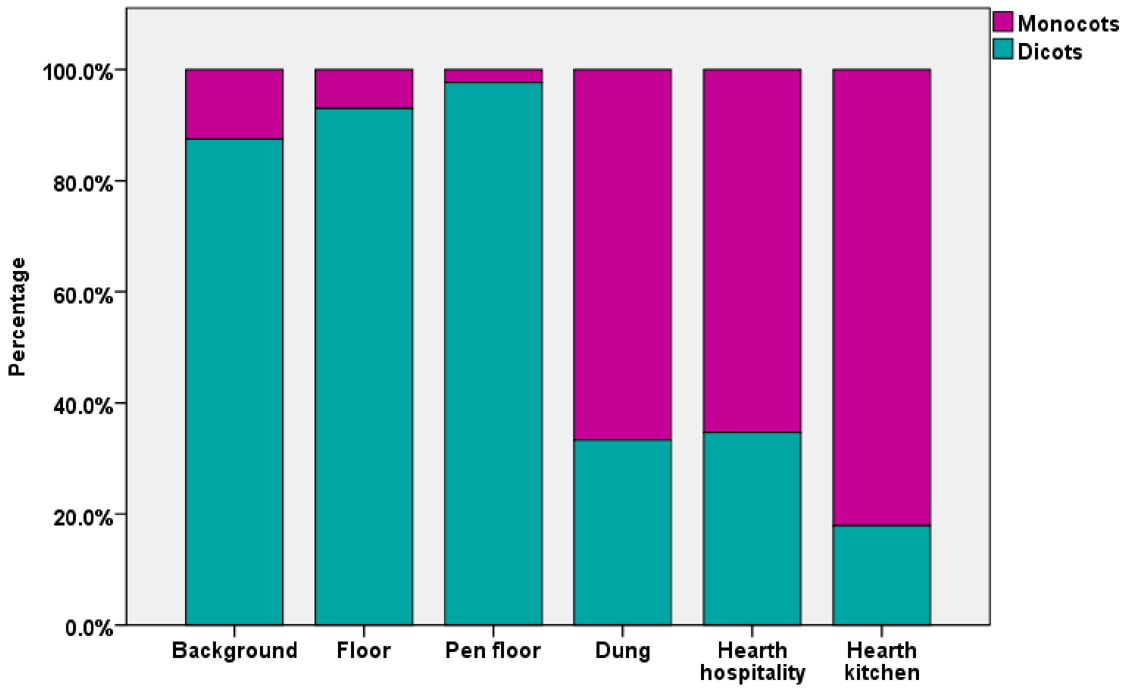


Figure 6.7. Monocot vs. dicot ratios per context, WF953.

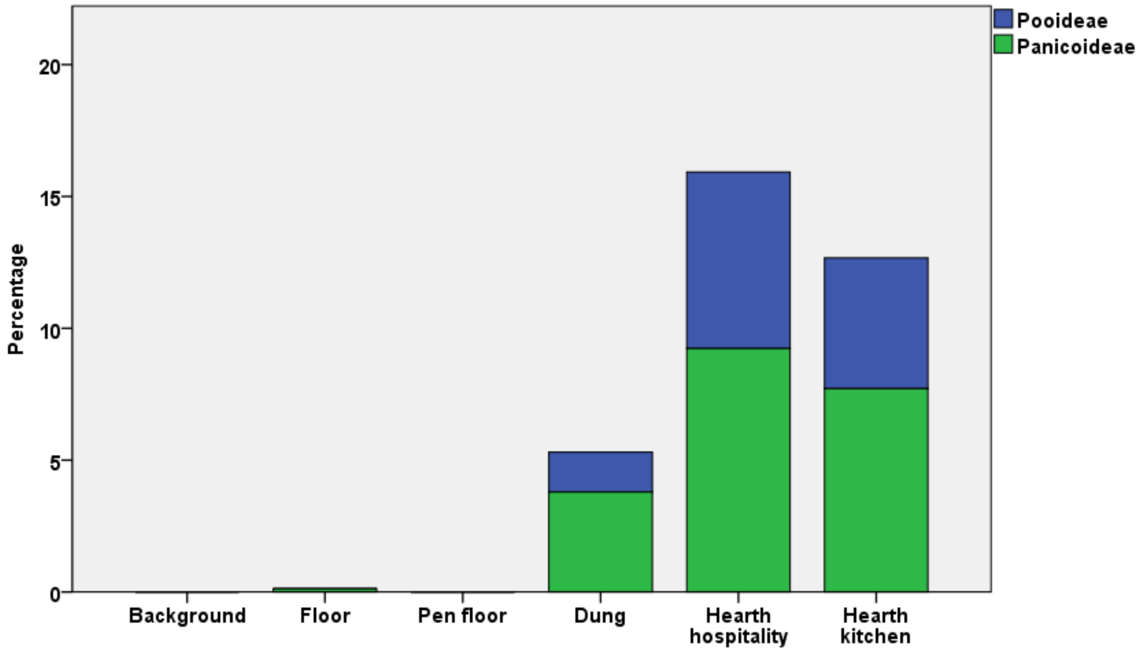


Figure 6.8. Phytoliths identified to sub-family level per context, WF953.

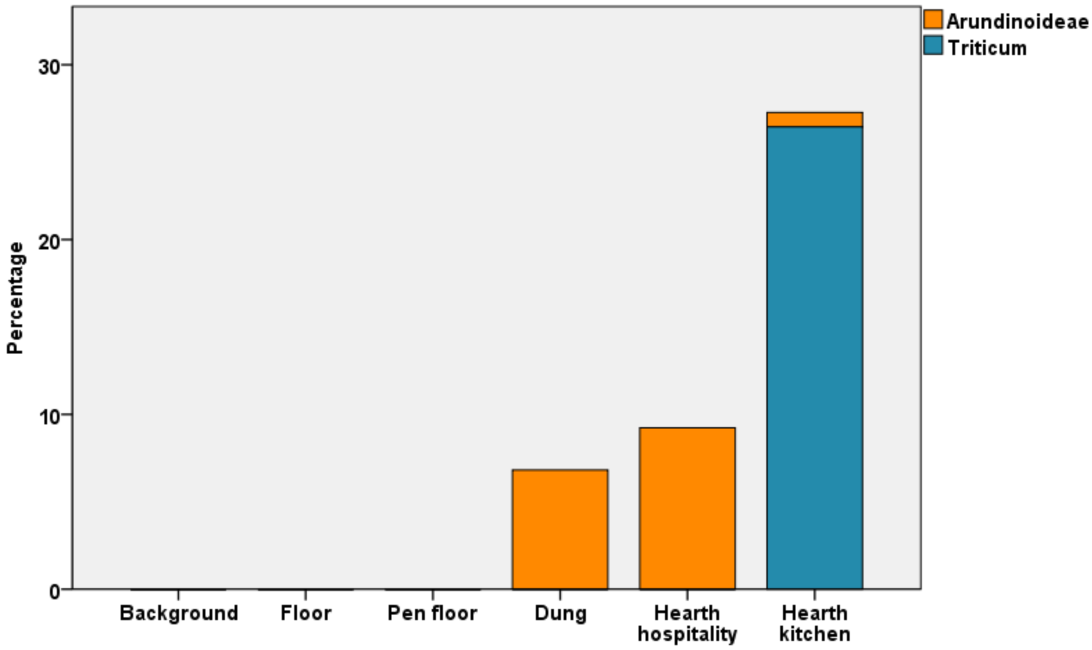


Figure 6.9. Phytoliths identified to species level per context, WF953.

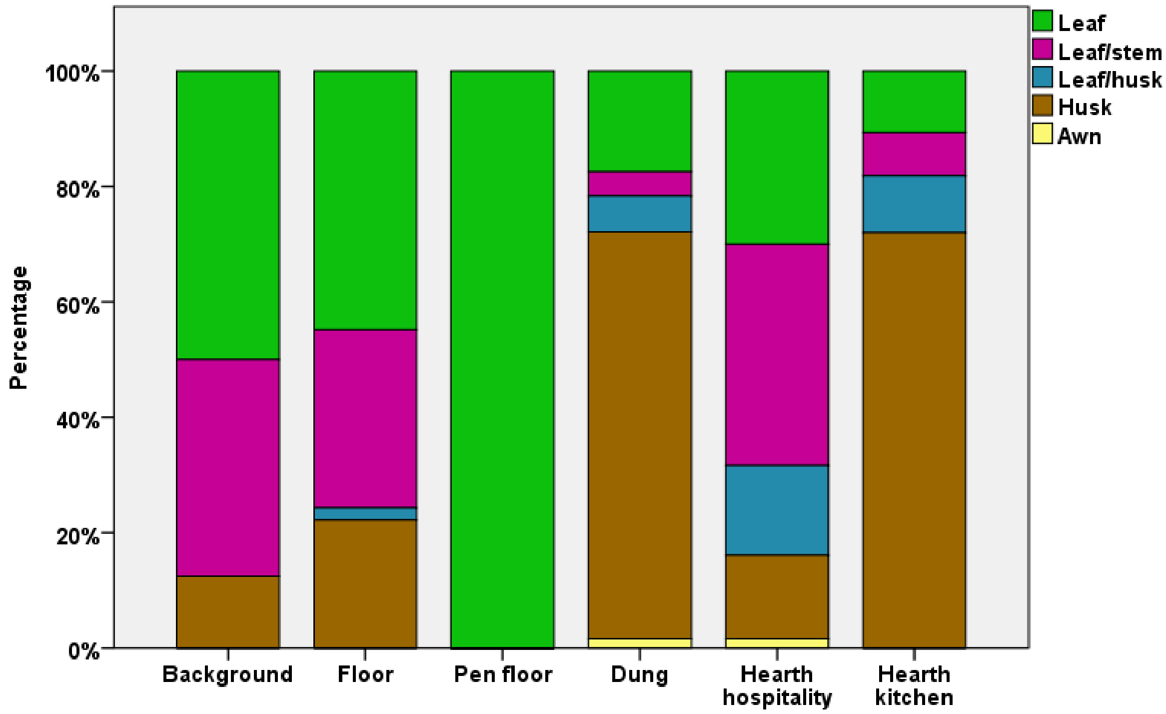


Figure 6.10. Plant part distribution per context, WF953.

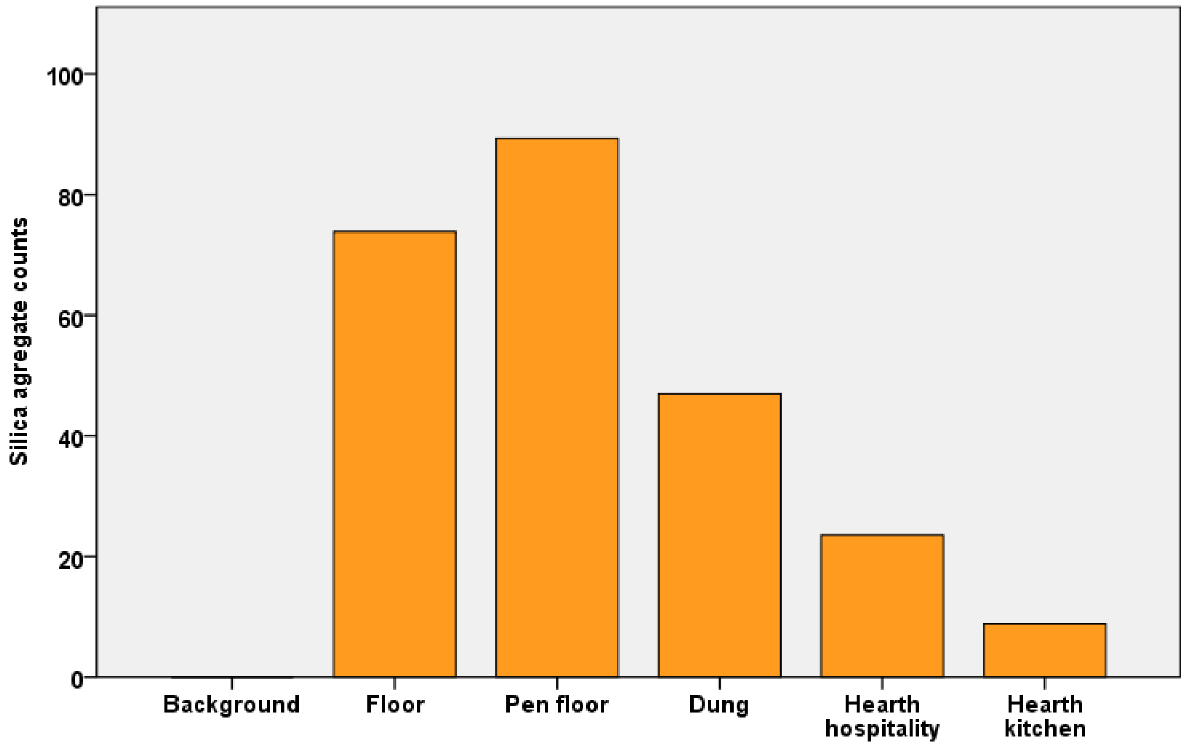


Figure 6.11. Counts of silica aggregates per context, WF953.

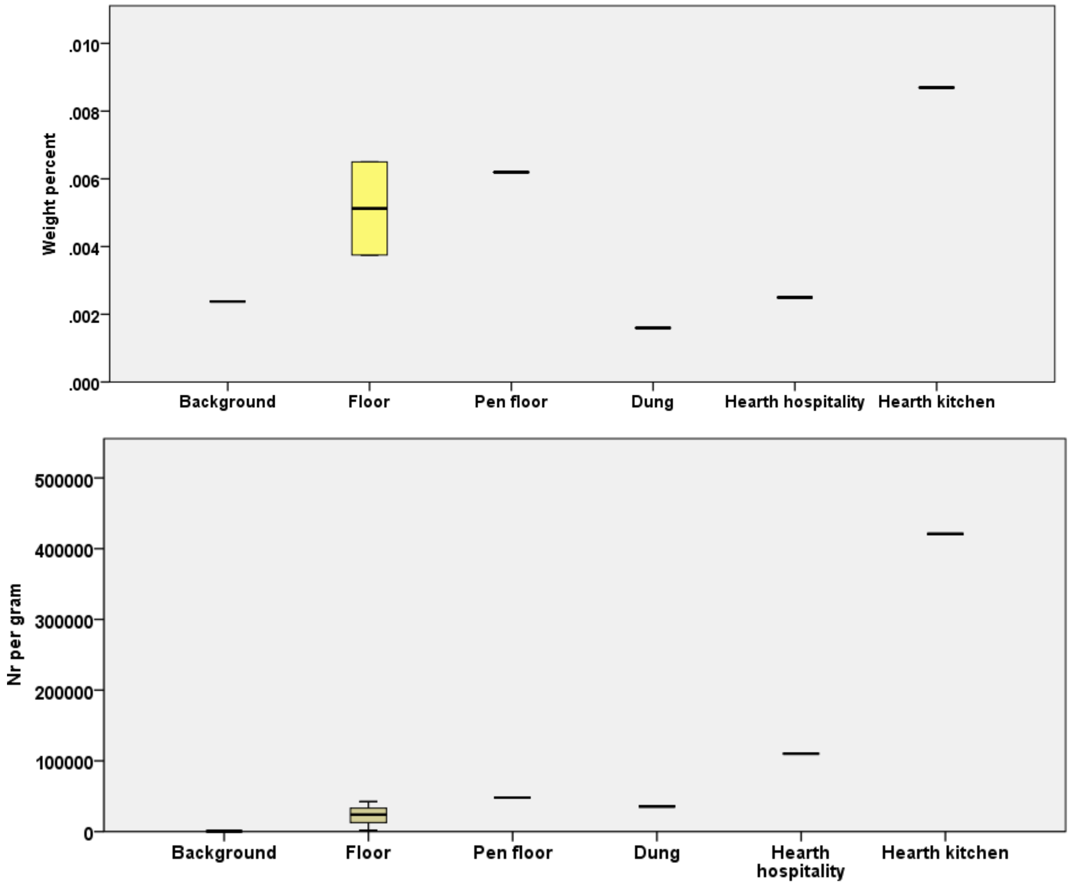


Figure 6.12. Weight percent and number of phytoliths per gram of sediment for each context, WF953.

6.2.3. Wadi Faynan 940 (WF940)

The PCA scatterplot below (figure 6.13.) shows two samples that stand out from the rest within this site, a floor sample at the top right and a hearth sample at the bottom left. The first component is influenced here by the monocot, multicelled phytoliths, sub-family and plant part categories while the second component represents single phytoliths, dicots and genus variables. The monocot to dicot ratios in the floor and hearth samples are similar, containing more monocots than other contexts, and a similar trend can be seen in the amount of multicelled vs. single phytoliths (figures 6.14., 6.15.). Within the distribution of silica aggregate however, a hearth related context seems to have the highest amounts, although elevations in silica aggregate in comparison to the background sample can be seen in the floor and hearth samples as well (figure 6.16.). Floors and floor related contexts have relatively high amounts of unidentified material, as does the background sample (figure 6.18.). The hearth and hearth related samples contain larger quantities of degraded, burnt and badly silicified material. Although the floor samples show a large variability when it comes to weight percent and number of phytoliths per gram, the hearth sample appears to have a higher number of phytoliths per gram than other contexts. Interestingly, this is not the case when looking at weight percent, where the floor category represents the largest weight percent (figure 6.17.).

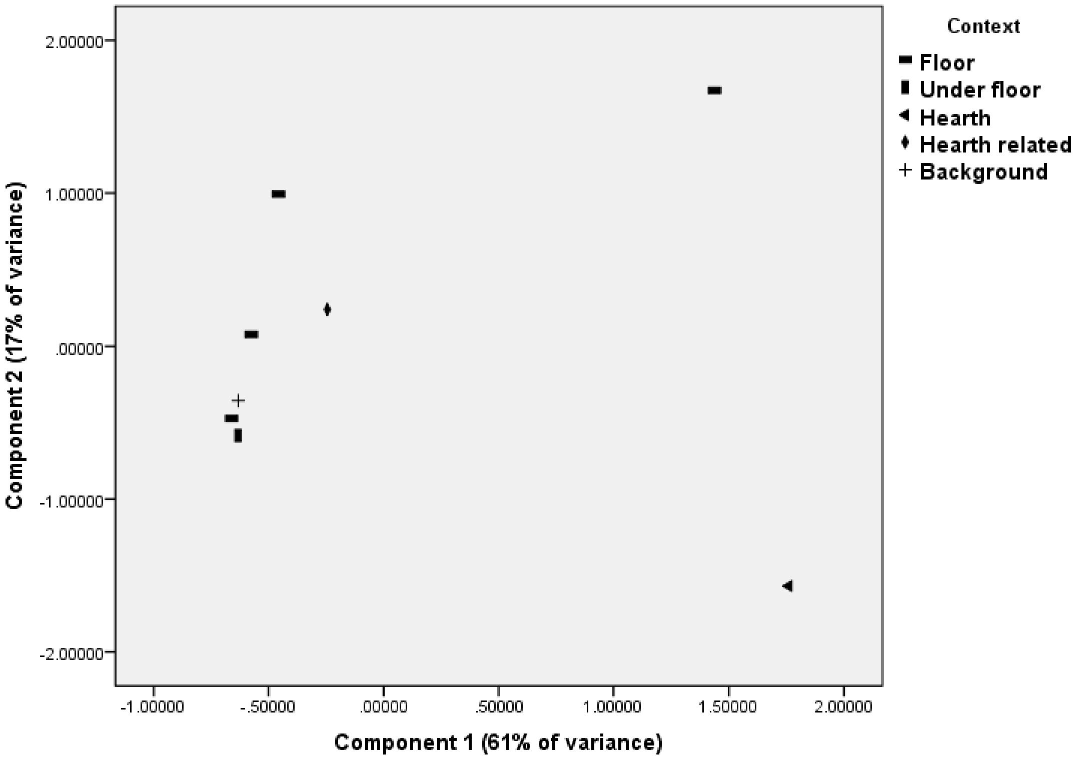


Figure 6.13. PCA scatterplot, WF940. The first component is driven by the variables multi-cell phytoliths, Panicoideae, Pooideae, Palmaceae, Arundinoideae, monocots, leaf, leaf/stem, leaf/husk, husk, nr per gram and poorly silicified phytoliths. The second component is driven by the variables unidentified phytoliths, *Triticum* sp., single-cell phytoliths and negatively by Chloridoideae, *Hordeum* sp. and burnt phytoliths.

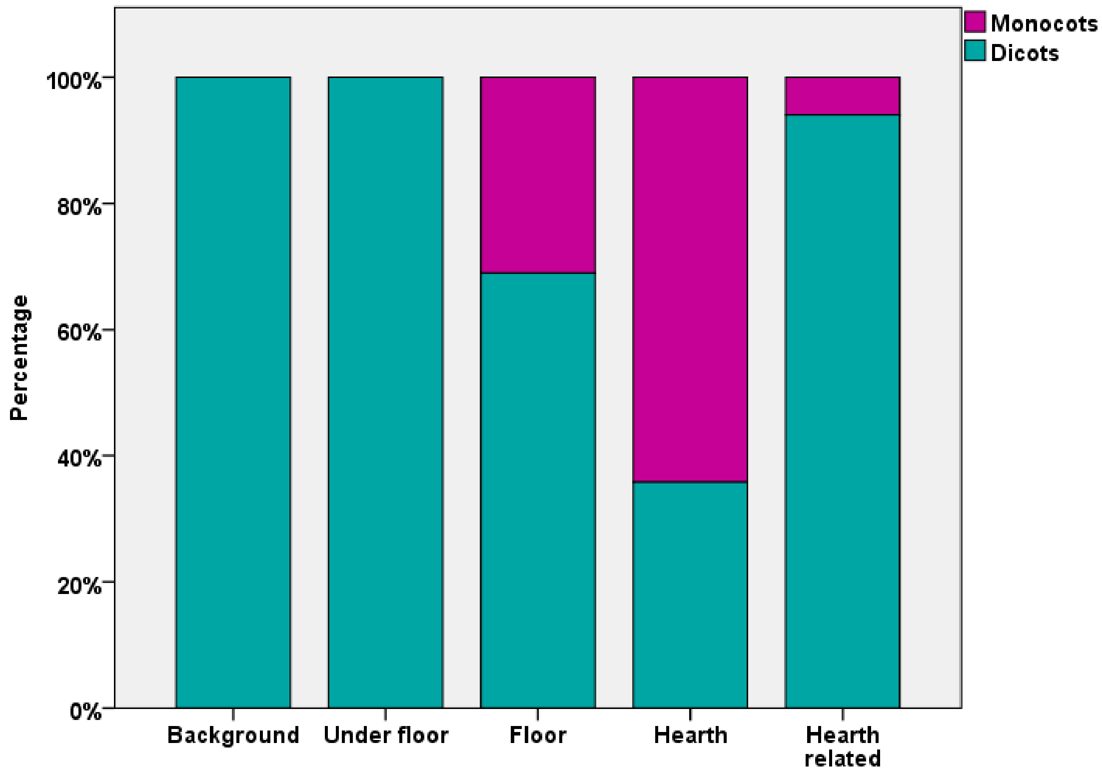


Figure 6.14. Monocot vs. dicot ratios per context, WF940.

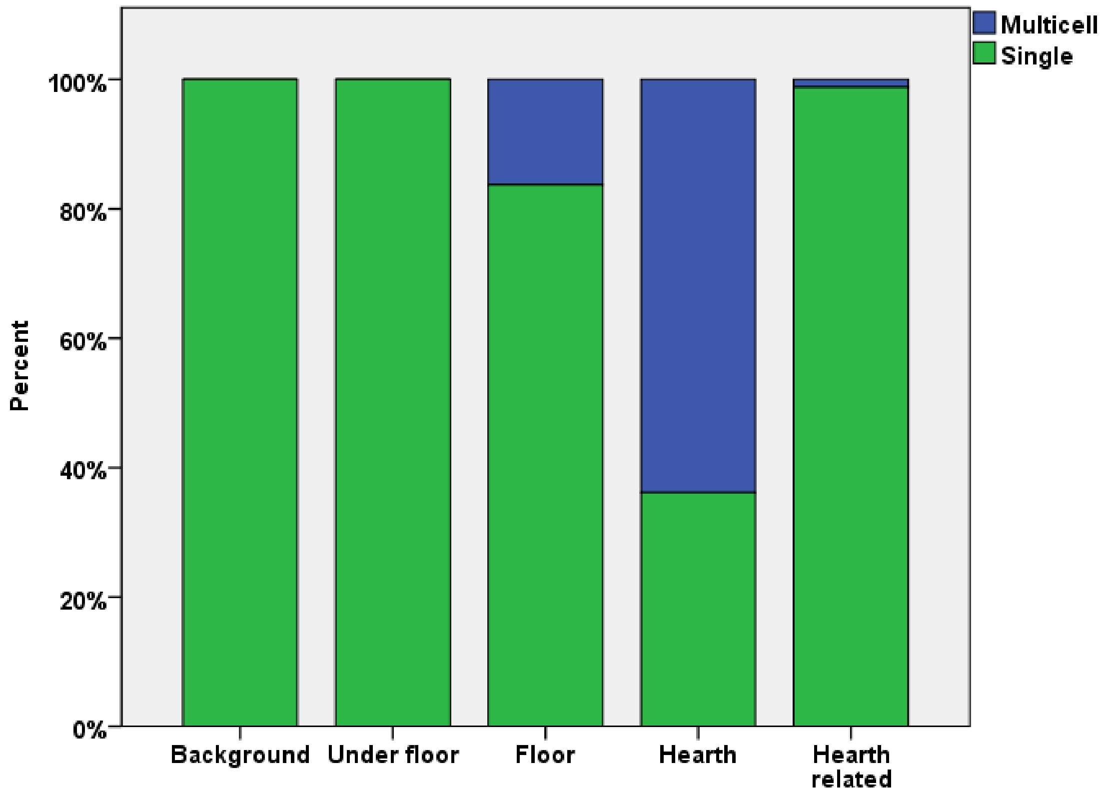


Figure 6.15. Single vs. multicelled phytoliths per context, WF940.

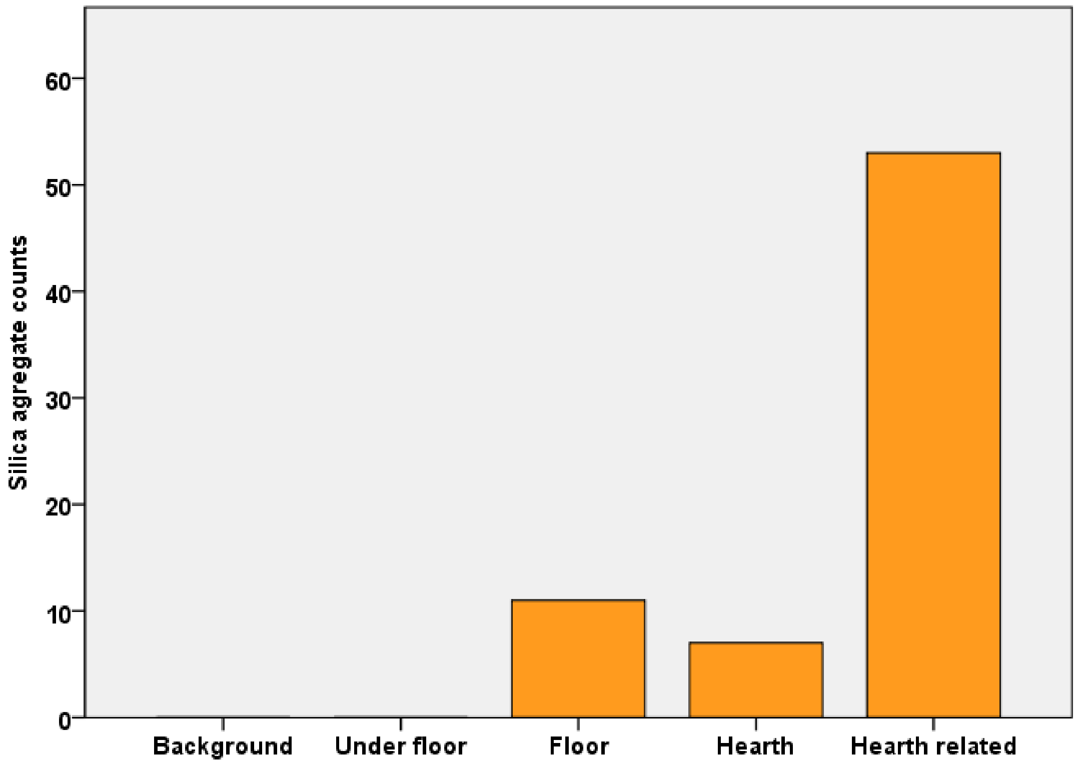


Figure 6.16. Silica aggregate counts per context, WF940.

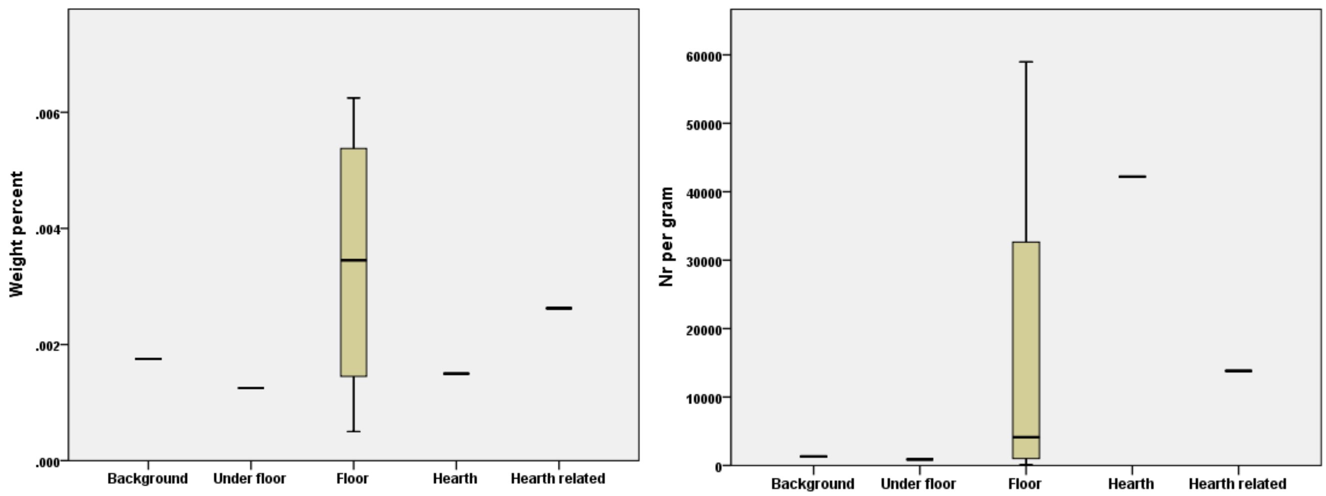


Figure 6.17. Weight percent and number of phytolith per gram, average for each context category, WF940.

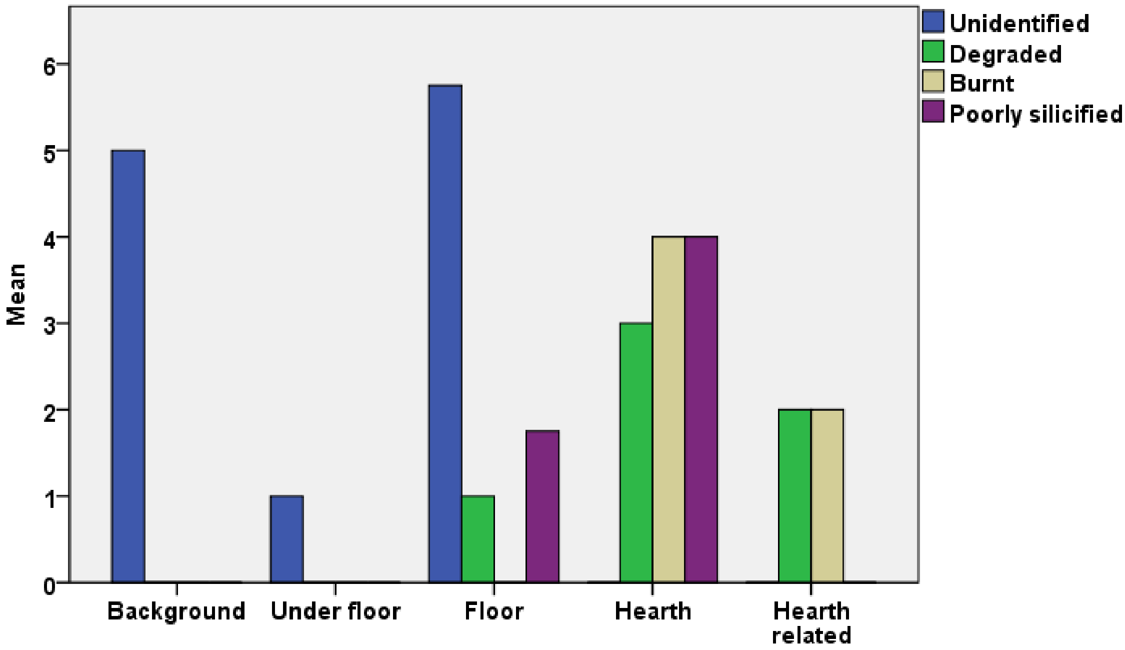


Figure 6.18. Amount of unidentified, degraded, burnt and poorly silicified phytoliths per context, WF940.

6.2.4. Wadi Faynan 982 (WF982)

This campsite was abandoned for approximately 10 to 15 years prior to sampling, and distinguishing between the hospitality and kitchen hearth could not be done with certainty. The PCA analysis shows an input from monocot to dicot ratios and plant parts for the first component, and is driven by the amount of multicelled phytoliths and silica aggregates for the second component (figure 6.19.). The two hearths plot differently to the other context categories on the second factor, while the dung sample and rattan layer plot closely on both factors. The other categories, including floor, background and samples taken under dung plot similarly on the graph.

The hearth samples are different to the other contexts in other aspects as well. The weight percent of the extracted phytolith material is the highest, and they contained the lowest amounts of degraded and unidentifiable phytoliths (figures 6.22., 6.20.). The rattan and dung samples seem to have higher amounts of monocots and multicelled phytoliths than other samples, however the two hearths contain even larger amounts of multicelled phytoliths (figures 6.23., 6.24.). A similar trend can be seen with the distribution of silica aggregate and number of phytoliths per gram of sediment, which are elevated in the rattan and dung layers, and even more so in the hearth samples (figures 6.21., 6.22.).

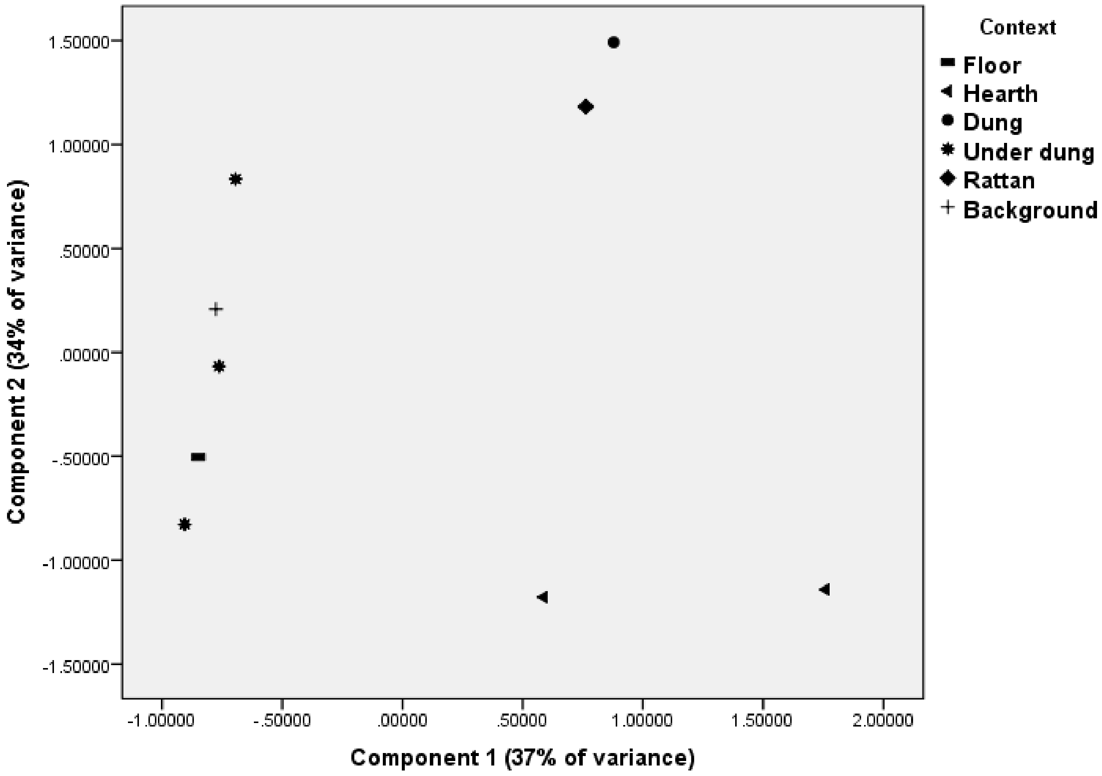


Figure 6.19. PCA scatterplot, WF982. The first component is driven by the variables nr per gram, silica aggregate, weight percent, multi-cell phytoliths, poorly silicified phytoliths and negatively by degraded phytoliths. The second component is driven by the categories leaf/husk, Pooideae, unidentified phytoliths, monocots, single-cell phytoliths, leaf, and negatively by dicots.

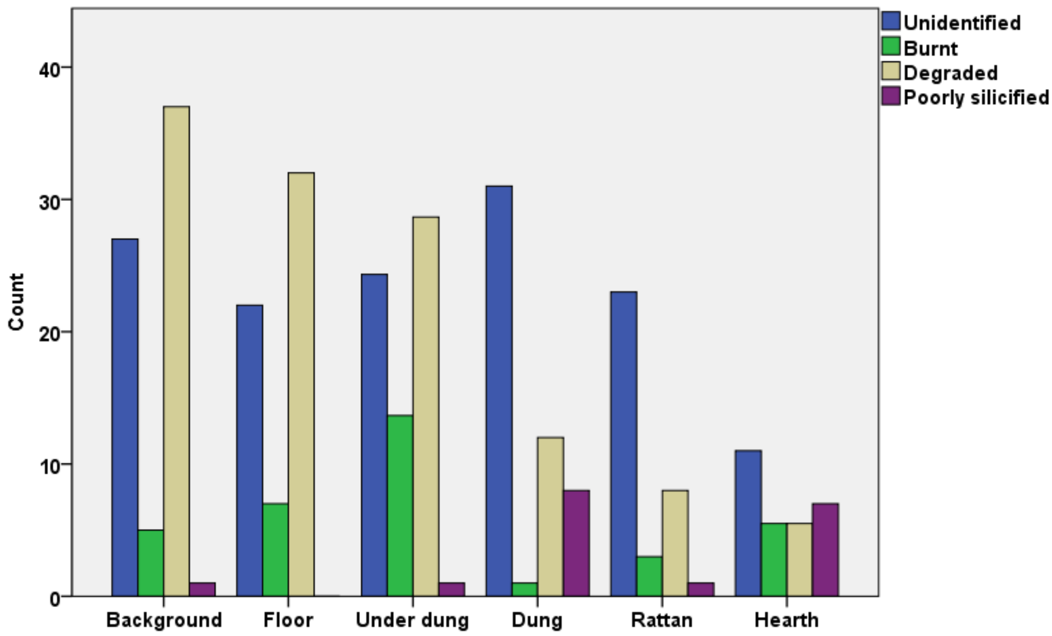


Figure 6.20. Amount of unidentified, burnt, degraded and badly silicified phytoliths per context, WF982.

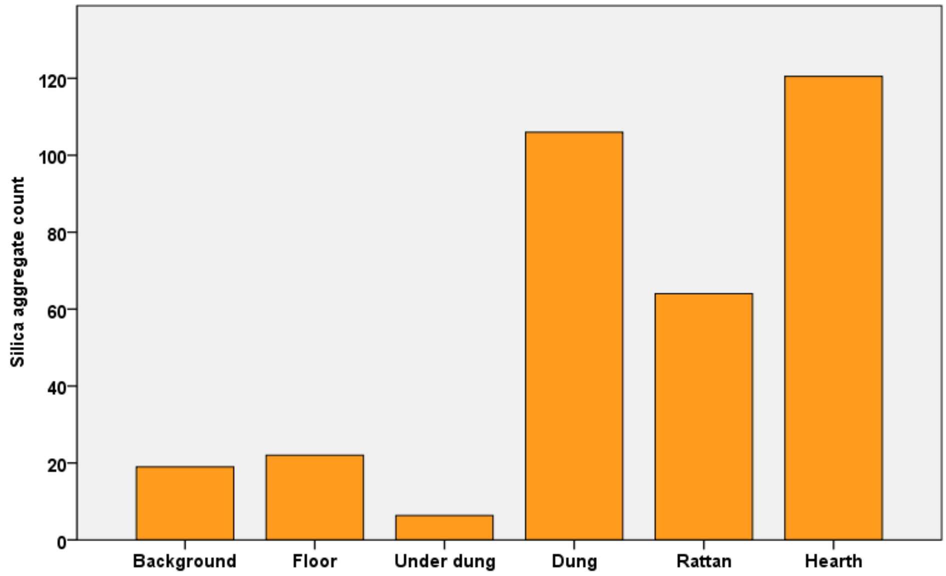


Figure 6.21. Amount of silica aggregate material per context, WF982.

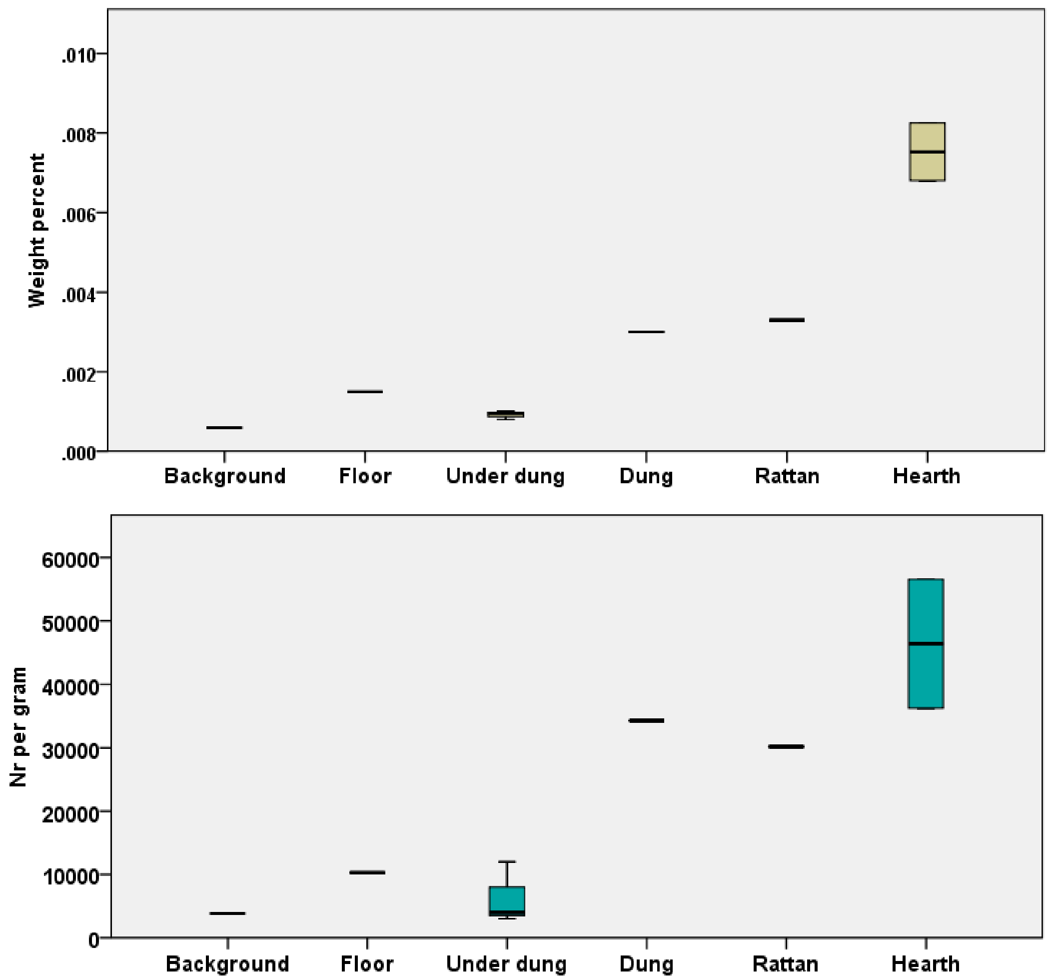


Figure 6.22. Weight percent and number of phytoliths per gram for each context, WF982.

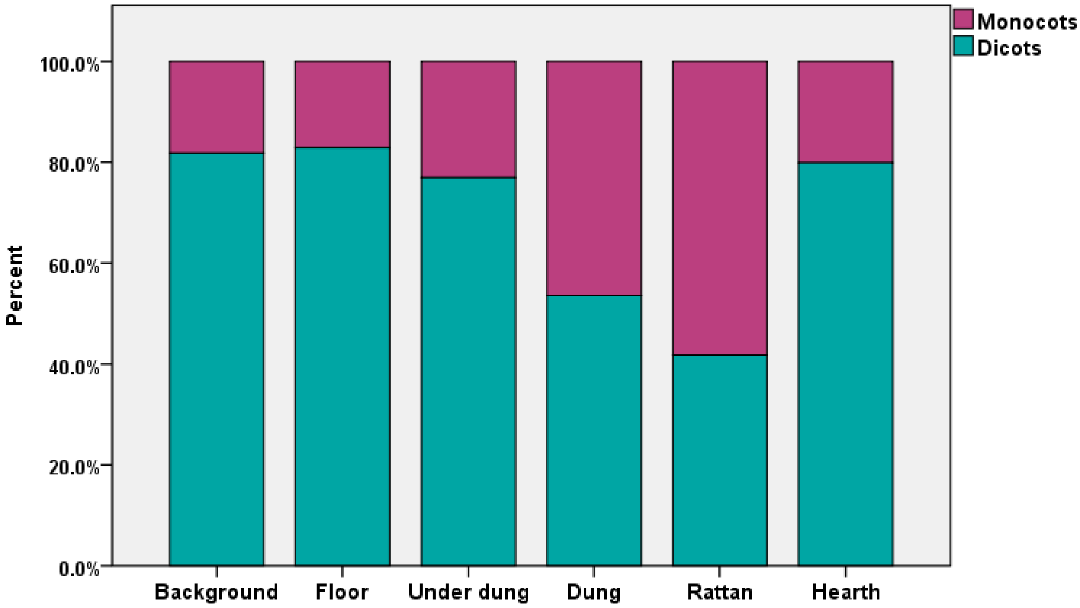


Figure 6.23. Monocot vs. dicot ratios per context, WF982.

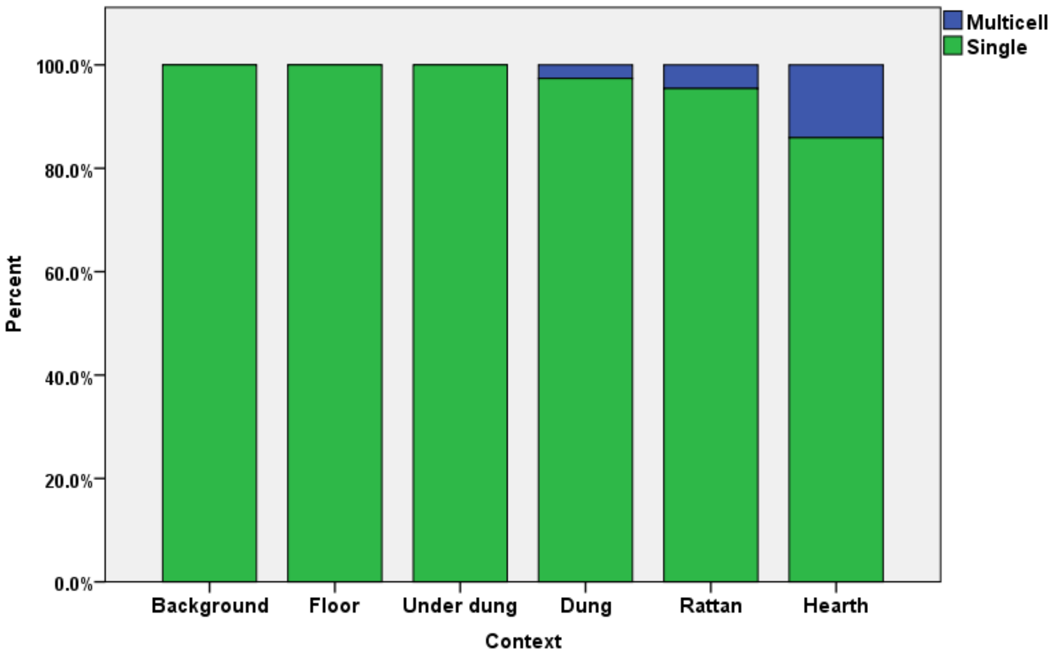


Figure 6.24. Single vs. multicelled phytoliths per context, WF982.

6.2.5. Wadi Dana (WD)

Although this tent site was occupied during sampling and therefore has a good preservation of phytolith material, the spatial trends that emerge from the analysis are not as straightforward as with the other campsites. One reason for this could be the long and continuous habitation, which would perhaps cause more mixing of material; another could be the untidy state of this tent which could have affected the distribution of material also.

Nevertheless, some differences can be observed among the various sampled areas. The monocot to dicot ratios in most living spaces/floors are different to most of the hearth and animal related contexts, which have a higher content of monocots (figure 6.26.). Four of the sampling locations contained phytoliths that could be identified to species level, *Triticum* sp. was found in general living area A and in a drainage gully nearby, while *Hordeum* sp. was abundant in the kitchen hearth and also present in the goat sleeping area (figure 6.27.). The PCA scatterplot below shows that the two hearths and one of the goat pen samples plot differently to the other contexts (figure 6.25.).

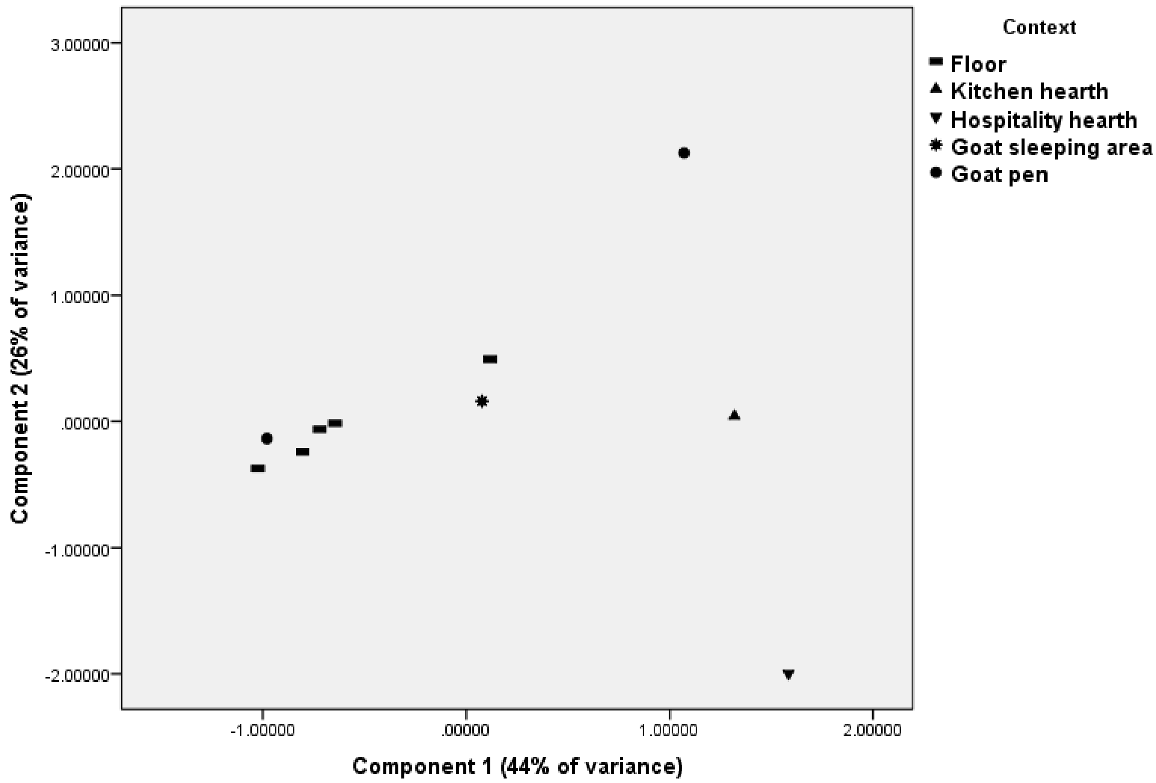


Figure 6.25. PCA scatterplot for WD. The first component is driven by monocot to dicot and single to multi-cell phytolith ratios, Poaceae and negatively by silica aggregate. The second component is influenced by Pooideae, Chloridoideae and plant part distribution.

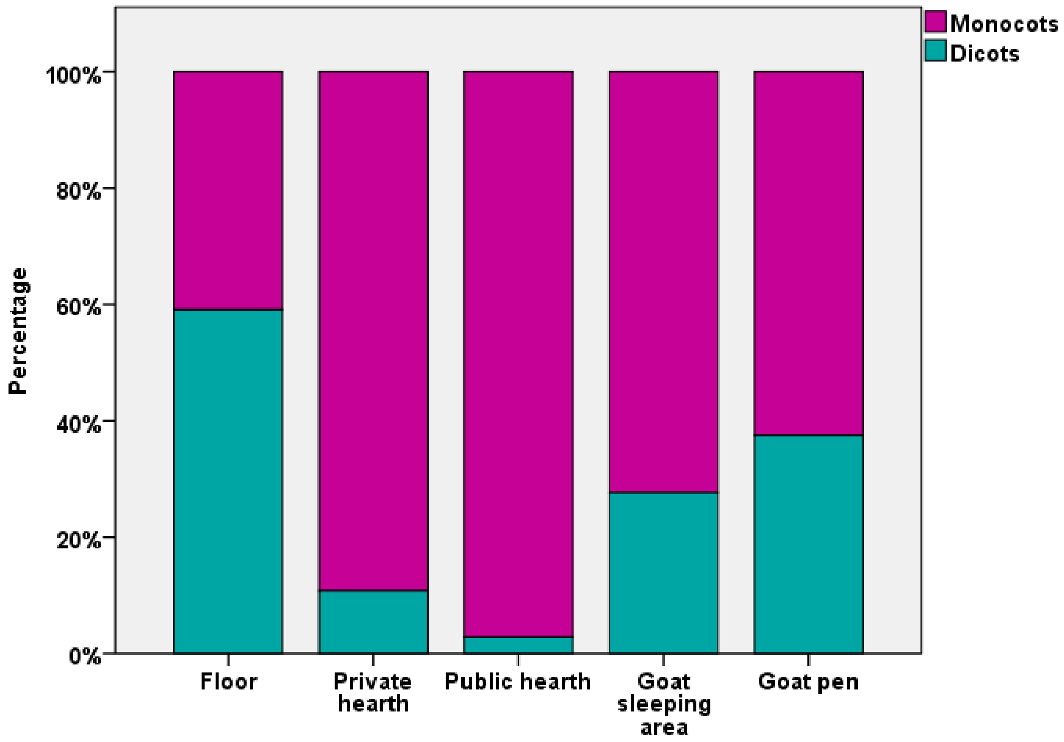


Figure 6.26. Monocot to dicot ratio per context, WD.

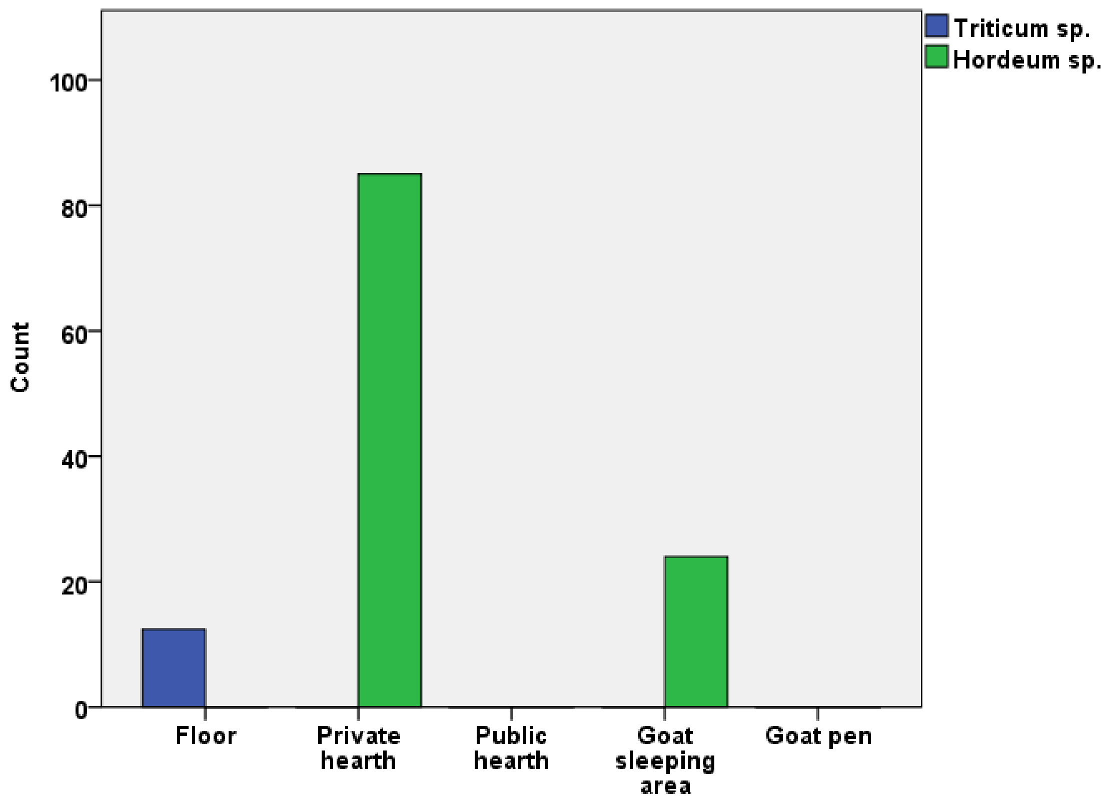


Figure 6.27. Phytoliths identified to genus level per context, WD.

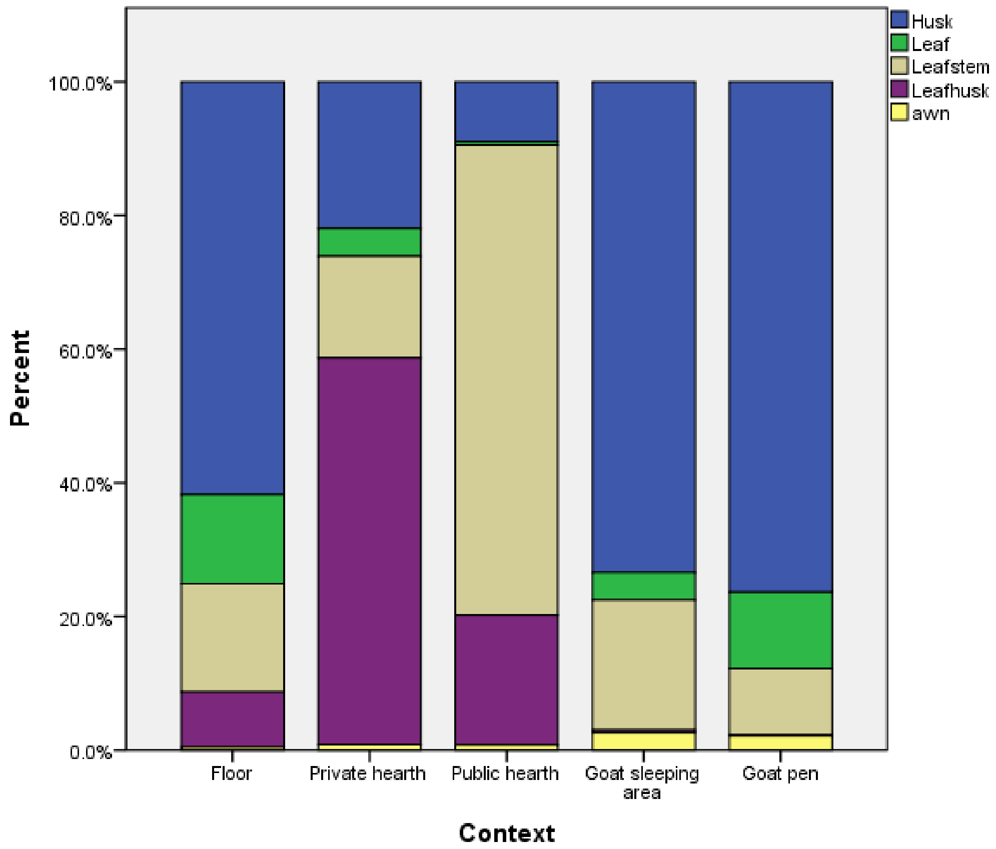


Figure 6.28. Distribution of plant parts per context, WD.

6.2.6. Jouma's tent summer (JTS)

Most of the context categories that have been sampled in this campsite plot similarly in the PCA scatterplot below, with the exception of the three hearths (figure 6.29.). These have a similar monocot to dicot ratio, however the hospitality hearth contains much higher levels of multicelled phytolith material (figures 6.30., 6.31.). The two contexts differ also in the distribution of plant parts, the kitchen hearth containing significantly higher levels of husk material while the outdoor hospitality hearths have larger amounts of leaf/stem material (figure 6.34.). One reason for this divergence could be the relatively high amount of poorly silicified material in the kitchen hearth sample, perhaps more conjoined phytoliths would have been recorded if the material was better silicified. Dung samples also differ from other contexts, containing larger amounts of monocots and multicelled phytoliths. Generally, there seems to be a slight enrichment in silica aggregate with all contexts in comparison to the background sample (figure 6.32.).

Looking at the weight percent of extracted phytolith material, a pattern emerges that does not conform to the rest of the data – the animal pen floor has (though largely varying) the highest weight percent (figure 6.35.), which would be expected to correlate to a richer phytolith assemblage. The number or phytoliths per gram is also largest in the animal pen floor context and in the hospitality hearth. It is unclear what these trends indicate.

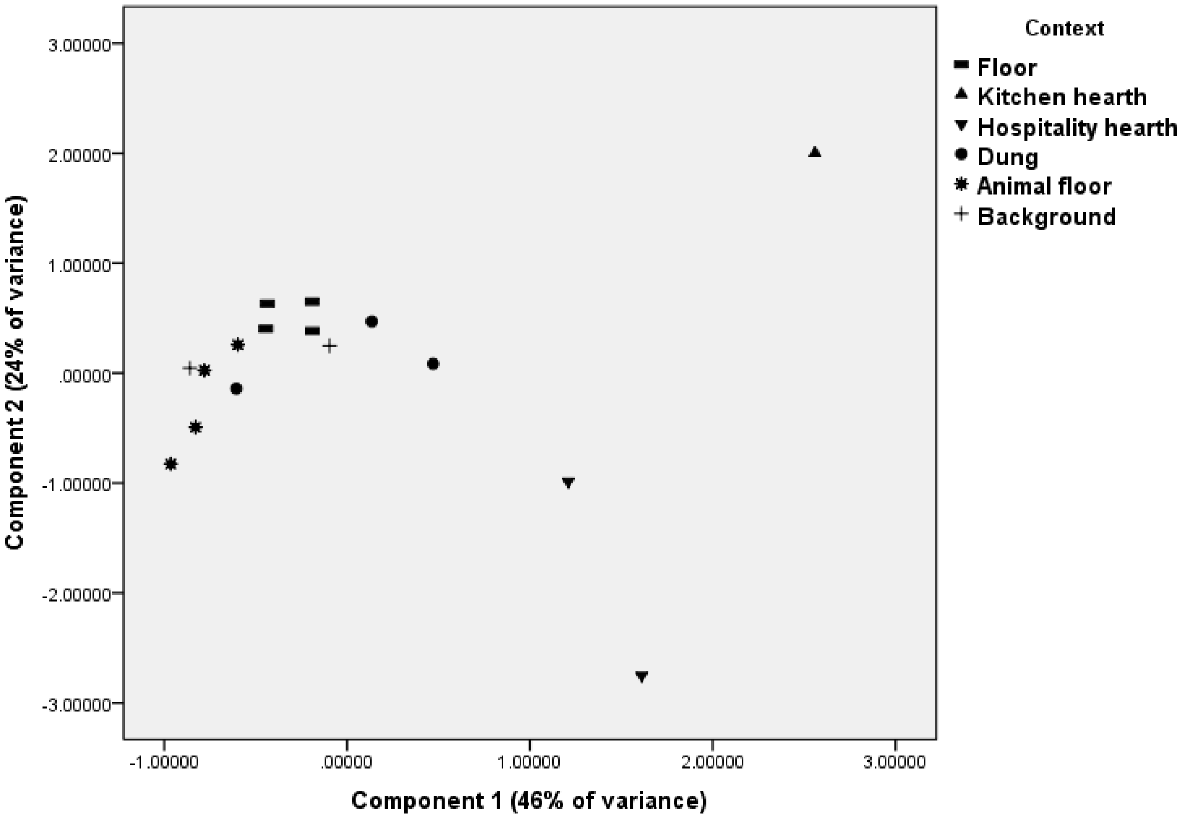


Figure 6.29. PCA scatterplot, JTS. The first component is driven by monocot to dicot ratio, Pooideae, leaf, leaf/husk, husk, multi-cell phytoliths. The second component is driven by single-cell phytoliths, unidentified phytoliths, degraded phytoliths, and negatively by nr per gram and leaf/stem.

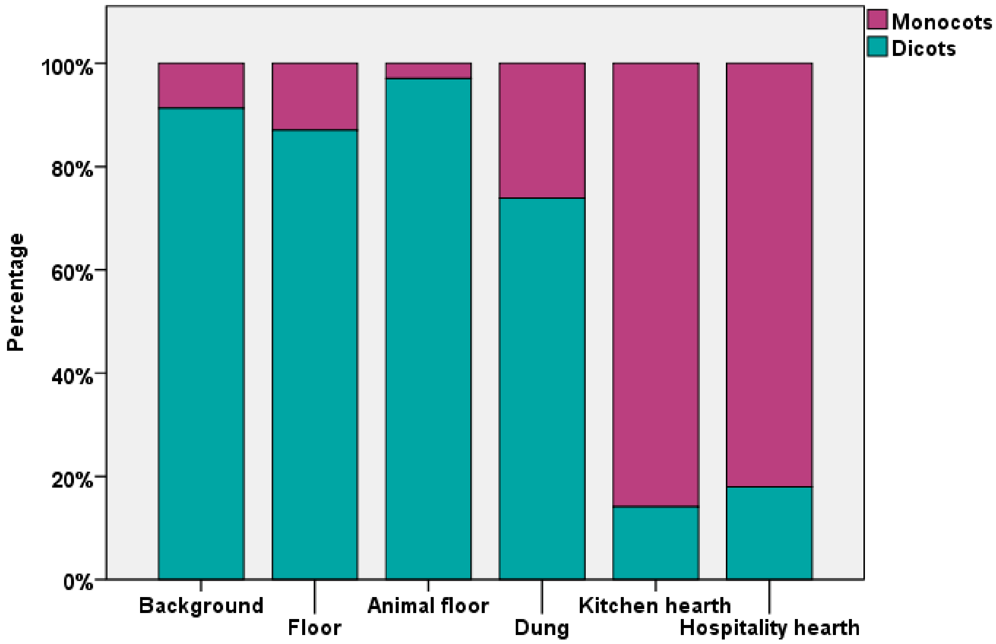


Figure 6.30. Monocot to dicot ratios per context, JTS.

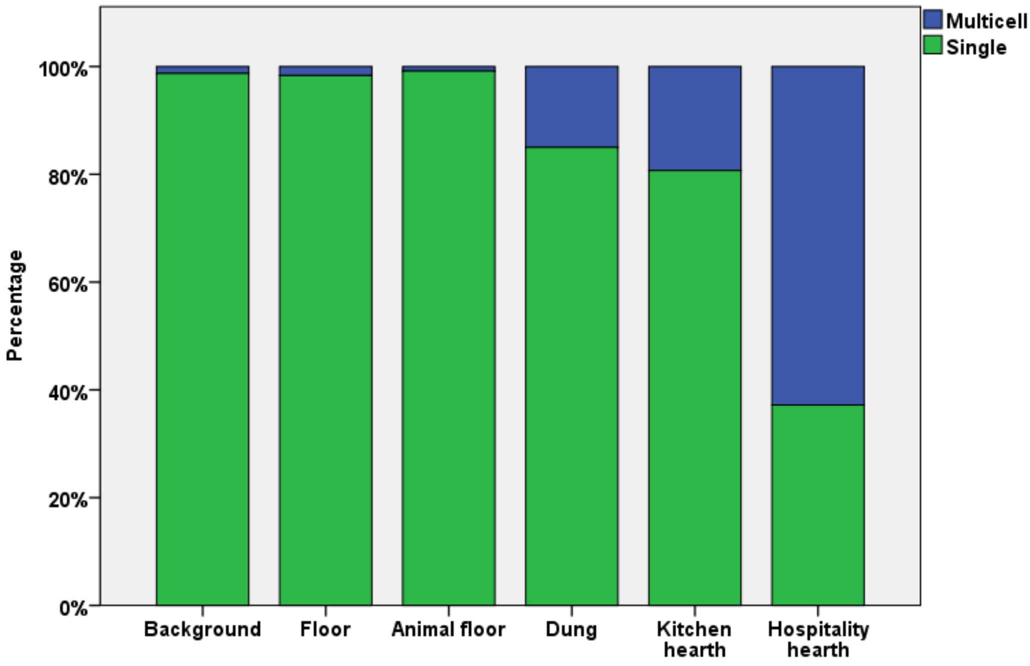


Figure 6.31. Number of multi-celled compared to single phytoliths per context, JTS.

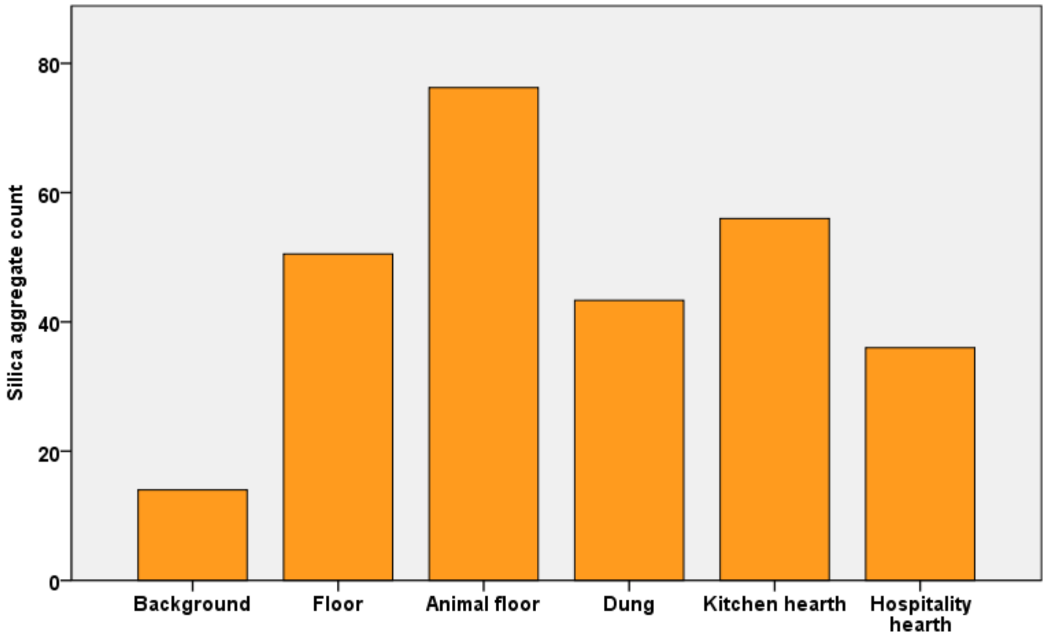


Figure 6.32. Amounts of silica aggregate compared to phytolith material per context, JTS.

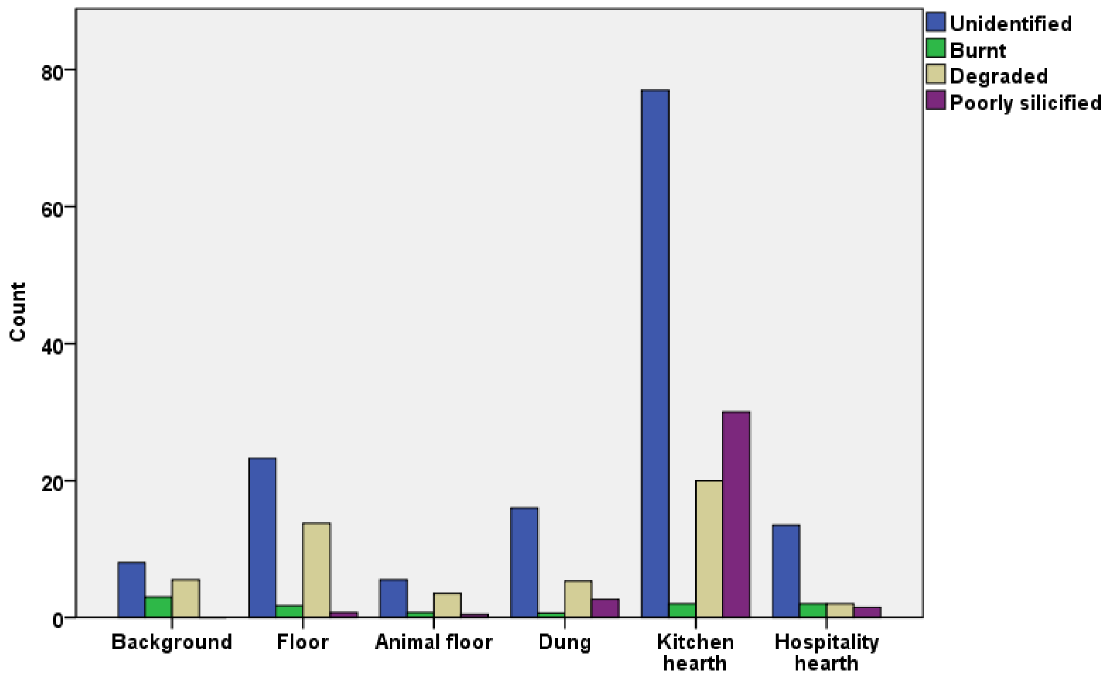


Figure 6.33. A chart showing the average number of unidentified, burnt, degraded and poorly silicified phytoliths for each context category, illustrating higher levels of poorly silicified and unidentified phytoliths in the kitchen hearth than in other contexts, JTS.

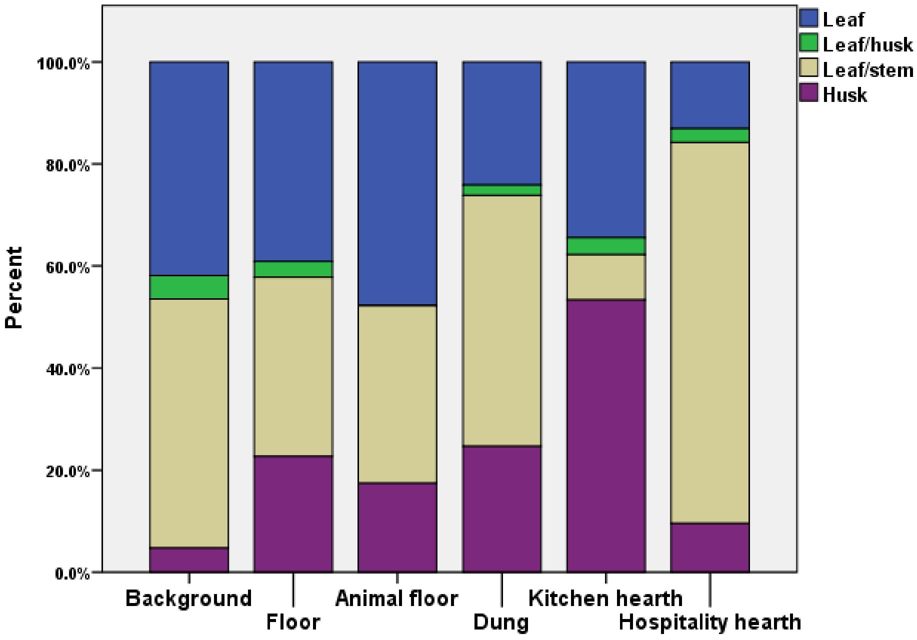


Figure 6.34. Distribution of plant parts per context, JTS.

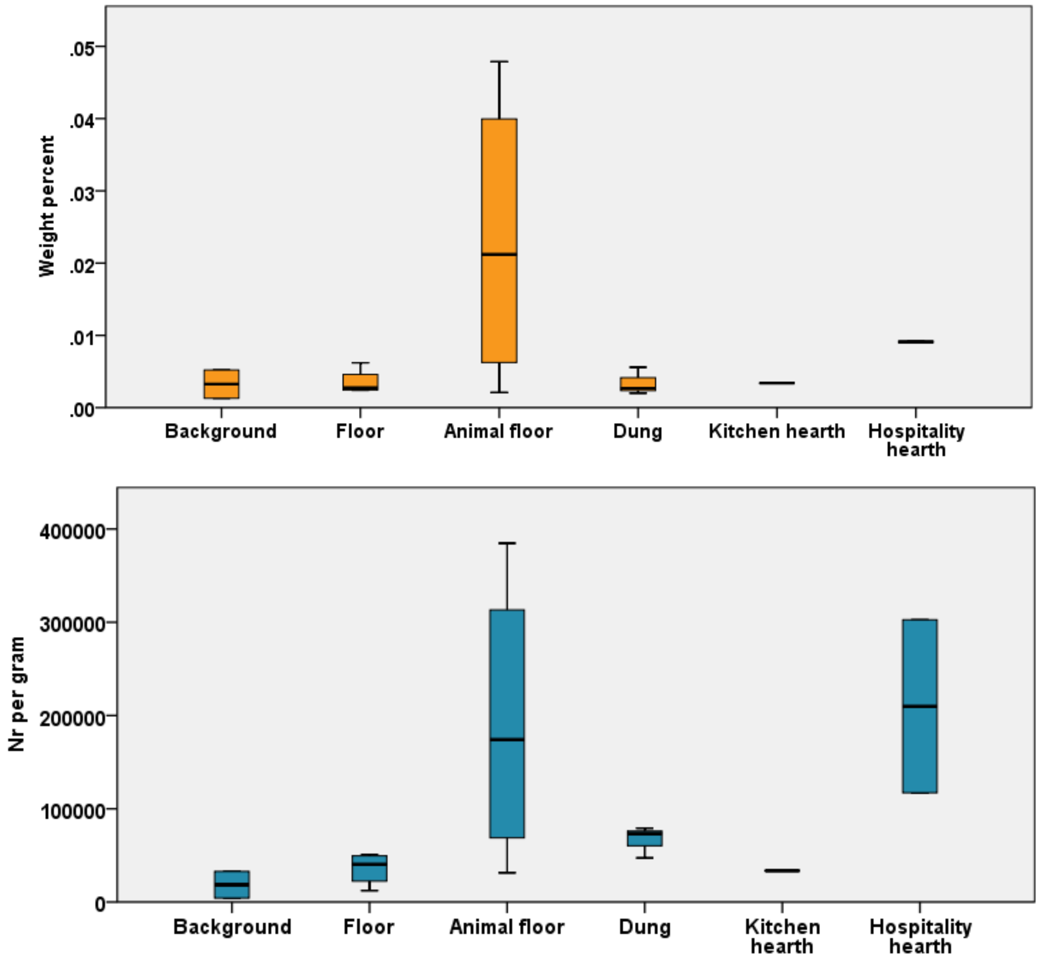


Figure 6.35. Weight percent and number of phytoliths per gram of sediment, JTS.

6.2.7. Jouma's tent winter (JTW)

The PCA scatterplot below shows an interesting pattern, where three out of the four dung samples plot together with a sample from the middle of the kitchen hearth (figure 6.36.). This was a fresh sample, still hot when bagged, and might represent the last activity which seems to be adding fuel. The sample that was taken from the edge of the kitchen hearth, and the other contexts, are all clustered. Although there is an elevation of monocots in all contexts compared to the background levels, the dung and kitchen hearth samples have the highest amount of monocots (figure 6.37.). A similar pattern can be seen when comparing the single to conjoined phytoliths, here the background and sample under the dung do not contain any multicell material, but the dung samples contain more than a third of conjoined phytoliths, followed by the kitchen hearth and other contexts (figure 6.38.).

The patterns of weight percent and number per gram are more consistent with the other data in this site than is the case with JT summer. The categories with the highest weight percent are the dung and kitchen hearth contexts (but notice that the two kitchen hearth samples behave differently), and a similar trend can be observed when examining the amount of phytoliths per gram in each context, although here the levels are much higher in the dung samples (figure 6.39.). This matches the other phytolith data, hinting towards a resemblance of the fresh kitchen hearth sample to the dung samples, all five plotting separately from the rest in the PCA scatterplot below (figure 6.36.).

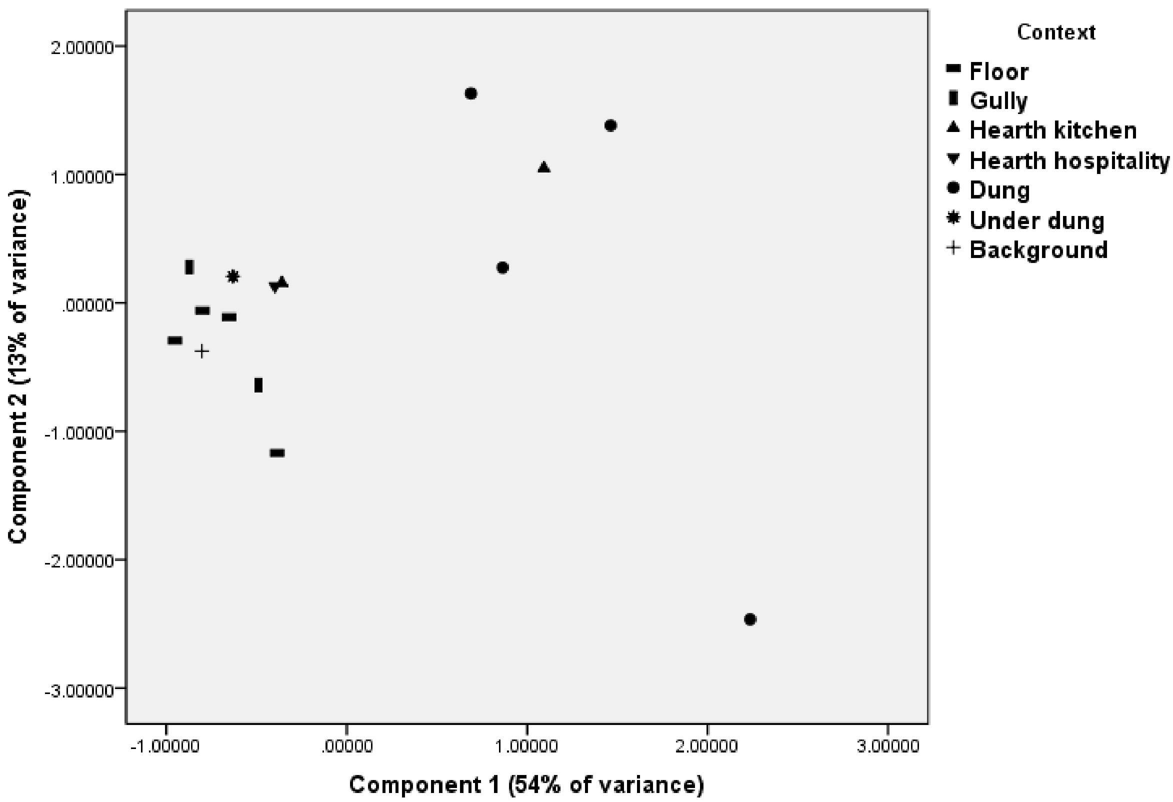


Figure 6.36. PCA scatterplot, JTW. The first component is driven by monocot to dicot and multi-cell to single-cell phytoliths ratios, leaf, Pooideae, nr per gram and husk. The second component is driven by the categories leaf/husk, Panicoideae, Arundinoideae and negatively by Chloridoideae and awn.

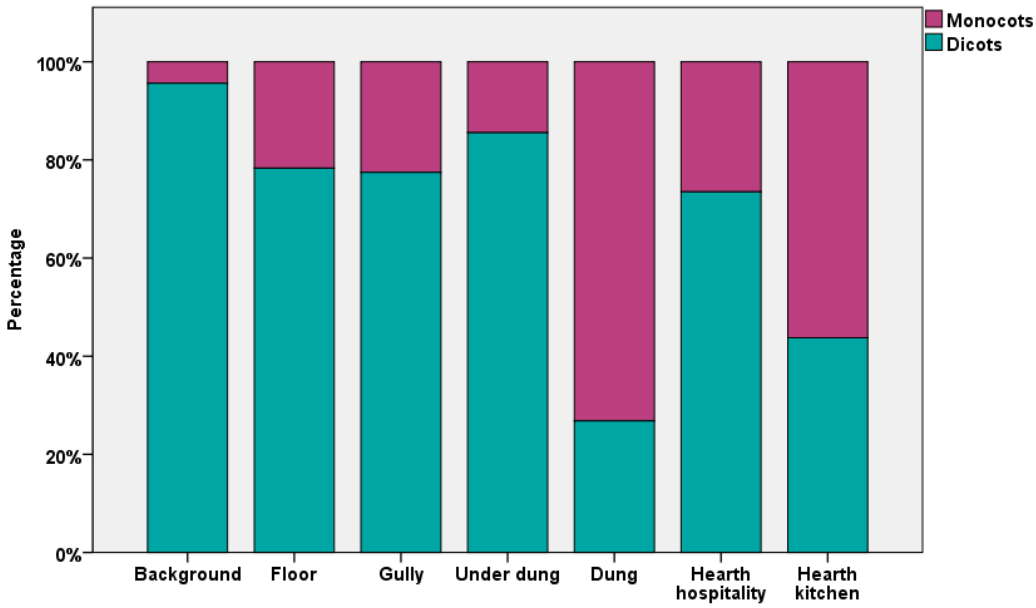


Figure 6.37. Monocot to dicot ratios per context, JTW.

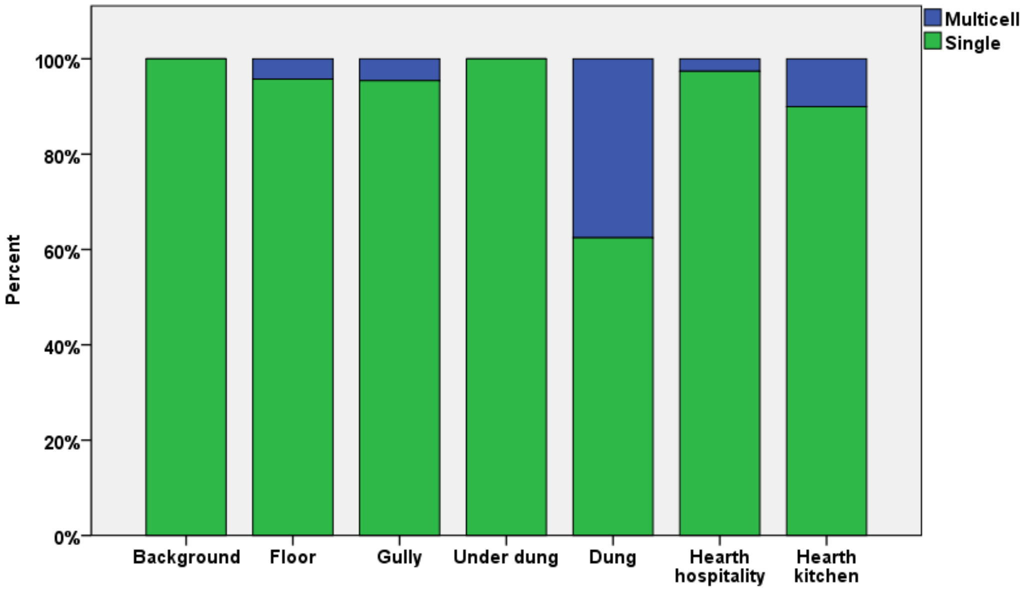


Figure 6.38. Muticelled vs. single phytoliths per context, JTW.

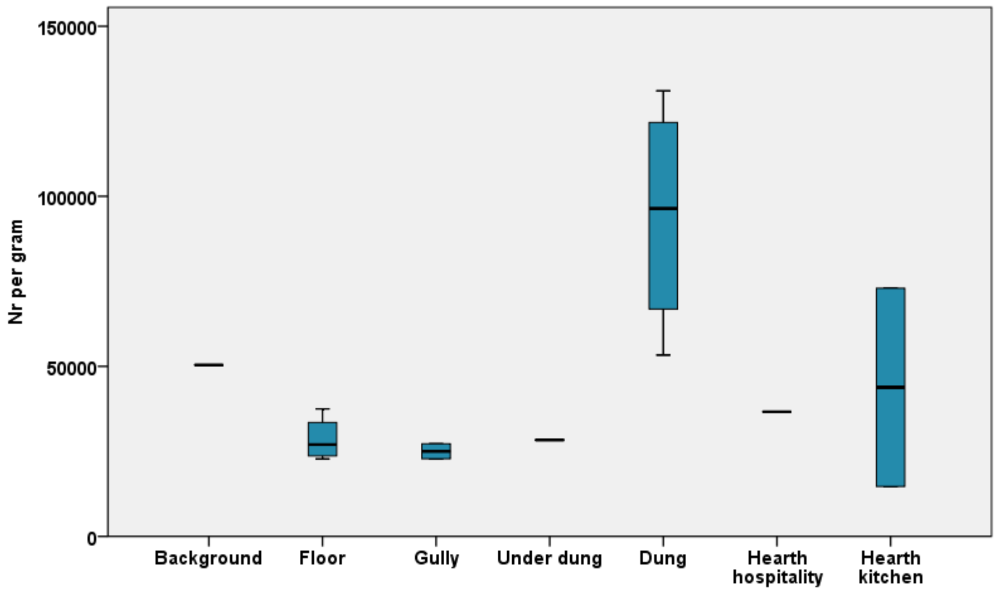


Figure 6.39. Number of phytoliths per gram of sediment for each context, JTW.

6.2.8. General trends in the ethnographic data

Certain general patterns emerge from the phytolith results for the ethnographic sites discussed above. Activity areas that have a high anthropogenic input, namely the dung samples and the kitchen and hospitality hearths, stand out in relation to the floor and background contexts. They often have higher ratios of monocot to dicot and multi-cell to single-cell phytoliths, and in some cases contain phytolith forms that can be identified to the genus level. The PCA scatterplot below (figure 6.40.) was produced for the following sites: JTW, JTS, WF916 and WF953 based on the results of their phytolith analysis, these four sites were chosen because they share the same context categories. The combined PCA analysis was carried out in order to see if the similarities observed across sites form clusters of activity areas within the data.

The PCA scatterplot displays a clustering of floor and background samples, which includes some of the animal pen floors and dung samples. The remaining animal pen floor samples form a cluster adjacent to the cluster of floor samples. The remaining dung samples form a weak cluster amongst the other context categories, separating between the kitchen and hospitality hearths clusters. Two samples, one of a kitchen hearth and one from a dung deposit, fall within the hospitality hearth cluster, and some of the other hearth samples can be found adjacent to the floor cluster. This suggests that although the dung and hearth contexts form weak, but visible individual clusters, there are similarities between the phytolith assemblages of these three types of activity areas. In addition, some of the dung and hearth samples do not contain phytolith patterns that are distinctive enough to separate them from the floor and background samples, and they fall within the cluster of floor samples.

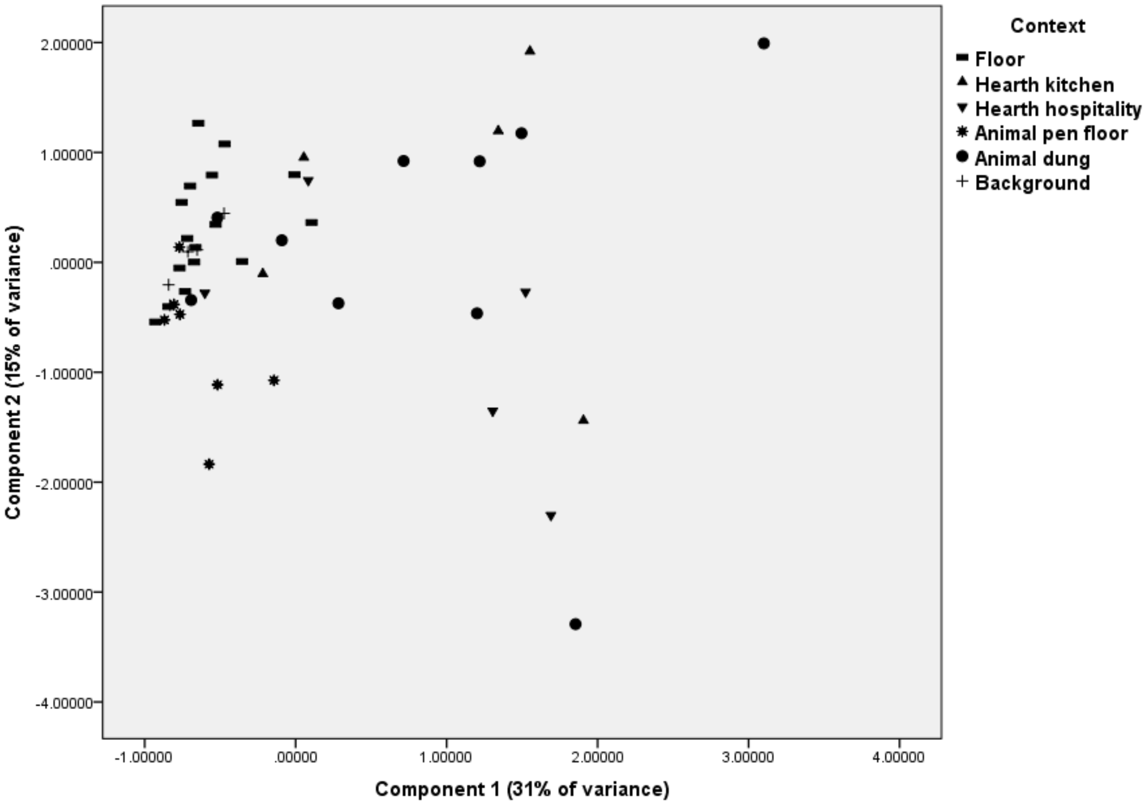


Figure 6.40. A combined PCA scatterplot for the sites JTS, JTW, WF916 and WF953. The first component is driven by monocots vs. dicots, multi-cell vs. single-cell phytoliths, husk material and Pooideae. The second component is driven by unidentified phytoliths, leaf, negatively by nr per gram, weight percent and *Triticum* sp.

6.2.8.1 Patterns through time within the ethnographic data

The amount of degraded and poorly silicified phytoliths, and the number of phytoliths per gram, were plotted in each of the campsites in order to detect differences in these among the sites. Discrepancies in degraded, poorly silicified or the amount of phytoliths could indicate change over time through taphonomic processes, or reflect the variance in the deposition environment among the sites such as the differences in setting and climatic between winter and summer campsites. The graphs in figures 6.41. – 6.43. show the mean count of each category per context for JTW, JTS, WF953 and WF916. The campsites are positioned on the graphs according to their duration of abandonment at the moment of sampling, from the most recently abandonment on the left to those with the longest abandonment on the right. The graphs do not portray changes in the conditions of phytoliths over time or in relation to deposition environment. However, floor contexts generally have the highest concentrations of degraded phytoliths, while some of the hearth and dung contexts contain the largest amounts of phytolith material. These trends might reflect an abrasion of phytolith material in "high traffic" floor areas, and the abundance of phytolith material in contexts which have a strong anthropogenic input; the hearth and dung contexts.

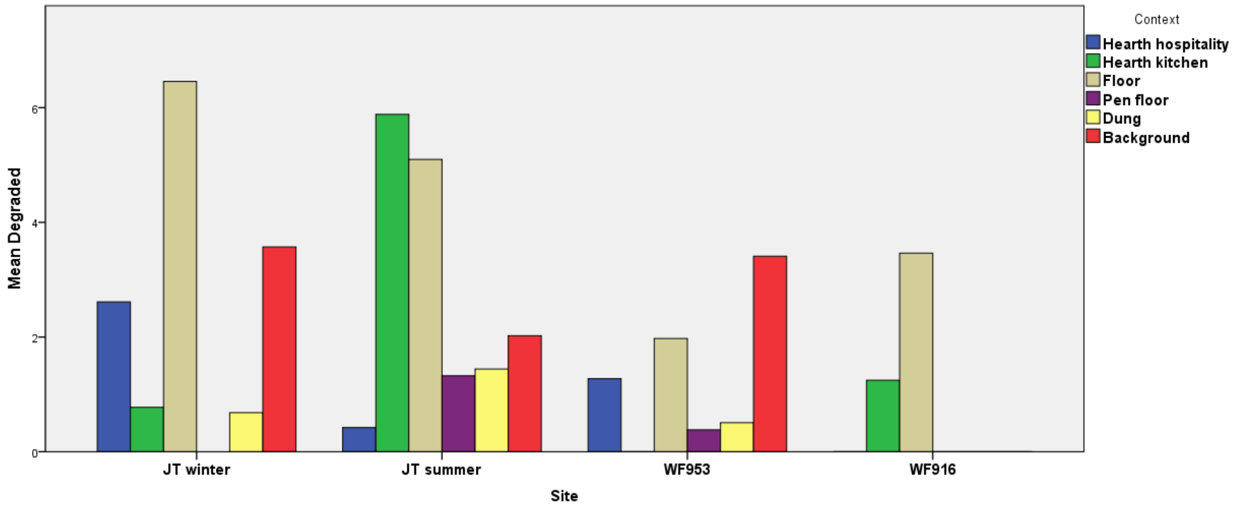


Figure 6.41. Mean counts of degraded phytoliths per context for JTW, JTS, WF953 and WF916.

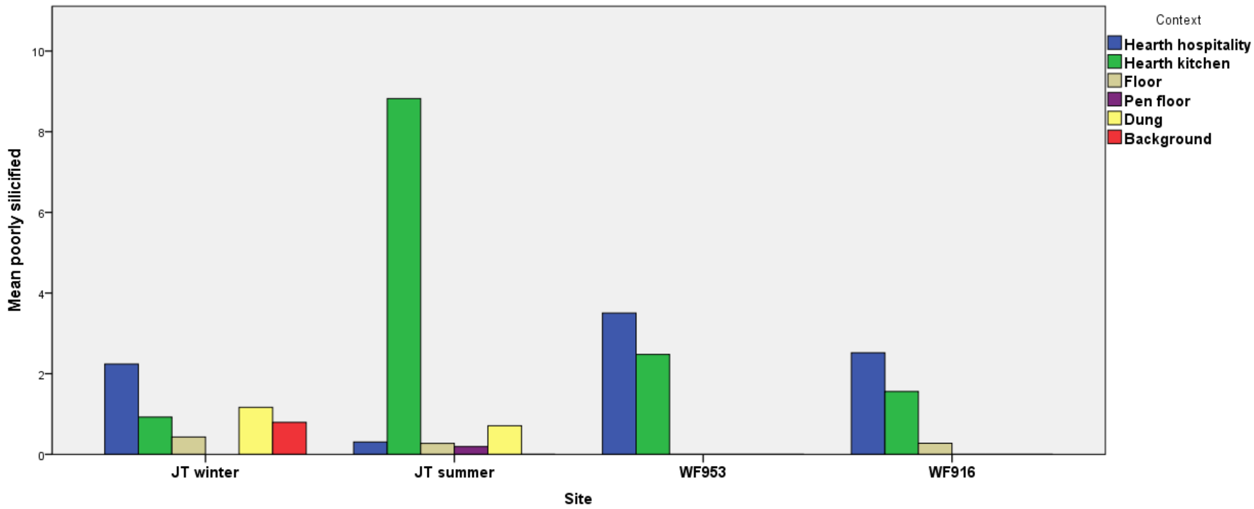


Figure 6.42. Mean counts of poorly silicified phytoliths per context for JTW, JTS, WF953 and WF916.

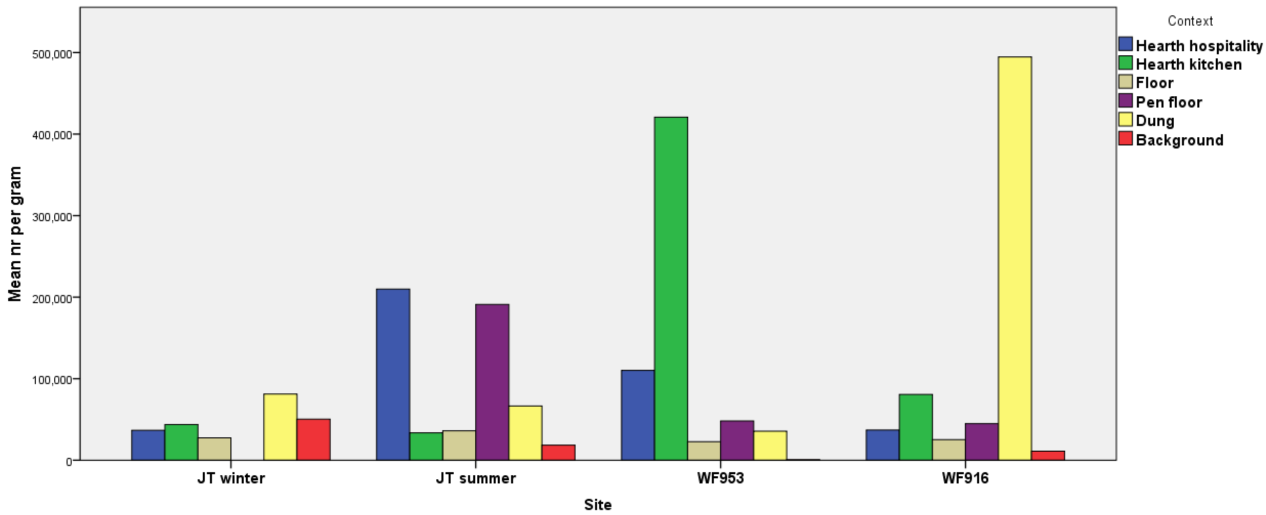


Figure 6.43. Mean number of phytoliths per gram for each context for JTW, JTS, WF953 and WF916.

6.3. Analysis of archaeological sites

6.3.1. Wadi el-Jilat 13 (WJ13)

The general trends that appear in the majority of samples throughout the site are similar to the other Wadi el-Jilat sites described below. The most common type of phytolith is tabular irregular, with single-celled dicots dominating most contexts. Silica aggregates are abundant, with the occasional elongate dendritic and elongate smooth cells. The bedrock features or postholes, however, appear to be distinguishable from the others. Within half of these, the count of 250 phytoliths could not be reached, and these samples contained a high amount of silica aggregates. In addition, this context category has the highest weight percent (figure 6.48.), but does not seem unusual when it comes to phytolith number per gram (figure 6.49.). It is likely that the high weight percent is derived from the amount of silica aggregate material, rather than phytoliths. Apart from the post holes, the data do not cluster well into groups, and although some samples in each context category seems to fit the expectation for the general type, others show entirely different trends. Nevertheless, the various on-site contexts are different to the background samples, generally containing more monocots and silica aggregate material.

From the PCA scatterplot below it is apparent that within the same context category there are individual samples that plot significantly differently to the other samples in the same category. Half of the postholes and one hearth sample seem to plot together, and the majority of the samples, including examples from all categories, plot closely to the background sample. The amount of silica aggregate seems to be the best indicator of difference from the background sample in this case, and is highest in the posthole category (figure 6.44.).

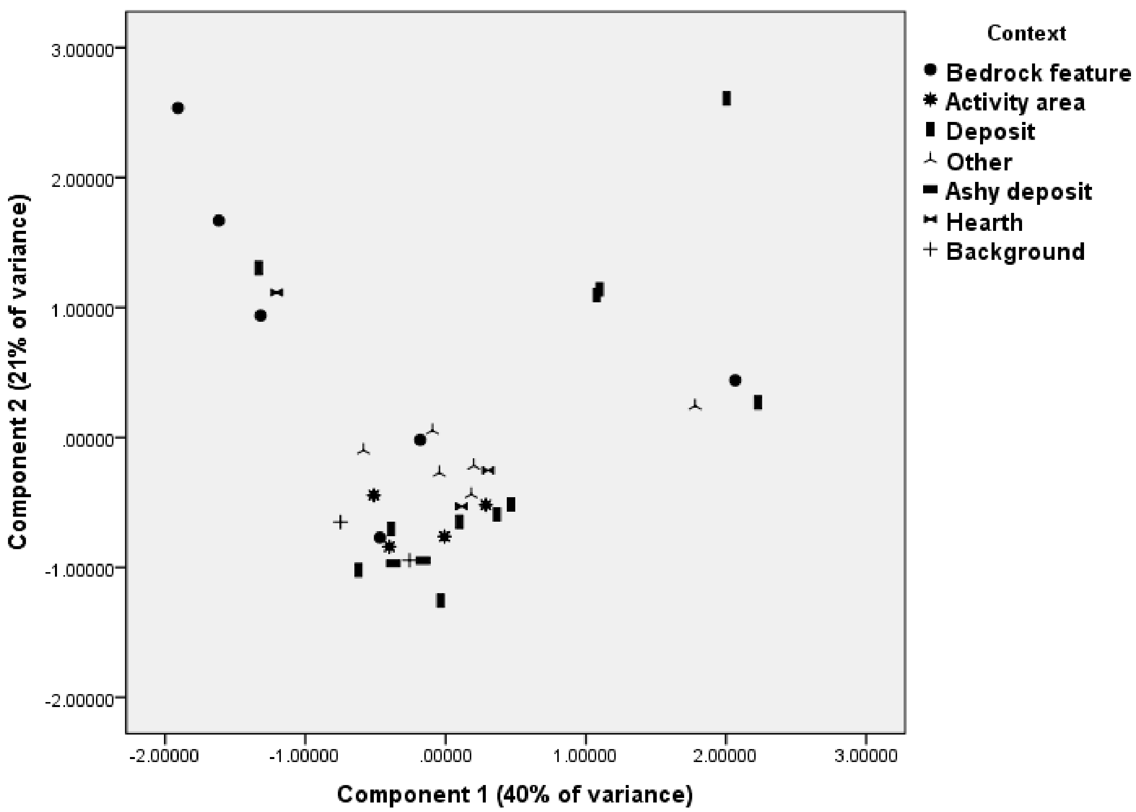


Figure 6.44. PCA scatterplot, WJ13. The first component is driven by the variables monocots, leaf and leaf/stem, the second is negatively driven by dicots and single-cell phytoliths.

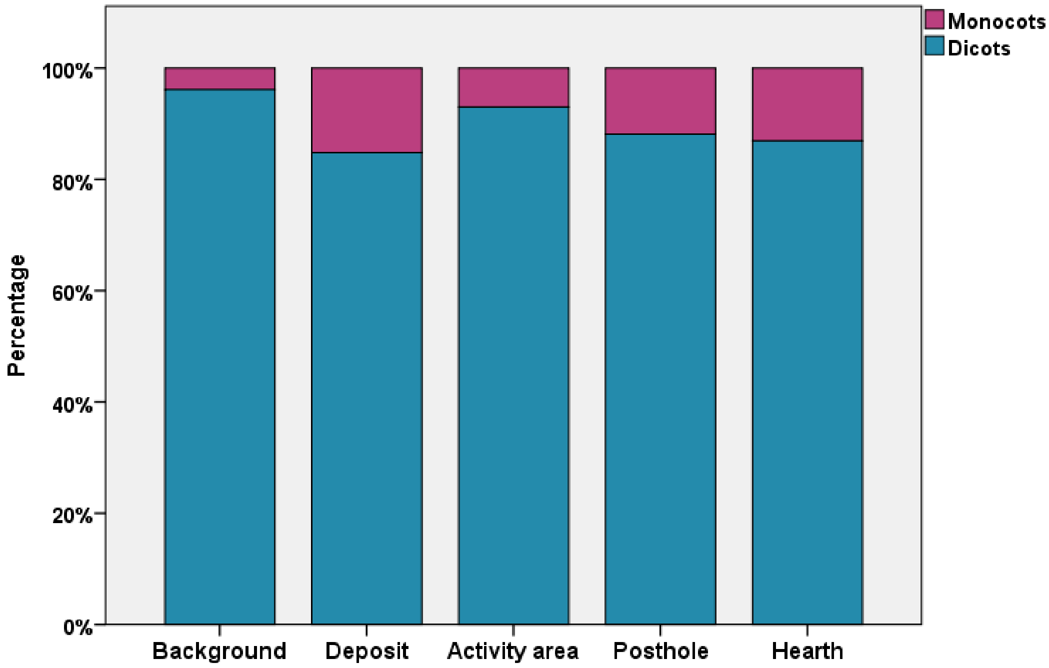


Figure 6.45. Monocot to dicot ratio per context, WJ13.

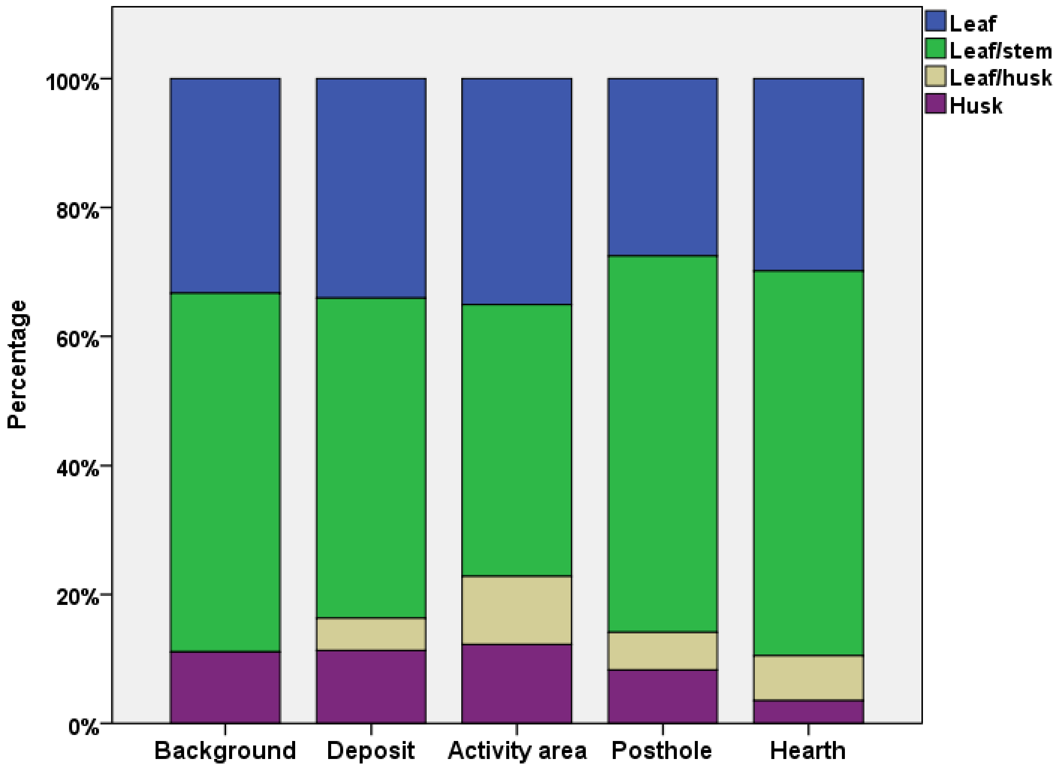


Figure 6.46. Plant part distribution per context, WJ13.

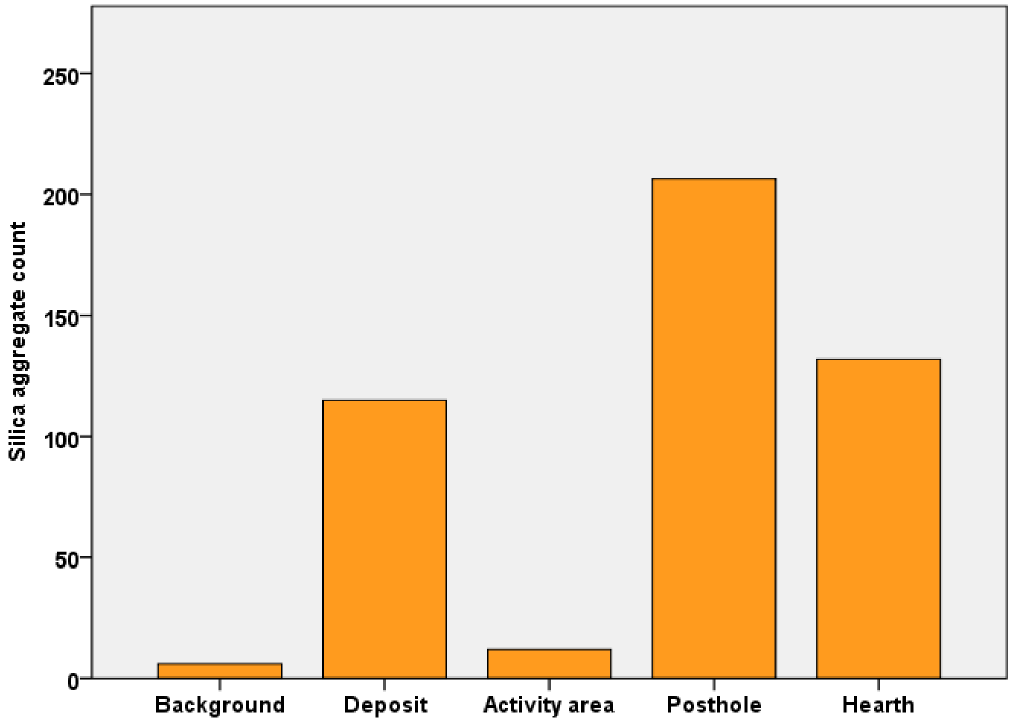


Figure 6.47. Amount of silica aggregate material in comparison to phytoliths, WJ13.

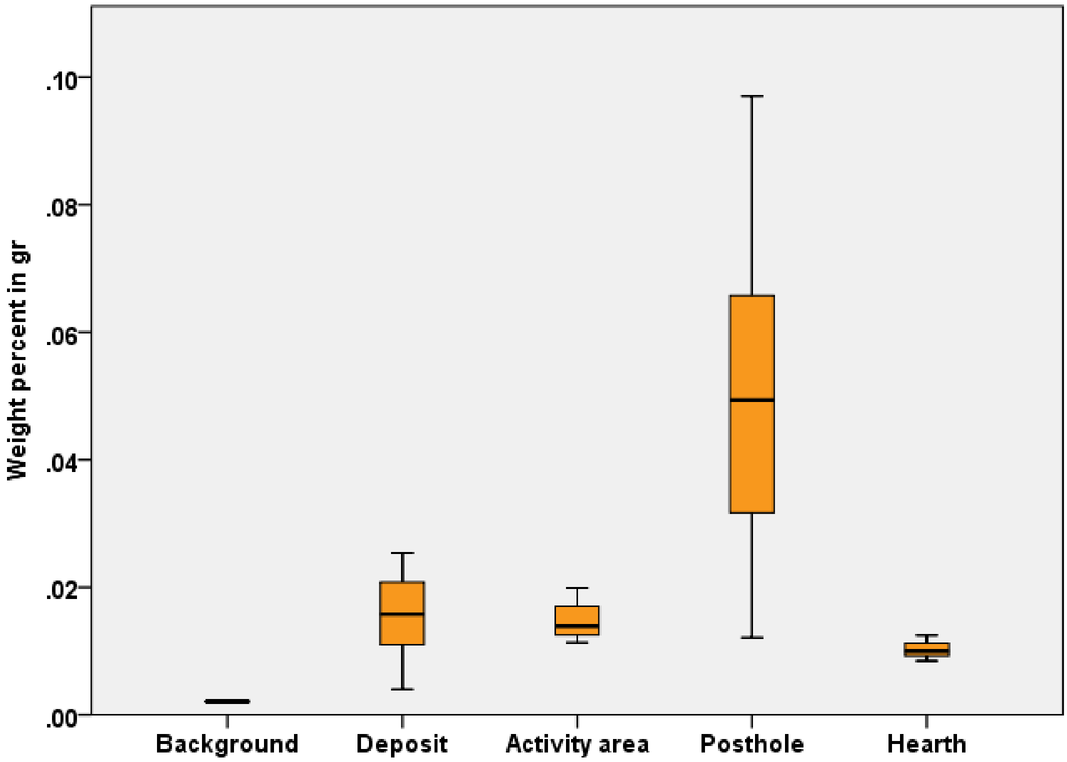


Figure 6.48. Weight percent per context, WJ13.

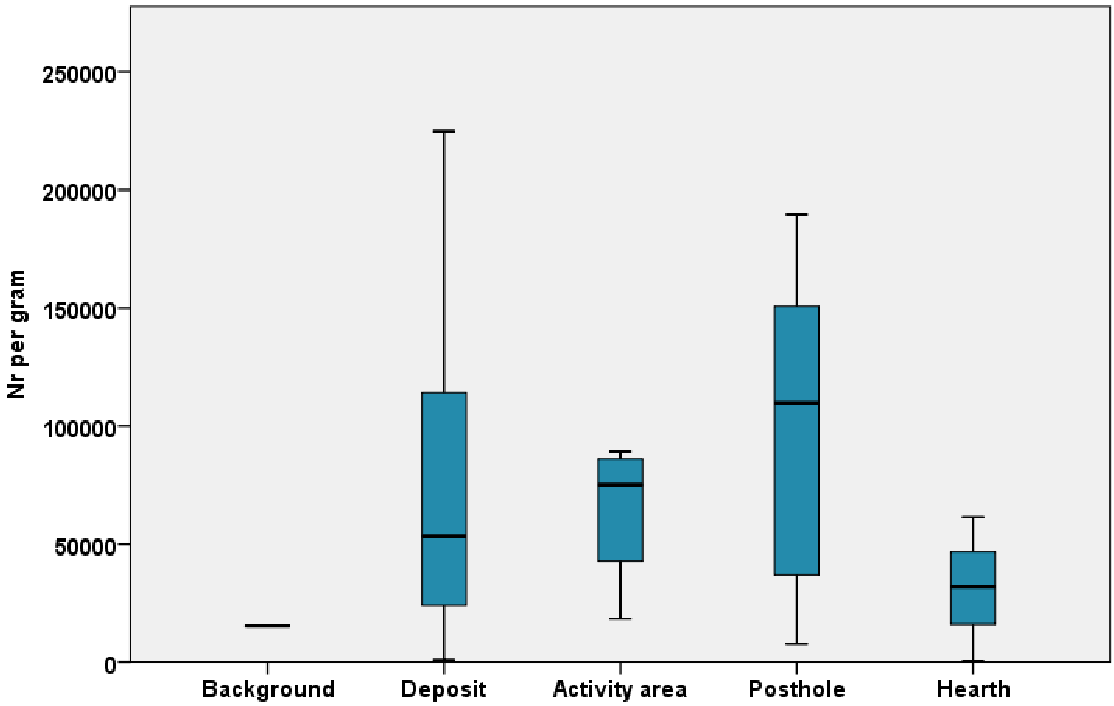


Figure 6.49. Number of phytoliths per gram for each context, WJ13.

6.3.2. Wadi el-Jilat 7 (WJ7)

Unlike WJ13, this site is comprised of several occupation areas, these were analysed as a whole focusing on the context categories that were used in the field. The phytolith analysis of the occupation areas in WJ7 are more helpful in distinguishing ancient activity areas than that of WJ13. Looking at the ratios of monocot to dicot material in the different contexts, all areas with the exception of postholes contain higher levels of monocots than the background sample. The (flint and bone rich) activity area sampled is similar to the ash fill in the monocot to dicot ratio, and resembles the compact ashy fills in the distribution of plant parts (figures 6.52., 6.53.). All occupation contexts at WJ7 contain more husk and husk/leaf material than the background sample. The latter, however, comprises larger amounts of silica aggregate material than the occupation deposits, and has a higher weight percent and amount of phytoliths per gram (figures 6.54., 6.55.).

These trends do not suggest dramatic differences between most areas, which is confirmed in the PCA analysis scatterplots. While the postholes form a distinct group, the deposits and other contexts seem less cohesive. The hearth sample and one of the compact ashy fills plot separately to the rest of the samples, as does the activity area sample. This reflects the higher concentration of monocots in these contexts (figures 6.50., 6.51., 6.52.).

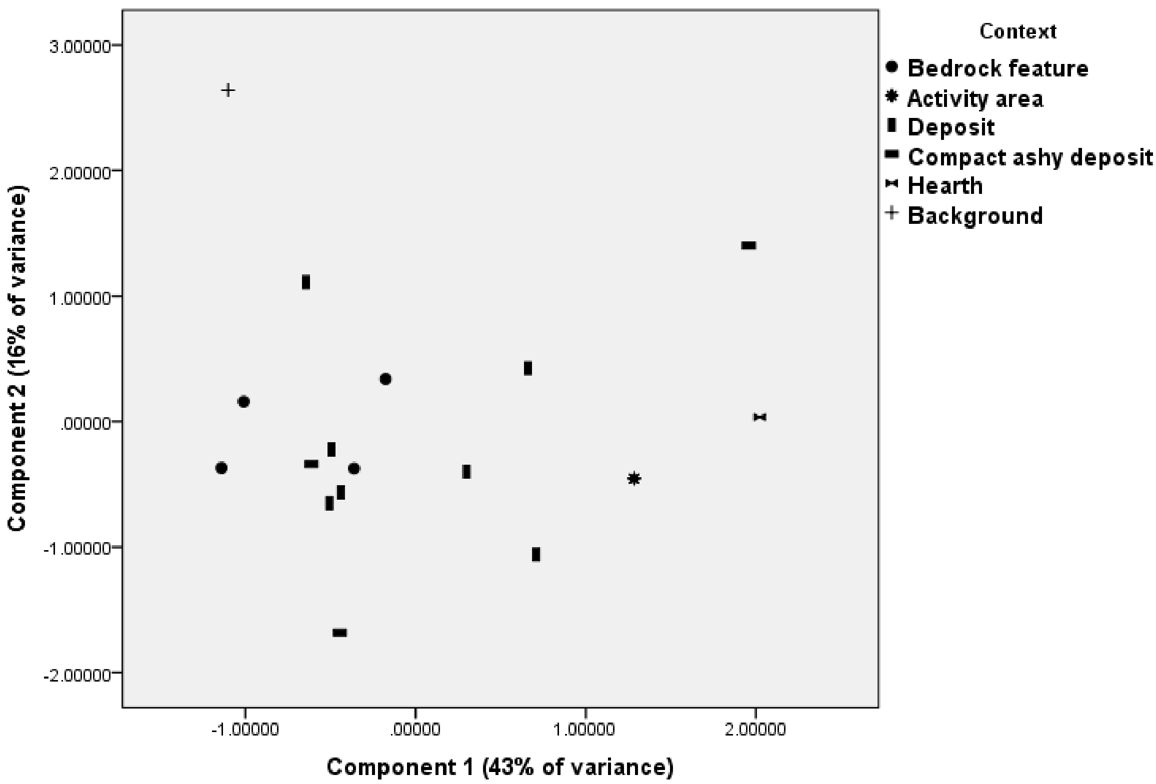


Figure 6.50. PCA scatterplot, WJ7. The first component is driven by monocots, unidentified and degraded phytoliths, leaf, leaf/stem, Pooideae and single-cell phytoliths. The second component is driven by weight percent, Chloridoideae and negatively by burnt phytoliths.

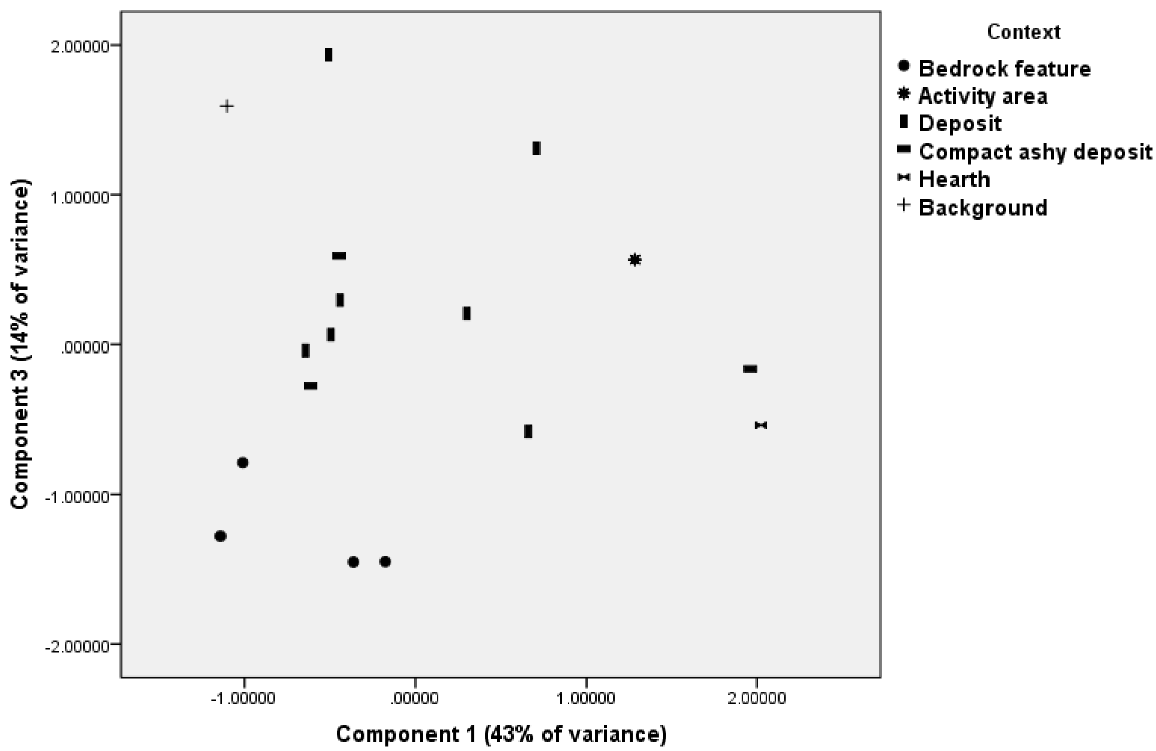


Figure 6.51. PCA scatterplot, WJ7. The first component is driven by monocots, unidentified and degraded phytoliths, leaf, leaf/stem, Pooideae and single-cell phytoliths. The third component is driven by Panicoideae, leaf/husk and weight percent.

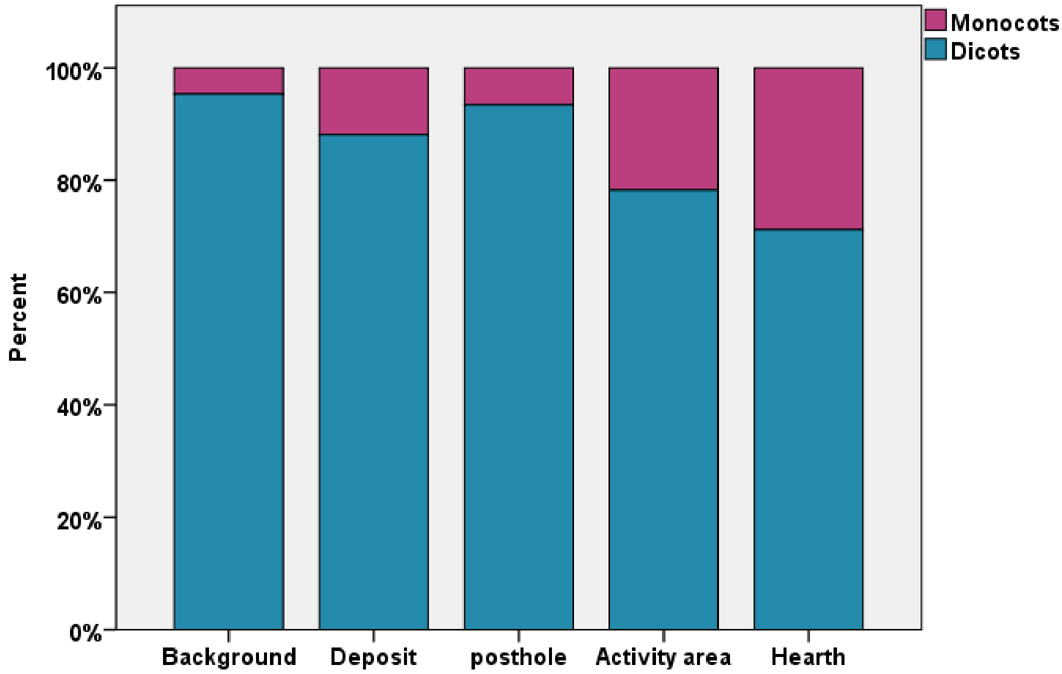


Figure 6.52. Monocot to dicot ratios per context, WJ7.

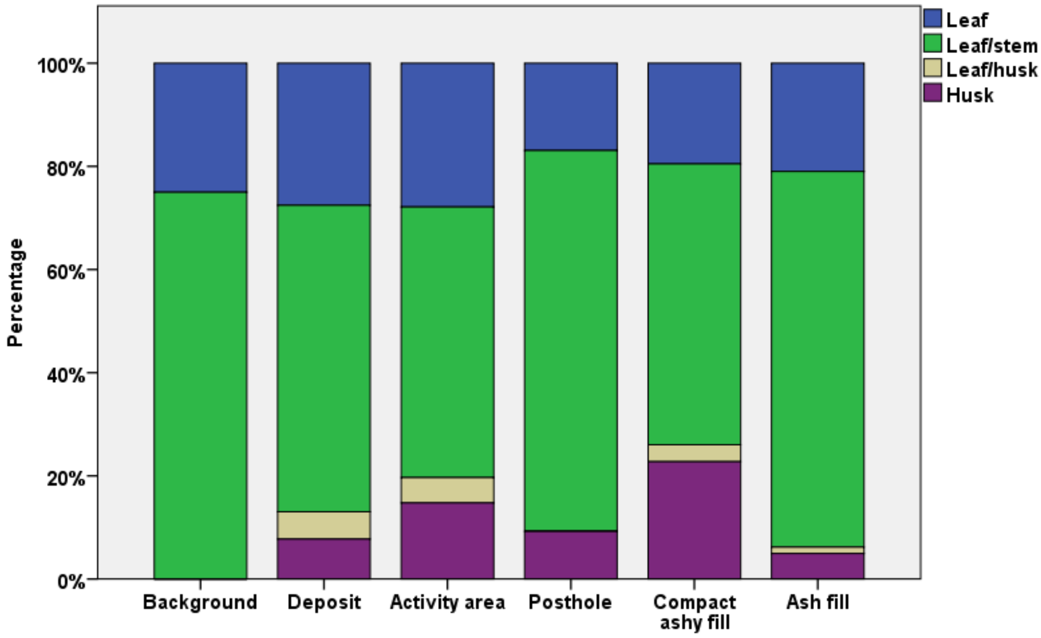


Figure 6.53. Distribution of plant parts per context, WJ7.

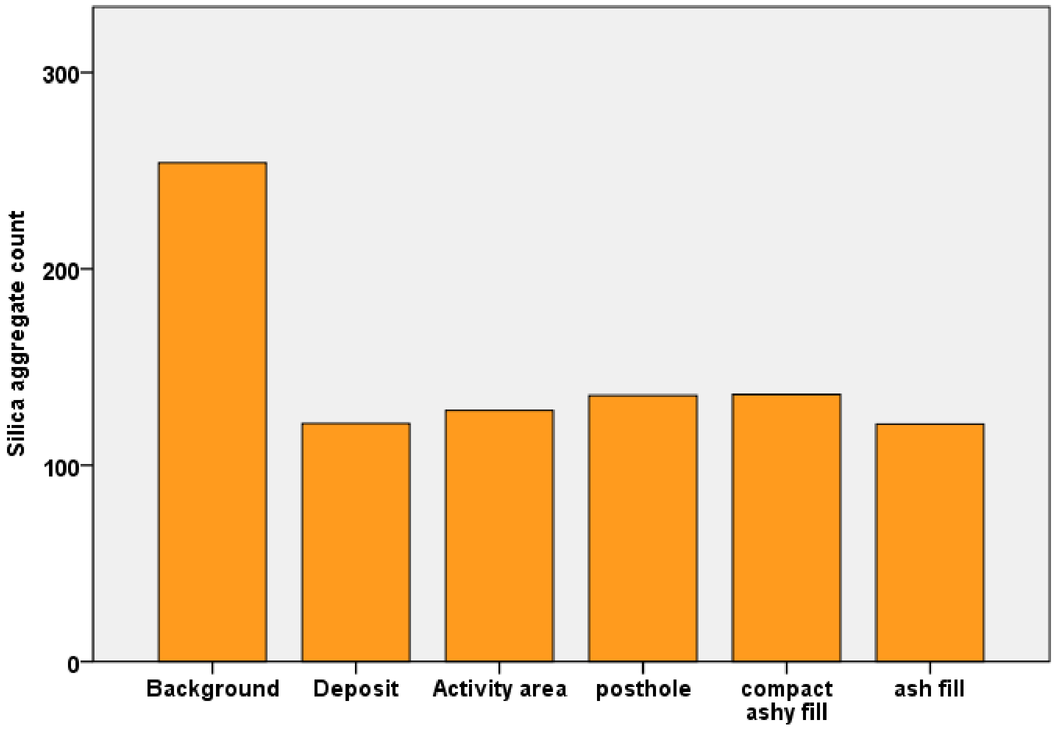


Figure 6.54. Amount of silica aggregates vs. total amount of phytoliths per context, WJ7.

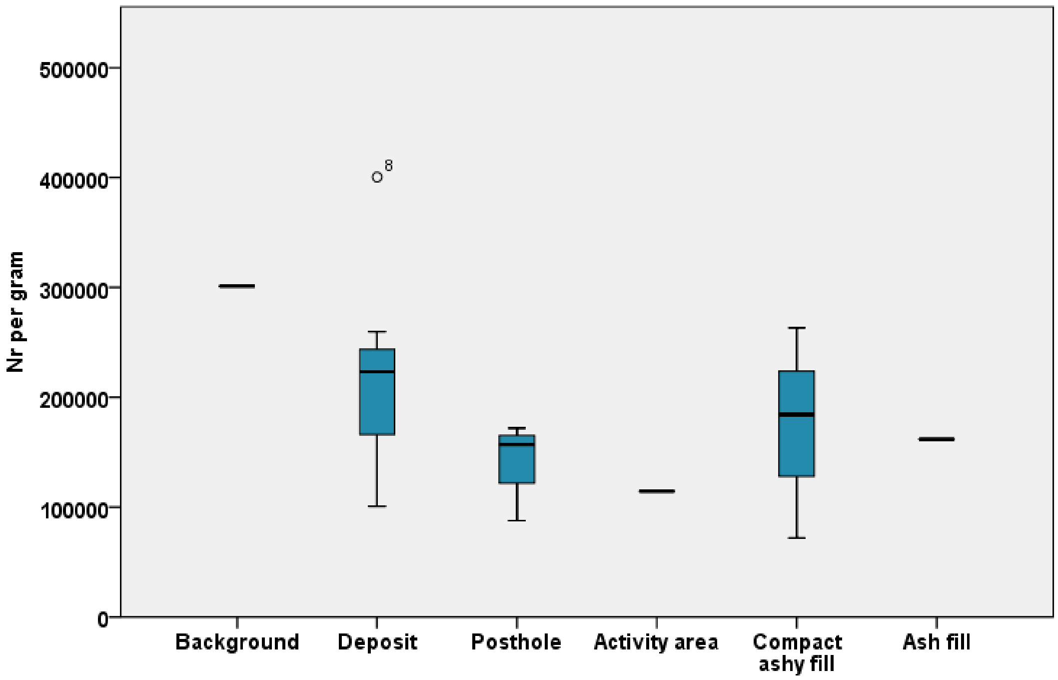


Figure 6.55. Number of phytoliths per gram of sediment for each context, WJ7.

6.3.3. Wadi el-Jilat 26 (WJ26)

As with WJ7, WJ26 comprises three occupation areas, each representing a building. The context categories were used to analyse the site as a whole. These, however, do not show much variation in the aspects of phytolith analysis that show variation in the other sites. Looking at the PCA scatterplots (figures 6.56., 6.57.), there seems to be some variation between the context categories, but still quite a large overlap between the main groups; deposits and hearths. The category of compact ashy deposits, probably representing areas of high activity, seem to plot closely to the hearths, with the exception of one sample (WJ26C 9 6) which was taken from a cut fill. The second PCA scatterplot, which represents the first and third components, explains less of the variance but displays a better clustering of context categories. This suggests that weight percent and silica aggregate quantities are key drivers of variability among the general deposits, bedrock features and hearths.

The problematic background samples, which were taken from the vicinity of WJ7 and WJ13, represent two extremes in the second PCA scatterplot (figure 6.57.). This is mainly due to a difference in weight percent between the two samples. If one follows the lower weight percent of the two background samples, it would seem that all occupation deposits have higher amounts of phytolith material, with ash fill and compact ashy fill categories enjoying higher phytolith weight than the fill and bedrock mortar contexts (figure 6.58.). However, the number of phytoliths per gram shows a different pattern to the weight percent, with compact ashy fills and one of the ash fill samples containing a large amount of phytoliths (figure 6.59.). As for the preservation of phytoliths, the two bedrock feature samples contained larger amounts of poorly silicified material (which could explain the lower phytoilth weight). Ash fills (hearths) may have a better preservation than other contexts (figure 6.60.).

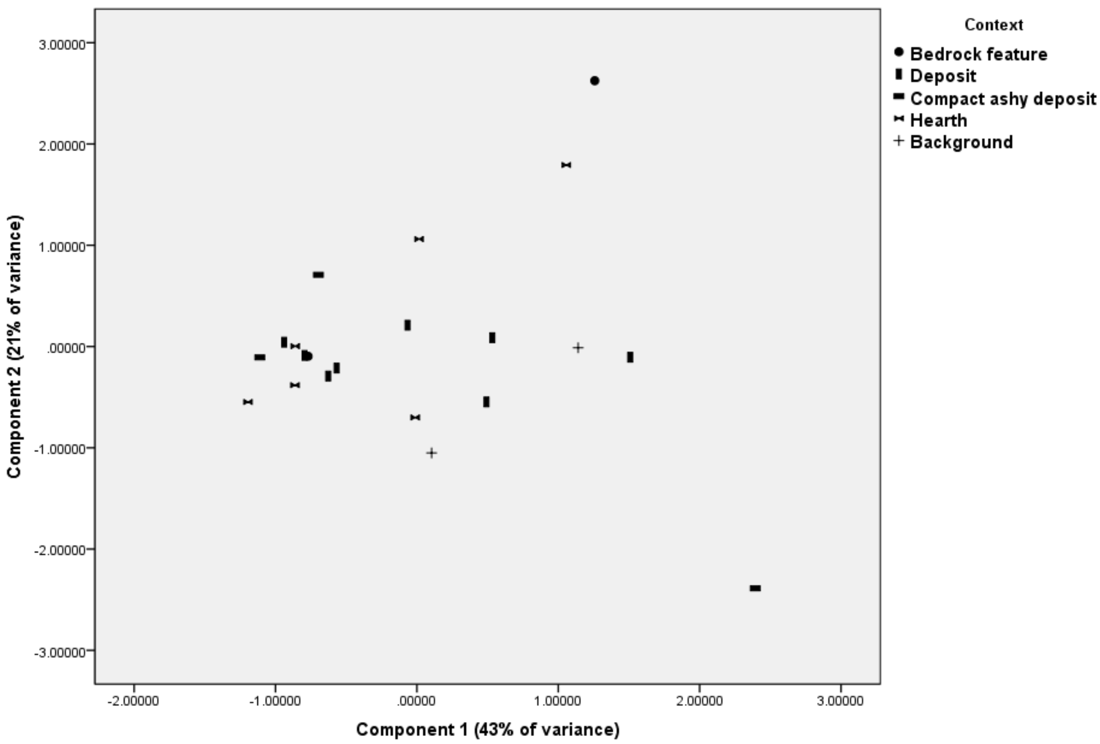


Figure 6.56. PCA scatterplot, WJ26. The first component is driven by monocots, plant parts and unidentified phytoliths. The second component by dicots, single-cell phytoliths, poorly silicified and burnt phytoliths.

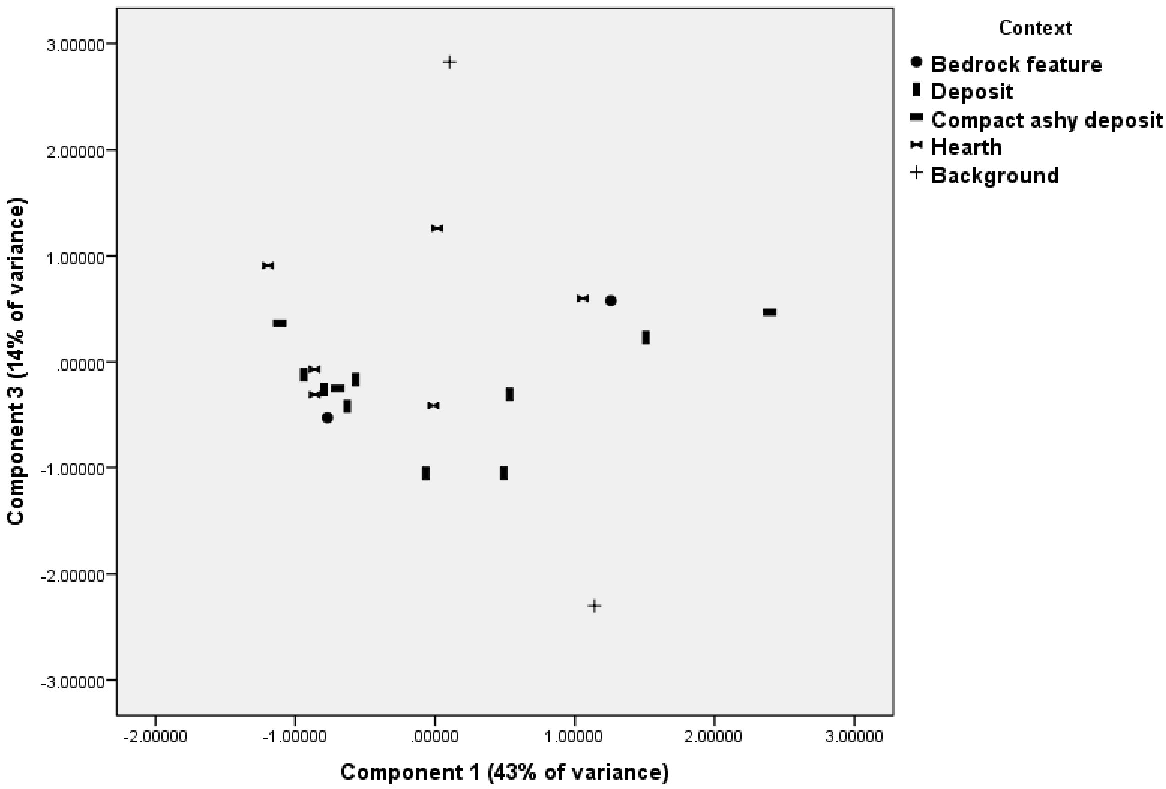


Figure 6.57. PCA scatterplot, WJ26. The first component is driven by monocots, plant parts, and unidentified phytoliths. The third component by weight percent and silica aggregate.

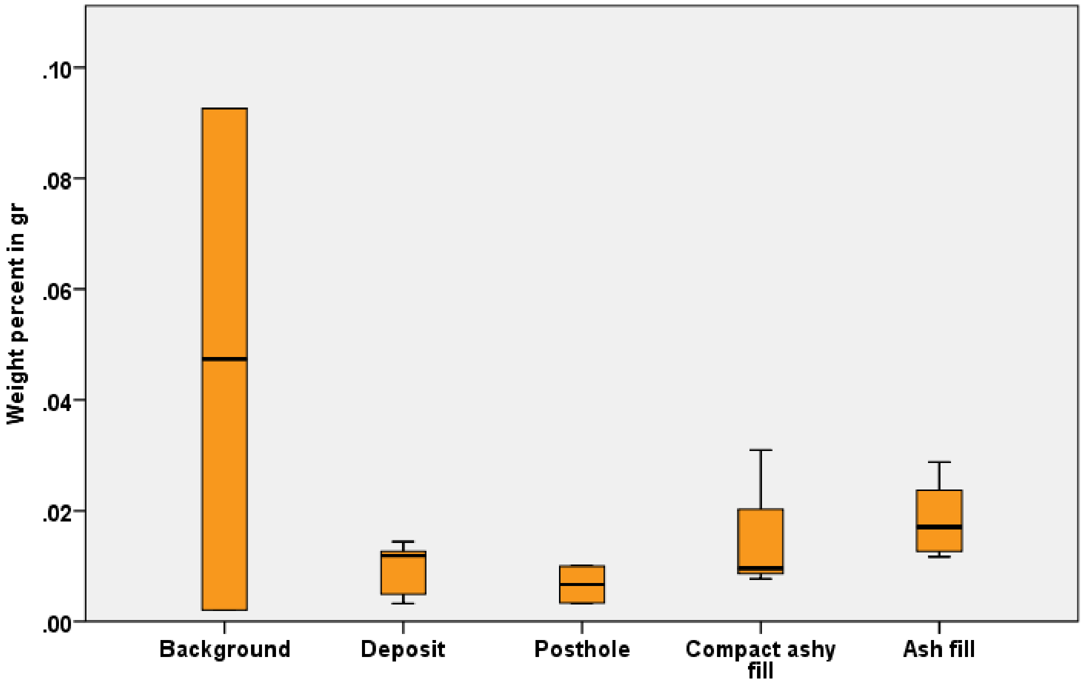


Figure 6.58. Phytolith weight as percent of sample weight per context, WJ26.

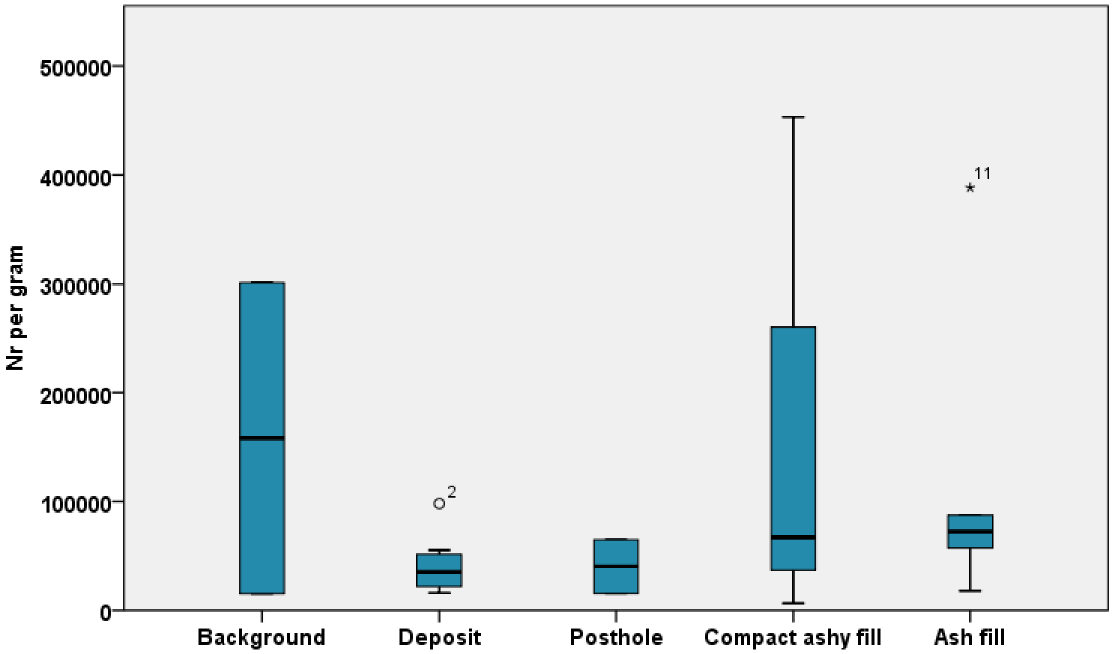


Figure 6.59. Number of phytoliths per gram of sediment, WJ26.

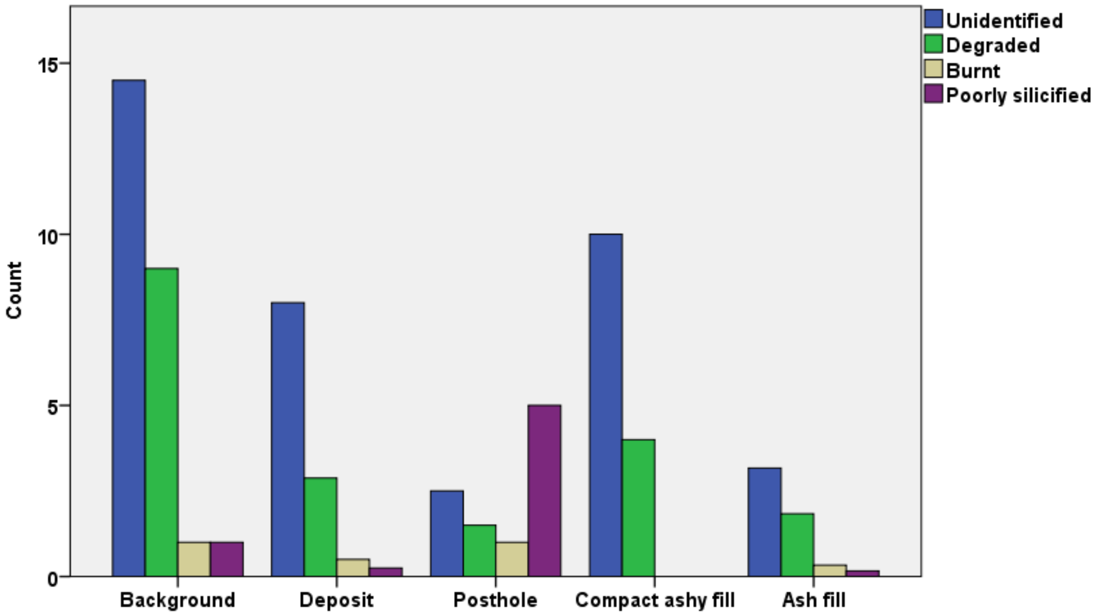


Figure 6.60. Amount of unidentified, degraded, burnt and badly silicified phyoliths per context, WJ26.

6.4. Discussion

The phytolith samples examined in this study provide several indicators of variation in the spatial use of these sites. Differences within the monocot to dicot ratios among the context categories seem to be one of the most useful indicators of different activity areas, and the identification of subfamilies or genus in specific localities can further help distinguish activity patterns. The proportions of different plants parts in each sample could be used to distinguish different types of activities as well, but in many of the cases outlined above this aspect of phytolith analysis does not tie in well with other indicators of variance. Still, it is always important to consider the distribution of plant parts and it may be revealing, as in the case of WD where the public hearth contained mainly leaf/stem material, while the kitchen hearth primarily comprised leaf/husk plant parts.

Estimates of weight percent, number of phytolith per gram and amount of silica aggregate material do not always mirror the trends seen by analysing the phytoliths themselves. In some cases the intensity of anthropogenic input in contexts such as "hearth" and "animal dung" will be reflected in these, but in other cases discrepancies are found between weight and number per gram. As the weight of extracted phytoliths can be influenced by other materials (such as minerals or silica aggregate), it would seem that number of phytoliths per gram is a better indicator of intensity. Nevertheless, number per gram does not closely relate to other indicators of activity (such as monocot-dicot distribution), and does not always behave as expected.

All in all, it seems that some phytolith indicators of activity work better than others in specific cases, and there is no clear test or feature within phytolith analysis that can globally predict specific activities. Analysing a range of samples within a single site as a whole, and comparing various signals, works best. The PCA analysis in this chapter, especially in the case of the Neolithic sites, enabled distinguishing clusters in most cases, even when other trends did not clearly emerge from observing the data through bar graphs for individual variables.

7 Results of geochemical analysis

7.1. Introduction

This chapter will present the results of the geochemical analysis of 160 samples, 92 from the ethnographic and 68 from the Neolithic sites (the methodology of the geochemical analysis is described in chapter 5). The data is displayed through PCA scatterplots and boxplot graphs for individual elements. This is done in order to explore both trends for individual chemical elements within each of the sites and across multiple sites, and more general patterns within the data which enable us to distinguish between different context categories.

First the results from each of the Bedouin campsites is presented, followed by the general trends from the Wadi Faynan sites. The ethnographic samples were collected from known activity areas (see Chapter 5 for a description of the sampling strategy and context categories). Most of the sites have samples for both the kitchen and hospitality hearths, floors, animal pen floors and dung, in addition to background samples. The sampling of the site at Wadi Dana did not include a background sample, and the length of time since abandonment at the sites Wadi Faynan 940 and Wadi Faynan 982 made it difficult to distinguish between the two types of hearths at these campsites. The identification of activity areas in these cases is therefore less secure than in the occupied and recently abandoned campsites.

The results from the Neolithic sites are presented individually, and then combined in order to explore general trends for the archaeological data. The differences in the period and nature of occupation at these sites are greater than within the ethnographic data (see description of the Neolithic sites in chapter 4). In addition, the identification of the various context categories, which was done in the field for these sites, is not as reliable as that of the activity areas sampled for the Bedouin campsites for obvious reasons (the sampling strategy is presented in chapter 5). This makes it more difficult to present the results of the geochemical analysis, as the samples might not be divided in the correct categories of activity. Nevertheless, several trends can be observed within the archaeological data which suggest that differentiation between activity areas can be observed geochemically.

7.2. Analysis of ethnographic sites

7.2.1. Wadi Faynan 916 (WF916)

The geochemical trends that can be seen at WF916 are characteristic of the general patterns of enrichment present at the Wadi Faynan sites, which are presented below. However, there are certain discrepancies in the elemental composition of the hearths and dung samples in this site and the other campsites. K, P and Zn, usually present in higher levels in hearths, are most abundant in the dung sample (figures 7.2. – 7.4.), which plots alone in the PCA scatterplot (figure 7.1.). The animal dung and pen contexts contain higher amounts of Cl, but while kitchen hearths from other campsites contain elevated levels of Cl too due to the use of dung cakes, this does not seem to be the case here (figure 7.5.). The hearths, as with other sites, do have the highest levels of Mg, Ca, Sr and Mn (figures 7.6. – 7.9.). There is a depletion in elements that are related to the background composition of the parent soil material such as Al, Fe, Ti and Si in the contexts that have enrichment of the elements related to anthropogenic activities discussed above (figure 7.10., 7.11.). The PCA scatterplot below (figure 7.1.) shows a main cluster containing the floor and gully samples, the background samples on the edge of this, and one of the two animal pen floor samples. The single dung, two hearths and other animal pen samples each plot separately.

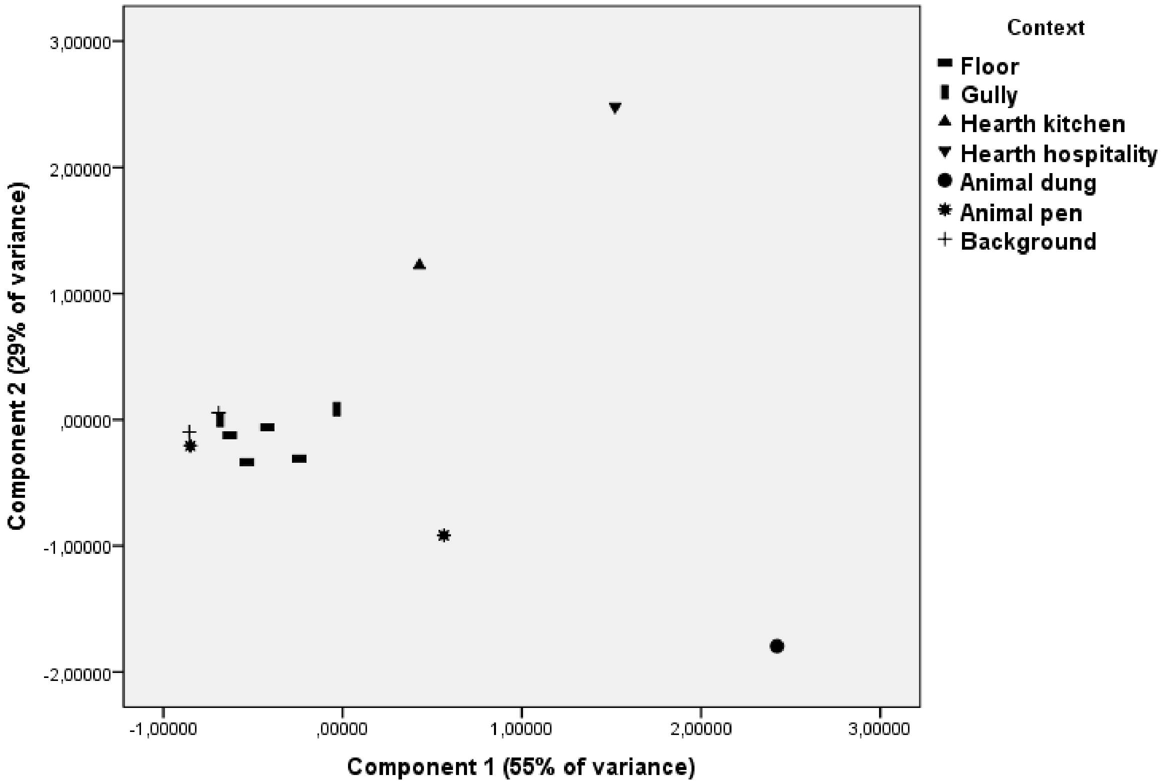


Figure 7.1. PCA scatterplot, WF916. The first component is driven by Zn, S, P, Cl and K, and negatively by Ti, Fe, Al, Si and Zr. The second component is driven by Ca, Mn, Sr and Mg.

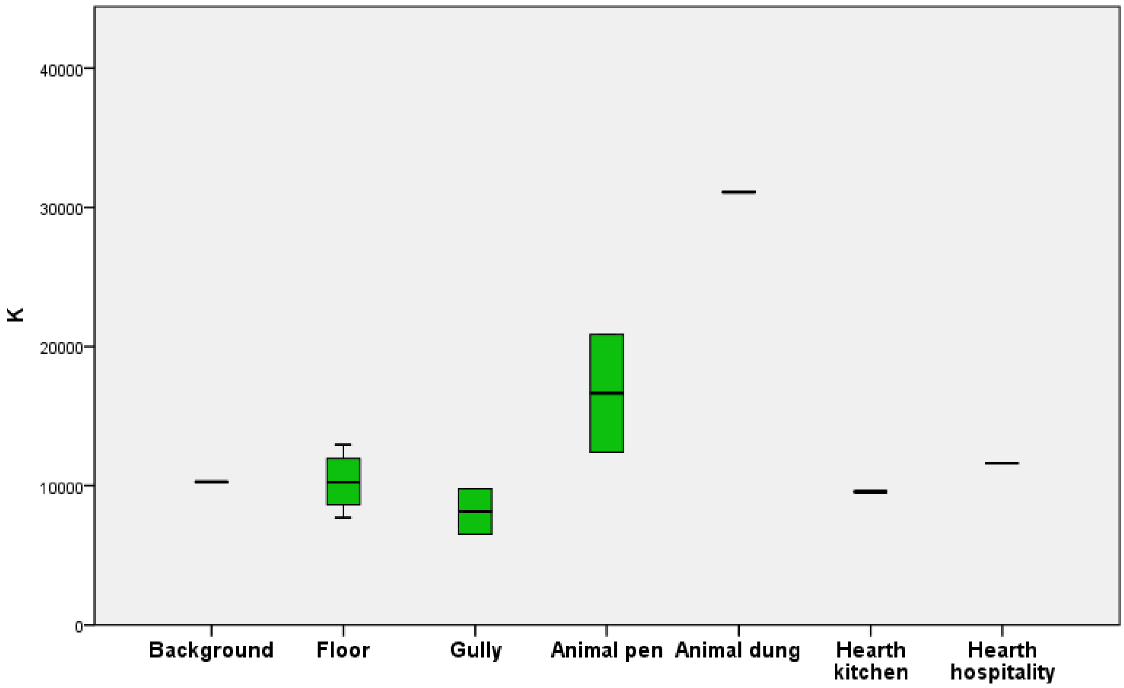


Figure 7.2. Potassium levels in PPM per context, WF916.

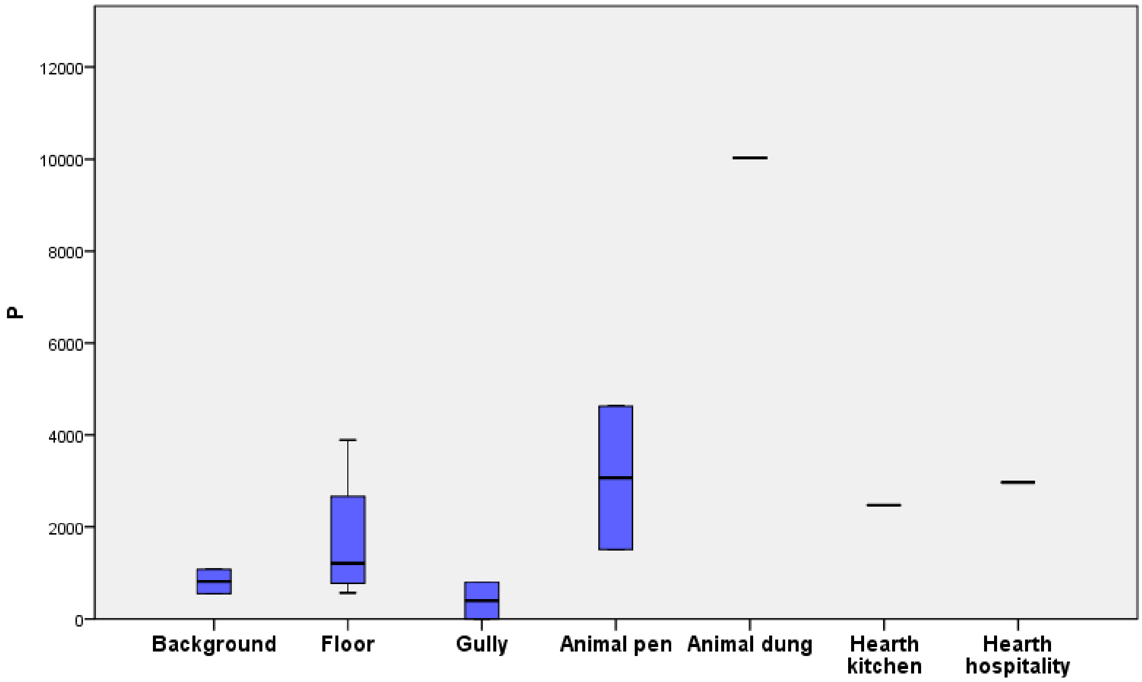


Figure 7.3. Phosphorus levels in PPM per context, WF916.

Figure 7.4. Zinc levels in PPM per context, WF916.

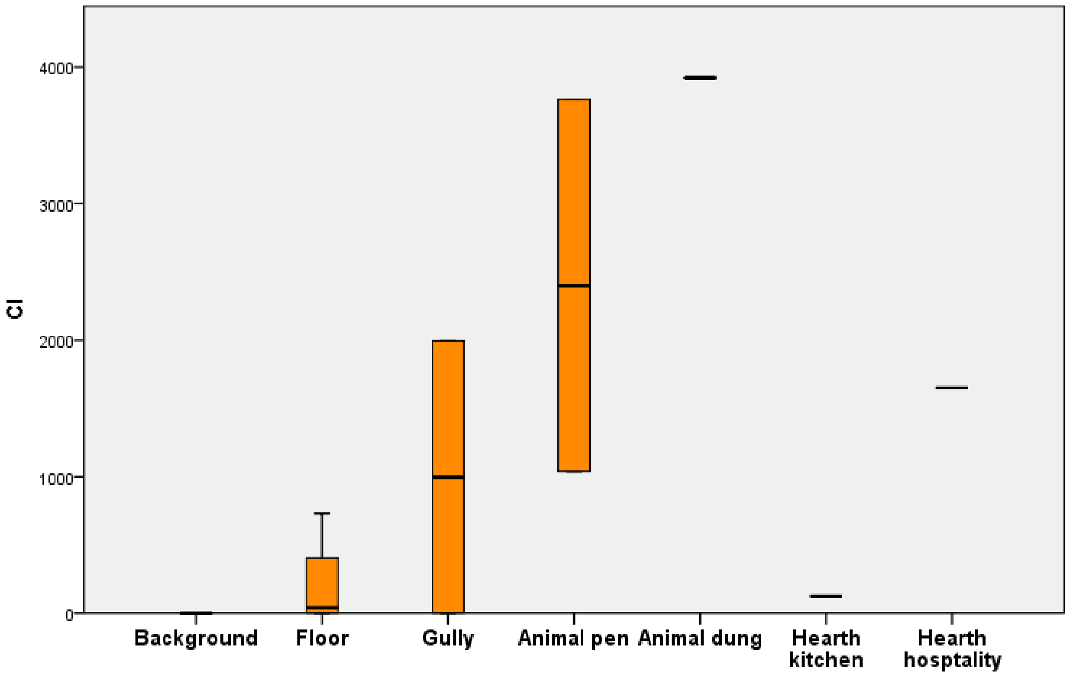


Figure 7.5. Chlorine levels in PPM per context, WF916.

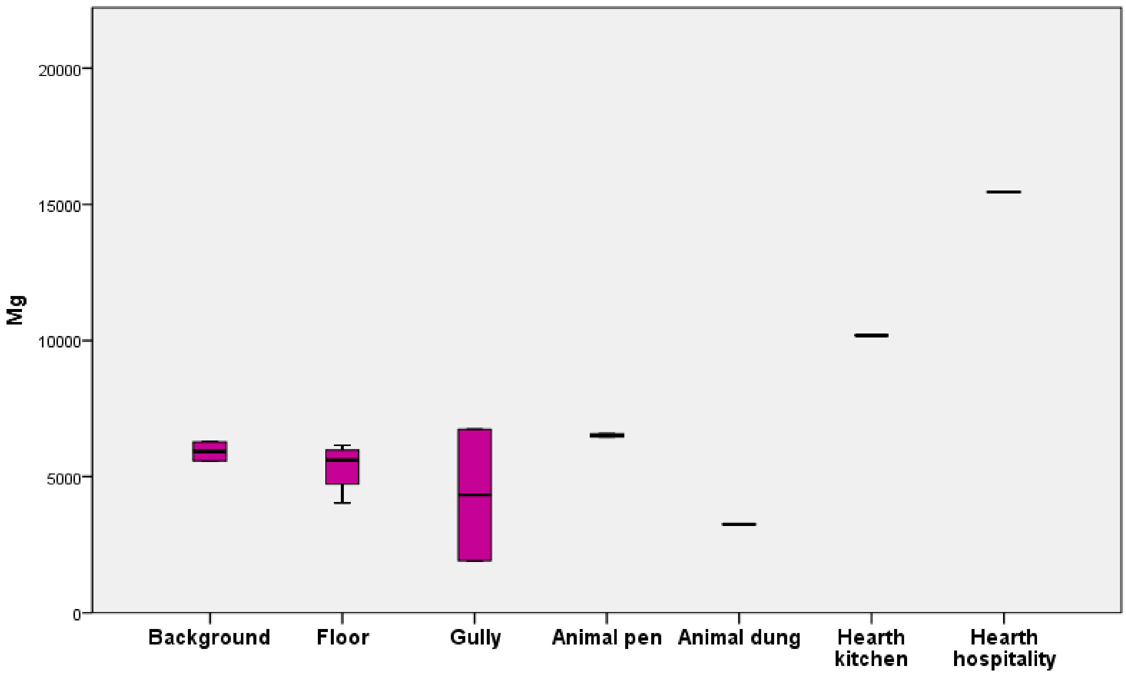


Figure 7.6. Magnesium levels in PPM per context, WF916.

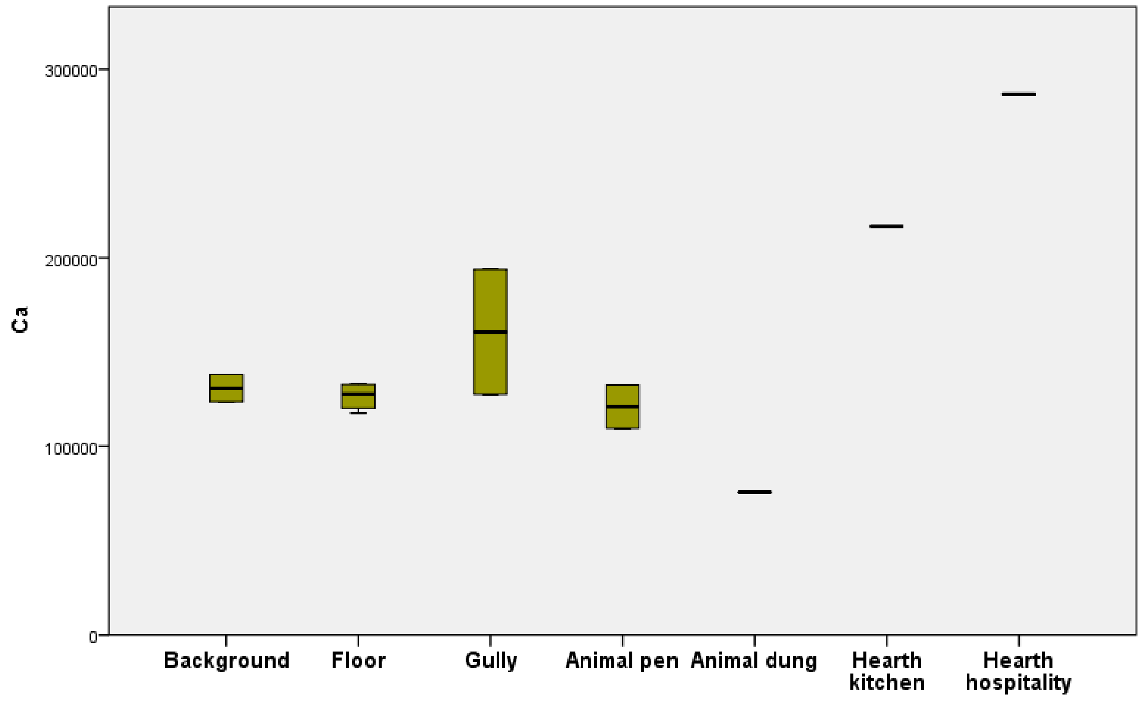


Figure 7.7. Calcium levels in PPM per context, WF916.

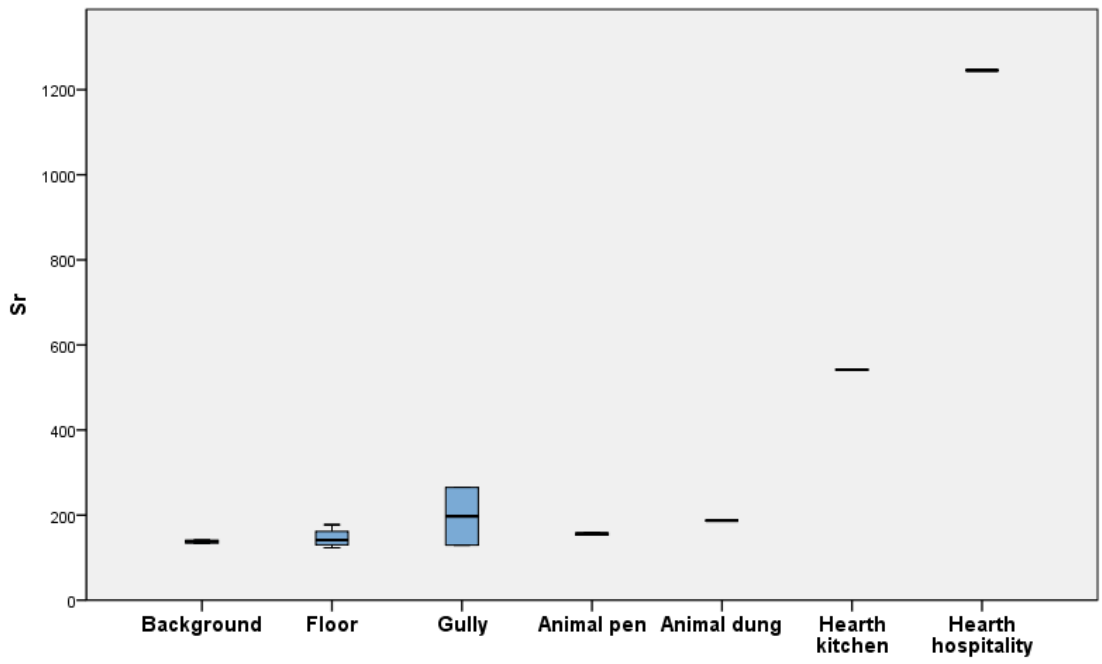


Figure 7.8. Strontium levels in PPM per context, WF916.

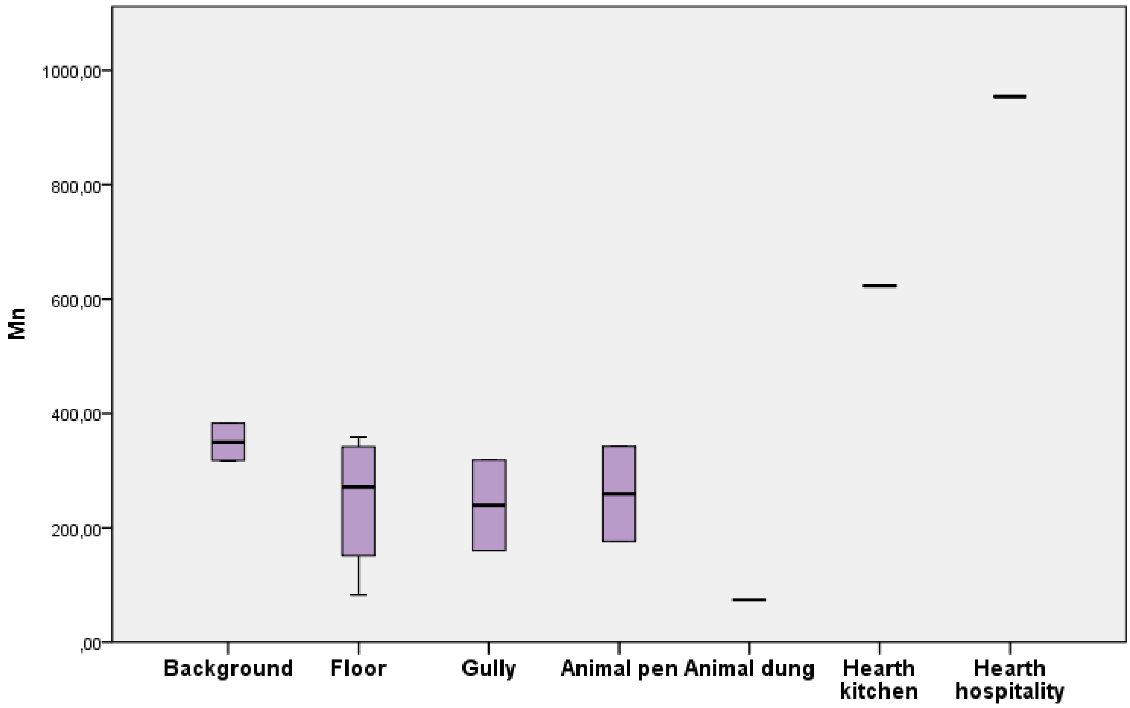


Figure 7.9. Manganese levels in PPM per context, WF916.

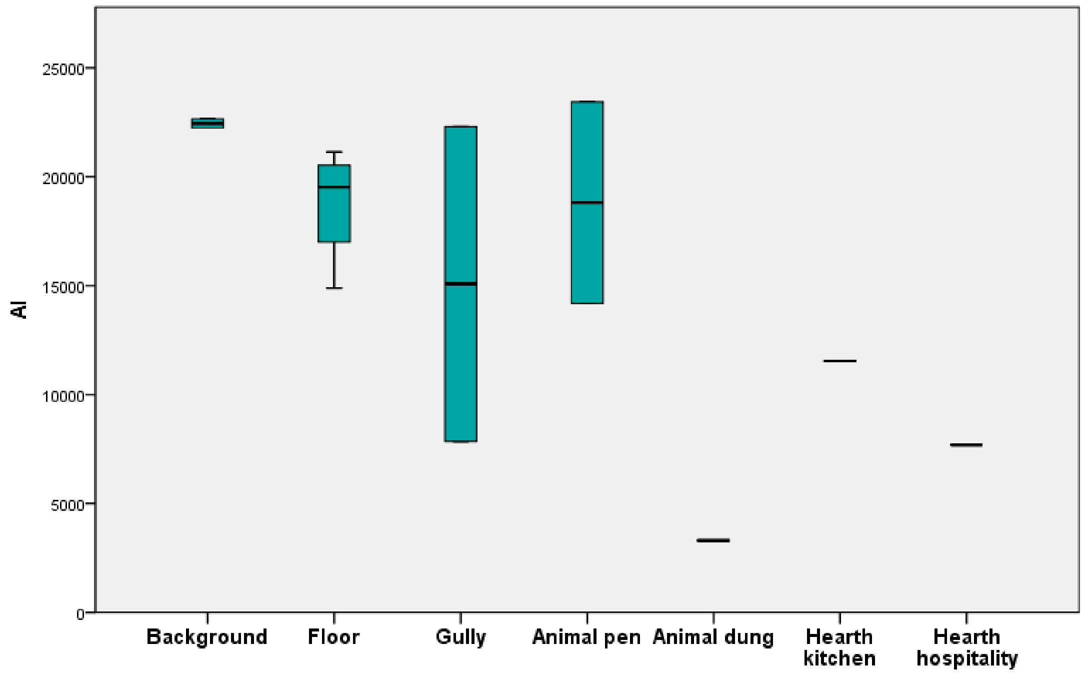


Figure 7.10. Aluminium levels in PPM per context, WF916.

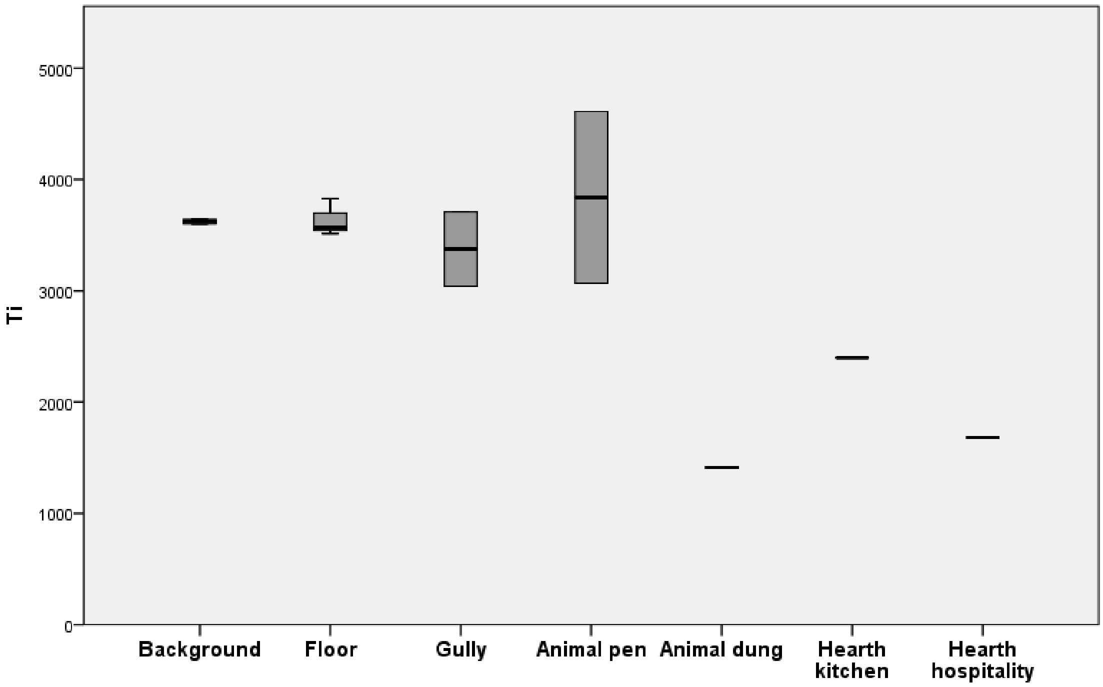


Figure 7.11. Titanium levels in PPM per context, WF916.

7.2.2. Wadi Faynan 953 (WF953)

The PCA scatterplot below shows clear differences between context categories with a strong anthropogenic enrichment (hearths and dung) and a lesser enrichment (floors, gully). The latter plot together with the background sample, while the hearths and dung sample each occupy a different corner of the scatterplot (figure 7.12.). The hearths have high concentrations of P, Mg and K, while the dung sample has a significant elevation of Cl (figures 7.13. – 7.16.). All three contexts have high amounts of S (figure 7.17.).

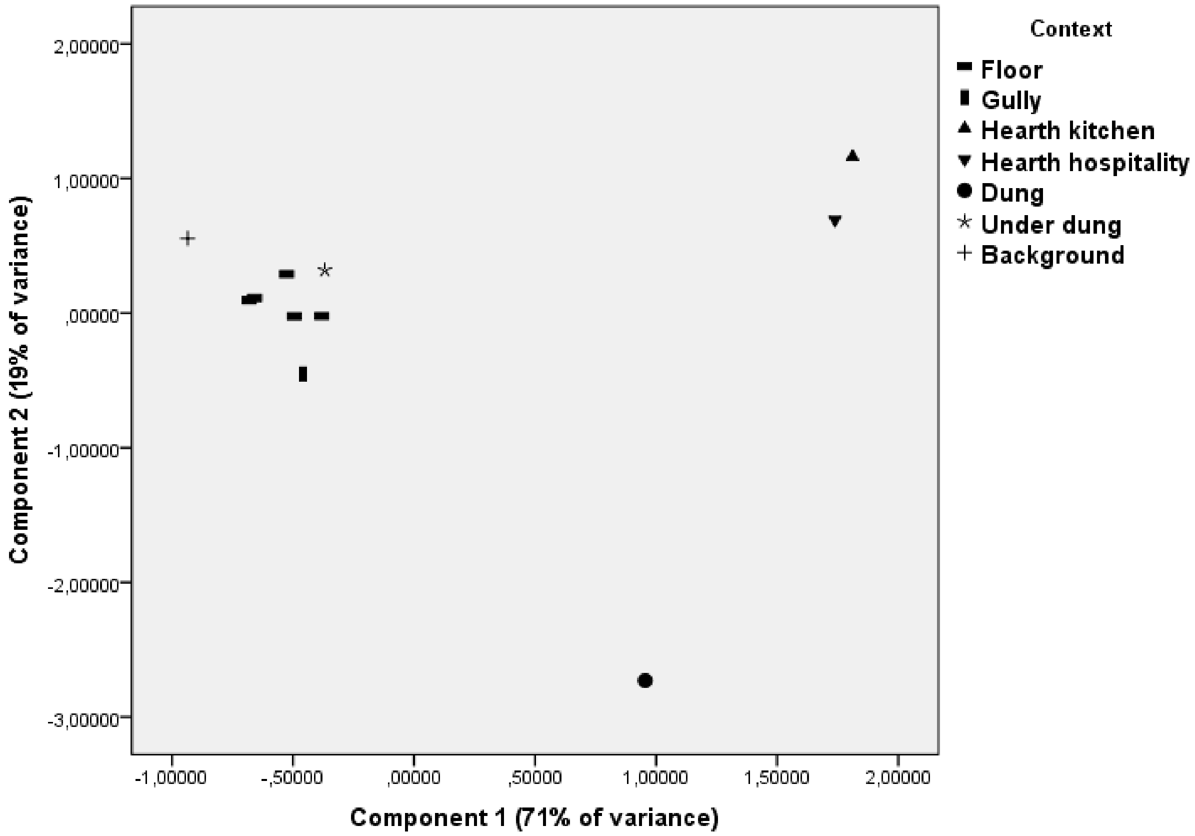


Figure 7.12. PCA scatterplot, WF953. The first component is driven by S, P, Sr, Mg, K and negatively by Si, Al, Ti, Fe and Zr. The second component is driven by Ca, Mg, Mn and negatively by Cl and K.

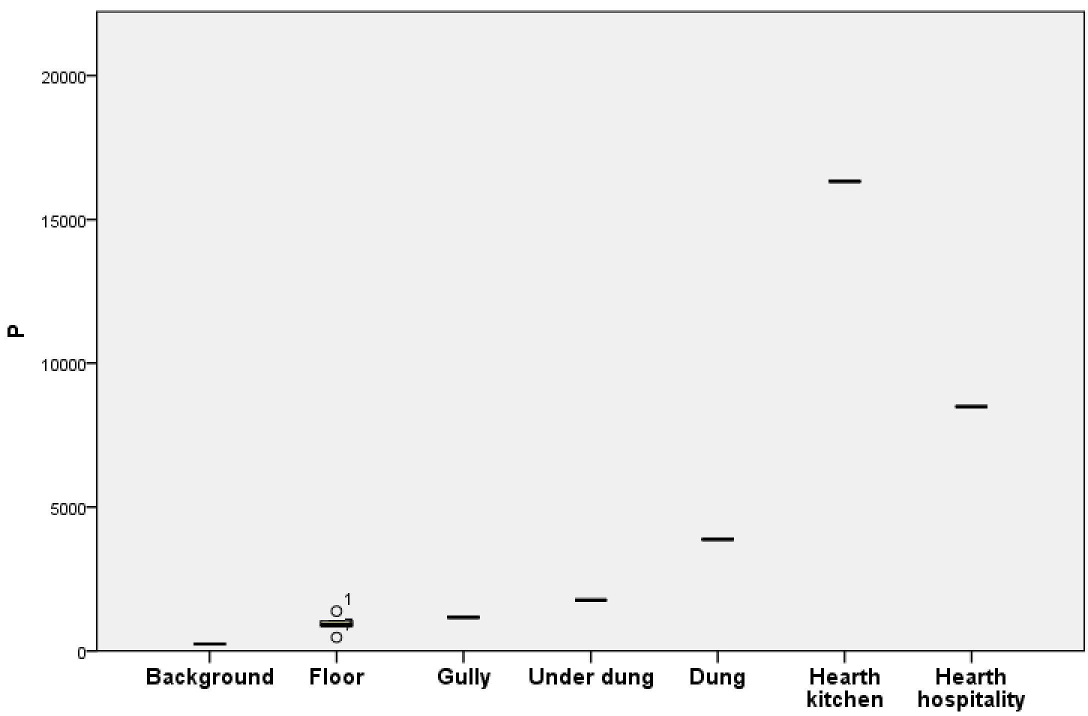


Figure 7.13. Levels of Phosphorus per context in PPM, WF953.

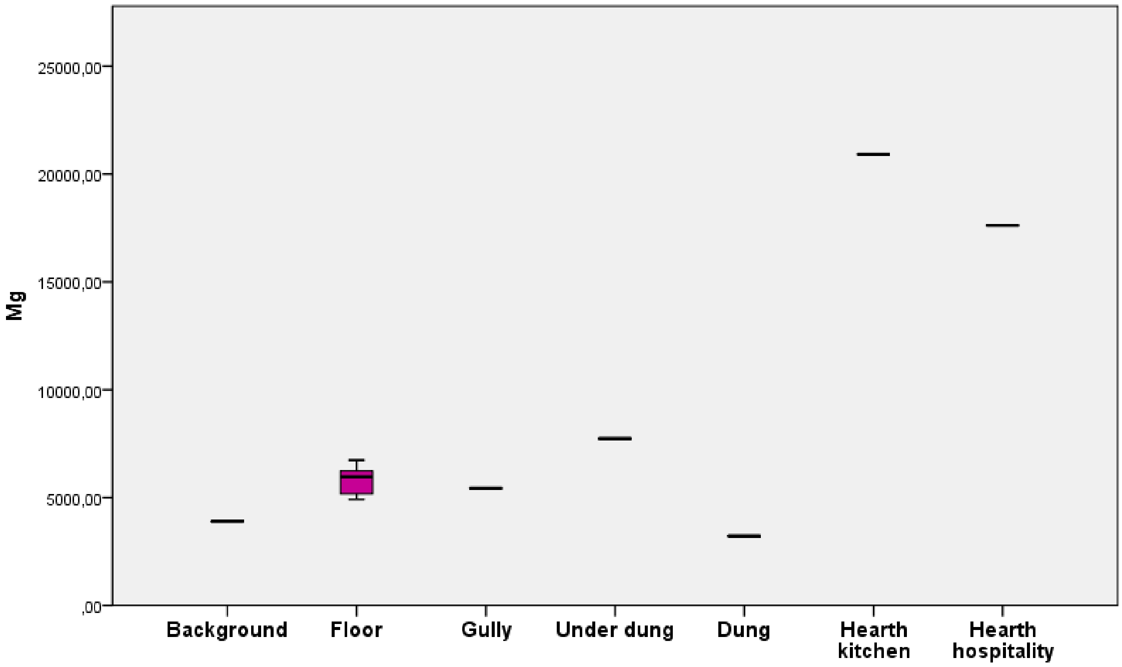


Figure 7.14. Amount of magnesium in PPM for each context, WF953.

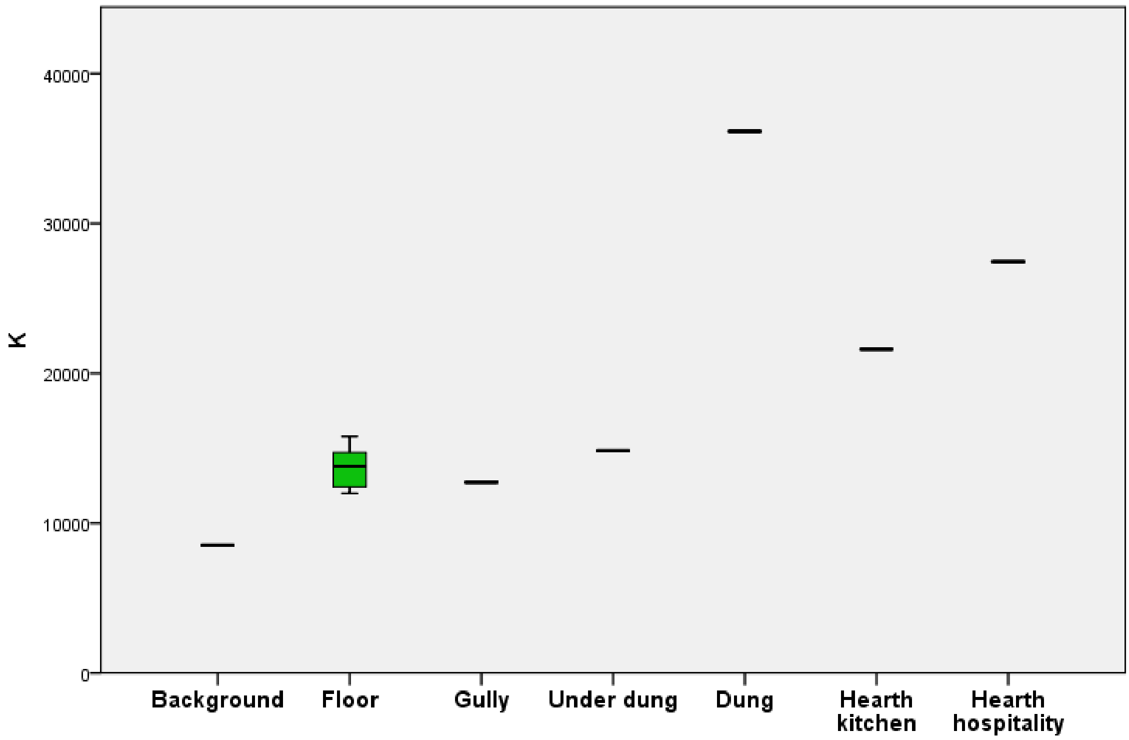


Figure 7.15. Potassium levels in PPM per context, WF953.

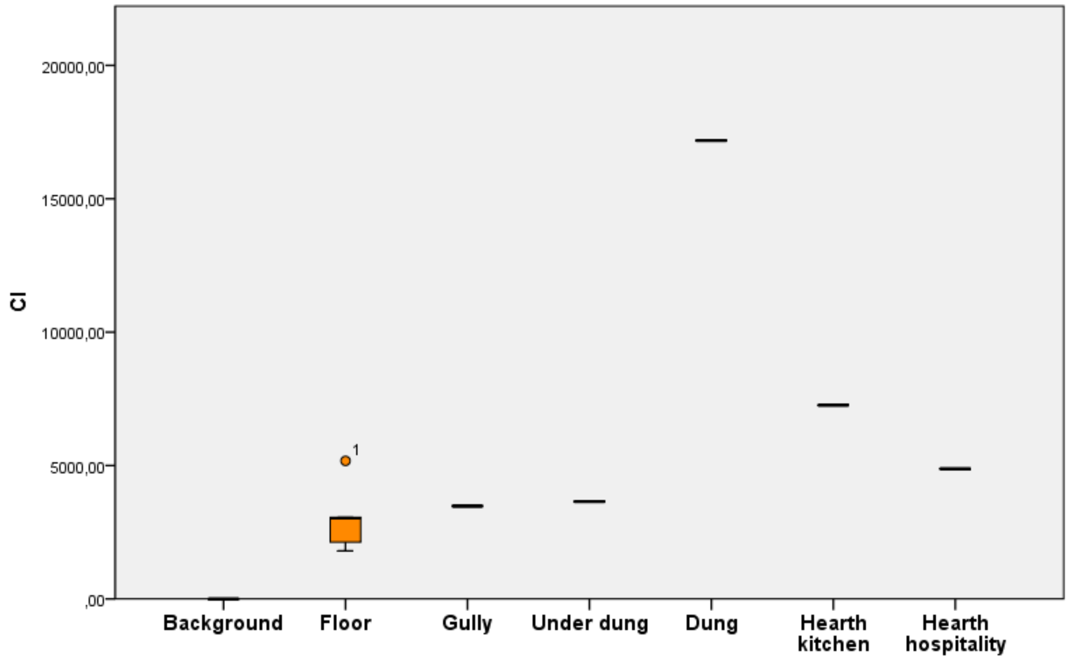


Figure 7.16. Levels of Chlorine per context in PPM, WF953.

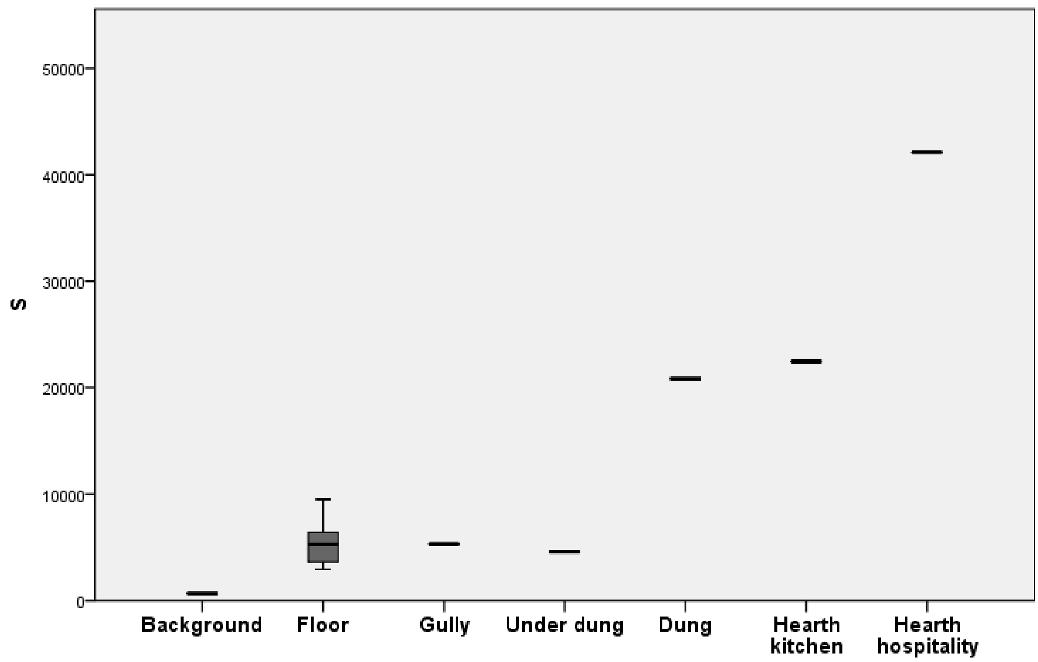


Figure 7.17. Sulphur content in each context category in PPM, WF953.

7.2.3. Wadi Faynan 940 (WF940)

The PCA scatterplot below shows a clustering of the floor samples in proximity to the background samples, the only hearth sample plots very differently from the rest, and the animal pen floor samples form a wide band between the floor and hearth samples (figure 7.18.). The hearth sample varies significantly from the other samples in several elements, mainly Mg, P, Mn, Zn and Sr (figures 7.19 – 7.23.). Generally, there is an enrichment of the elements S, K and Cl in the hearth and animal pen samples, demonstrating a more intensive anthropogenic input, and a depletion in the same contexts of background elements such as Si and Al (figures 7.24. – 7.29.). The floor samples behave similarly to the background samples.

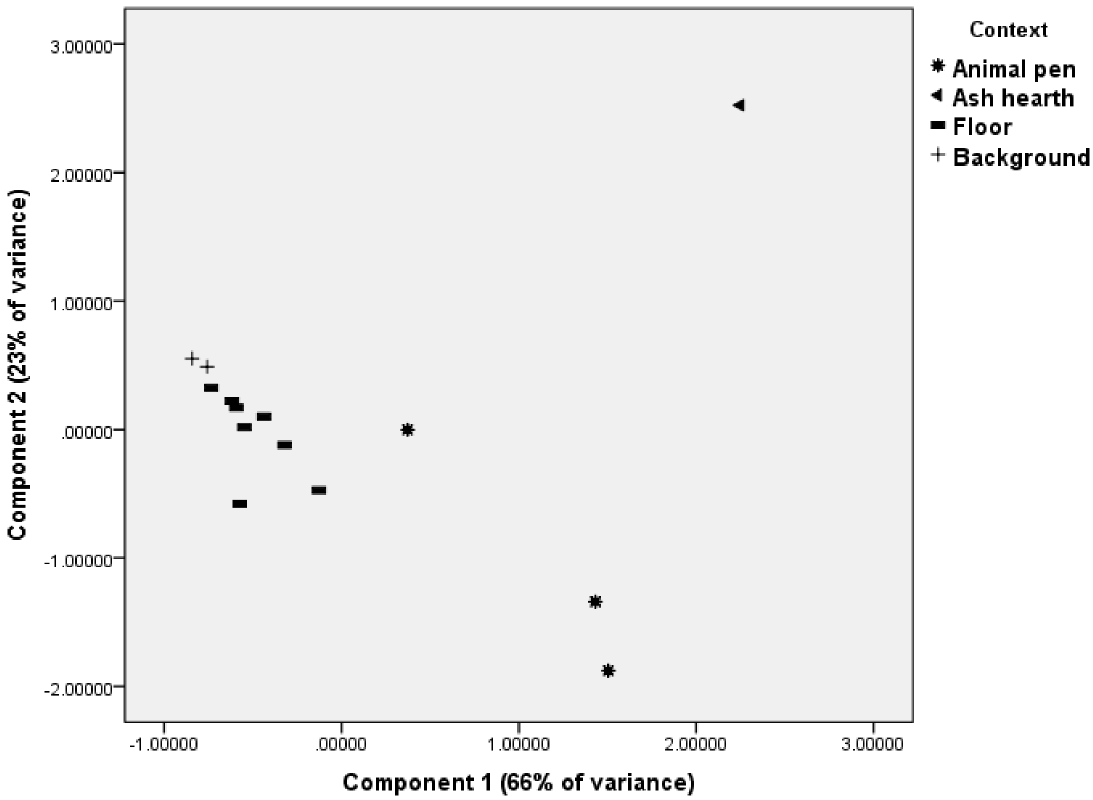


Figure 7.18. PCA scatterplot, WF940. The first component is driven by P, S, Zn, K, Cl and Sr, and negatively by Si, Al and Fe. The second component is driven by Mg, Mn and Ca.

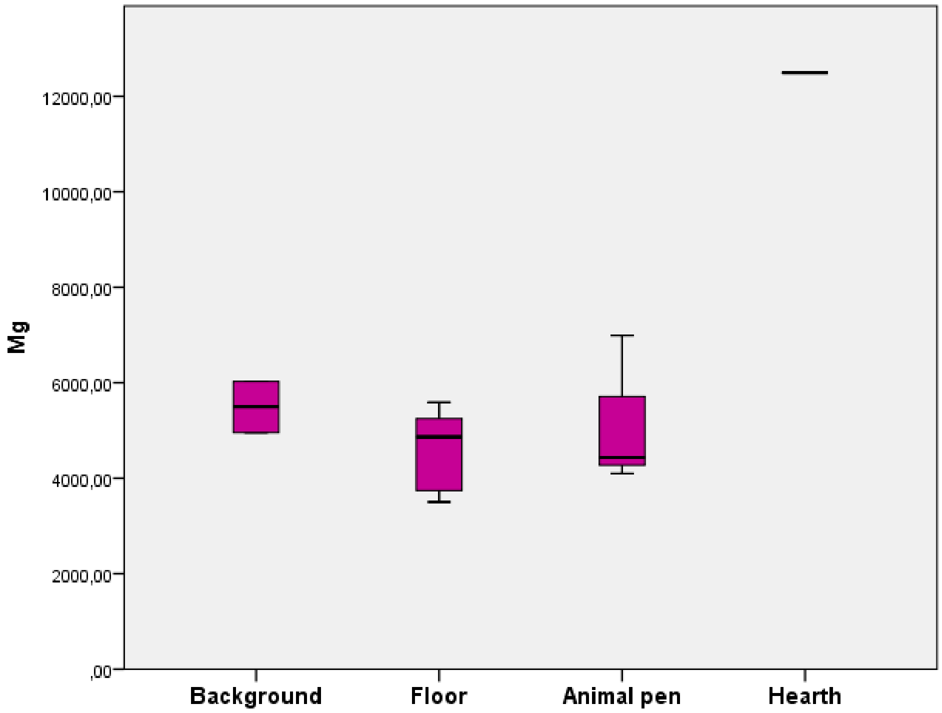


Figure 7.19. Magnesium levels in PPM per context, WF940.

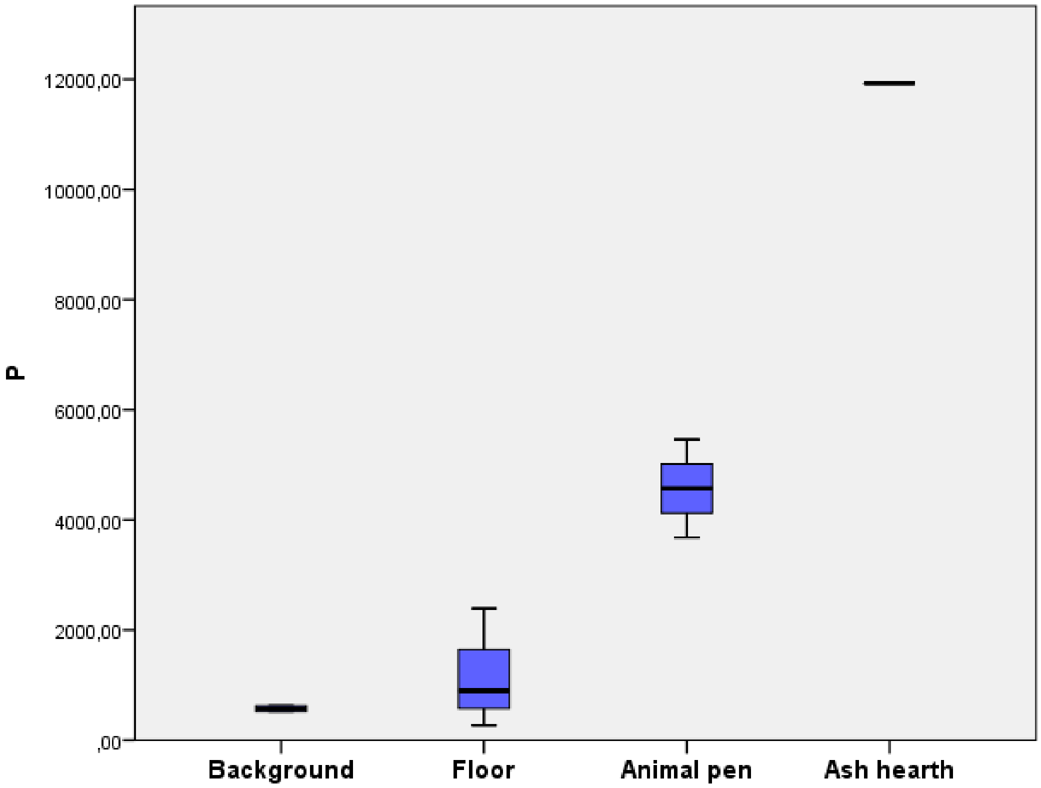


Figure 7.20. Phosphorus levels in PPM per context, WF940.

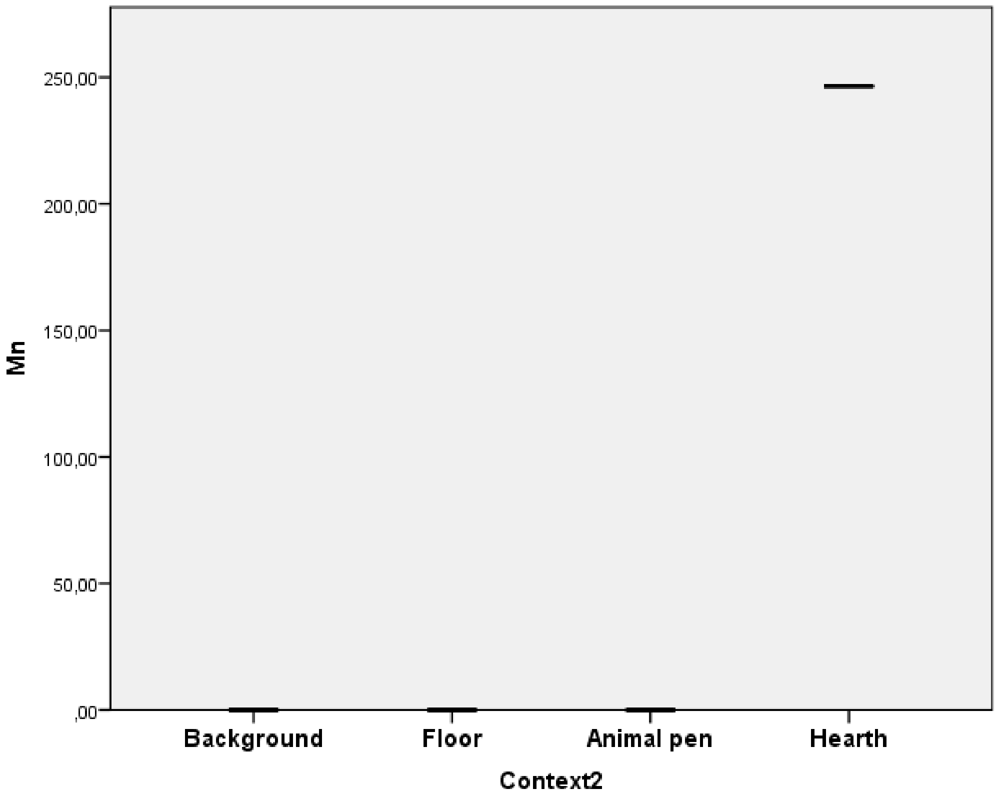


Figure 7.21. Manganese levels in PPM per context, WF940.

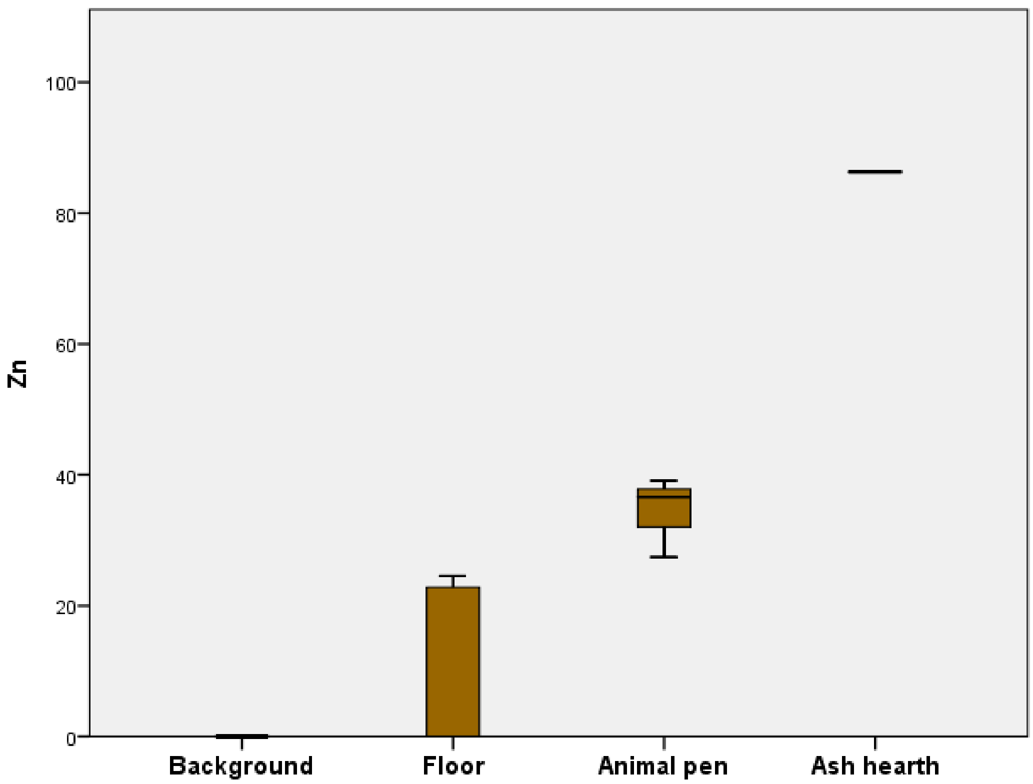


Figure 7.22. Zinc levels in PPM per context, WF940.

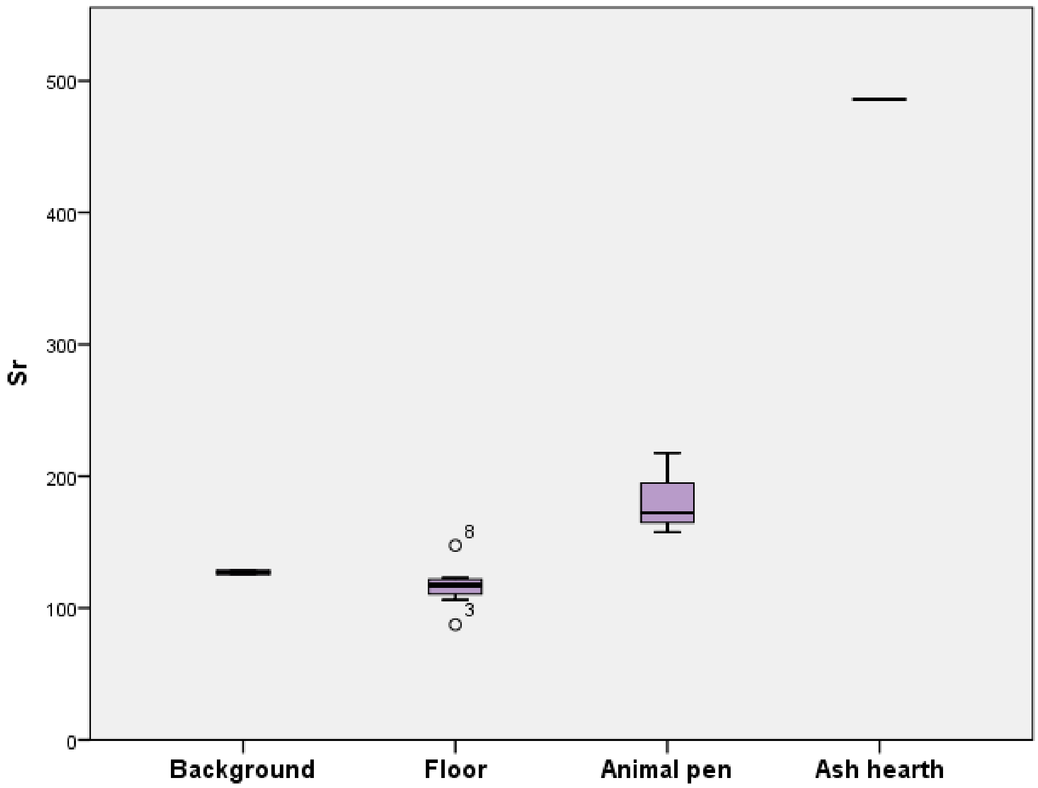


Figure 7.23. Strontium levels in PPM per context, WF940.

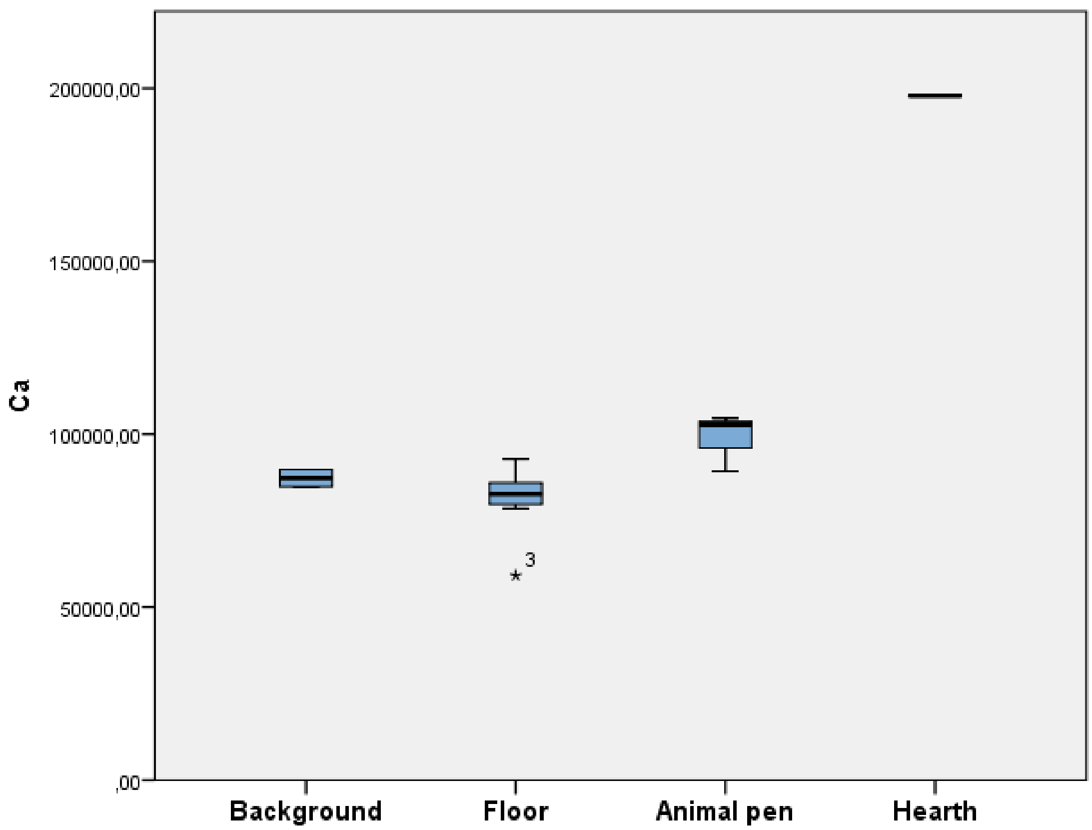


Figure 7.24. Calcium levels in PPM per context, WF940.

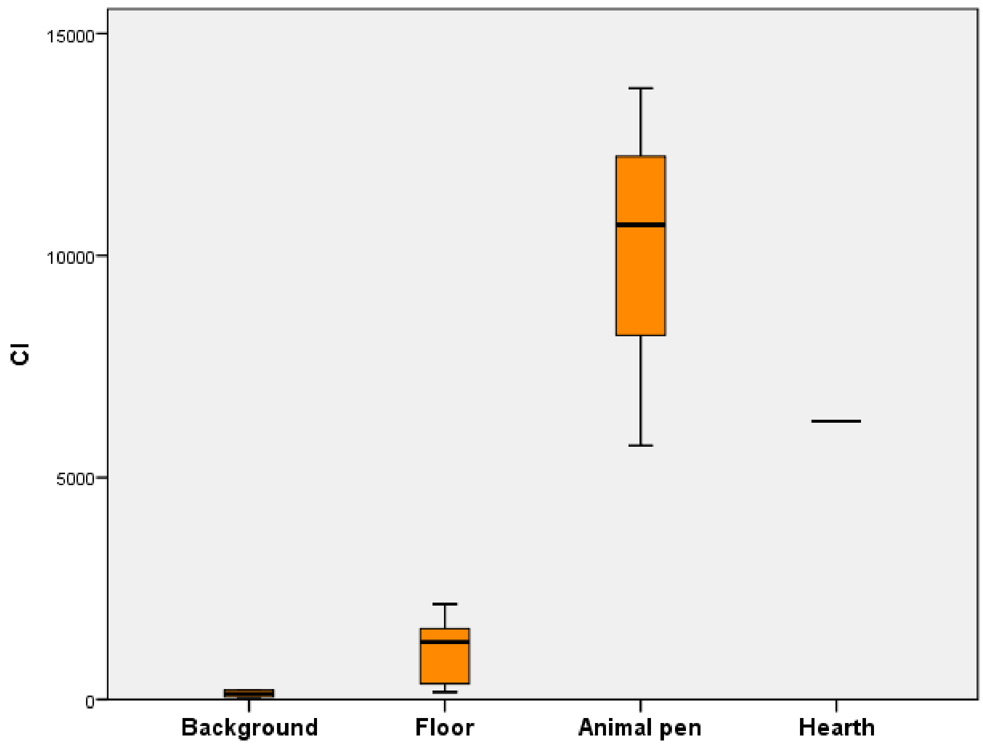


Figure 7.25. Chlorine levels in PPM per context, WF940.

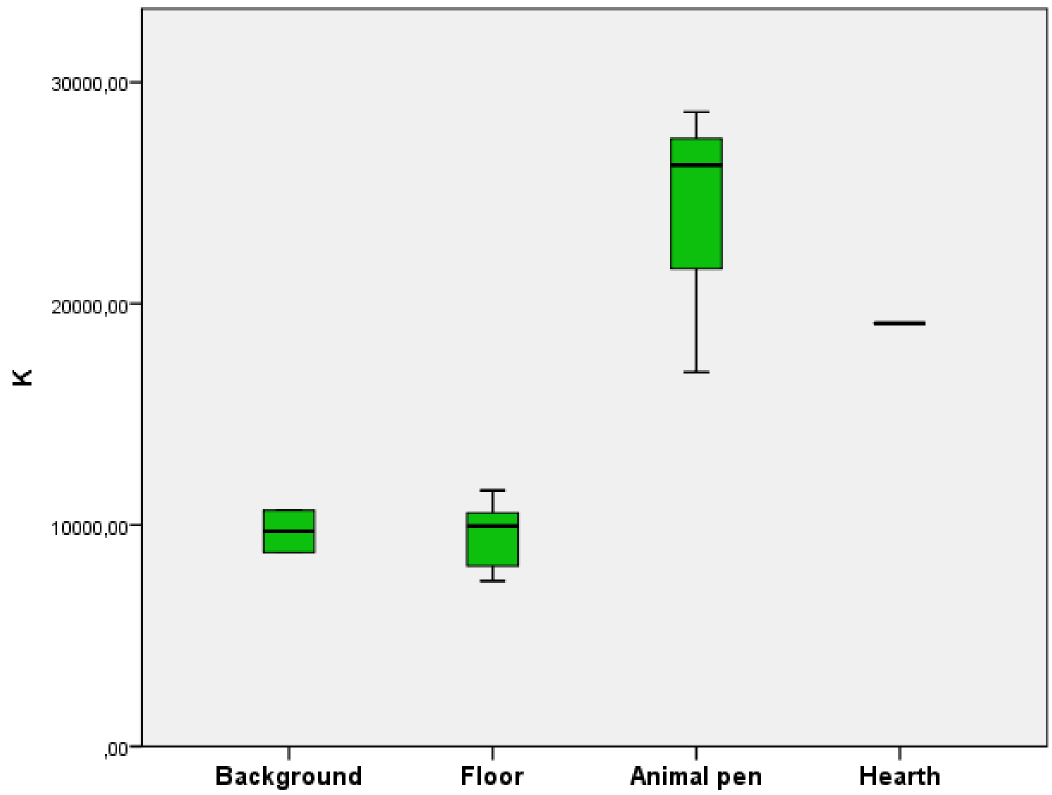


Figure 7.26. Potassium levels in PPM per context, WF940.

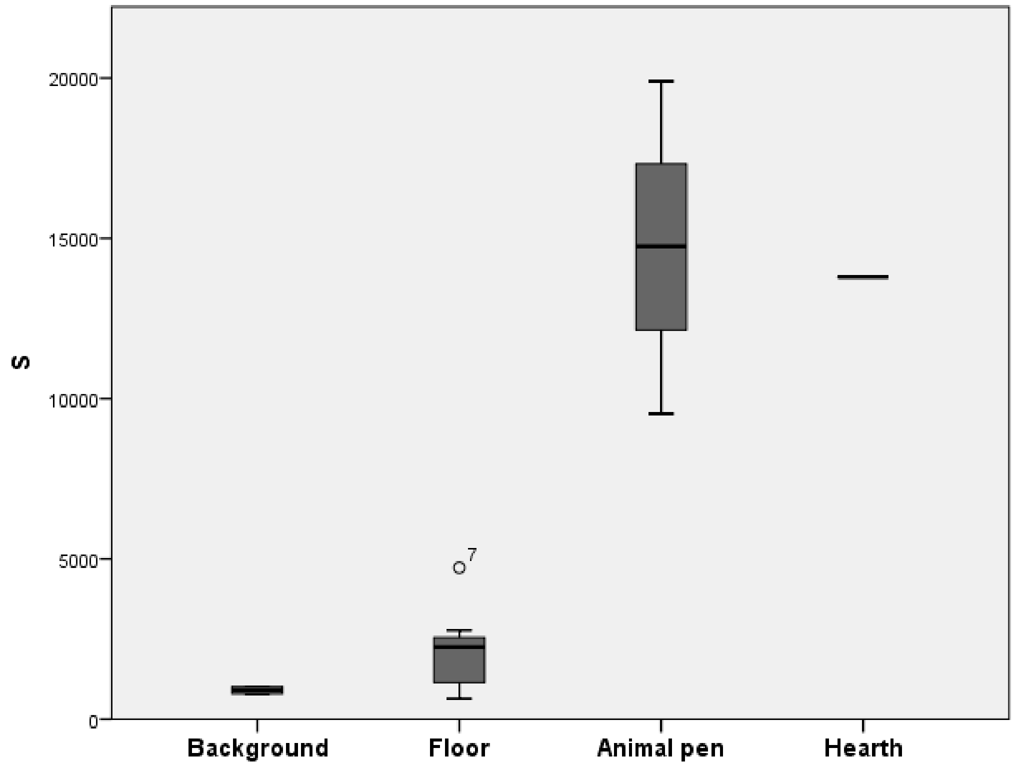


Figure 7.27. Sulphur levels in PPM per context, WF940.

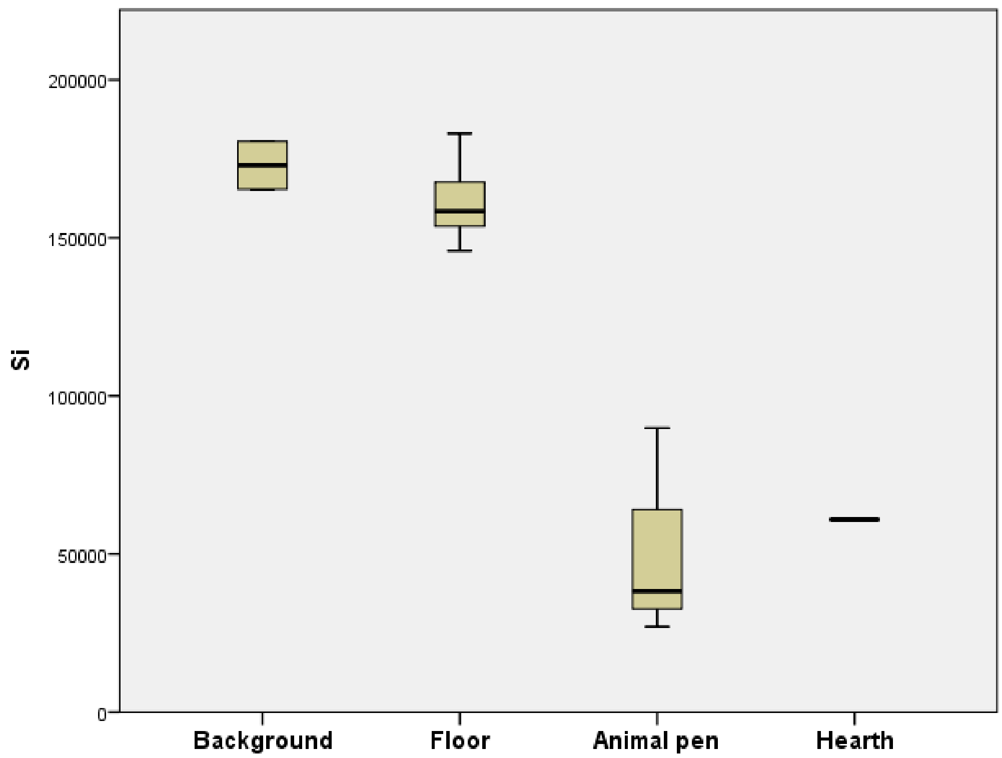


Figure 7.28. Silica levels in PPM per context, WF940.

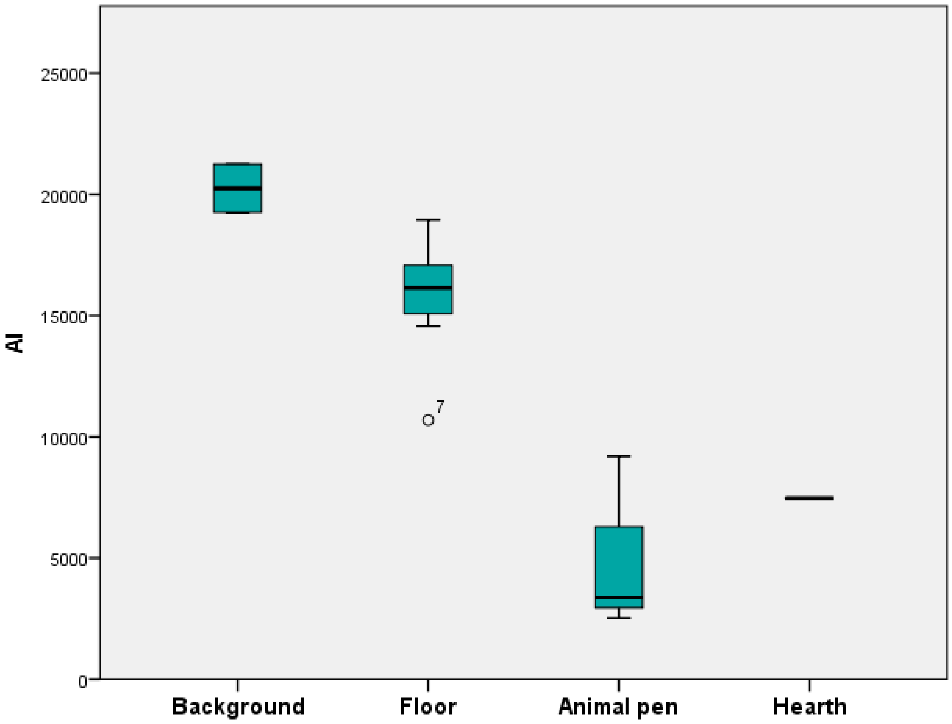


Figure 7.29. Aluminium levels in PPM per context, WF940.

7.2.4. Wadi Faynan 982 (WF982)

The first two components in the PCA scatterplot below (figure 7.30.) represent 72% of the variation within the data. However, in this case the third component seems more useful than the second, even though it carries less weight. The second PCA scatterplot (figure 7.31.) shows three strong clusters, one including the background samples, floors and animal pen floor contexts, a second the ash from the two hearths, and a third contains a dung and rattan layer sample. The input of the third component, including P, S, and Ba, seems to better represent the anthropogenic input, which can be seen more specifically on a case basis in the element graphs below (figure 7.32. – 7.36.). Mg, Sr, Mn and Ca are highest in the ash samples, while P levels are highest in the rattan and dung samples, which behave similarly and may represent related activities. Although Cl levels are the highest in dung samples in the other campsites studies here, this does not seem to be the case at WF982, where the ash and even some of the floor samples contain a larger enrichment of Cl (figure 7.37.).

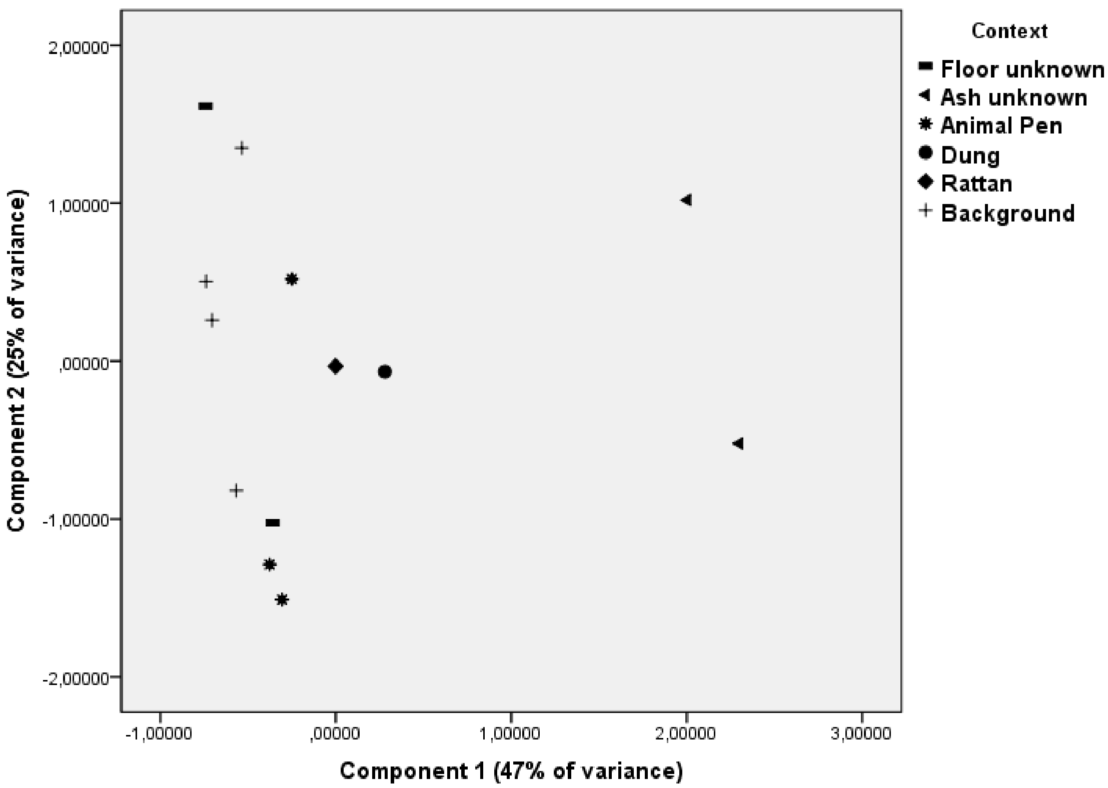


Figure 7.30. PCA scatterplot, WF982. The first component is driven by Sr, Ca, Mg, Zn and negatively by Al, Si, and Ti. The second component by Cr, Cl, K, Fe.

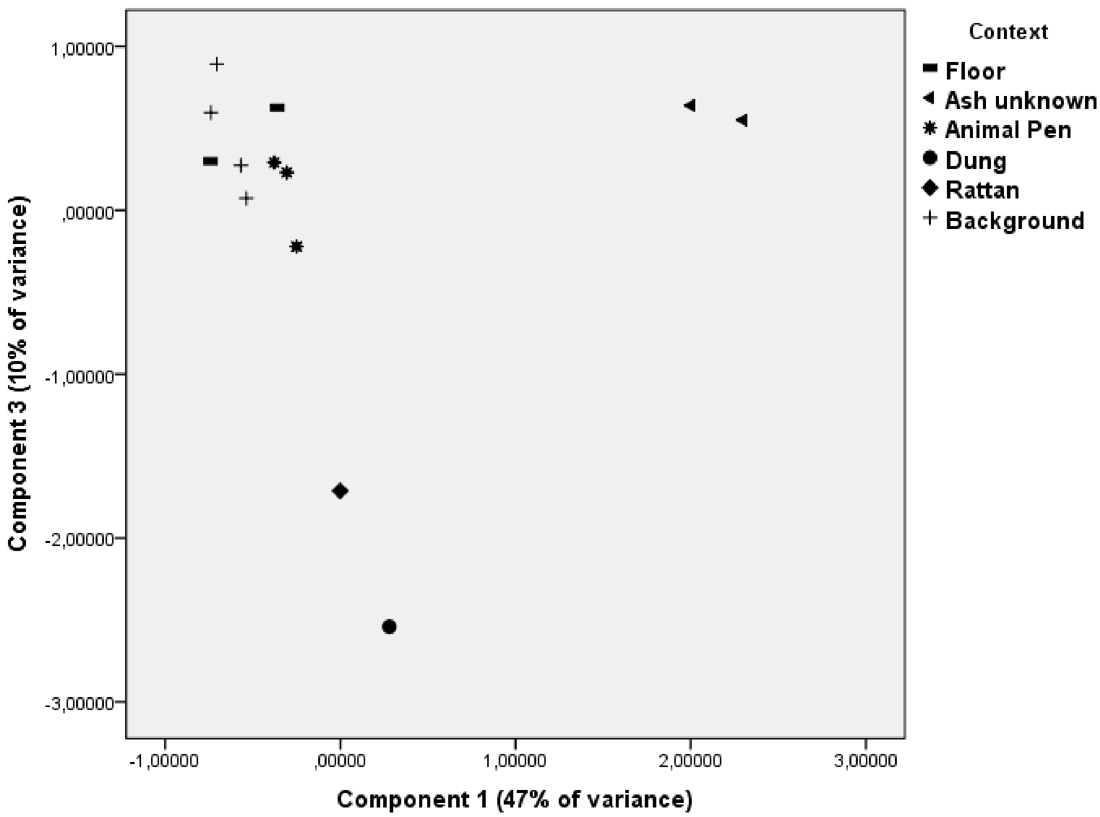


Figure 7.31. PCA scatterplot, WF982. The first component is driven by Sr, Ca, Mg, Zn and negatively by Al, Si, and Ti. The third component by Ba, and negatively by S and P.

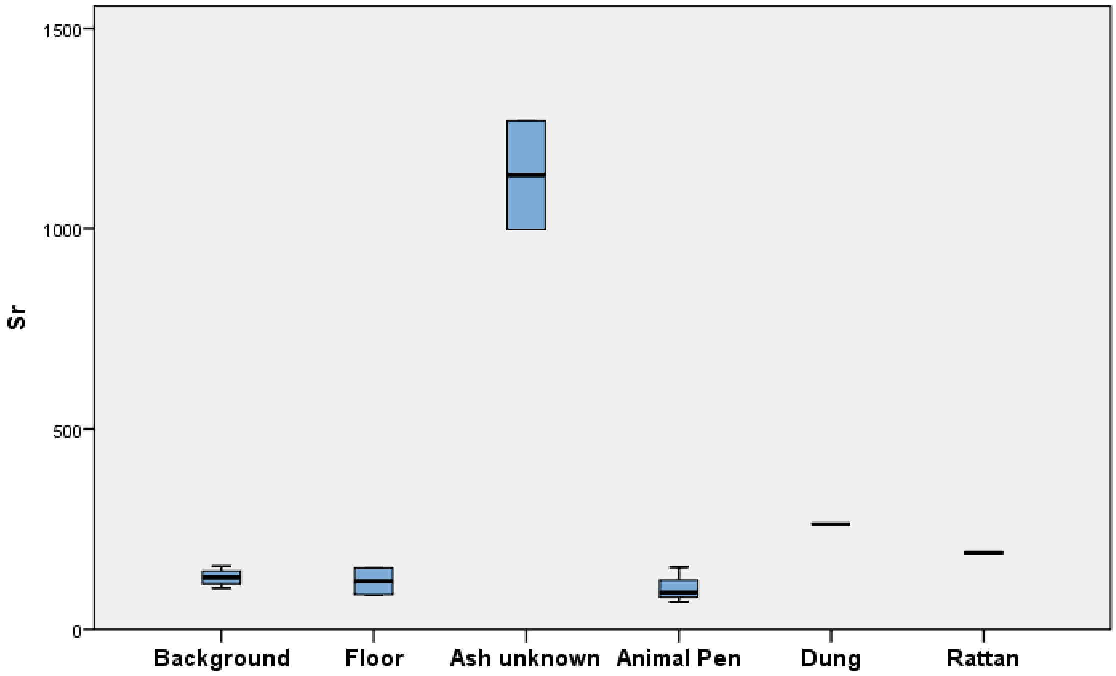


Figure 7.32. Strontium levels per context in PPM, WF982.

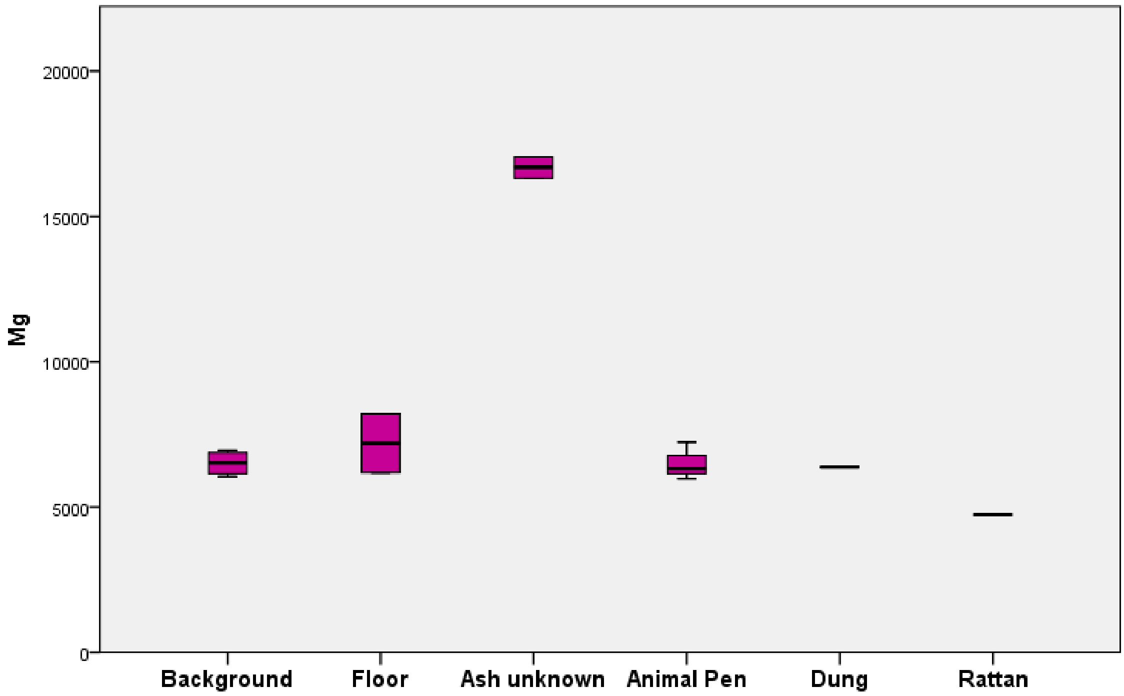


Figure 7.33. Magnesium levels per context in PPM, WF982.

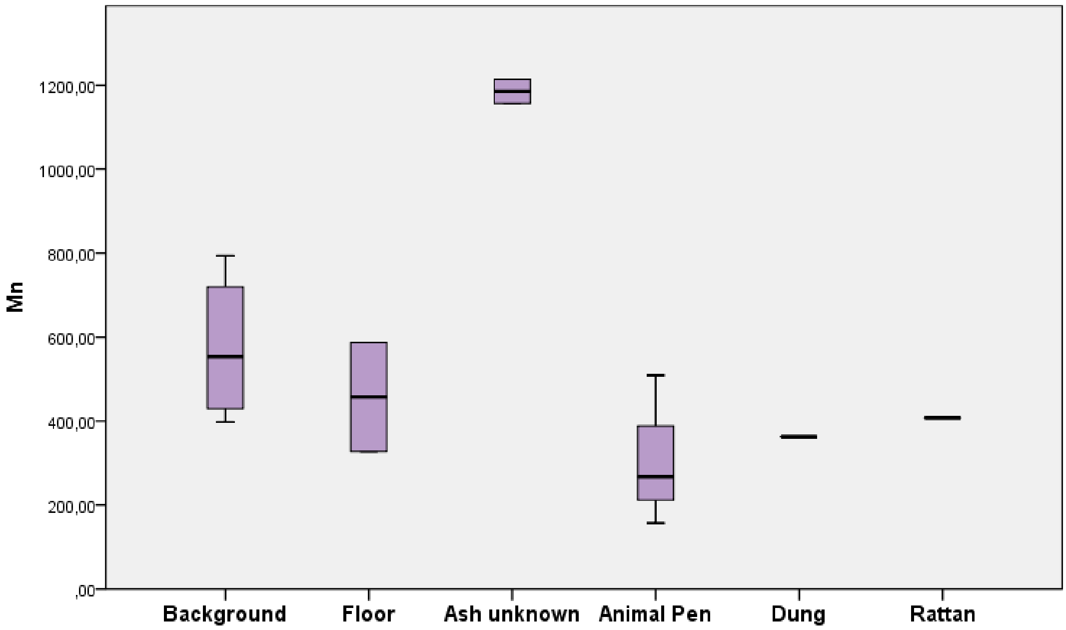


Figure 7.34. Manganese levels per context in PPM, WF982.

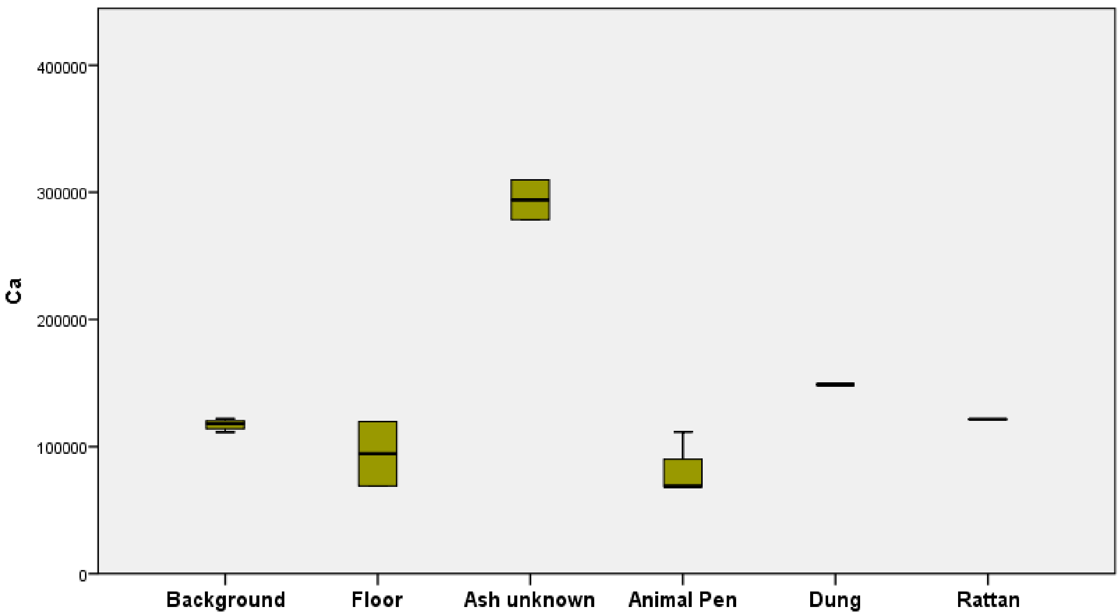


Figure 7.35. Calcium levels per context in PPM, WF982.

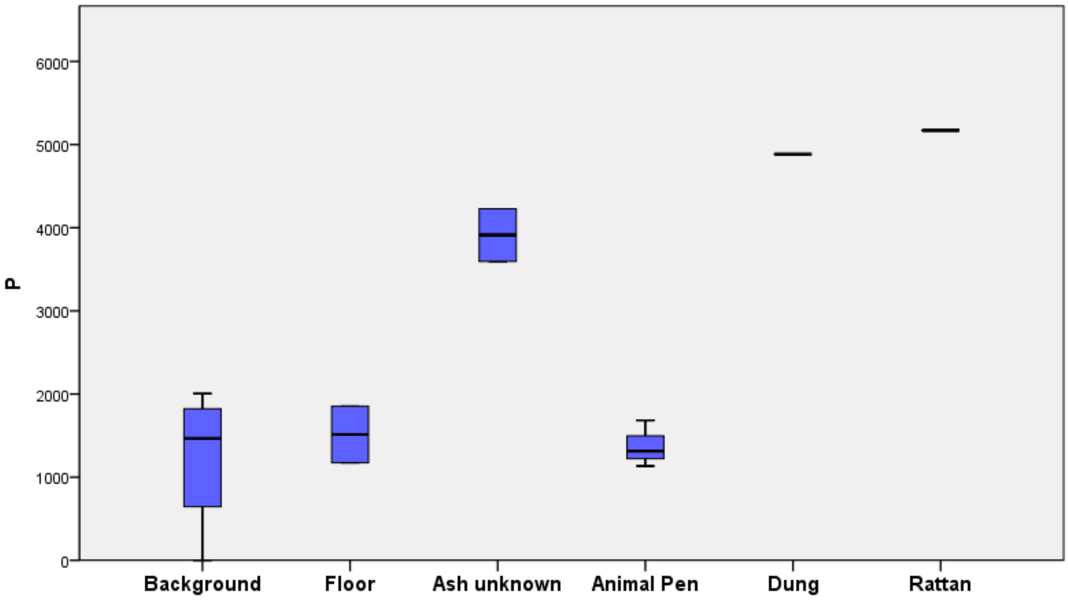


Figure 7.36. Phosphorus levels per context in PPM, WF982.

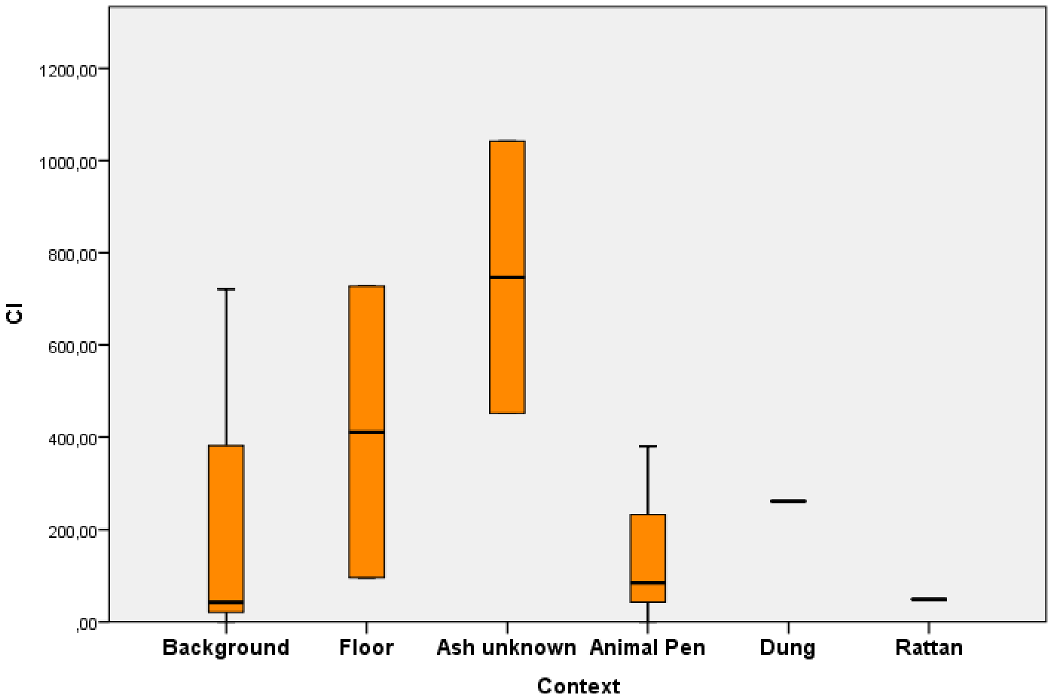


Figure 7.37. Chlorine levels per context in PPM, WF982.

7.2.5. Wadi Dana (WD)

The two hearths clearly stand out within this data, both the kitchen and the hospitality hearths contain higher levels of Mg and Ca. They differ in the levels of other elements, the kitchen hearth containing larger amounts of P, Zn and Mn, while the hospitality hearth has higher levels of K and Sr (figures 7.39. – 7.45.). Unlike the case in other campsites, Cl levels are higher in the hearth kitchen and some of the floor samples (which may have been used by animals, see section 3.4.) (figure 7.46.). It is possible that if dung samples were available for this site they would have presented the highest levels of Cl, and the large amount in the kitchen hearth could attest to the preference for the use of dung cake in this area, as is common in other sites in the Wadi Faynan area.

The PCA scatterplot below (figure 7.38.) does not present a very strong clustering of the various context categories, with three very general clusters of floors, hearths and animal areas, but each of these integrating samples from other contexts. In addition, the lack of background samples for this site do not allow for the establishment of anthropogenic vs. natural enrichment and depletion patterns.

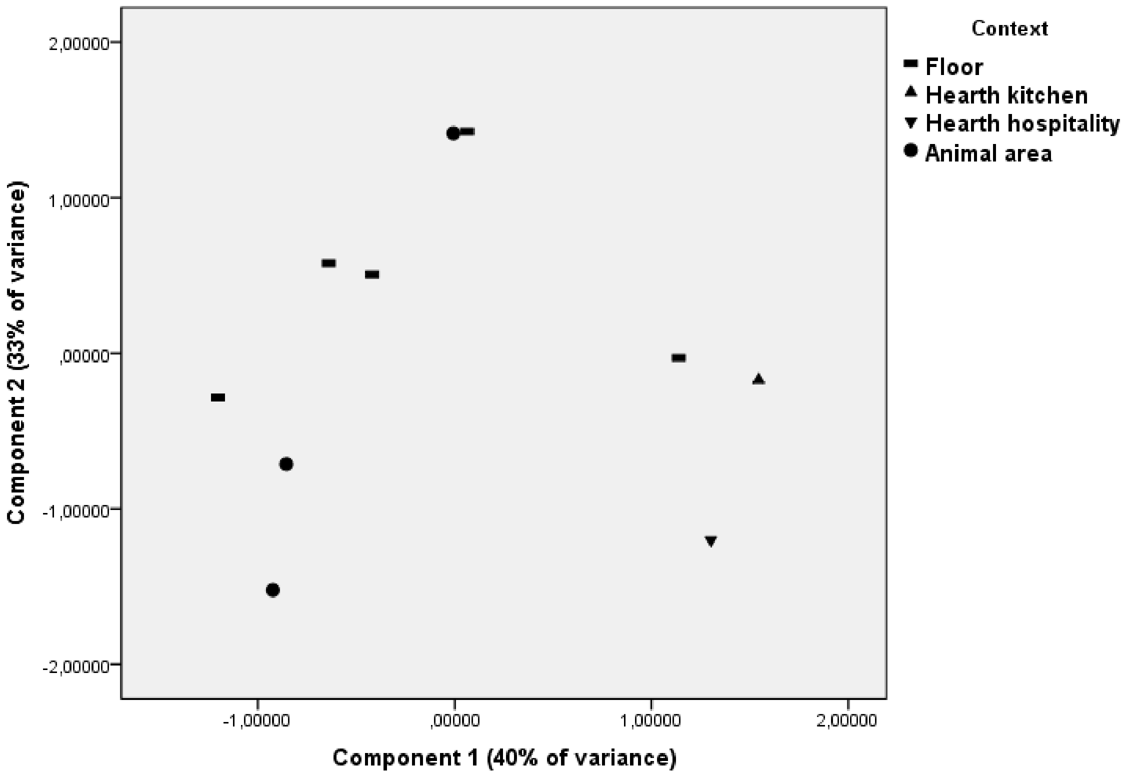


Figure 7.38. PCA scatterplot, WD. The first component is influenced by Mg, Mn, Ca, Ba, Sr, Rb and K. The second is driven by Fe, Ti, Si, V and Cr.

Figure 7.39. Magnesium levels in PPM per context, WD.

Figure 7.40. Calcium levels in PPM per context, WD.

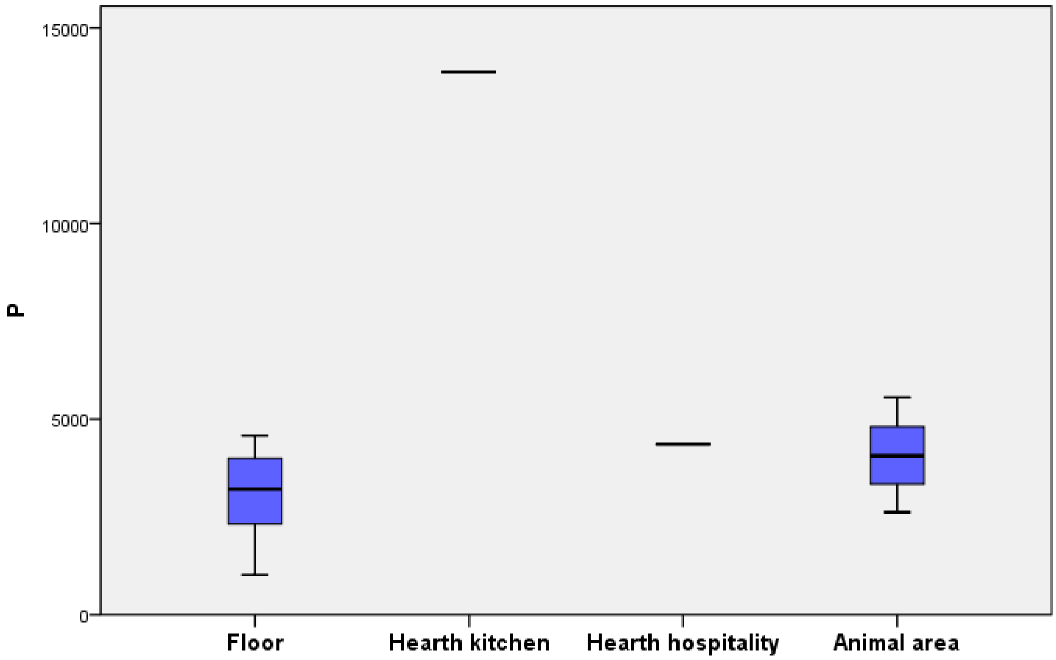


Figure 7.41. Phosphorus levels in PPM per context, WD.

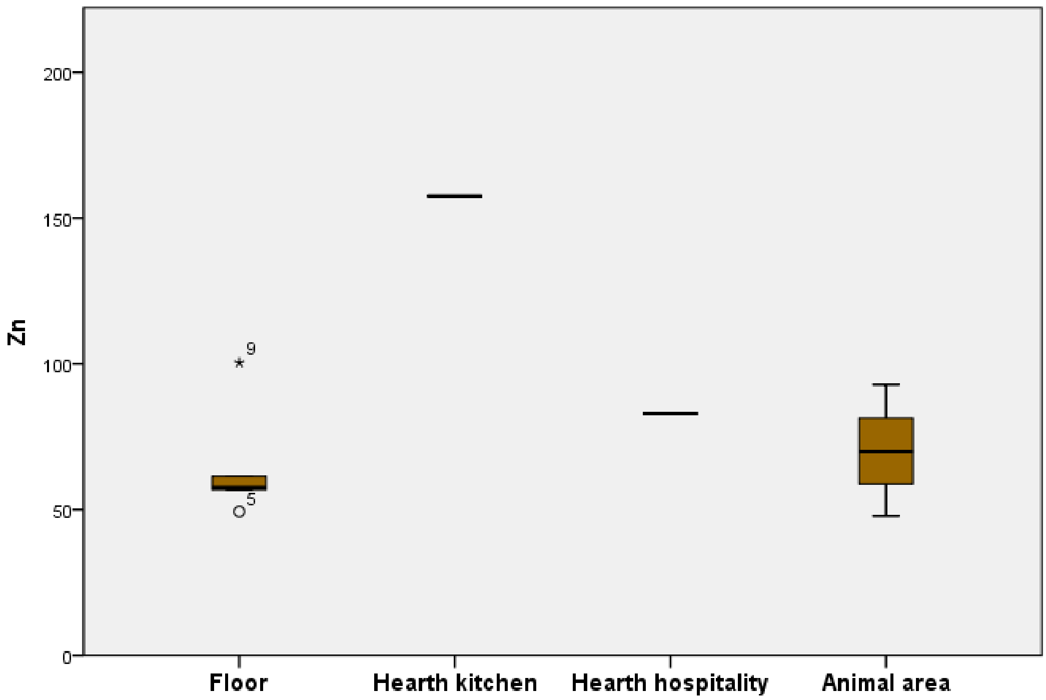


Figure 7.42. Zinc levels in PPM per context, WD.

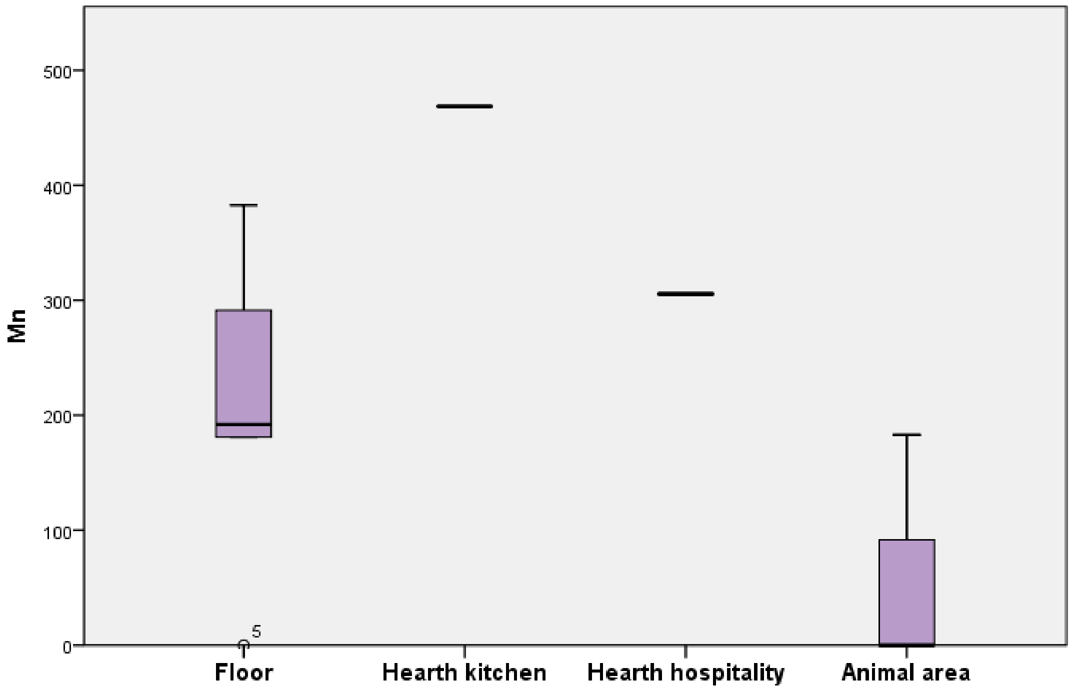


Figure 7.43. Manganese levels in PPM per context, WD.

Figure 7.44. Potassium levels in PPM per context, WD.

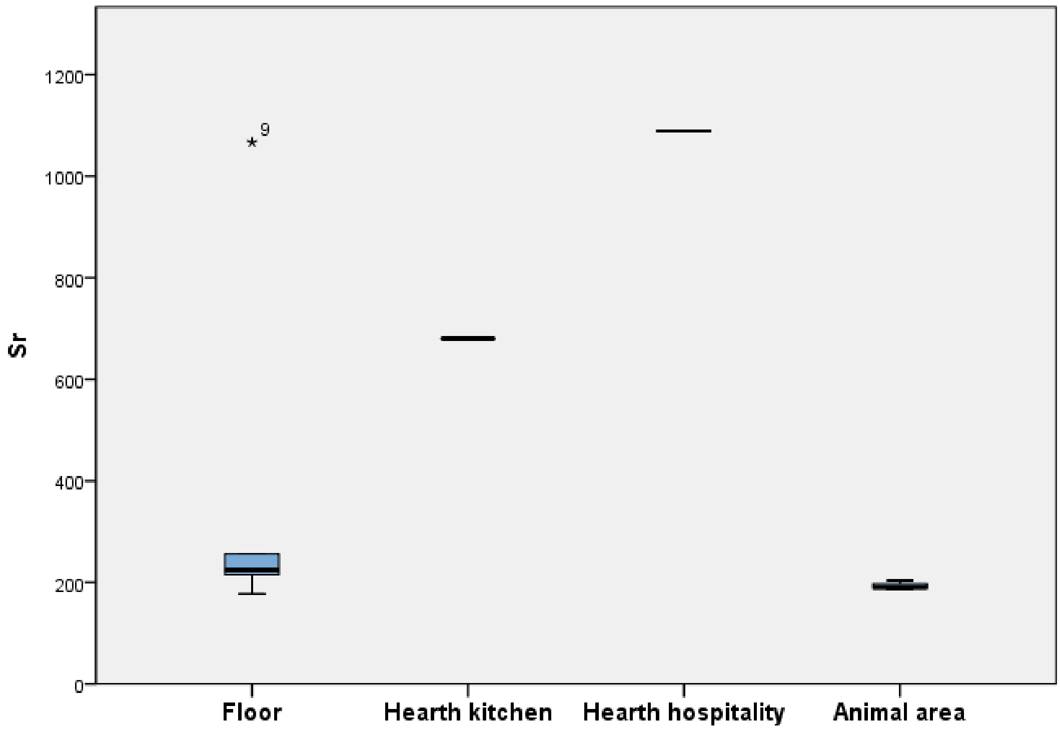


Figure 7.45. Strontium levels in PPM per context, WD.

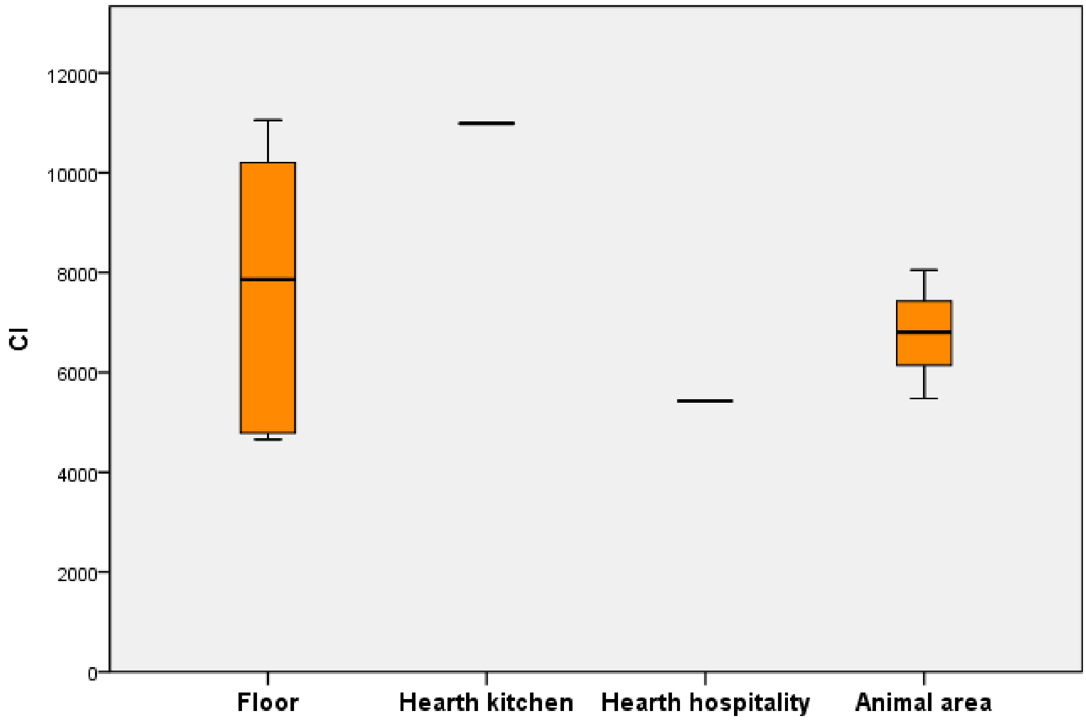


Figure 7.46. Chlorine levels in PPM per context, WD.

7.2.6. Jouma's tent summer (JTS)

The three components extracted in the PCA show clustering on two levels. Both graphs incorporating the second component (driven by Ca, Mn, Mg and Sr), the first scatterplot (figure 7.47.) is additionally driven by P, S and Zn while the second scatterplot (figure 7.48.) includes K, Fe, Mn and Cl. While in the first PCA scatterplot the kitchen hearth plots differently to the hospitality hearths, one of which falls within the animal pen floor cluster, in the second scatterplot the clustering is not as strong within individual context groups, but the three hearths plot closer. However, the second scatterplot also shows a discrepancy between the two background samples, one falling within the floor cluster and the other plotting differently from all samples.

As can be seen in the graphs below (figures 7.49. – 7.58.), the hearths, mainly the kitchen one, have high levels of Mg, Zn, Sr, S, Ca and P, while the dung (and related samples) have enrichment of Cl and K. In addition, these contexts of increased anthropogenic input show a depletion in background elements such as Fe and Al. The kitchen hearth has the clearest enrichment and depletion patterns, more so than the hospitality hearths. Perhaps this attests to a more intensive use of this feature than the other hearths.

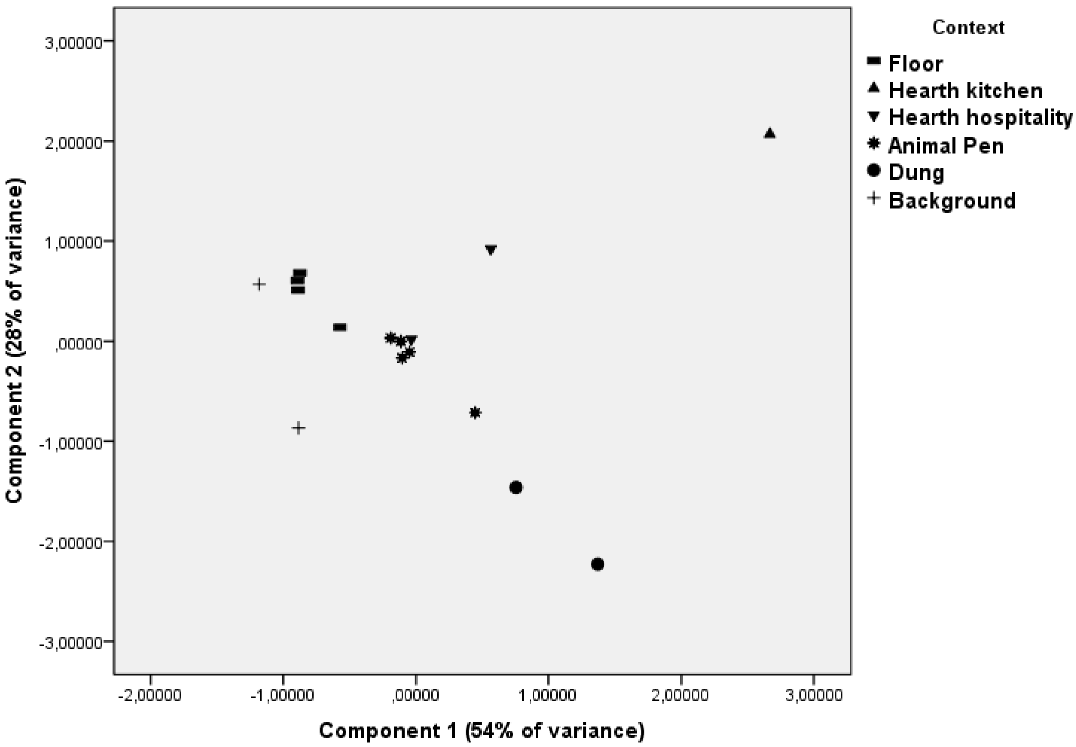


Figure 7.47. PCA scatterplot, JTS. The first component is driven by P, S, Zn and negatively by Si, Ti, Al and Zr. The second factor is driven by Ca, Mn, Mg and Sr.

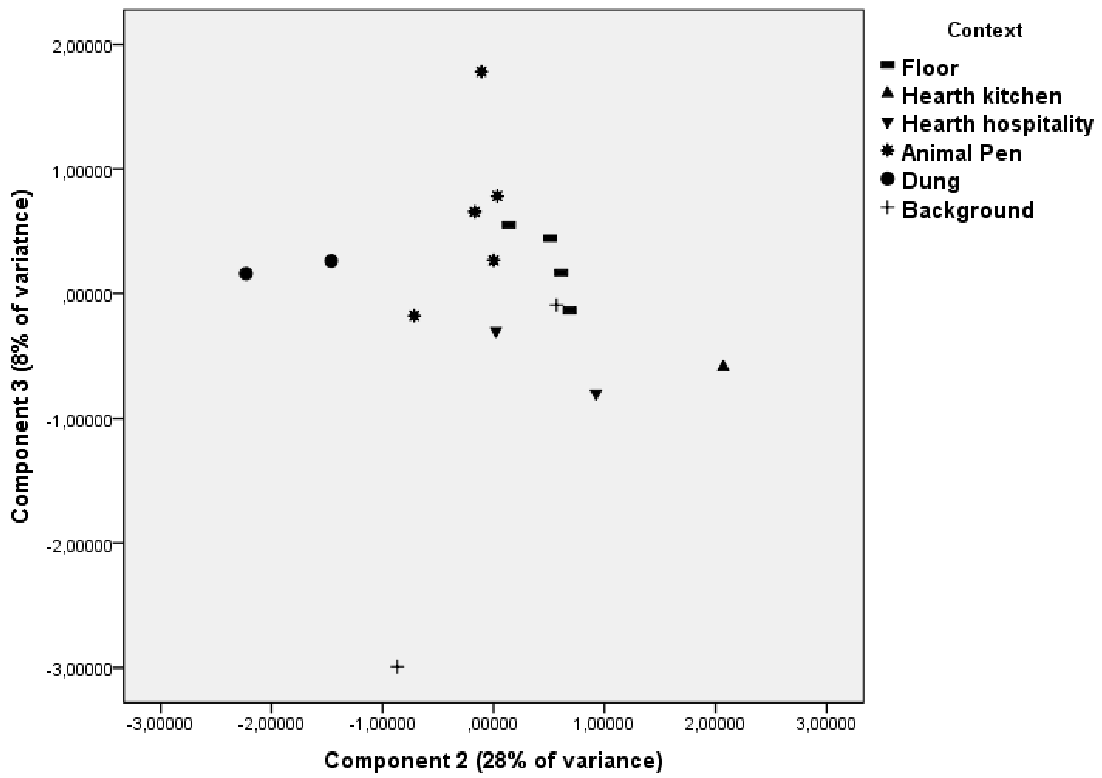


Figure 7.48. PCA scatterplot, JTS. The second component is driven by Ca, Mn, Mg and Sr, the third by K, Fe, Mn and Cl.

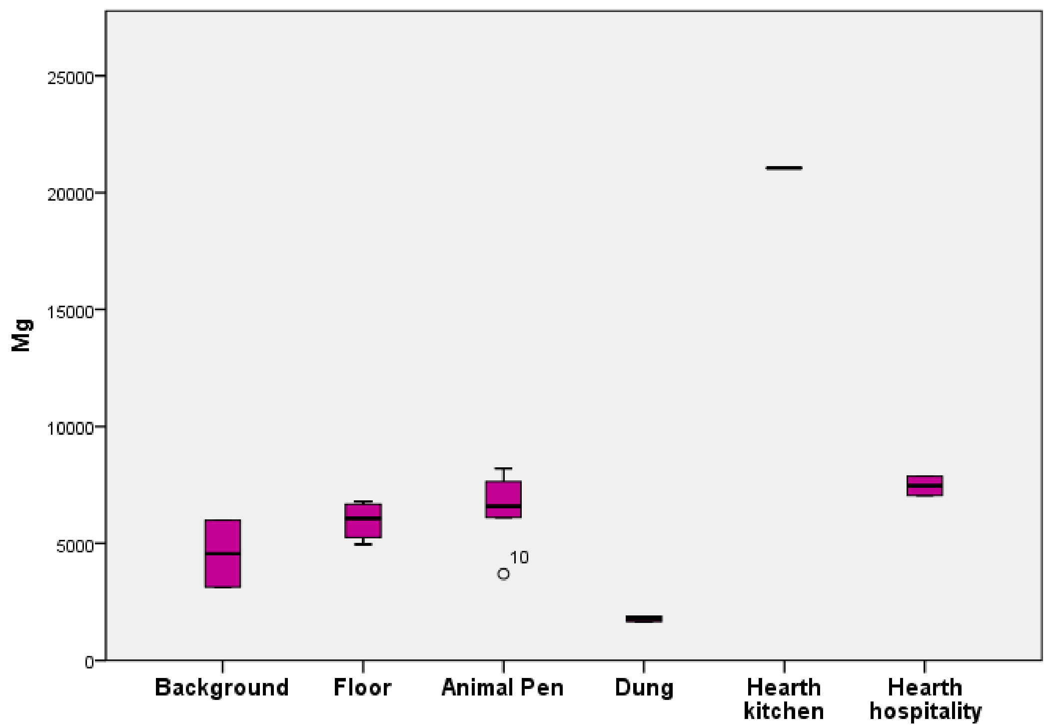


Figure 7.49. Magnesium levels in PPM per context, JTS.

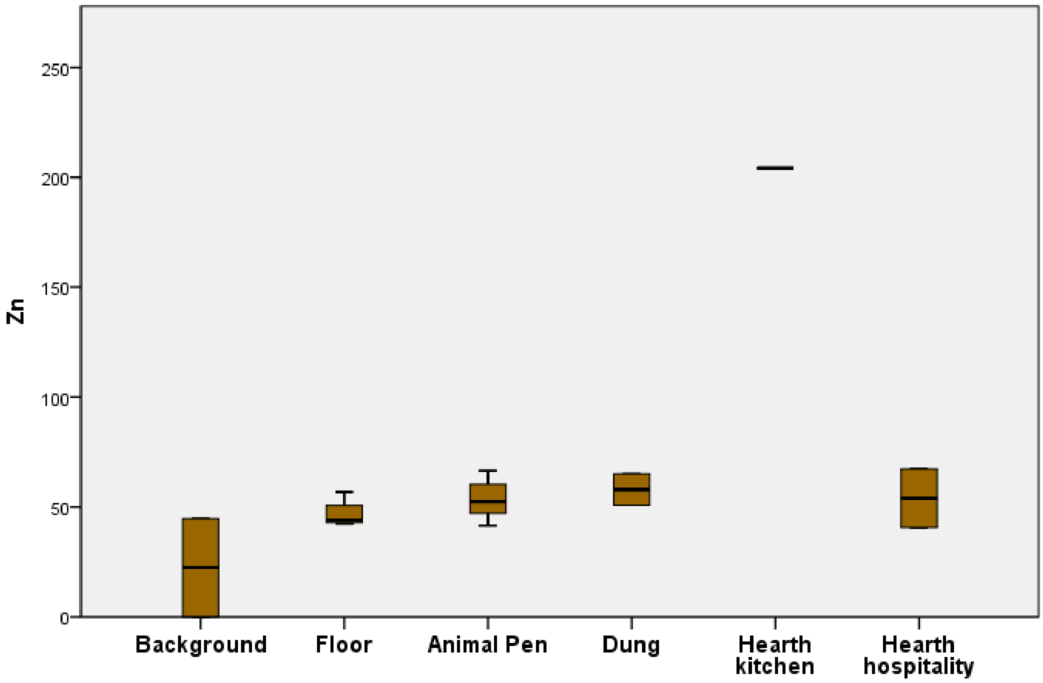


Figure 7.50. Zinc levels in PPM per context, JTS.

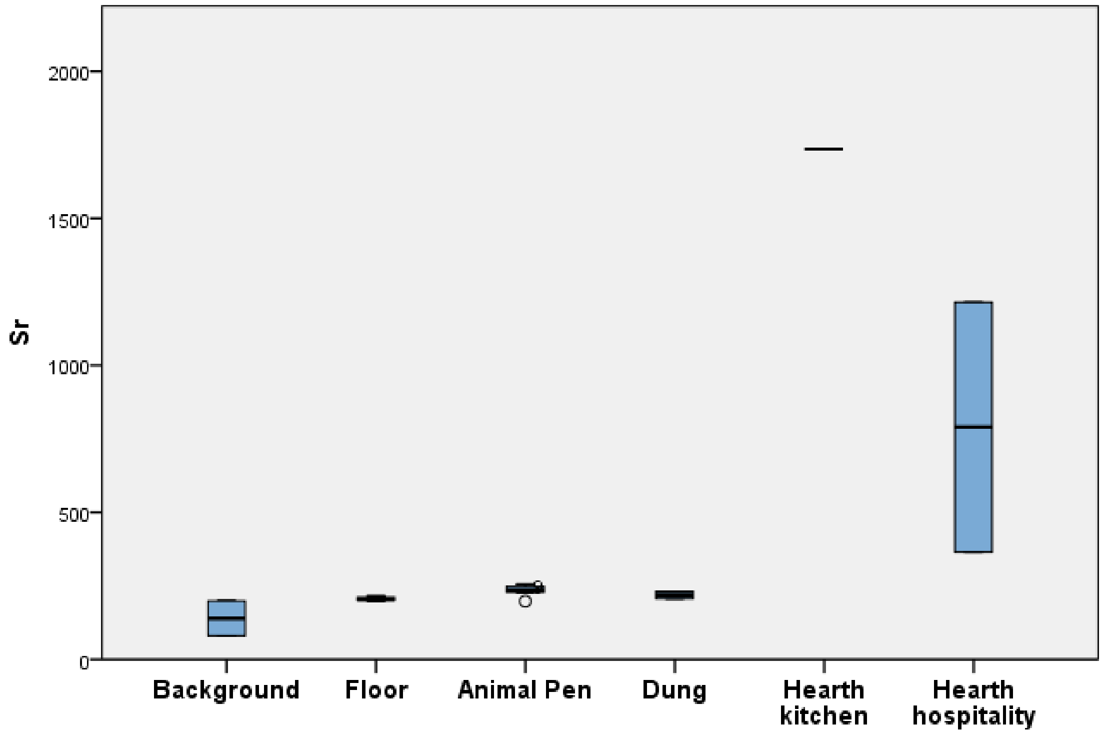


Figure 7.51. Strontium levels in PPM per context, JTS.

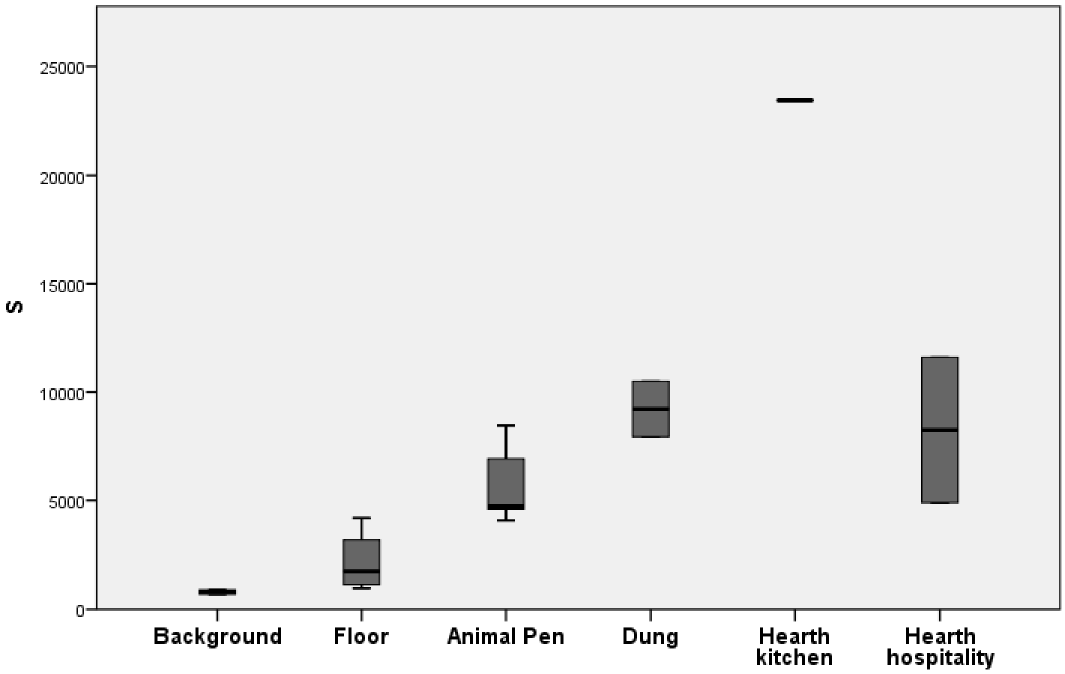


Figure 7.52. Sulphur levels in PPM per context, JTS.

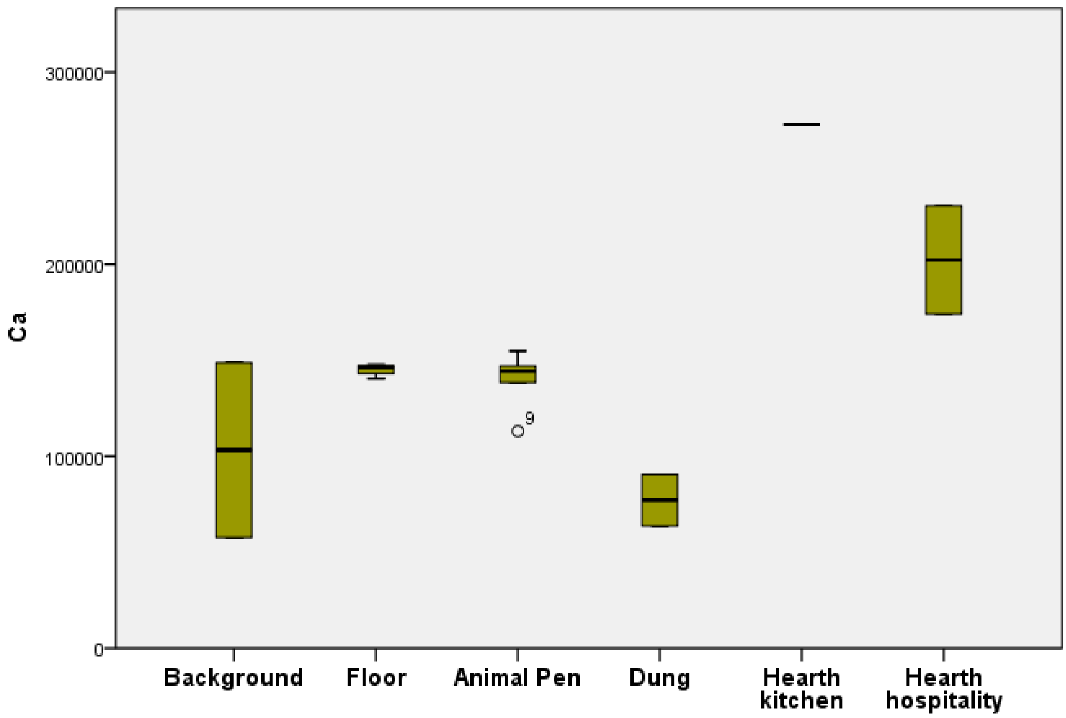


Figure 7.53. Calcium levels in PPM per context, JTS.

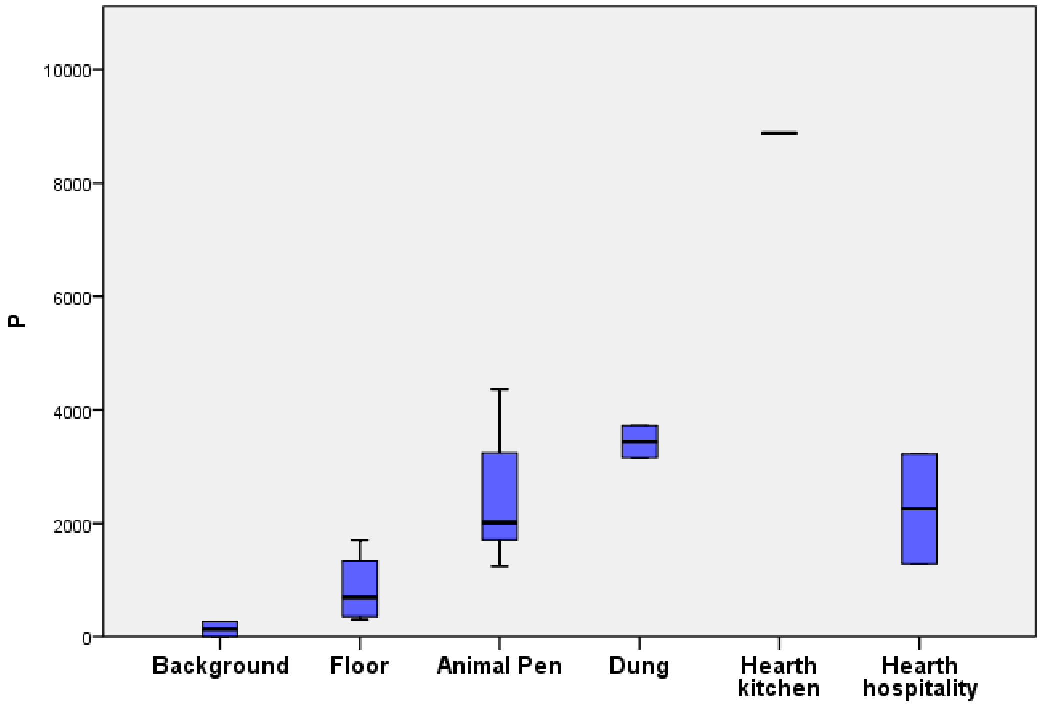


Figure 7.54. Phosphorus levels in PPM per context, JTS.

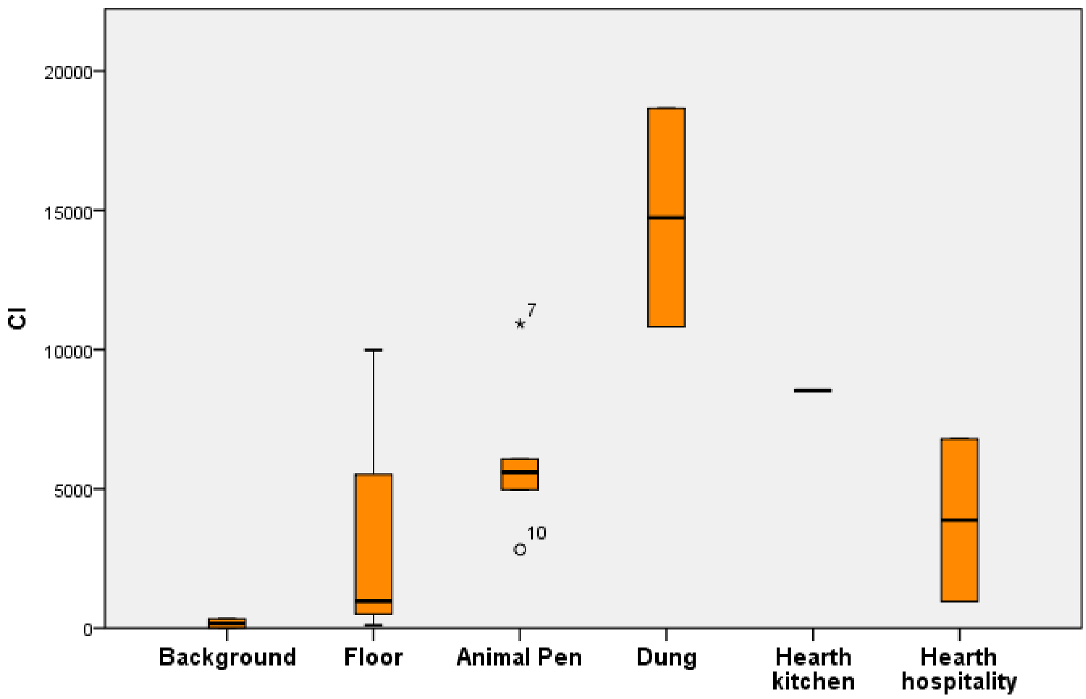


Figure 7.55. Chlorine levels in PPM per context, JTS.

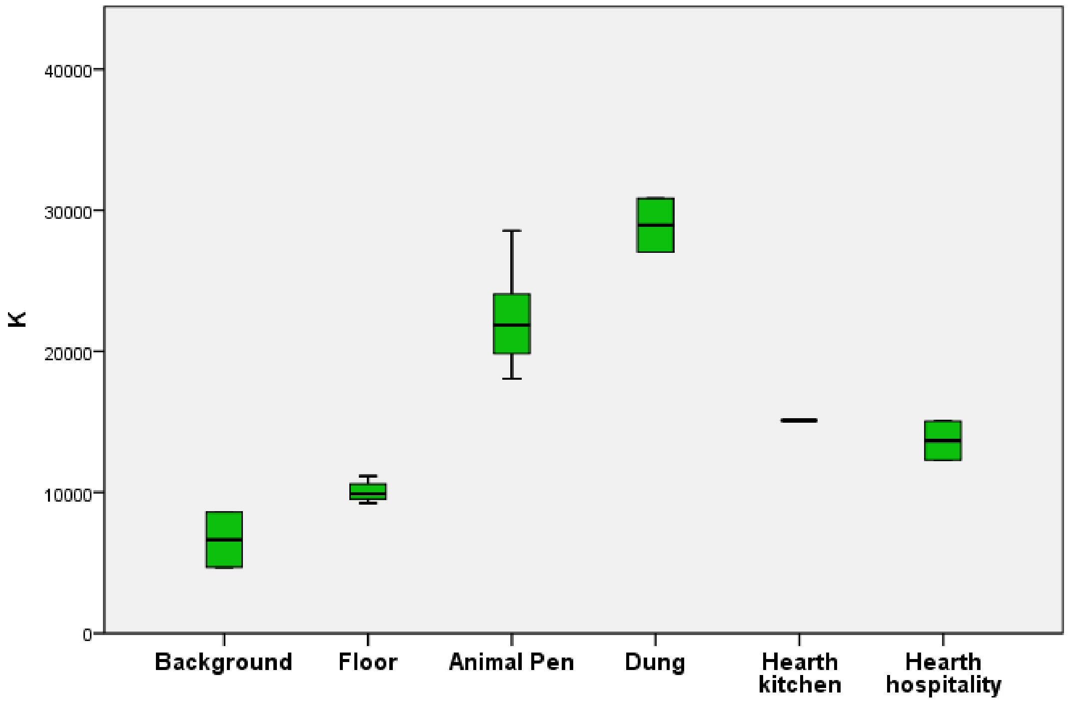


Figure 7.56. Potassium levels in PPM per context, JTS.

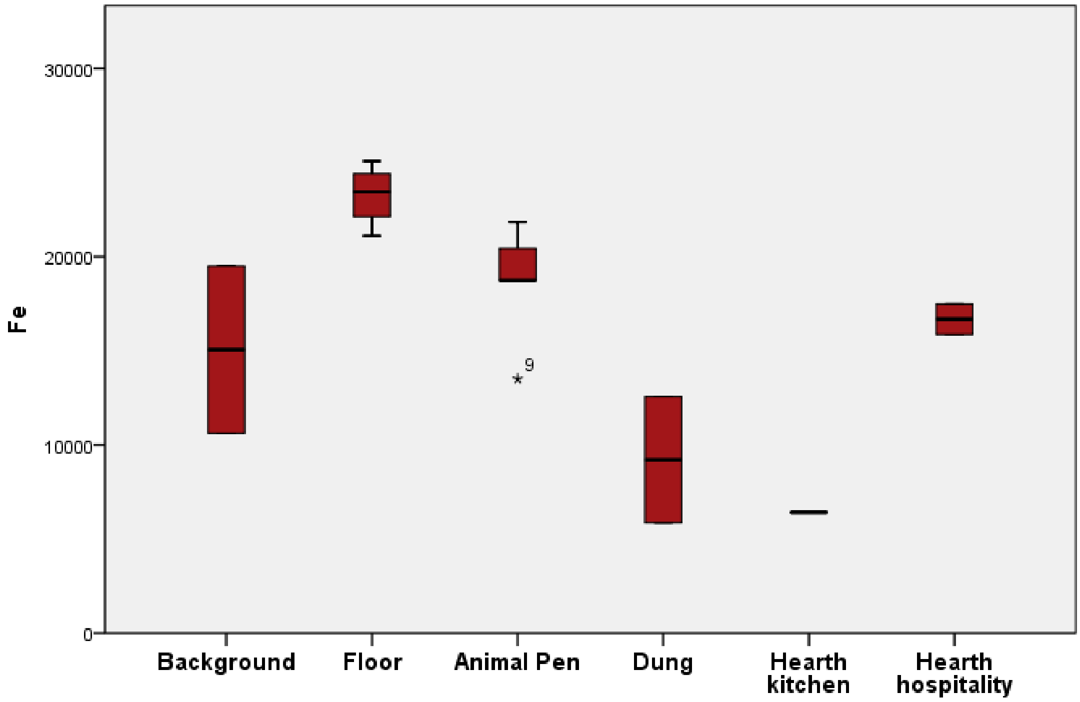


Figure 7.57. Iron levels in PPM per context, JTS.

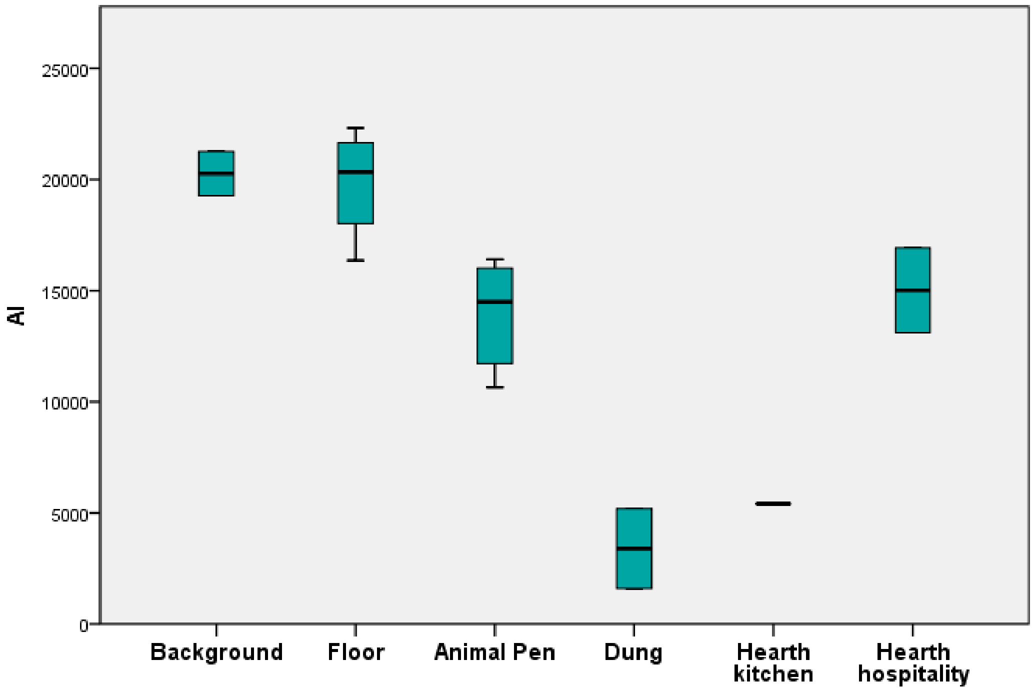


Figure 7.58. Aluminium levels in PPM per context, JTS.

7.2.7. Jouma's tent winter (JTW)

The various context categories are displayed in the PCA scatterplot below (figure 7.59.), which shows a main cluster including all floor samples, a sample from the animal pen floor and the background sample, a cluster of the three hearths, and one of three dung samples, with the remaining animal pen floor sample plotting between the dung and the floor clusters. Both hearths exhibit high levels of Sr and Ca, and the kitchen hearth samples contain higher levels of Mg, Mn, Zn and P than the hospitality hearth, which in turn has a larger enrichment of S (figures 7.60. – 7.66.). Both the kitchen hearth and the dung samples have high levels of K, while the amount of Cl is largest within the dung samples, followed by the kitchen hearth (figures 7.67., 7.68). As expected, a depletion in background elements such as Al and Fe (figures 7.69., 7.70.) can be seen in the hearth and dung contexts.

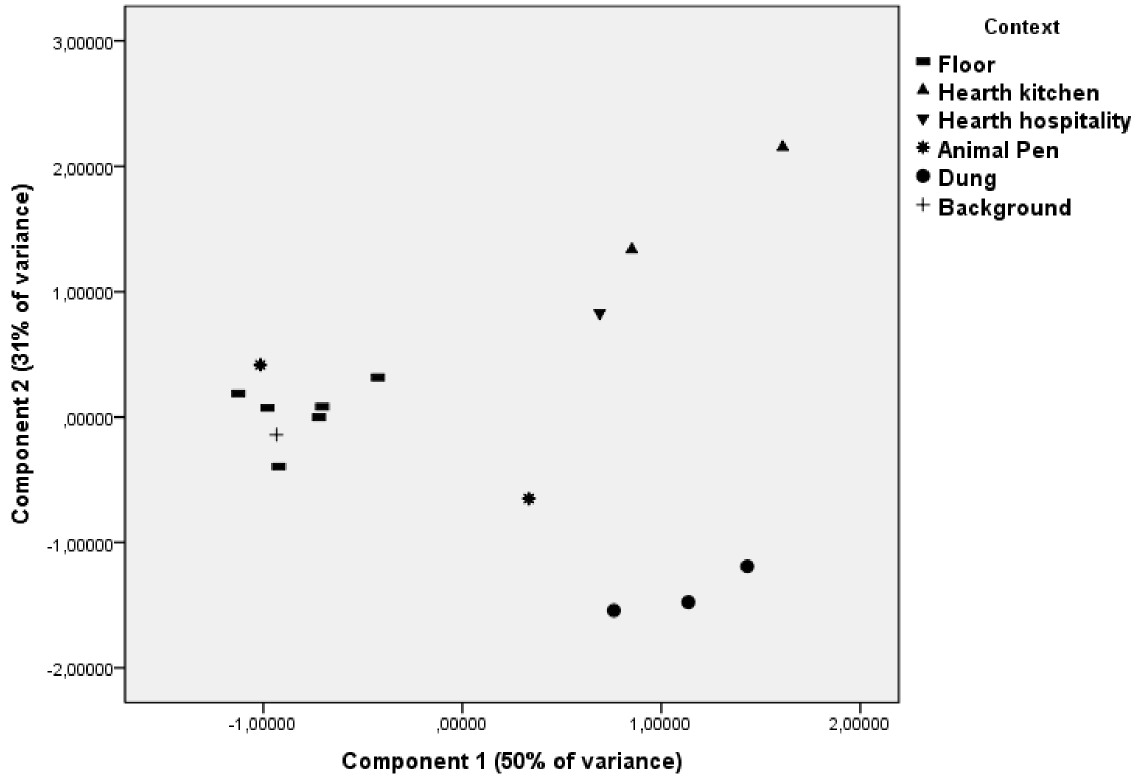


Figure 7.59. PCA scatterplot, JTW. The first component is driven by K, Zn, P, Cl and negatively by Ti, Al, Si, and Fe. The second component is influenced by Ca, Mn, Mg and Sr.

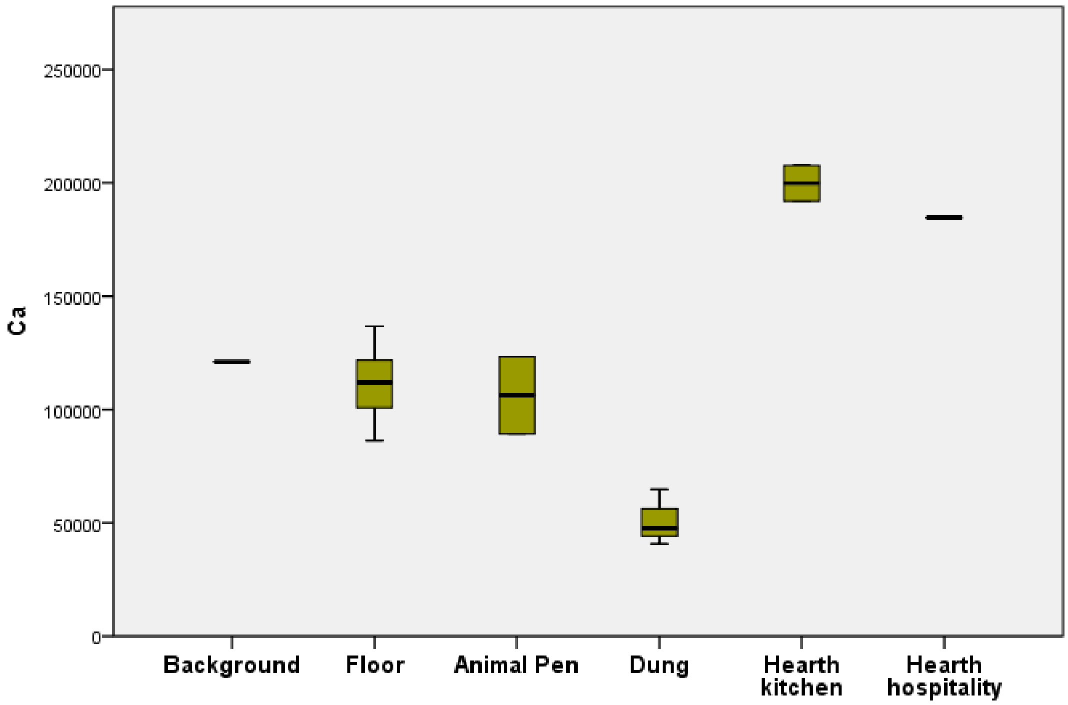


Figure 7.60. Calcium levels in PPM per context, JTW.

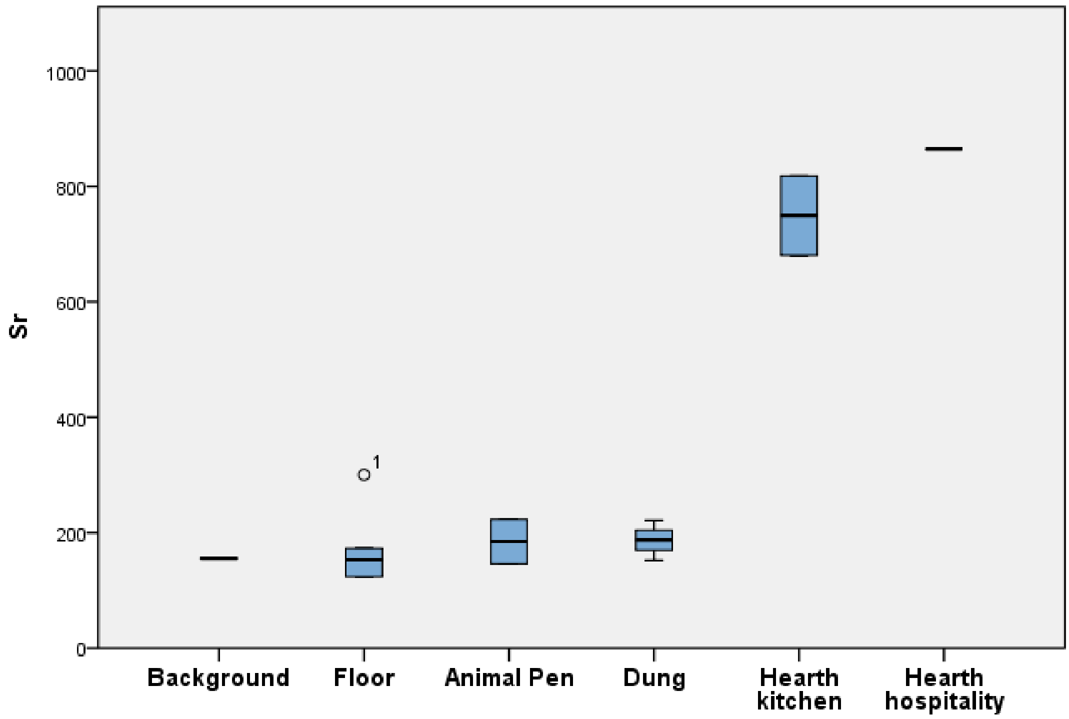


Figure 7.61. Strontium levels in PPM per context, JTW.

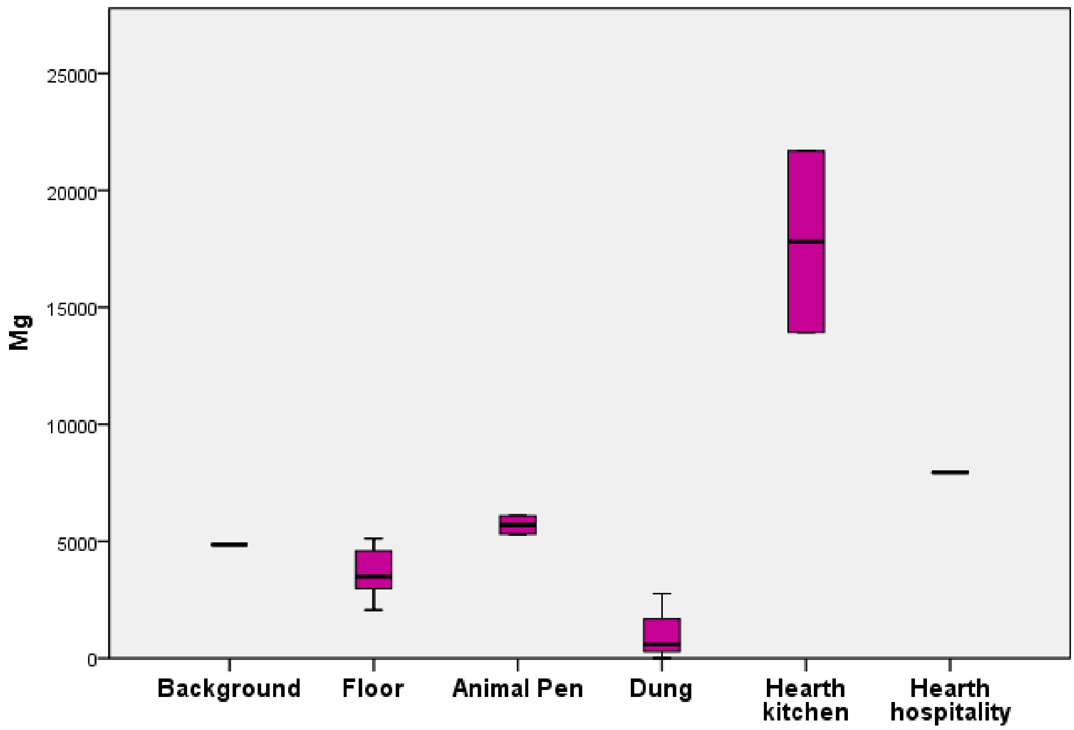


Figure7.62. Magnesium levels in PPM per context, JTW.

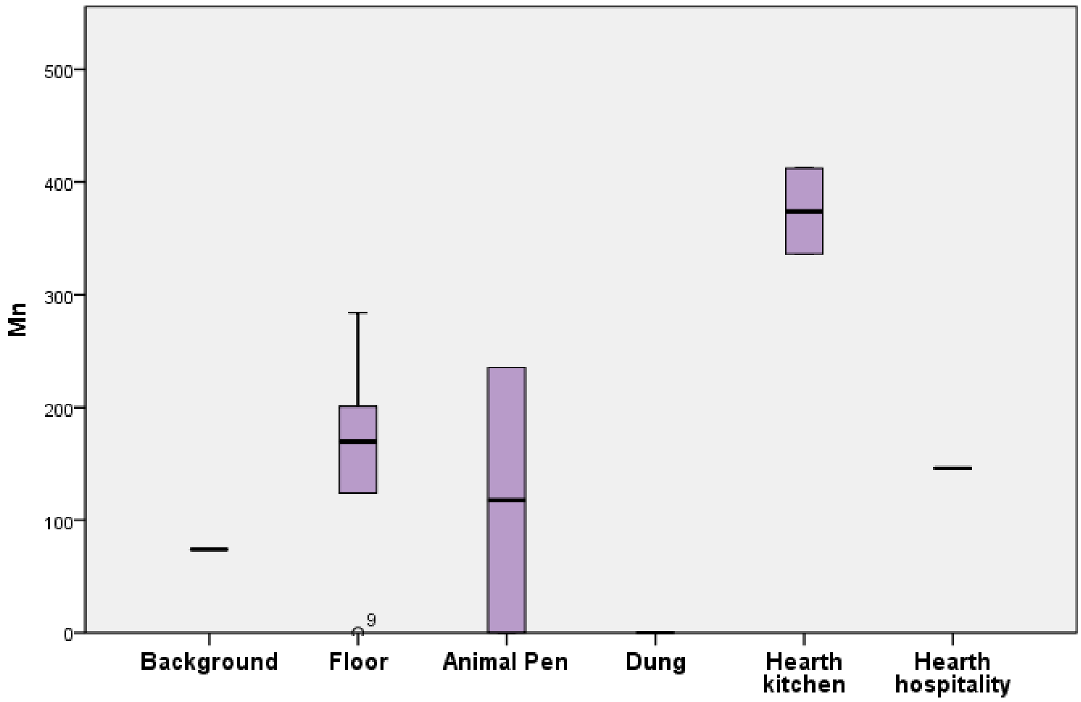


Figure 7.63. Calcium levels in PPM per context, JTW.

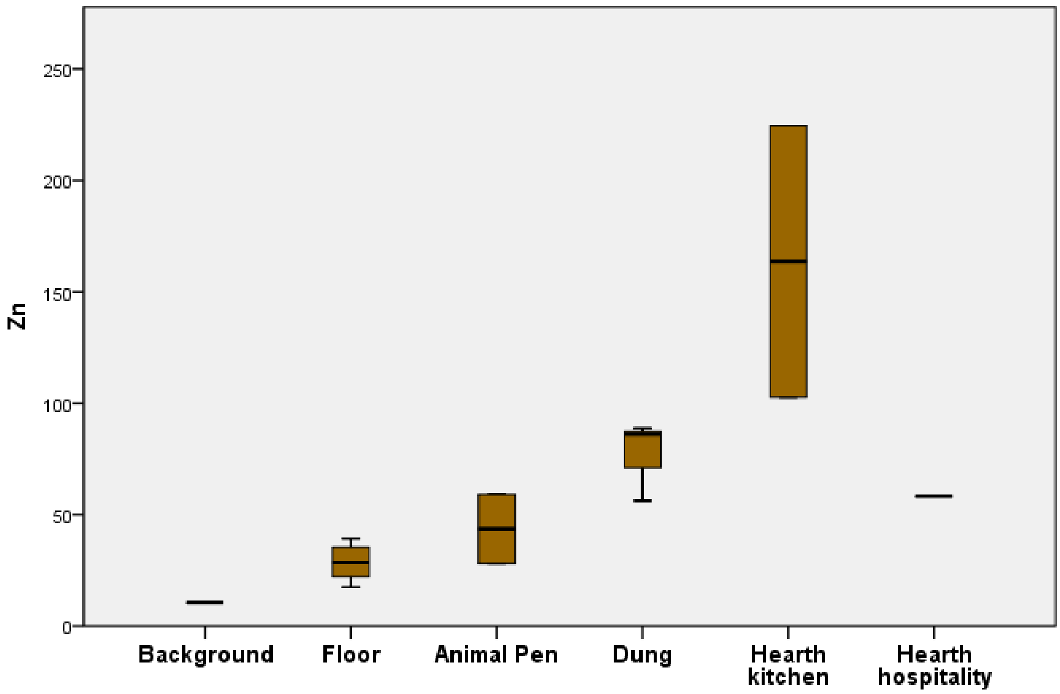


Figure 7.64. Zinc levels in PPM per context, JTW.

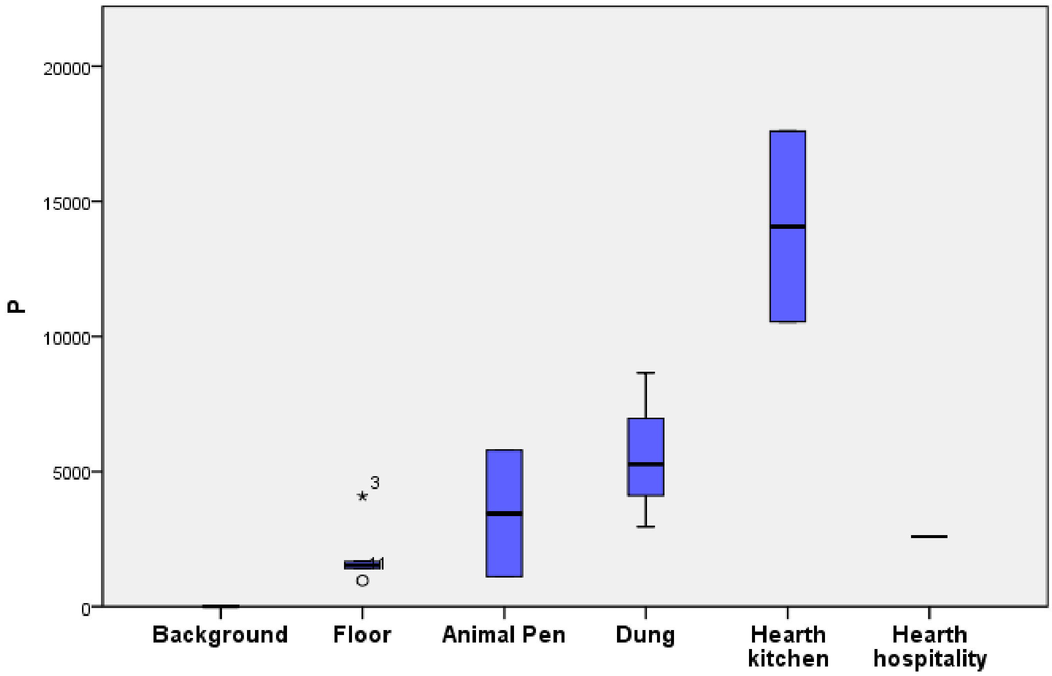


Figure 7.65. Phosphorus levels in PPM per context, JTW.

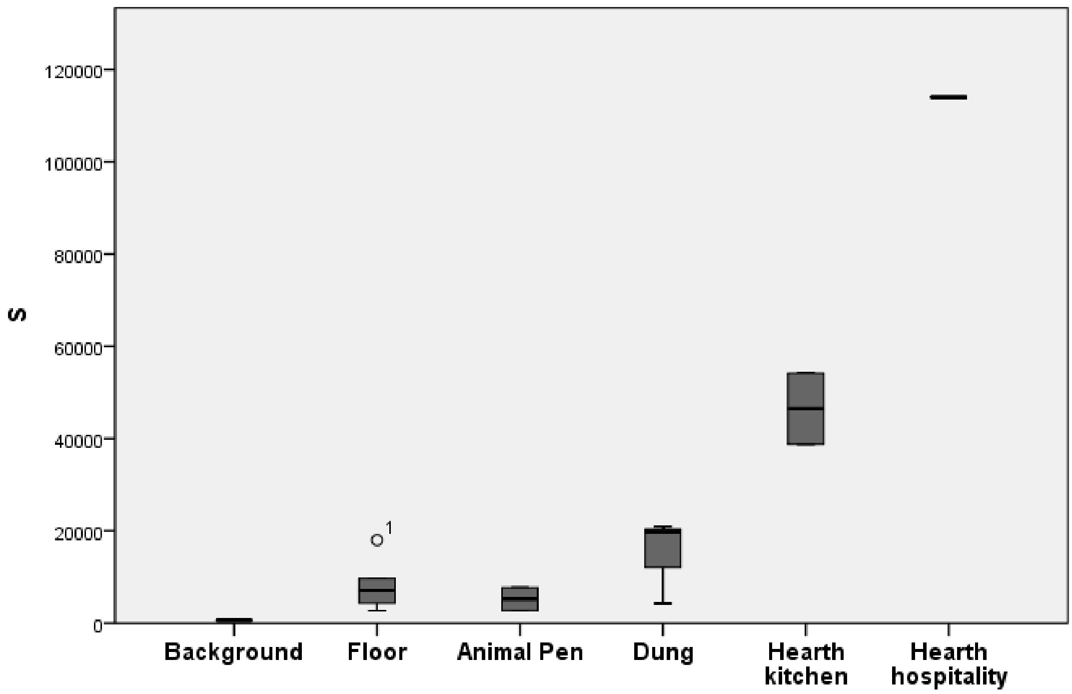


Figure 7.66. Sulphur levels in PPM per context, JTW.

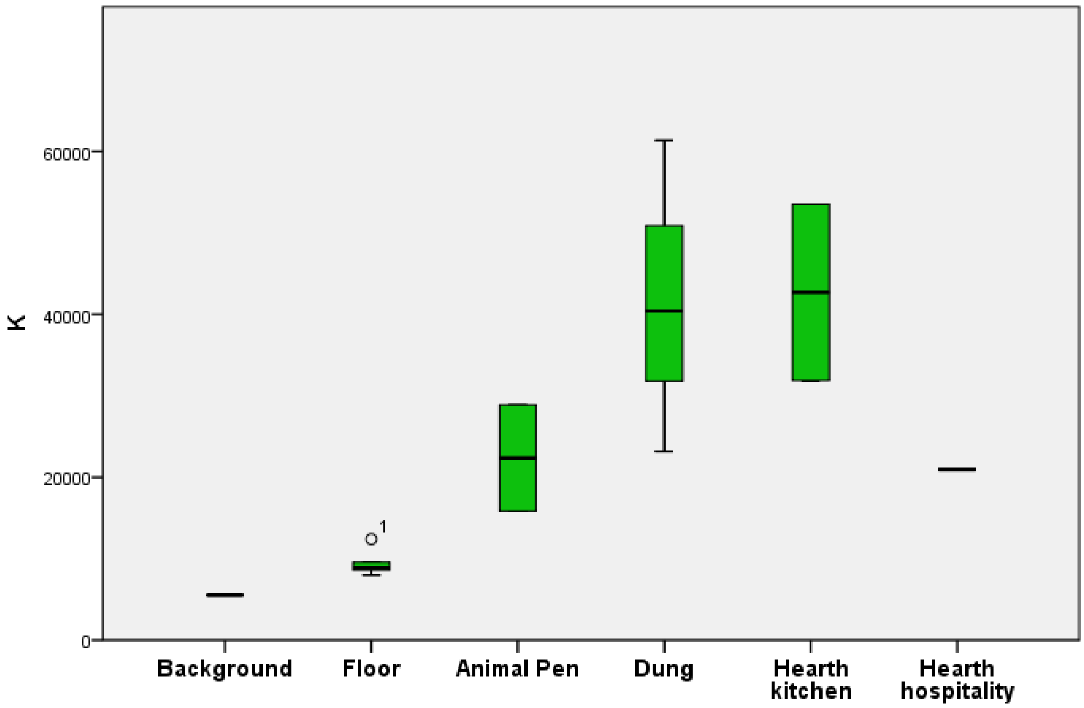


Figure 7.67. Potassium levels in PPM per context, JTW.

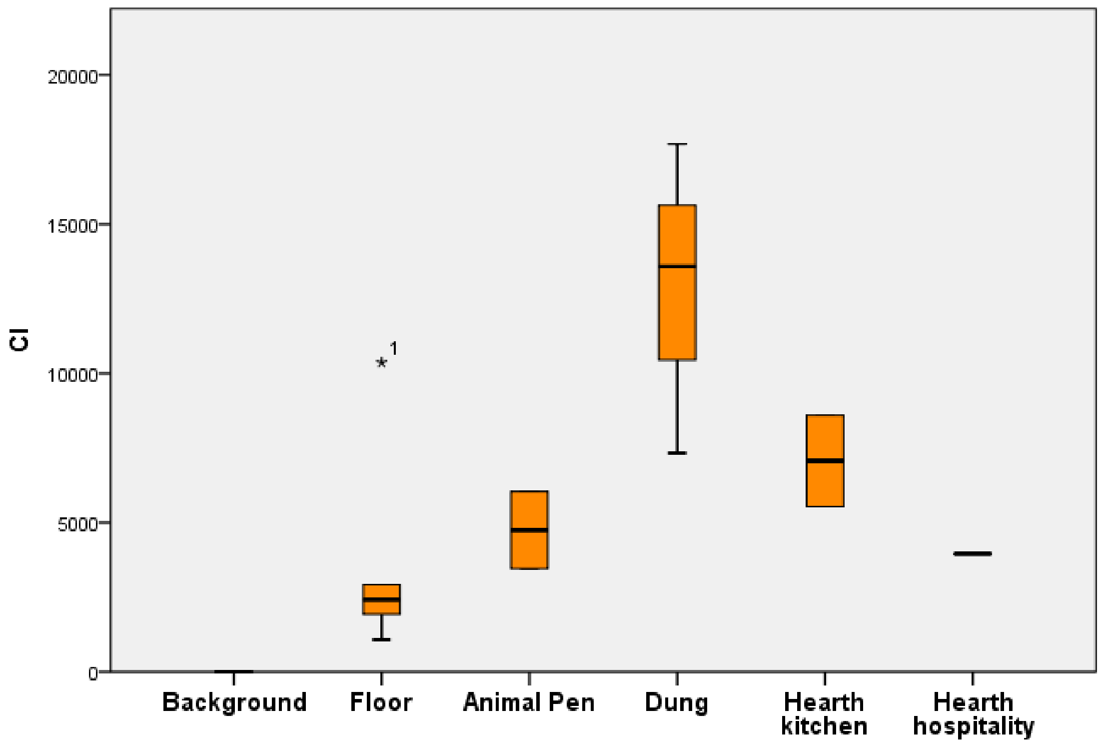


Figure 7.68. Chlorine levels in PPM per context, JTW.

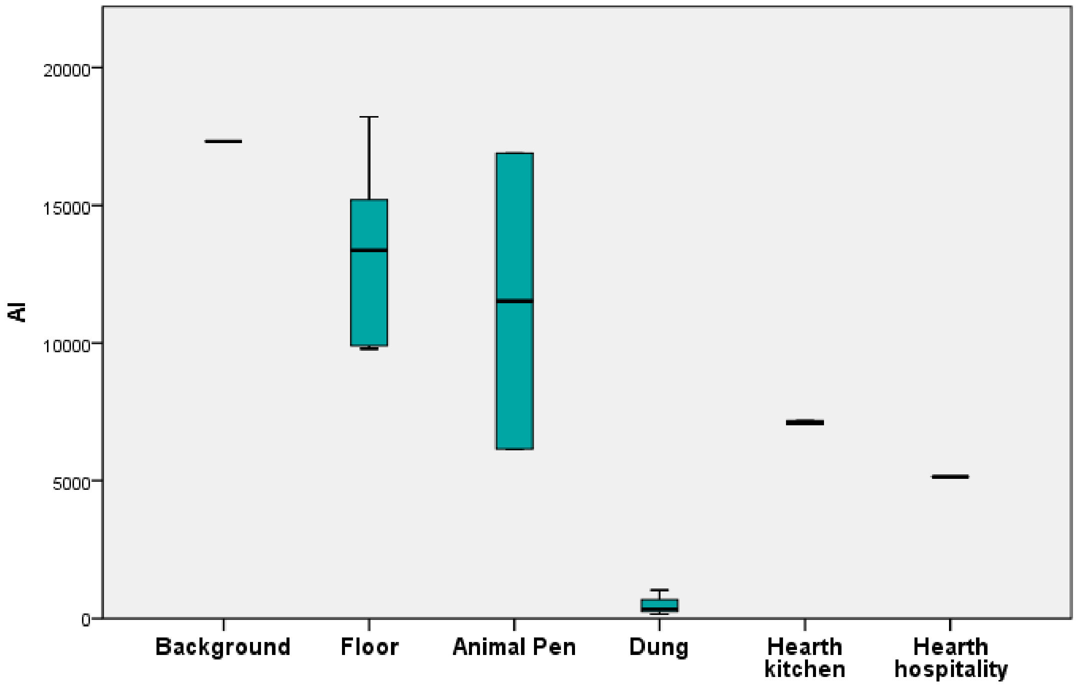


Figure 7.69. Aluminium levels in PPM per context, JTW.

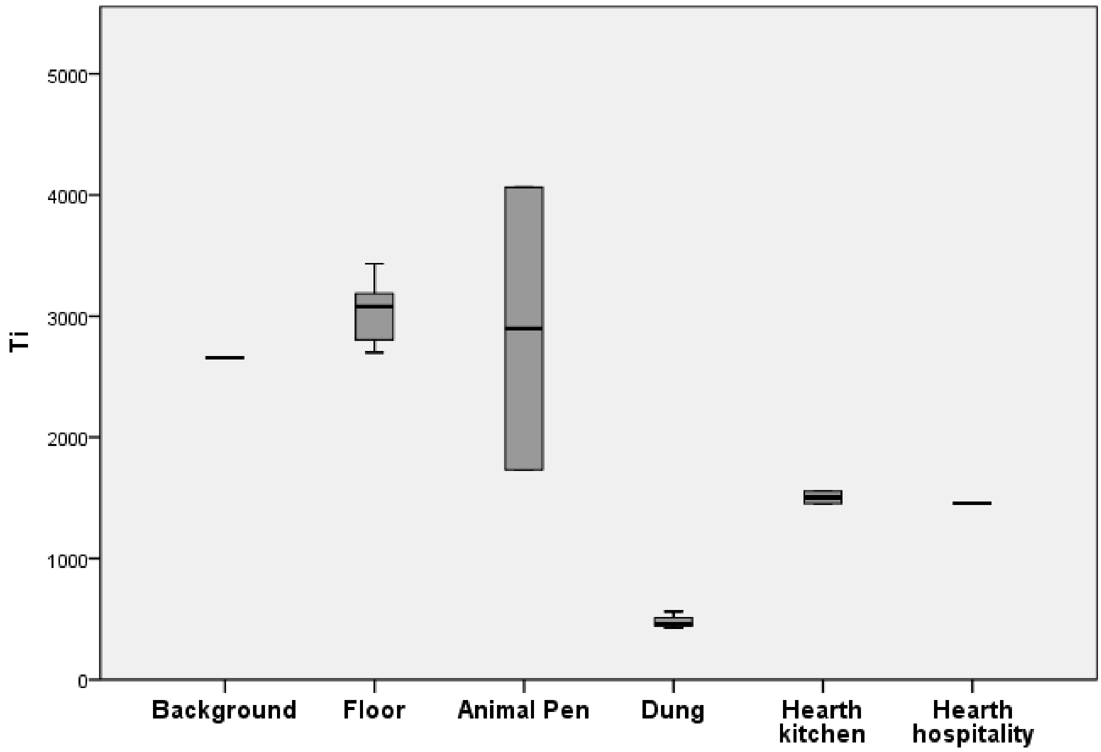


Figure 7.70. Titanium levels in PPM per context, JTW.

7.2.8. General patterns Wadi Faynan sites

WF982 and WD were not incorporated in this section as the length of time since abandonment for WF982 has influenced the patterns seen after short abandonment (see section 7.1.3.), and because the context categories for WD, which is located further up the Wadi, diverge from the ones used in this analysis. The remaining sites show consistent enrichment and depletion patterns of various elements in the different contexts, which translates into high levels of MG, K, Ca, Sr, S, P, Mn in the hearths, Cl and S in the dung samples, and larger concentrations of background elements such as Al and Ti in the contexts less effected by anthropogenic activity such as floors and gullies (figures 7.74. – 7.82.).

The PCA scatterplot below shows three clear clusters, with the background samples in one extreme, followed closely by floor and gully samples, and two clusters on the other side, of the hearths and the dung contexts (figure 7.71.). The animal pen floor samples fall between the floor samples and dung samples in, as one would expect. The PCA scatterplot marking the individual sites within the graph (figure 7.72.) confirms that the same pattern is repeated in each of the sites. When the second component is replaced by the third (figure 7.73.), which is mainly influenced by Cl, a similar pattern is reached but the hearths and dung contexts plot closer together. This is not surprising as Mg and Ca, driving the second component, are important distinguishing factors for the hearths, and Cl is high in both dung and hearth contexts due to the use of dung cakes as fuel.

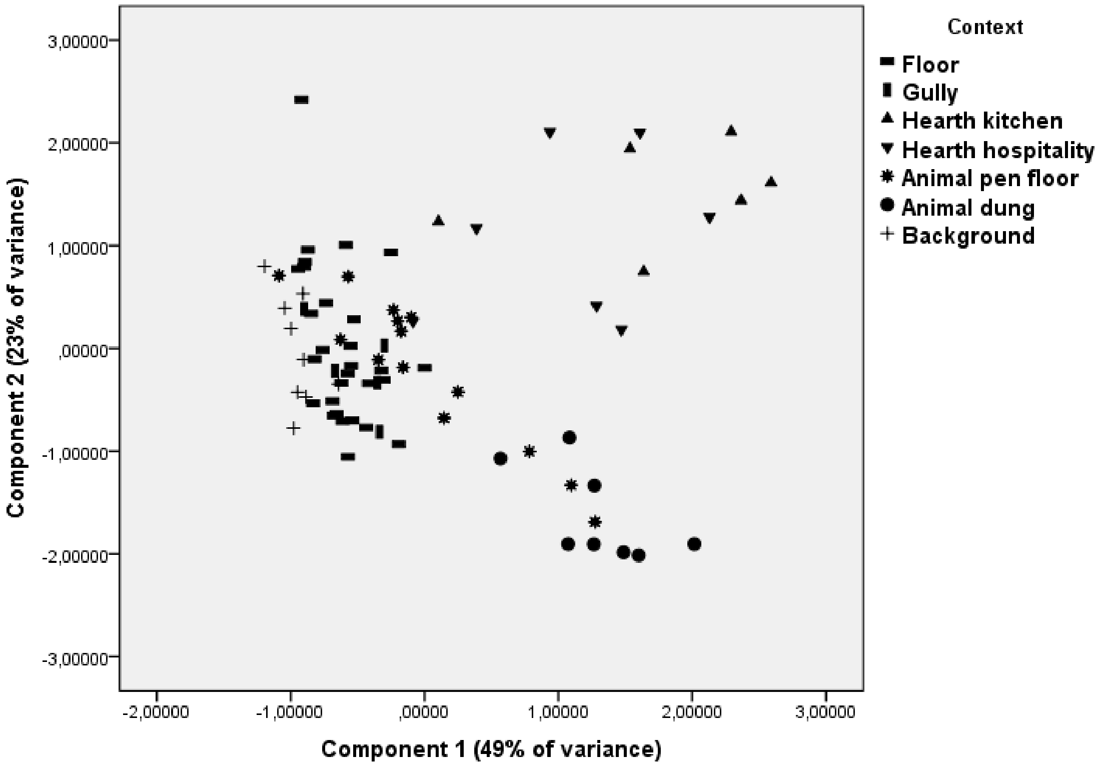


Figure 7.71. PCA scatterplot for all Wadi Faynan sites. The first component is driven by P, K, Zn and negatively by Si, Al, Ti and Zr. The second component is driven by Ca, Mn and Mg.

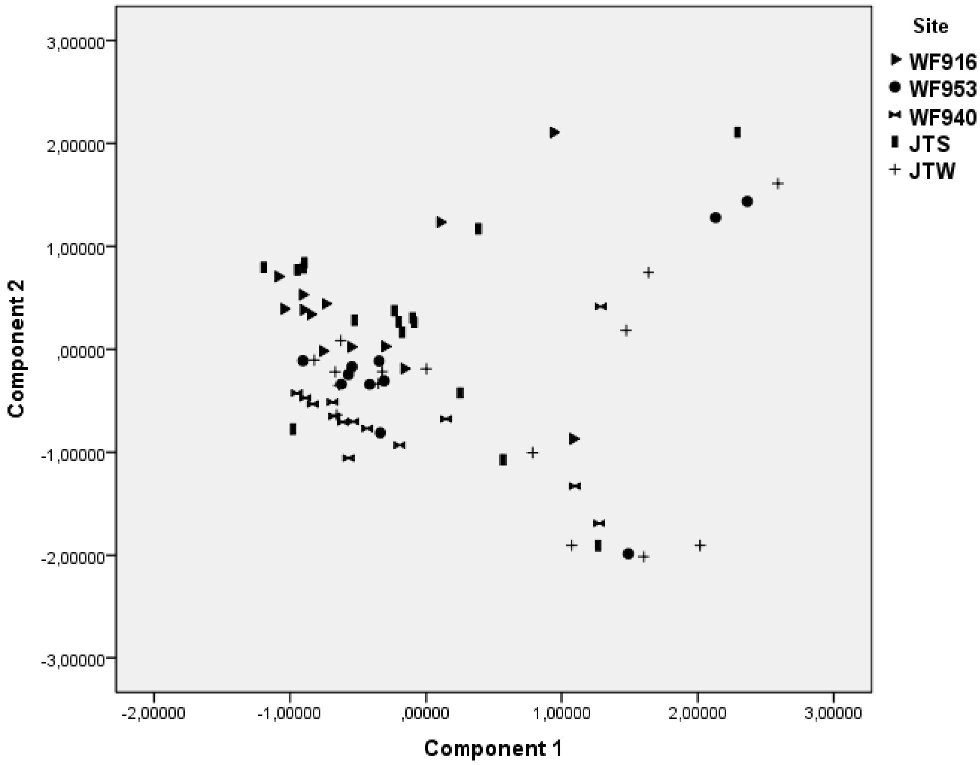


Figure 7.72. PCA scatterplot showing the location of the individual sites within the graph.

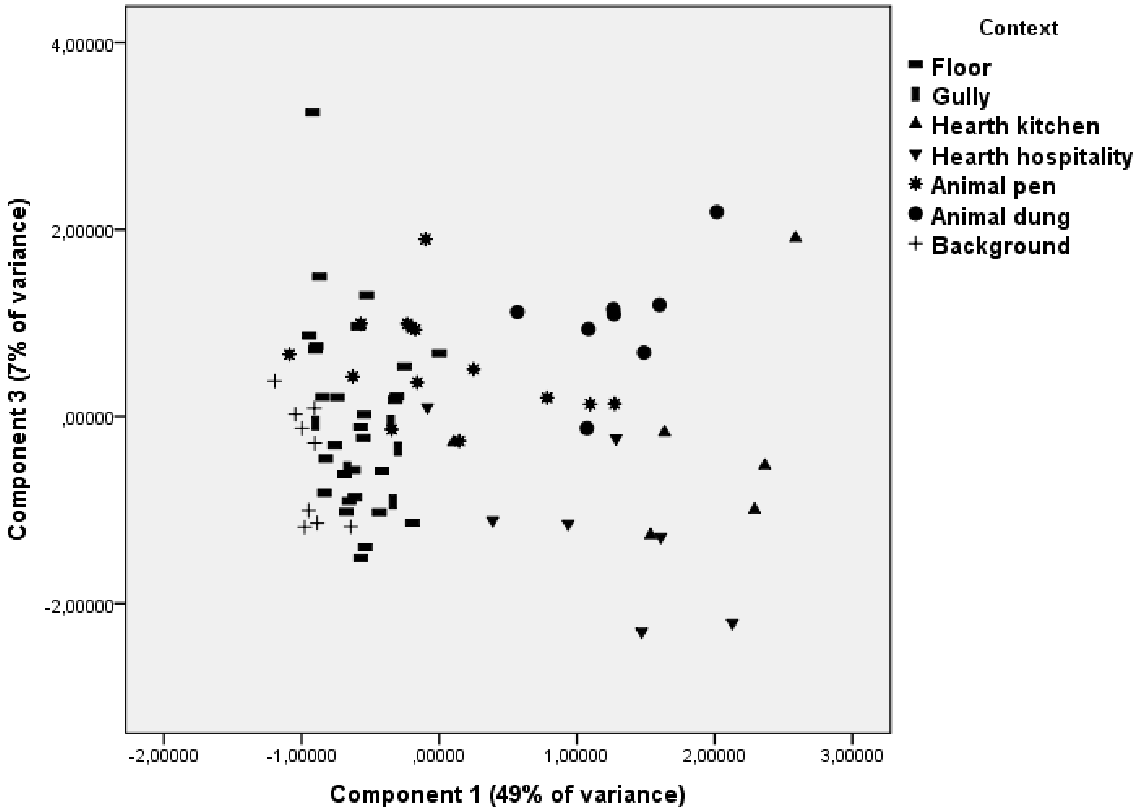


Figure 7.73. PCA scatterplot for all Wadi Faynan sites. The first component is driven by P, K, Zn and negatively by Si, Al, Ti and Zr. The third component is driven by Cl, Fe, Zn.

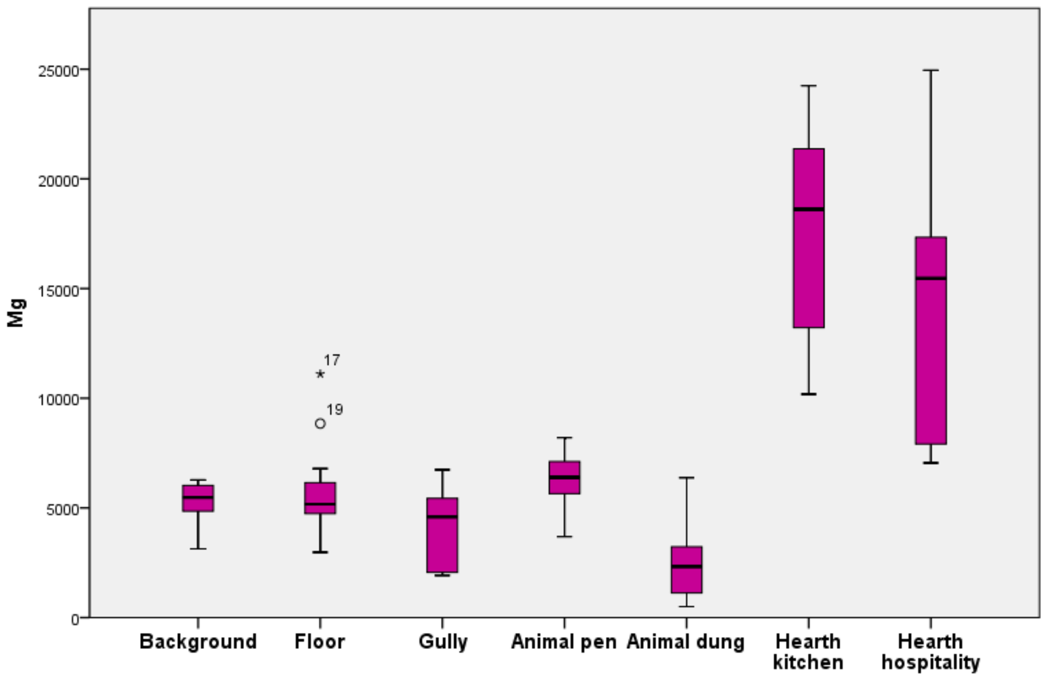


Figure 7.74. Magnesium levels in PPM for each context, WF sites.

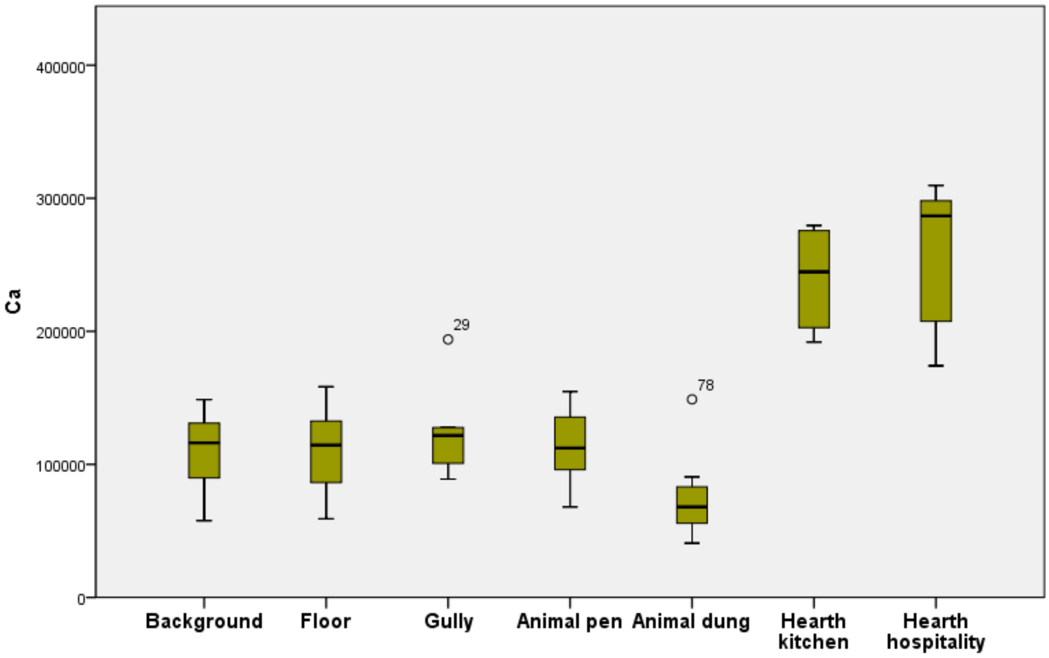


Figure 7.75. Calcium amounts per context in PPM, WF sites.

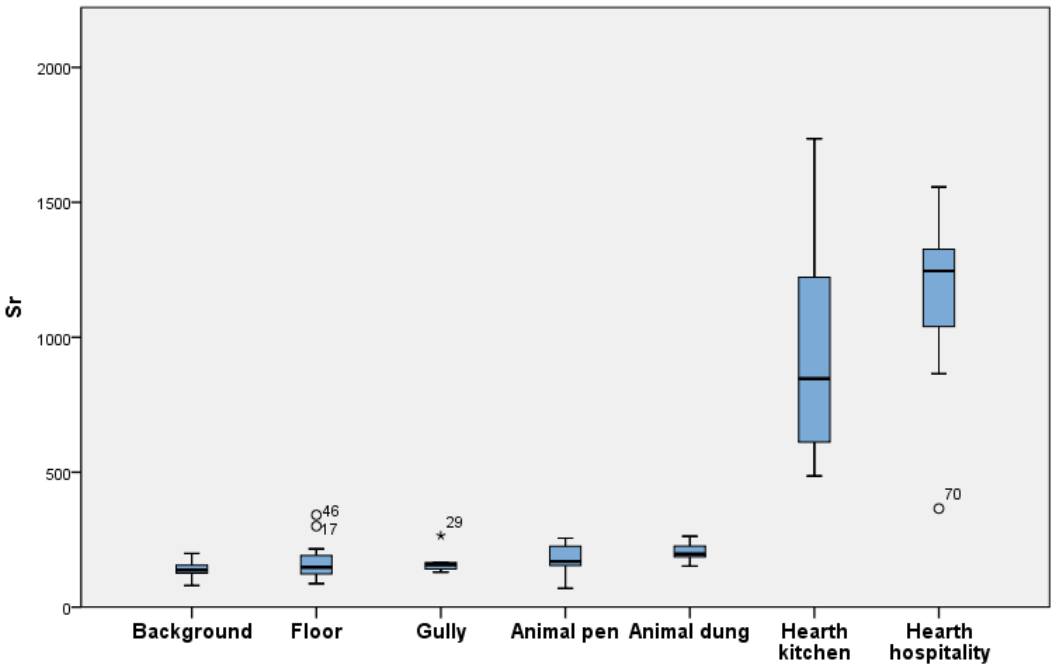


Figure 7.76. Levels of Strontium in PPM per context, WF sites.

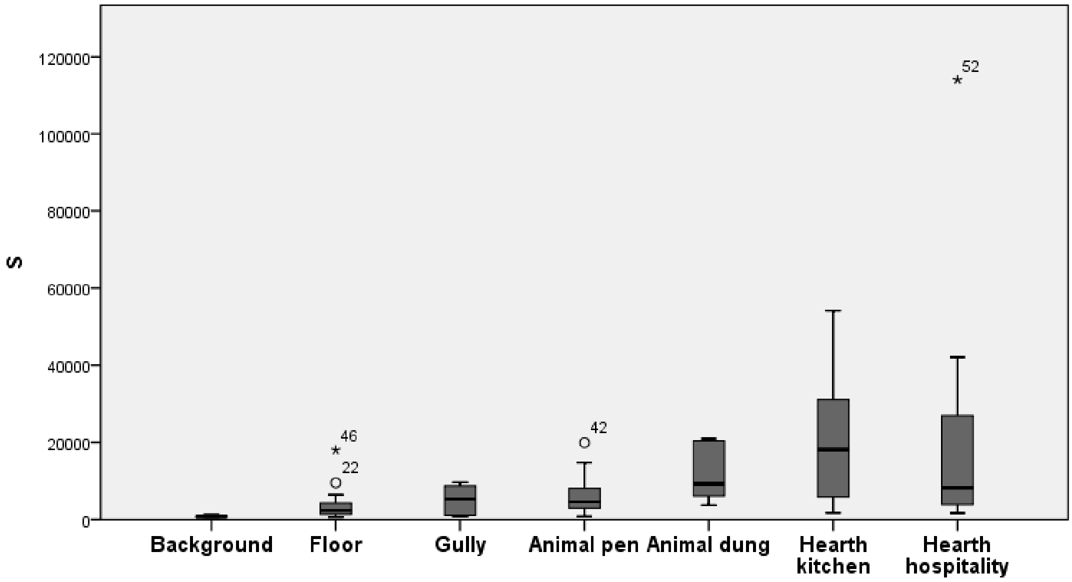


Figure 7.77. Sulphur levels in PPM per context, WF sites.

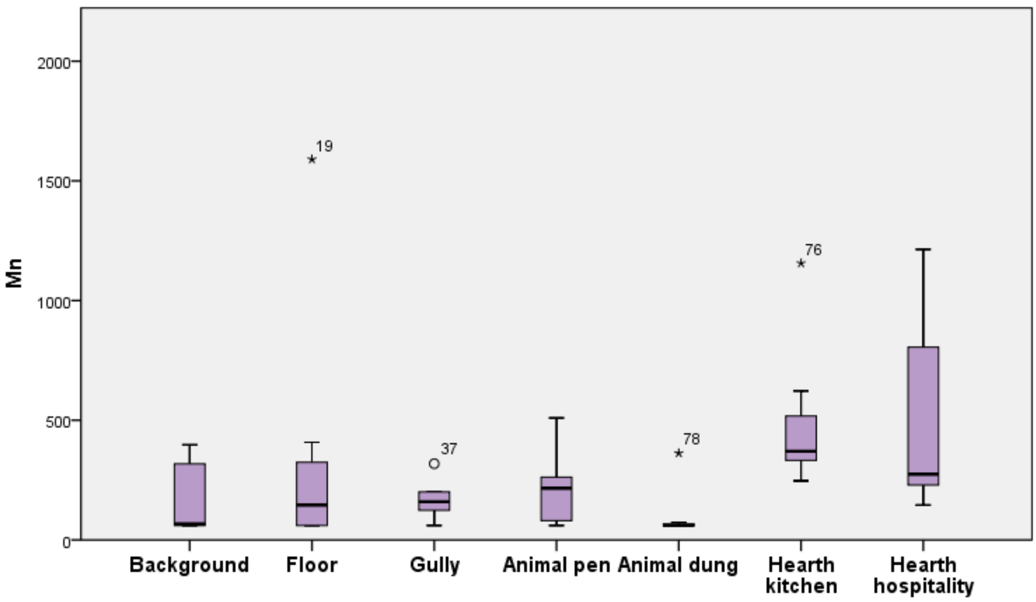


Figure 7.78. Amount of Manganese per context in PPM, WF sites.

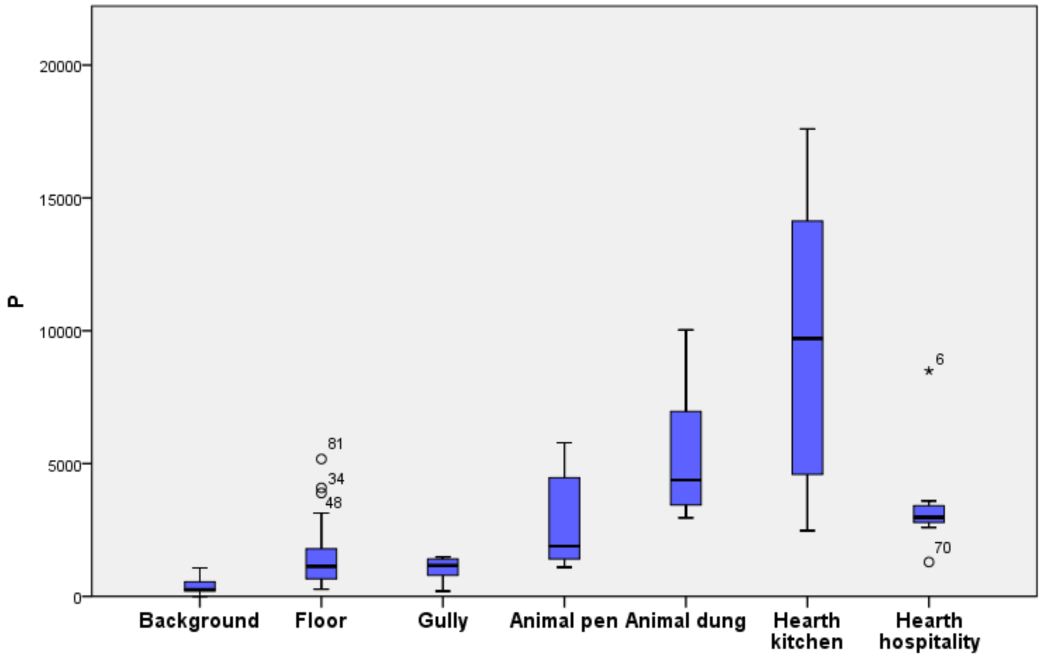


Figure 7.79. Amount of Phosphorus per context in PPM, WF sites.

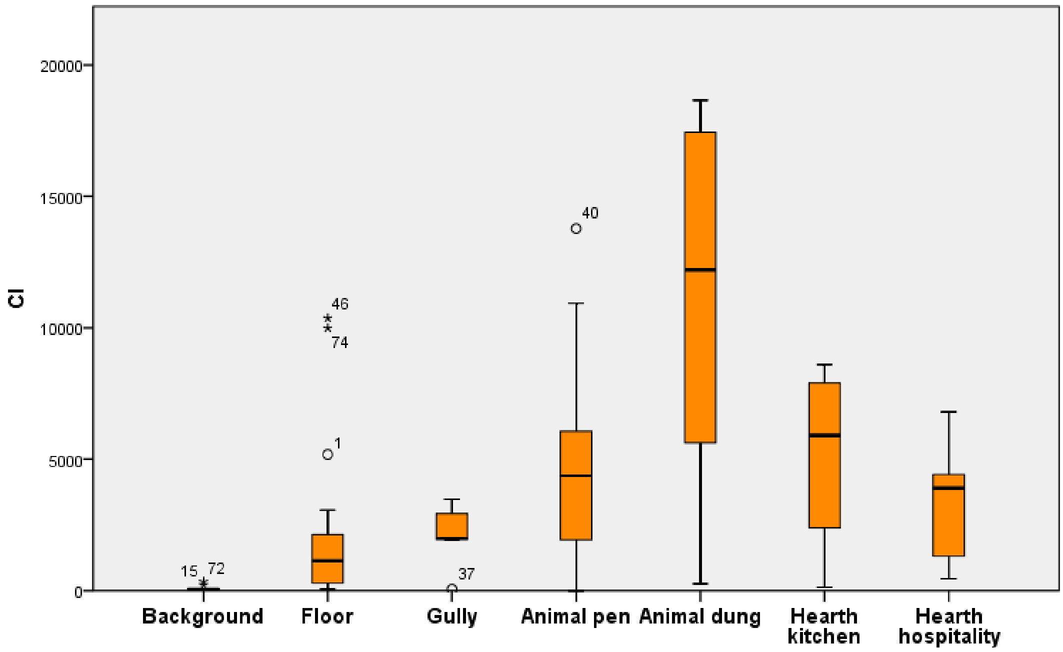


Figure 7.80. Chlorine levels per context in PPM, WF sites.

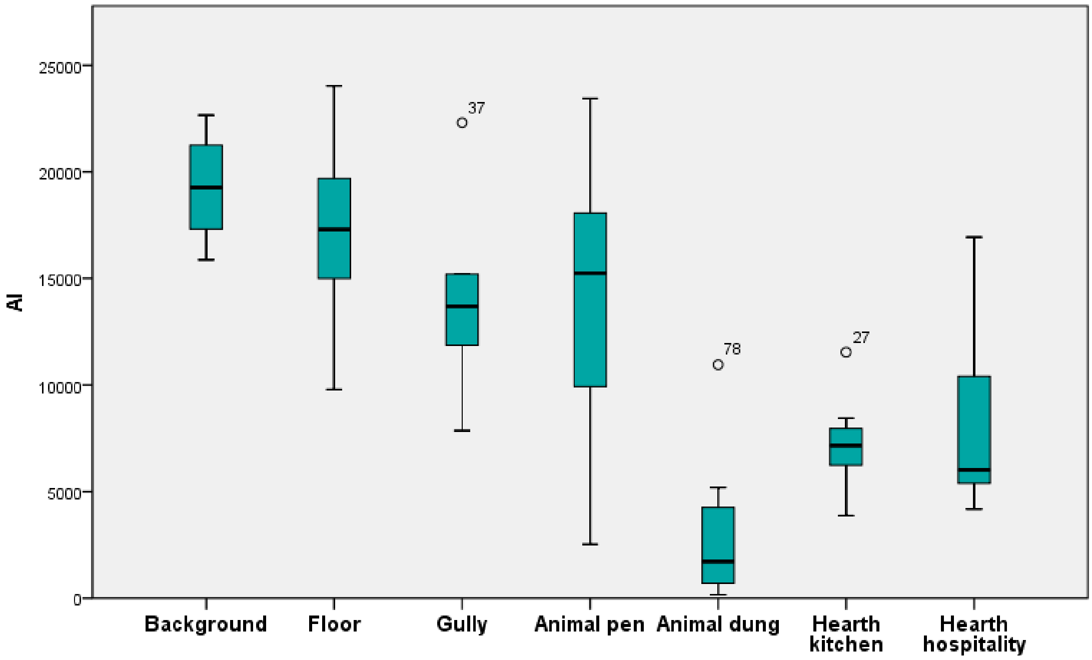


Figure 7.81. Levels of Aluminium per context in PPM, WF sites.

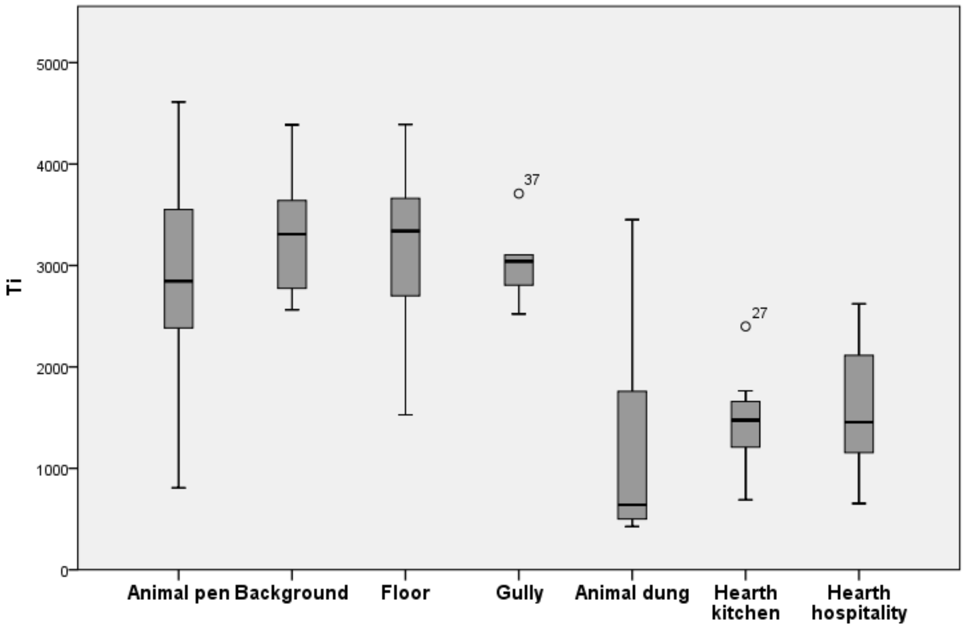


Figure 7.82. Levels of Titanium in PPM per context, WF sites.

7.2.8.1 Patterns through time at the Wadi Faynan sites

The concentrations of individual chemical elements were plotted in each of the campsites in order to detect differences in these among the sites, which could indicate change over time through taphonomic processes or alternatively a variation in anthropogenic input. The graphs in figures 7.83. – 7.85. show the mean concentration of each element per context category, and the mean concentration of each element for all context categories across the sites is shown in figure 7.86. The campsites are positioned on the graphs according to their duration of abandonment at the moment of sampling, from the most recently abandonment on the left to the longest length of abandonment on the right. While most chemical elements do not portray clear differences among the campsites, there seems to be a reduction over time in K and Cl levels. The largest depletion of K in WF982, which was abandoned for the longest period, is mainly related to contexts with high anthropogenic input; the animal related contexts and hearths. The reduction in Cl levels can be seen in all activity areas across sites. An opposite trend is observable in the concentrations of Si, an element which is abundant in the background, floor and gully categories, which have higher concentrations of Si in the campsites abandoned for longer durations of time. JTW portrays higher concentrations of P and lower amounts of Al than the other sites, which probably reflects strong anthropogenic enrichment resulting in a depletion of the background material due to the relative measurement level – PPM.

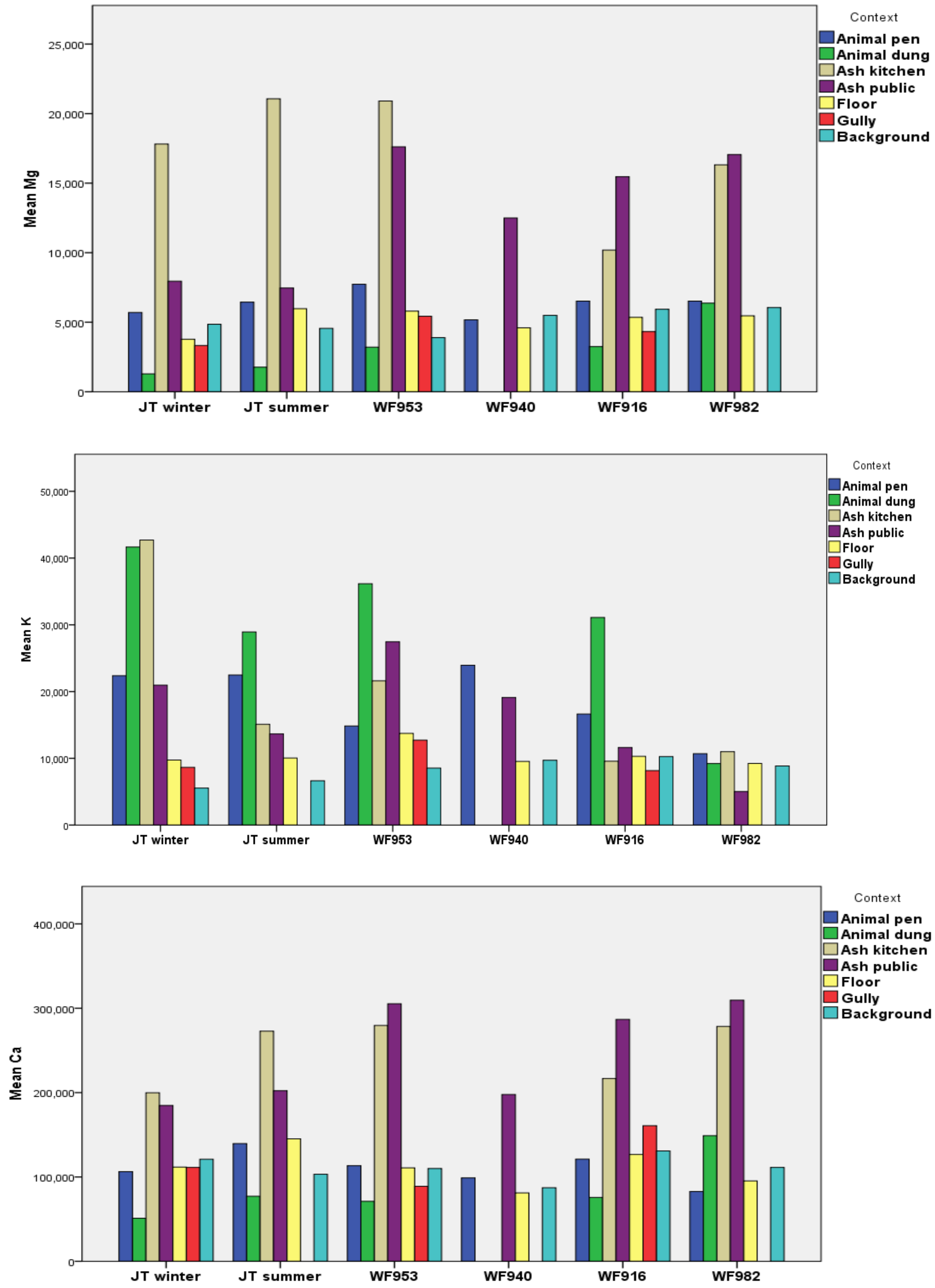


Figure 7.83. Mean concentration of Mg, K and Ca per context for each of the Wadi Faynan campsites.

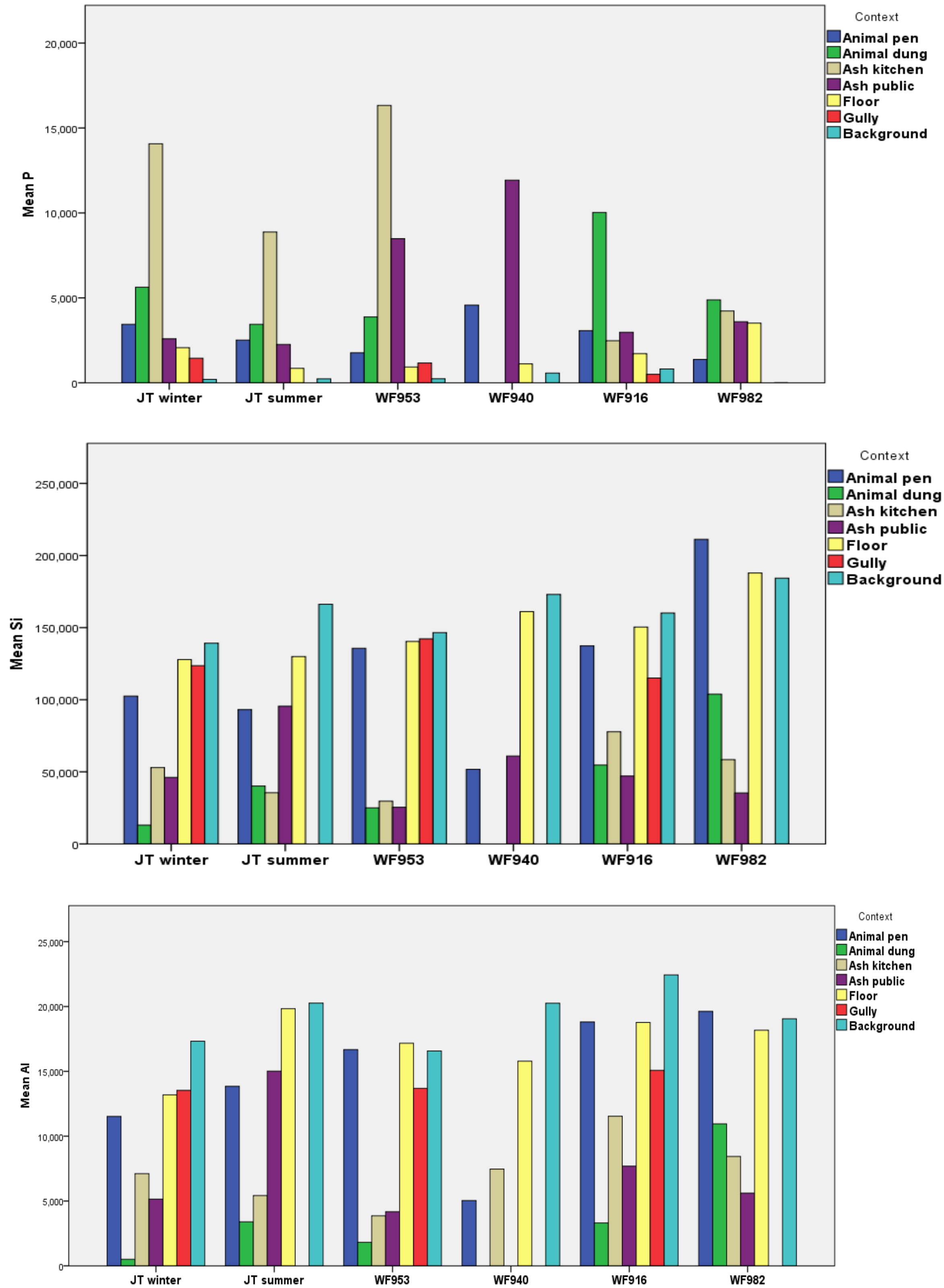


Figure 7.84. Mean concentration of P, Si and Al per context for each of the Wadi Faynan campsites.

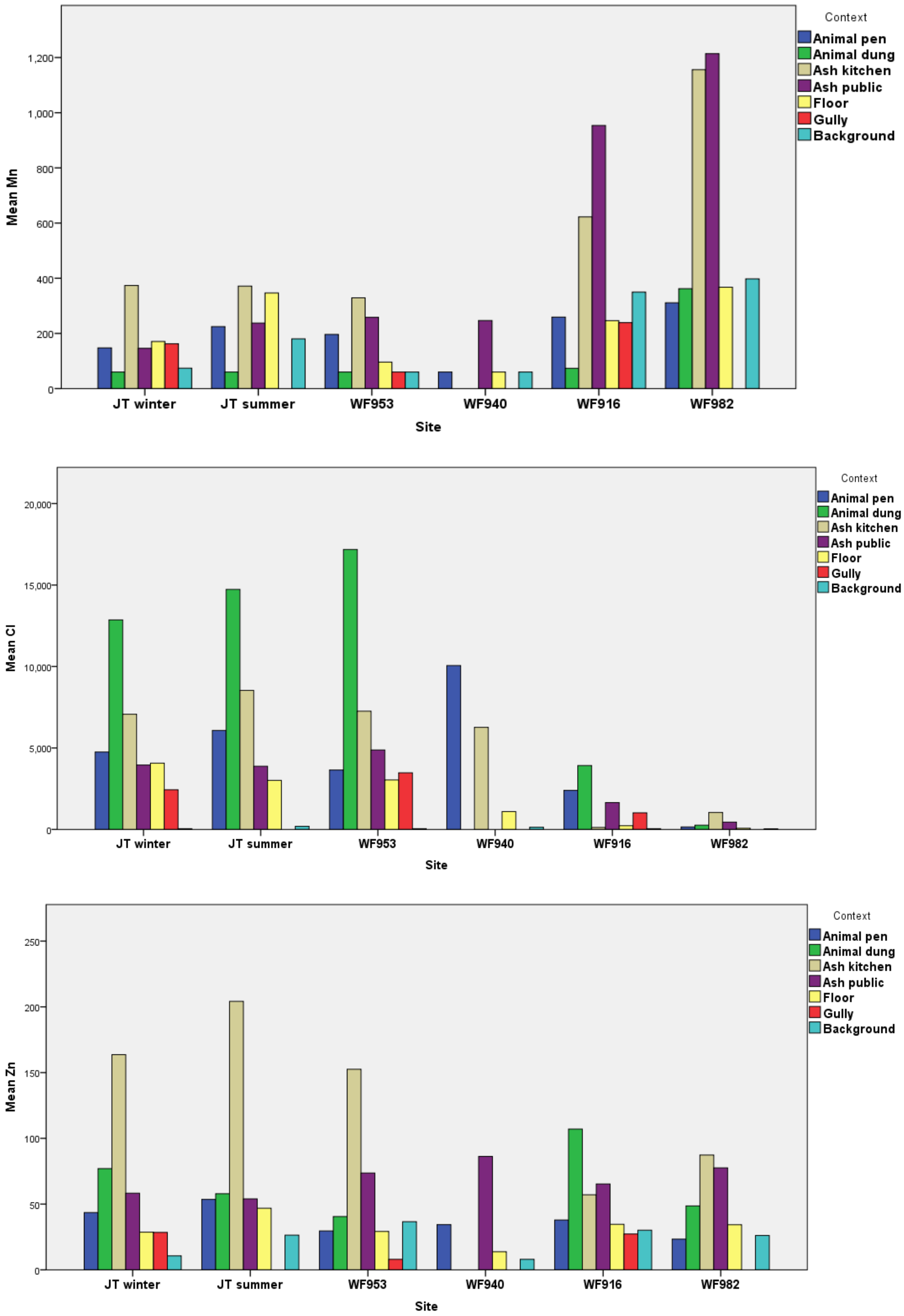


Figure 7.85. Mean concentration of Mn, Cl and Zn per context for each of the Wadi Faynan campsites.

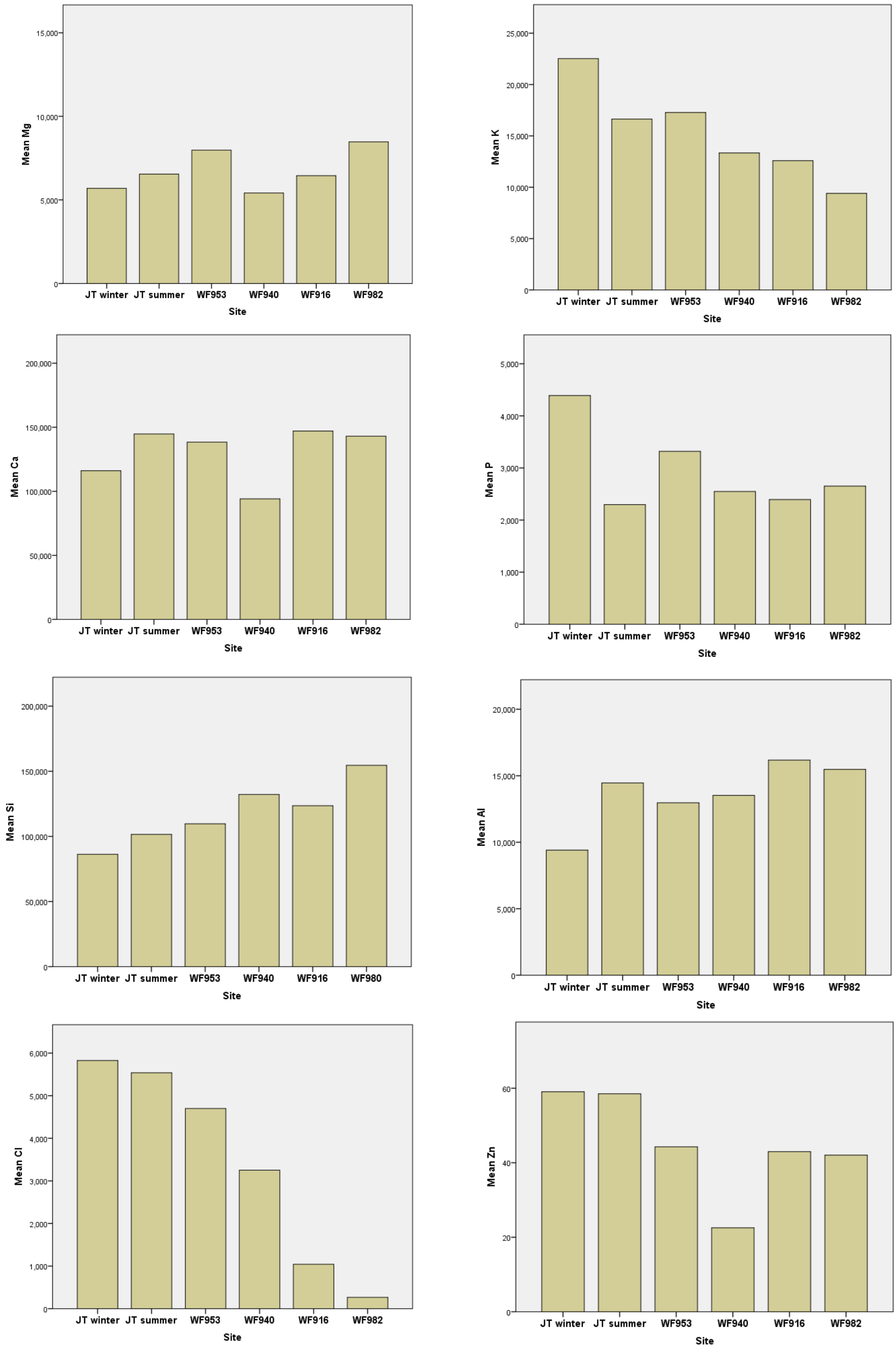


Figure 7.86. Mean concentration of Mg, K, Ca, P, Si, Al, Cl and Zn for each of the Wadi Faynan campsites.

7.3. Analysis of archaeological sites

7.3.1. Wadi el-Jilat 13 (WJ13)

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 (figure 7.87.). However, the anthropogenic input is better represented by the second, third and fourth components. Scatterplots combining these three factors show a clustering of the bedrock features, hearths, and to a certain degree also the deposits and activity areas (figures 7.88., 7.89.). The main elements that drive the second, third and fourth components are P, Mg, Cl, Mn, Zn, Ba, Ca, Cr, Sr and S negatively. P levels are increased in all anthropogenic contexts in comparison to the background samples, noticeably mostly in the posthole samples (figure 7.90.). This could be explained by leaching of P downwards, but then one would expect to see a similar pattern in the other WJ sites, which is not the case. There is a very slight elevation of K and Mg in the hearths (figures 7.91., 7.92.), and of Mn in activity areas (figure 7.93.).

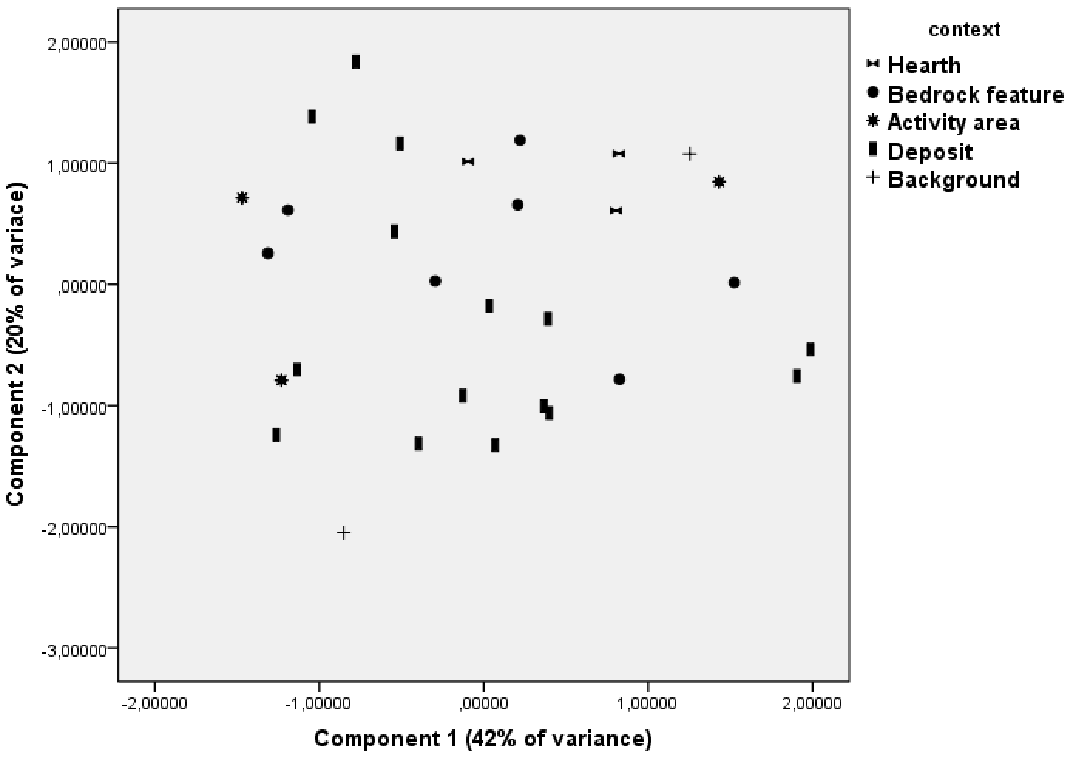


Figure 7.87. PCA scatterplot, WJ13. The first component is driven by Ti, Si, Fe, K, Al, Zr and Nb. The second component is driven by Mg, Ba, Sr and Ca.

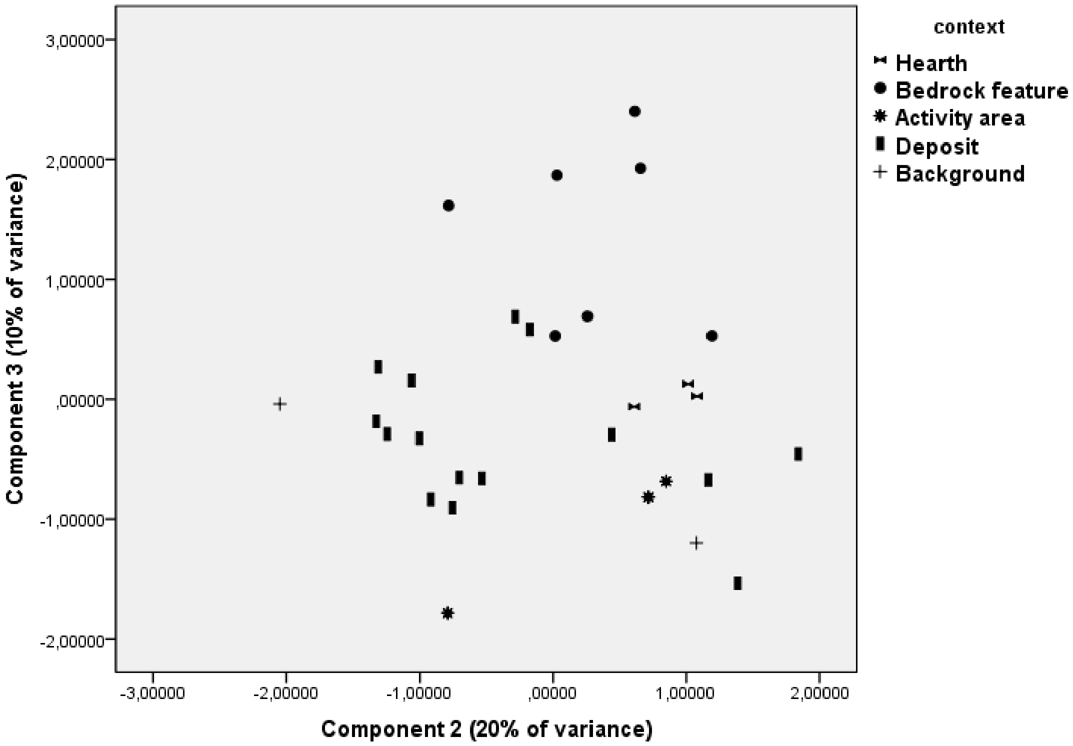


Figure 7.88. PCA scatterplot, WJ13. The second component is driven by Mg, Ba, Sr and Ca. The third by Cr, P, Rb, Cl and negatively by V.

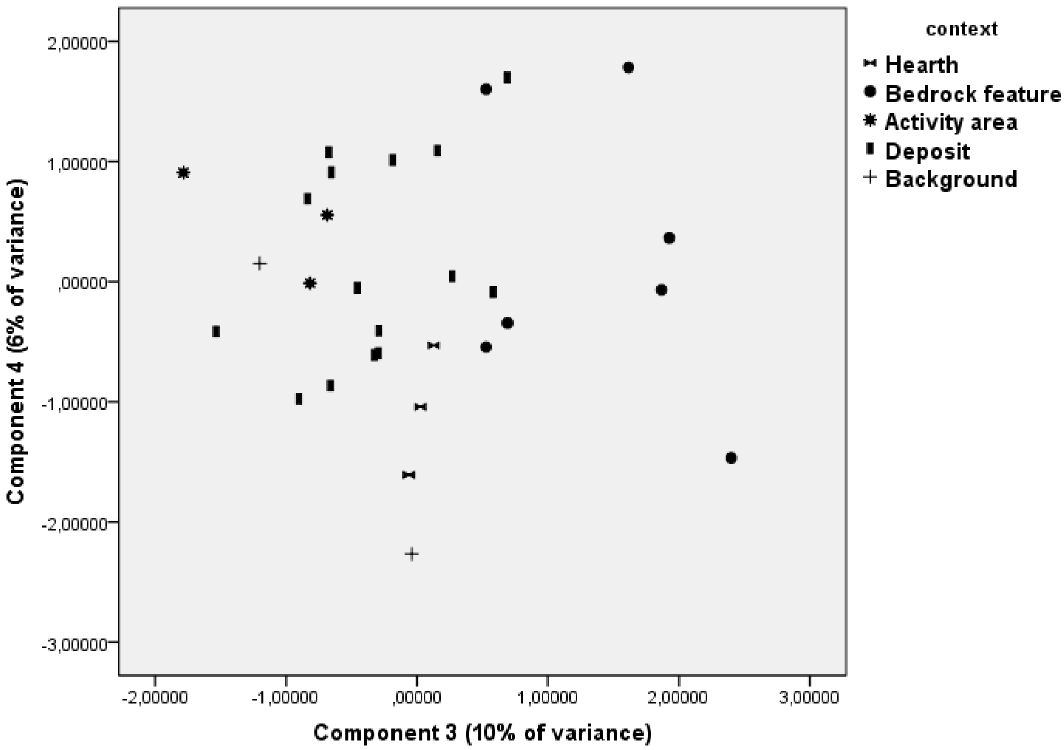


Figure 7.89. PCA scatterplot, WJ13. The third component is driven by Cr, P, Rb, Cl and negatively by V, the fourth by Mn, V, P, Zn and Cl.

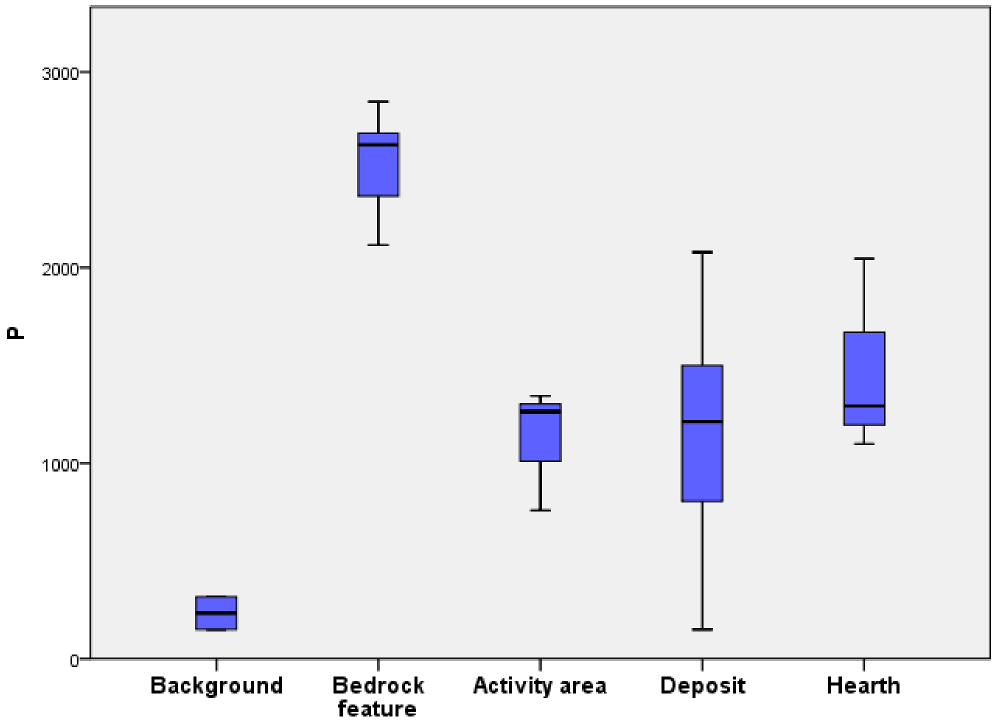


Figure 7.90. Phosphorus levels in PPM per context, WJ13.

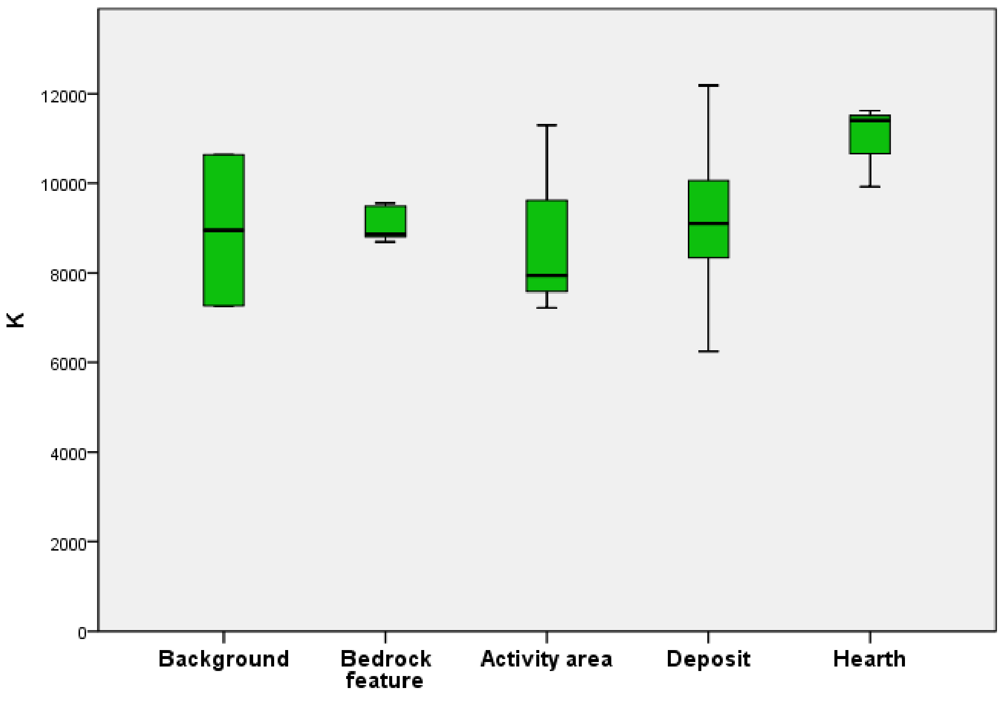


Figure 7.91. Potassium levels in PPM per context, WJ13.

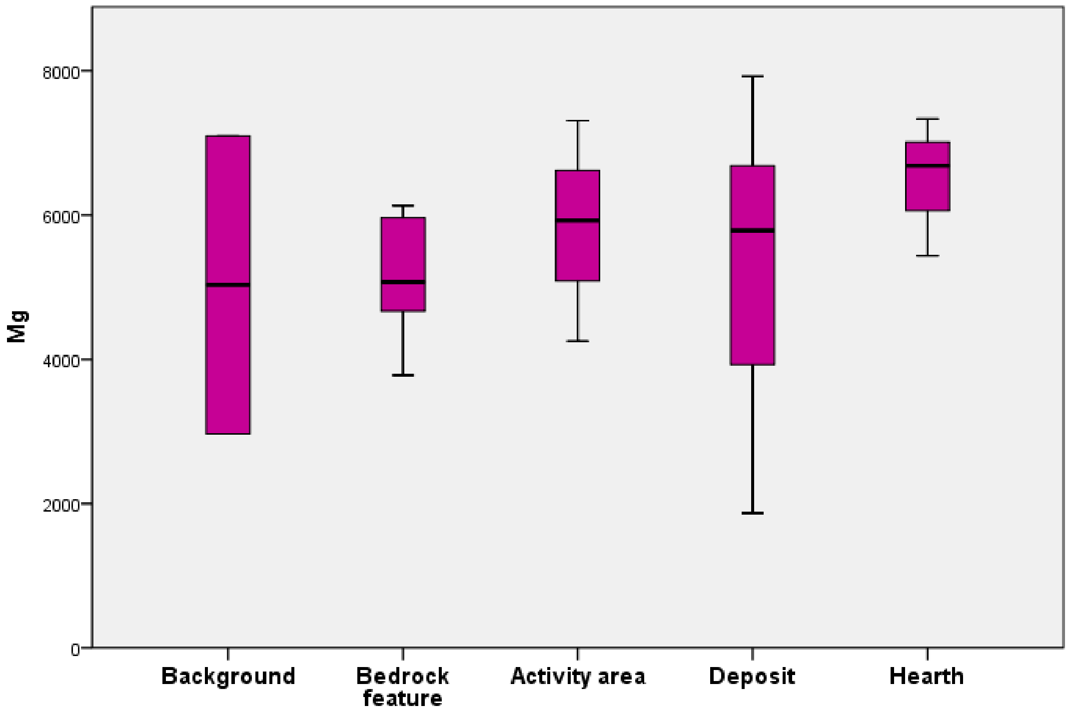


Figure 7.92. Magnesium levels in PPM per context, WJ13.

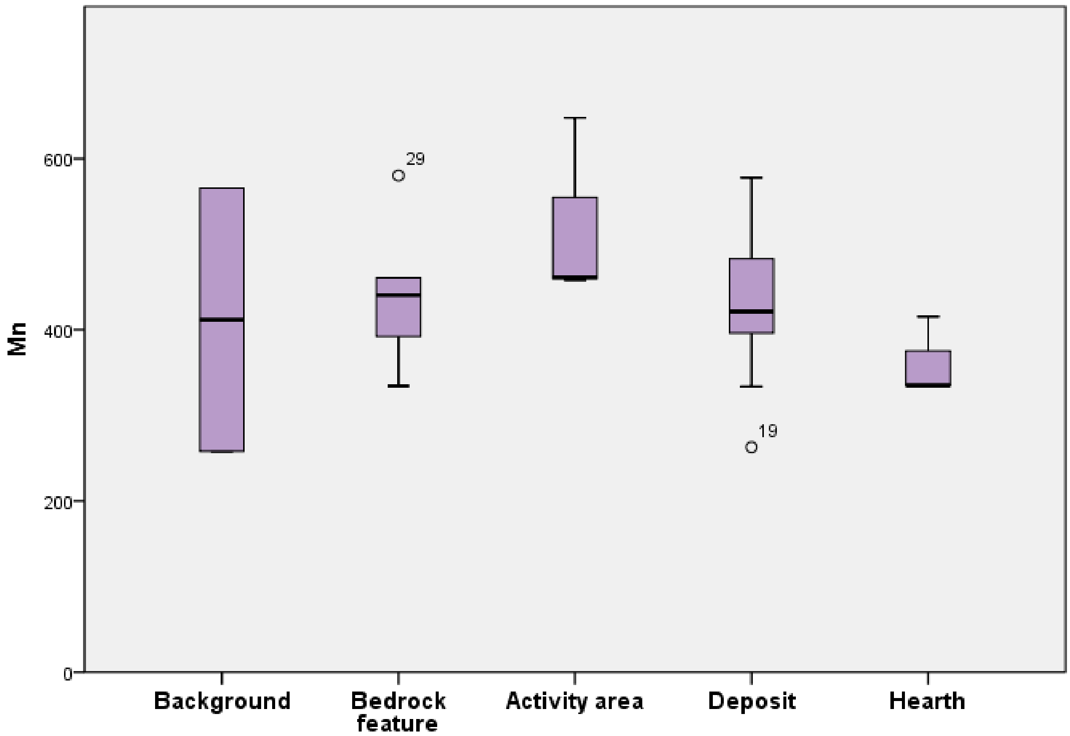


Figure 7.93. Manganese levels in PPM per context, WJ13.

7.3.2. Wadi el-Jilat 7 (WJ7)

When looking at the distribution of the levels of individual elements among the contexts of WJ7, most do not appear to show remarkable trends. Generally, the context category that is most different 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 aspects. Bedrock features at WJ7 had the lowest levels of Mg, K and P, yet the highest amount of S (figures 7.95. – 7.98.). 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 (figure 9.98.). Nevertheless, the PCA scatterplot below (figure 7.94.) reveals that overall, samples in the same context category do cluster and that all categories vary significantly from the background sample.

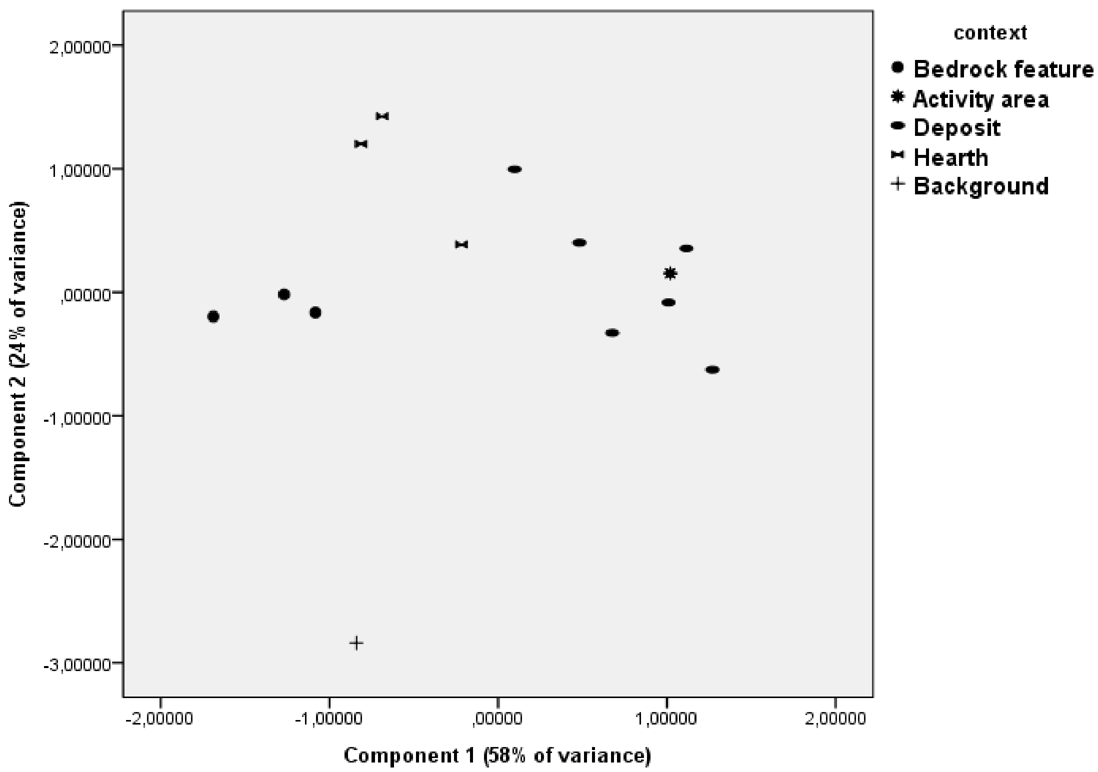


Figure 7.94. PCA scatterplot, WJ7. The first component is driven by Mg, Si, Ti, Fe, S, Zr, K and P, and the second component by Ca, Sr and Rb.

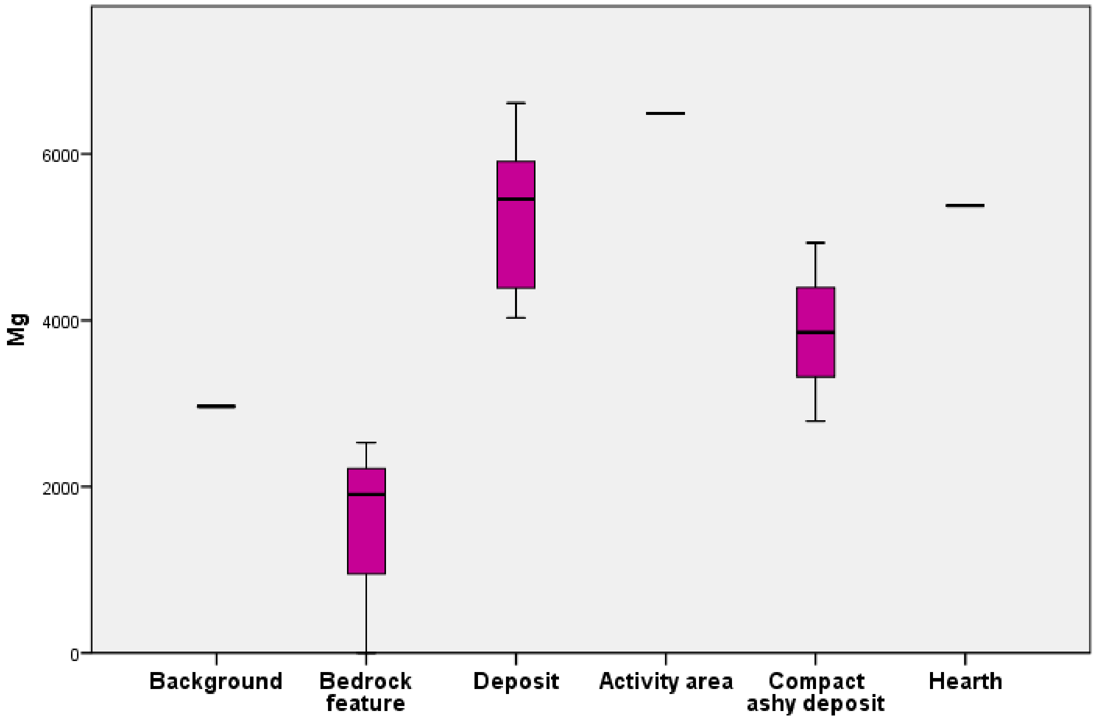


Figure 7.95. Magnesium levels in PPM per context, WJ7.

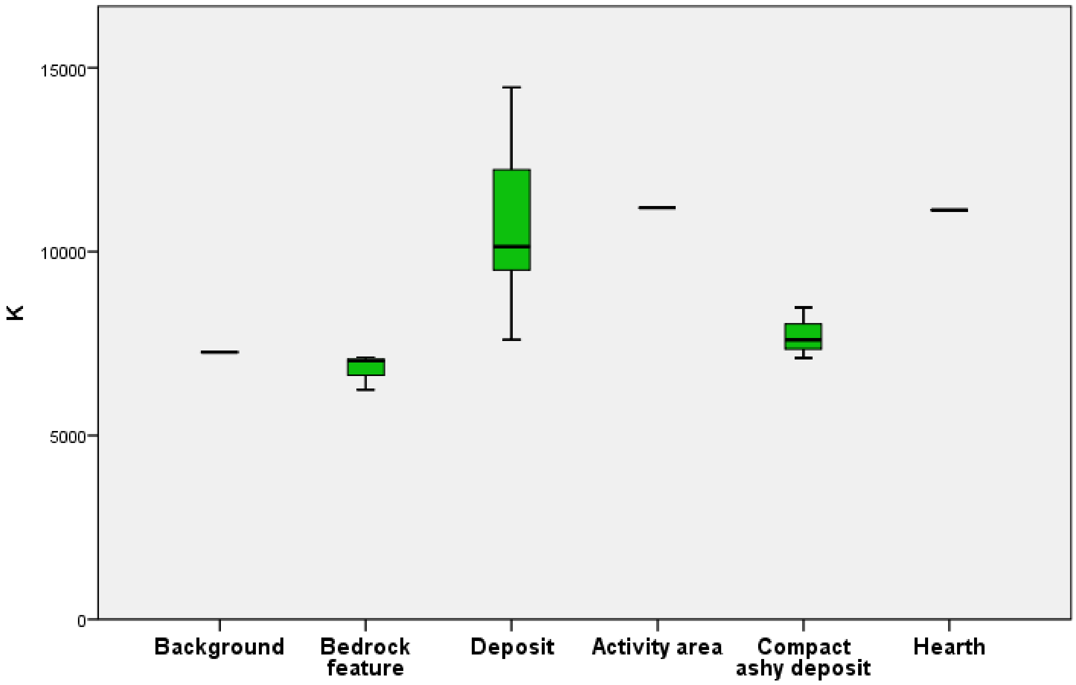


Figure 7.96. Potassium levels in PPM per context, WJ7.

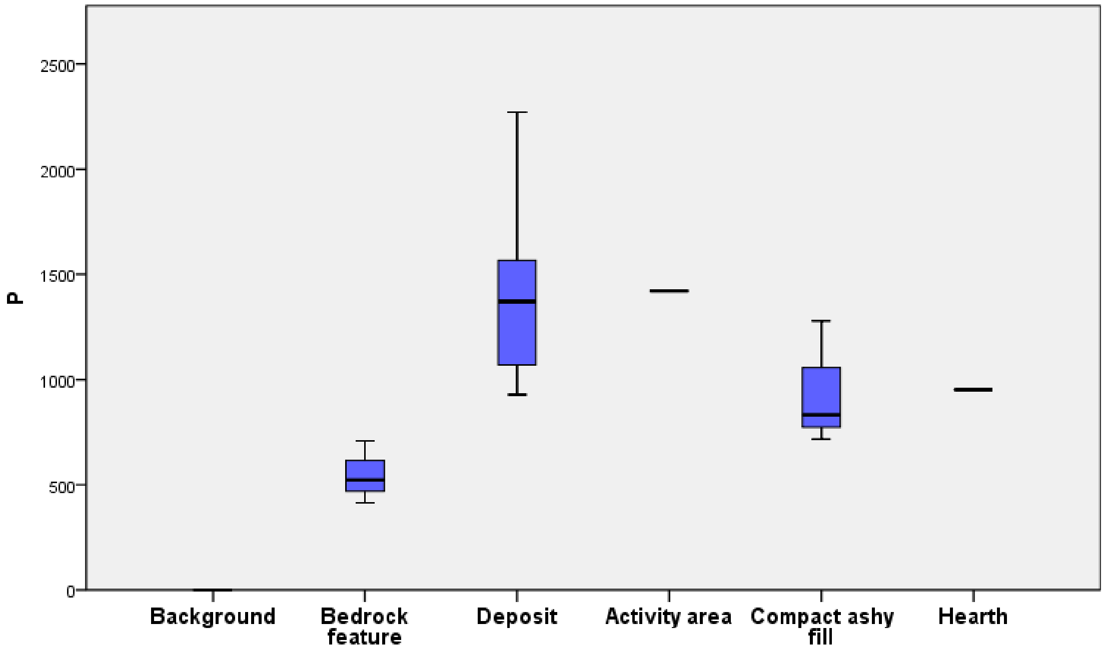


Figure 7.97. Phosphorus levels in PPM per context, WJ7.

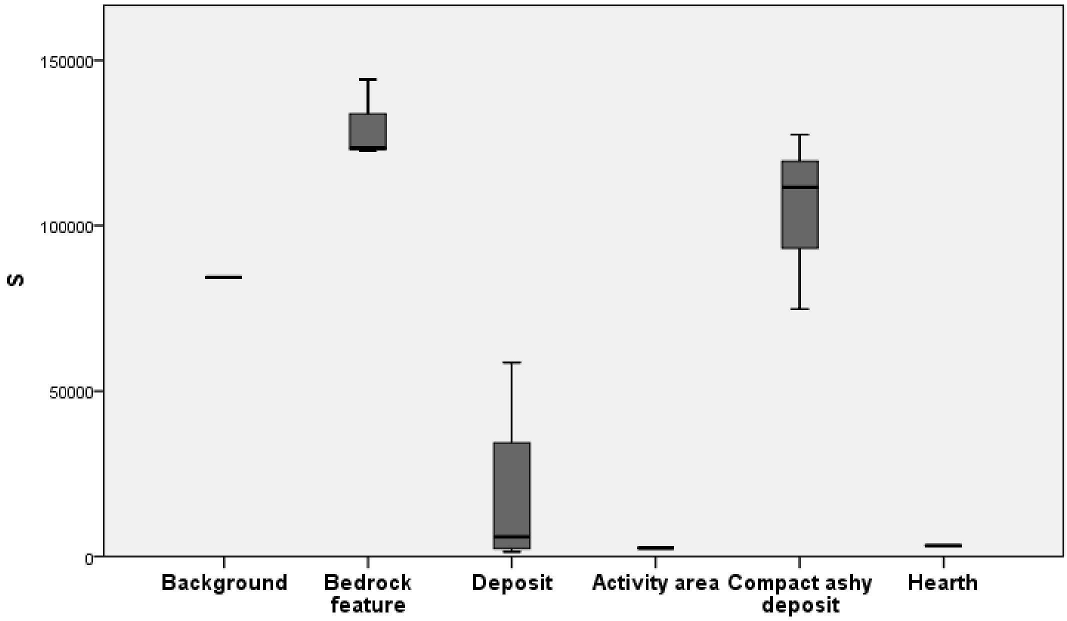


Figure 7.98. Sulphur levels in PPM per context, WJ7.

7.3.3. Wadi el-Jilat 26 (WJ26)

The three areas of WJ26 analysed in this research are substantially different from each other, and the samples that were available for each area represent the activities typical for that location. And so, although the PCA scatterplot below shows clustering of samples from the same context, this reflects to a certain degree the differences between the three sub-sites, which cluster according to area (figures 7.99. – 7.100.).

Nevertheless, it is clear that context-related divergence plays a role within WJ26. The three compact deposits samples of area C plot differently to the single hearth, and the fills of area E cluster together with the area A deposits, separately from the hearths of area E. This clustering disappears when the first component is combined with the third (figure 7.101.), which is driven by P and Sr. Perhaps these elements represent here a more general signal of human activity, or are more soluble than the ones driving the second factor. As has been mentioned previously (section 4.6.), the background samples for the WJ sites are problematic, and while one plots differently to the Neolithic samples, the other falls within the hearth cluster.

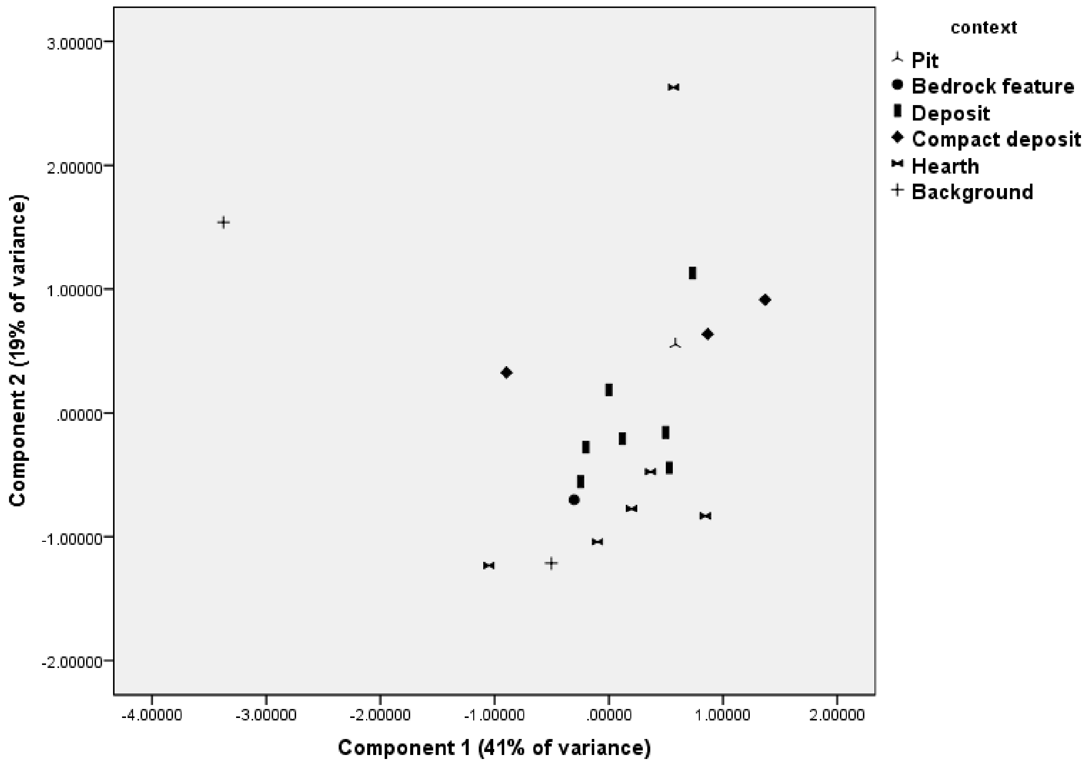


Figure 7.99. PCA scatterplot, WJ26. The first component represents Si, Ti, Al, Fe and Nb, the second is driven by Cr, S, Zn, V and negatively by Mn and Ba.

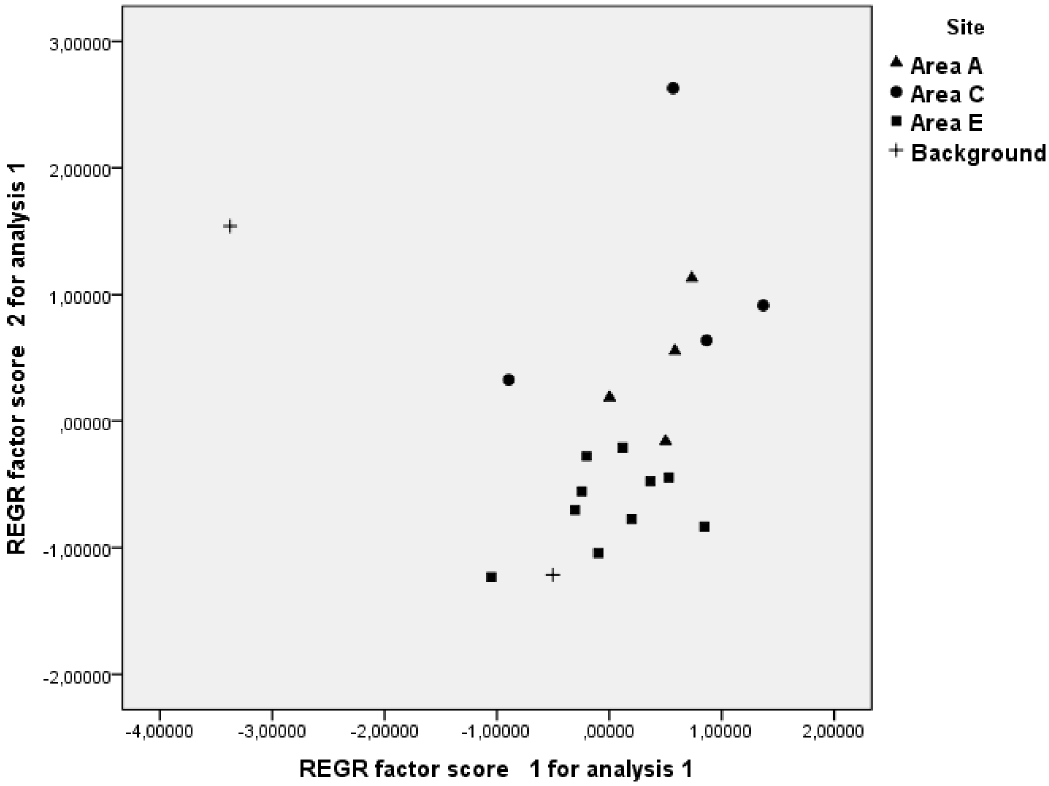


Figure 7.100. PCA scatterplot, WJ26. This graph is similar to the one shown in the previous figure, but rather than the context, the markers represent the three areas in WJ26: A, C and E.

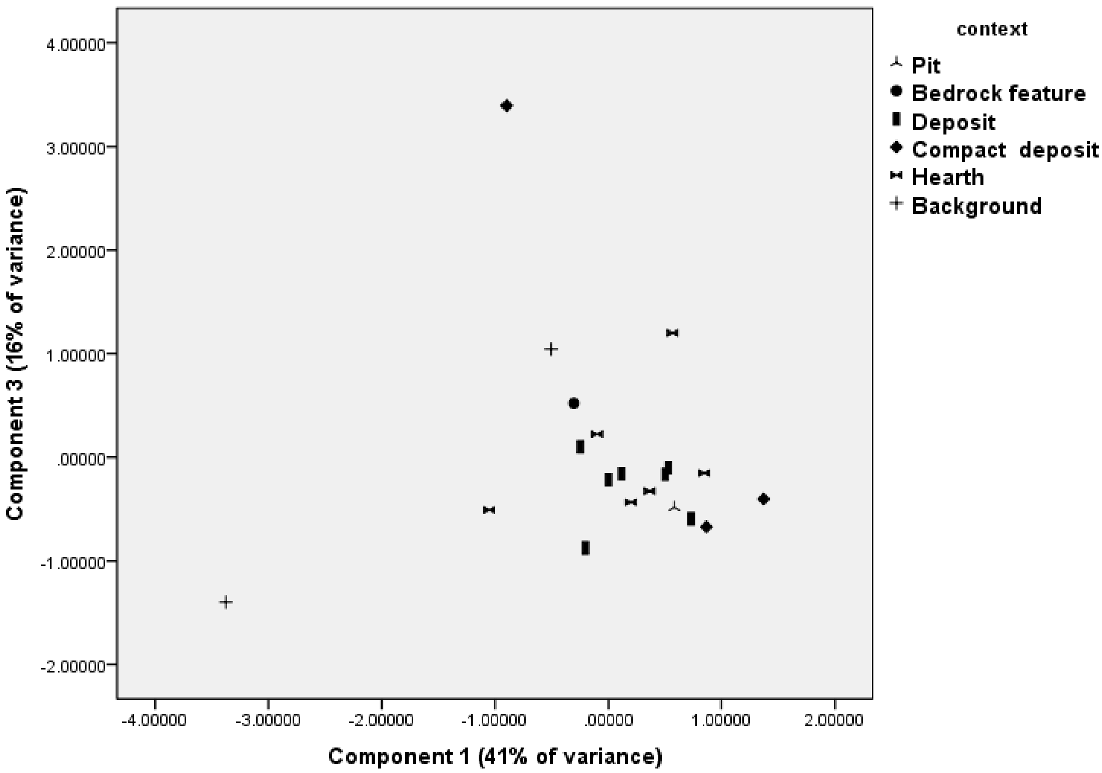


Figure 7.101. PCA scatterplot, WJ26. The first component represents Si, Ti, Al, Fe and Nb, the third is driven by P and Sr.

7.3.4. General patterns Wadi el-Jilat sites

The PCA analysis differentiated three main factors, the first driven by Si, Ti, Fe, Al, Nb, K, Zr, Mg and negatively by Ca, the second by Sr, P, Zn and negatively by Rb, and the third by Zn, Cl, P and negatively by Ba. Plotting the first two components shows a certain clustering of hearth fills and most of the compact ashy fills on one side of the second component, and about half of the postholes to the other side of the second component (figure 7.102.). This pattern becomes clearer when plotting the first and third components. One of the background samples plots significantly different from the Neolithic samples, while the other plots similarly to the postholes (figure 7.103.).

The Neolithic samples have higher levels of P, Mg, Mn, Cl, and K than the background samples. The quantities of these elements vary both within the context categories and between sites (figures 7.104. – 7.108.). Postholes present the most variation across sites, with Mg levels high in WJ13 and WJ26 while lower in WJ7, and P amounts low in WJ7 and WJ26 postholes while highest in WJ13. The levels of P, Cl and K vary between sites in the 'fill' category, WJ26 fills containing lower levels of P yet larger amounts of K, and WJ7 fills producing the lowest readings of Cl. It is unclear if these discrepancies are influenced by the difference in the location of the individual sites, or if they represent a variation in anthropogenic input.

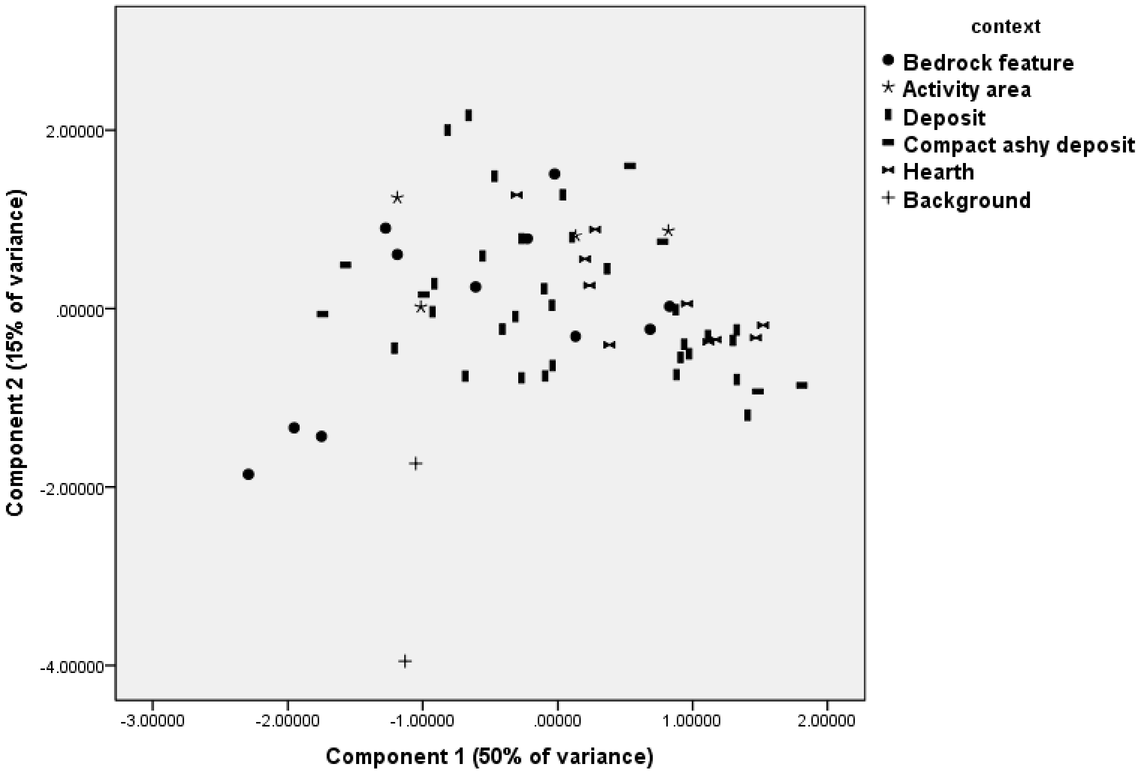


Figure 7.102. PCA scatterplot, WJ sites. The first component is driven by Si, Ti, Fe, Al, Nb, K and Zr. The second component is driven by Sr, P, Ca and negatively by Rb.

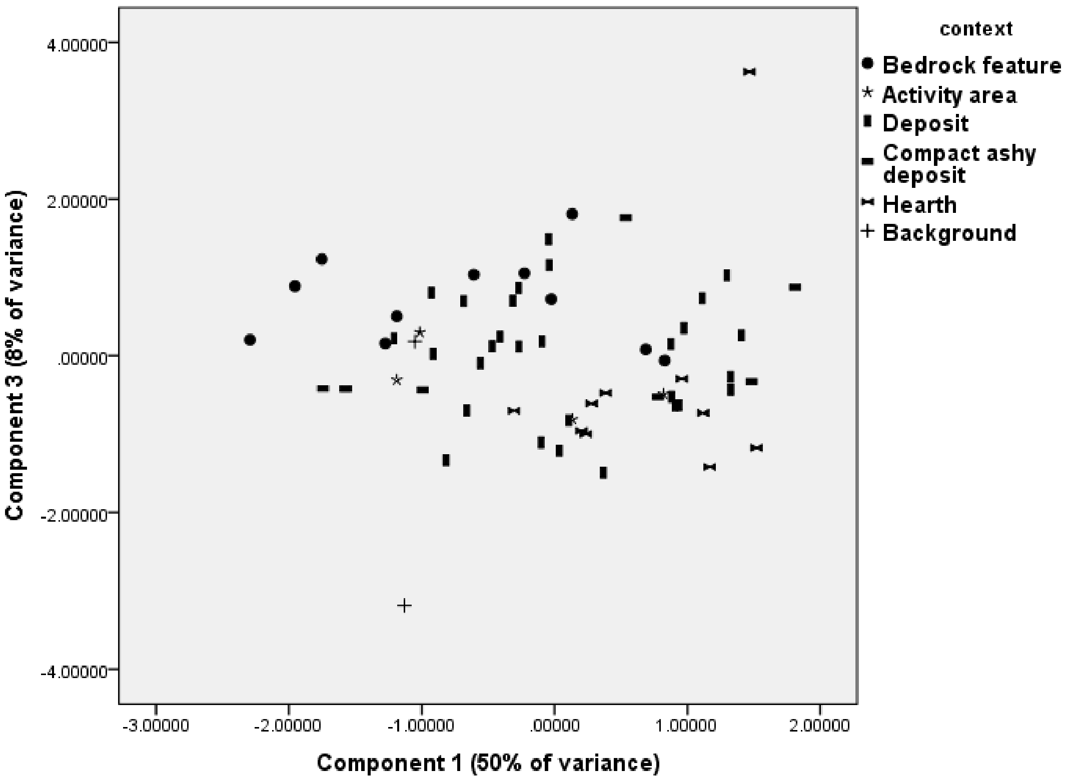


Figure 7.103. PCA scatterplot, WJ sites. The first component is driven by Si, Ti, Fe, Al, Nb, K and Zr. The third component is driven by Zn and Cl.

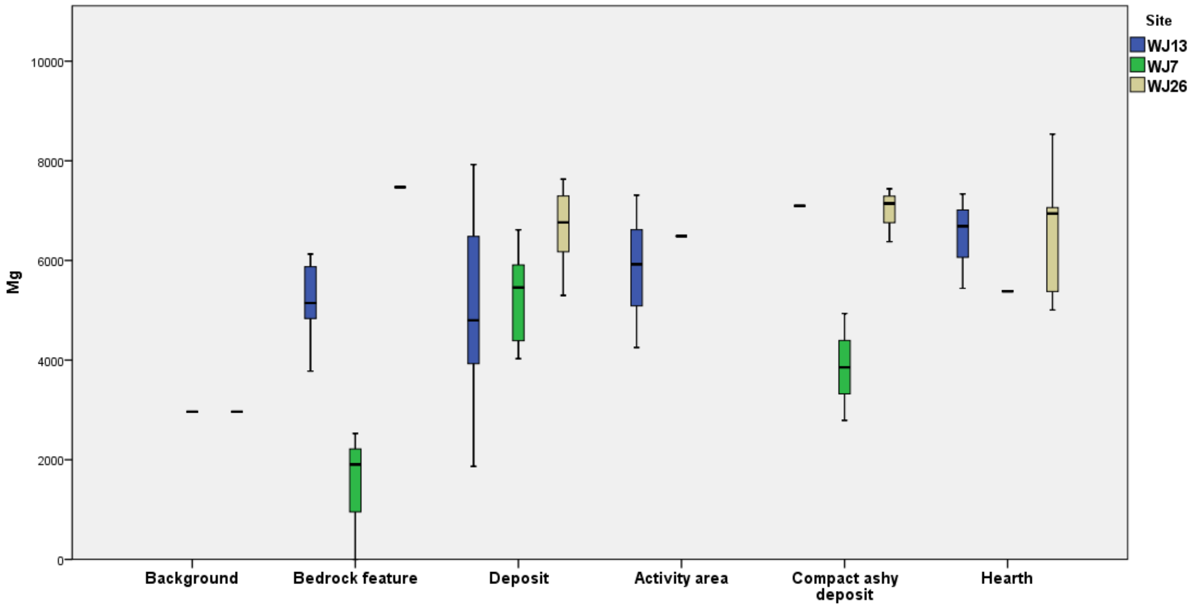


Figure 7.104. Magnesium levels per context for each site, WJ sites.

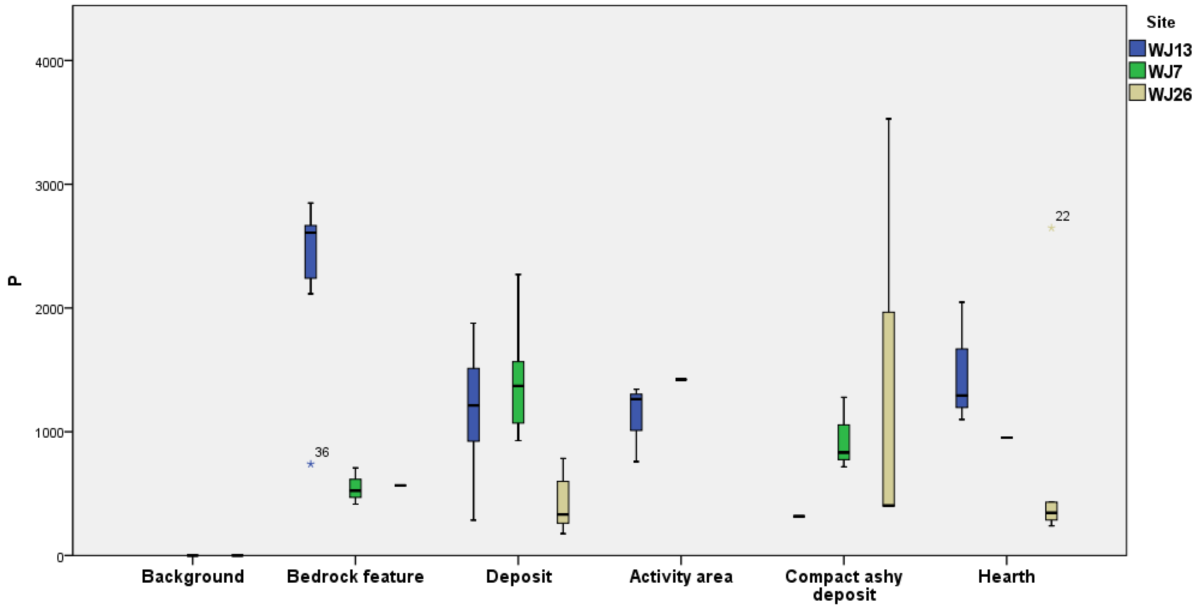


Figure 7.105. Phosphorus levels per context for each site, WJ sites.

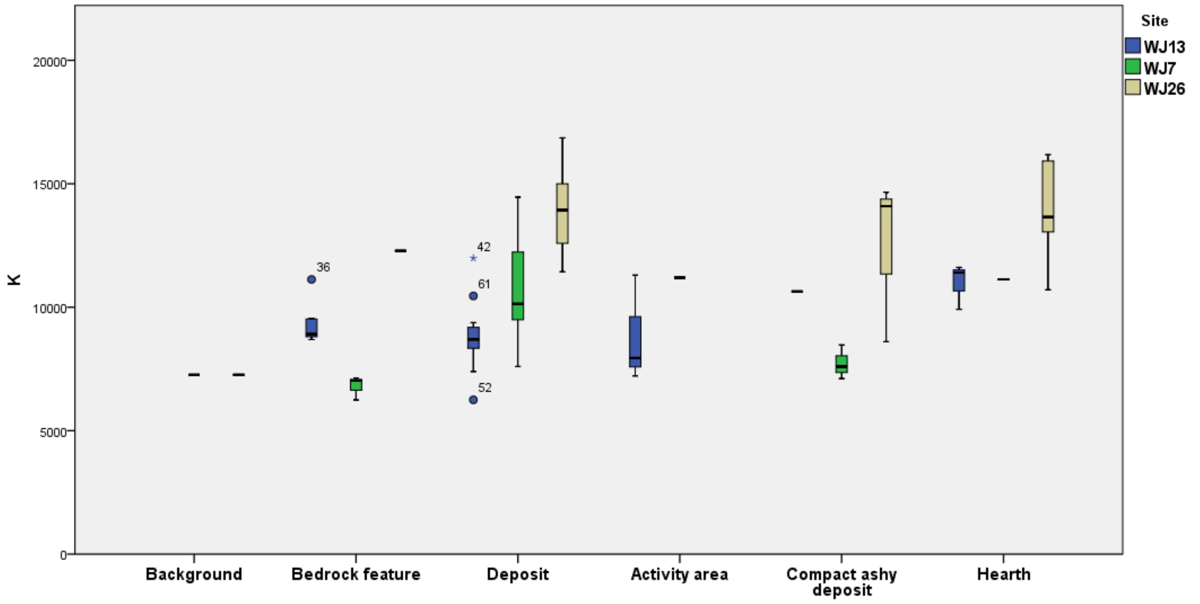


Figure 7.106. Potassium levels per context for each site, WJ sites.

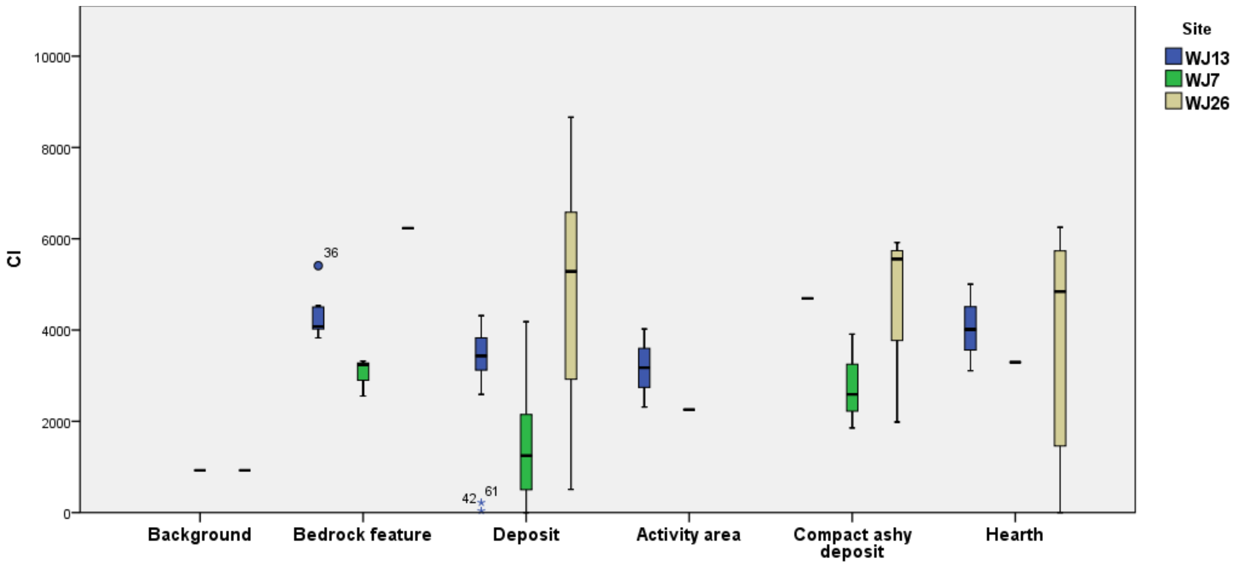


Figure 7.107. Chlorine levels per context for each site, WJ sites.

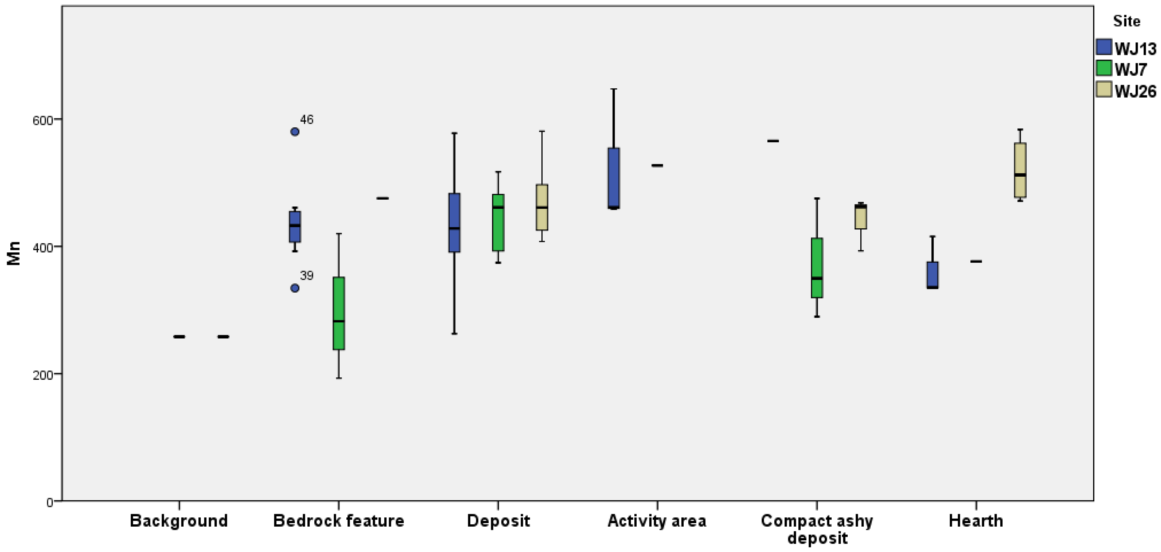


Figure 7.108. Manganese levels per context for each site, WJ sites.

7.4. Discussion

The geochemical analysis of the various ethnographic sites, both individually and as groups, has revealed that geochemistry is a powerful tool for uncovering anthropogenic patterns of spatial behaviour at these kinds of sites. As in the case of the phytolith analysis, PCA displays the results in the best way, allowing for patterns to be seen that would not be as clear when looking at individual element graphs. The latter are more useful in identifying specific patterns, such as the high levels of P in postholes in the case of WJ13. The PCA scatterplots allow for an examination of the clustering of the data, which implies how well the geochemical patterns correlate to the known activity areas in the ethnographic sites and context categories identified in the field at the Neolithic sites.

The elements that represent anthropogenic activities best are P (general), Mg, K, Ca, Zn (mainly hearths), Cl (dung through urine input), Mn and S, although the most determinant of these will be variable for each individual site. The background elements, Al, Ti, Fe, Zr and Si, are often the main driving force behind the variance seen in the PCA in the analysis of these ephemeral sites. They can also fall together with elements representing anthropogenic input (such as P and Mg) within the same factor, as a negative contribution. Patterns of enrichment and depletion are characteristic of anthropogenic sites. These are apparent when samples are studied as a whole, and context categories are compared within a site. Since areas with intense anthropogenic input acquire an enrichment of activity related elements, a depletion of the background elements occurs.

8 Combined trends for activity areas

8.1. Introduction

The previous two chapters discussed the results of the phytolith and geochemical analyses separately on the basis of each site, later combining the ethnographic and the Neolithic sites as two groups. This chapter will combine the geochemical and phytolith results to look at more general trends in relation to the defined context categories. Each context category was considered to reflect a certain activity at the time of sampling, and was defined according to observations in the field. The suitability of these definitions to describe each context category and their associated characteristic soil signatures will be discussed in the following sections, considering findings made in earlier studies (described in Chapter 2).

8.2. The use of a dual methodology to characterise activity areas

8.2.1. Is there a need for a dual methodology?

The main aim of this research is to assess the potential of a dual phytolith and geochemical methodology for the identification of soil signatures of activity areas in archaeological ephemeral sites. Part of this aim concerns the compatibility between the two methods, phytolith analysis and geochemistry. Is each activity represented by a specific phytolith and geochemical signature, or are some only detectable using one of the analyses? Do they point towards the same patterns, or different trends? Are each of these analyses sufficient in identifying activity areas alone, or are they more useful used together?

When looking into the site specific patterns discussed in the sixth and seventh chapters, it appears that certain phytolith variables can clearly distinguish between some of the context categories, but that these trends are site dependent. The geochemical elements influenced by anthropogenic activity, however, are less affected by site conditions and most are repeated in every ethnographic site. While the geochemical trends in the Neolithic site are less universal, some of the patterns seen in the ethnographic data are also present within the Neolithic sites, such as the enrichment in Mg and K in the hearths of WJ13. Therefore, it appears that the phytolith data have a larger site effect than the geochemical analysis, and can therefore not be used in the same manner. In addition, the various aspects of phytolith analysis are different to the more comparable measurements of chemical elements (see section 6.1.). The results of both types of analysis must be considered in relation to the processes that could have led to their formation and preservation at each of the sites. However, the geochemical patterns can generally be directly correlated to known activities such as burning and food preparation, which are associated with specific elements, while the phytolith trends must be explored within the context of the site since phytoliths derived from activities such as burning or animal husbandry may vary across sites depending on the local availability and use of plants and other materials leading to an indirect phytolith signature (such as the use of dung for construction or fuel - see overview in section 2.2.4.2.).

Decision trees created for the geochemical and phytolith analyses and for the two techniques together suggest that combining the variables from both analyses does not provide a better classification of cases than the geochemistry alone. The latter was able to classify 77% of cases correctly within the ethnographic cases and 70% within the Neolithic sites when excluding the context categories "activity area" and "compact ashy fills" (figures 8.5., 8.16.). The phytolith decision trees classified a third of the ethnographic cases and 45% of the Neolithic samples correctly (when excluding the context categories "activity area" and "compact ashy fills", figure 8.27.). In addition, the PCA scatterplots created for the geochemical data from both the Wadi Faynan and Wadi el-Jilat sites generally showed a better degree of clustering than the PCA scatterplots presenting the phytolith analysis results, and explained a higher degree of variance (see Chapter 6 and 7). Decision trees combining variables from the geochemical and phytolith analyses achieved 60% correctly classified cases within the ethnographic data, using only one variable from the phytolith analysis, and 41% correctly classified cases within the Neolithic samples (figures 8.1., 8.2.). It appears that investigating a combination of geochemistry and phytolith variables does not add more certainty to the identification of activity areas than considering geochemistry alone.

If the geochemical analysis can provide the best certainty of identification of activity areas, why bother using the phytolith analysis? Although the geochemistry might explain the largest amount of variation within the data, it does not explain all of it. The strength of the phytolith analysis results lies within site specific trends, where they can be used to fine-tune the more general interpretation provided by initial definition of context categories in combination with the geochemical analysis. Adding information from the phytolith analysis will not only be used to strengthen the classifications made through the geochemistry, but to add new ones not visible within the geochemical results. The discriminant analysis scatterplot graphs created for the ethnographic data show how this can work (figures 8.3., 8.4.). While the scatterplot presenting the results of the geochemical analysis exhibits a differentiation between clusters of background and floor samples, animal pen, dung, and hearths, the one created for the phytolith analysis results provides a better separation between the kitchen and hospitality hearths, while the animal pen category plots closer to the floor and background samples.

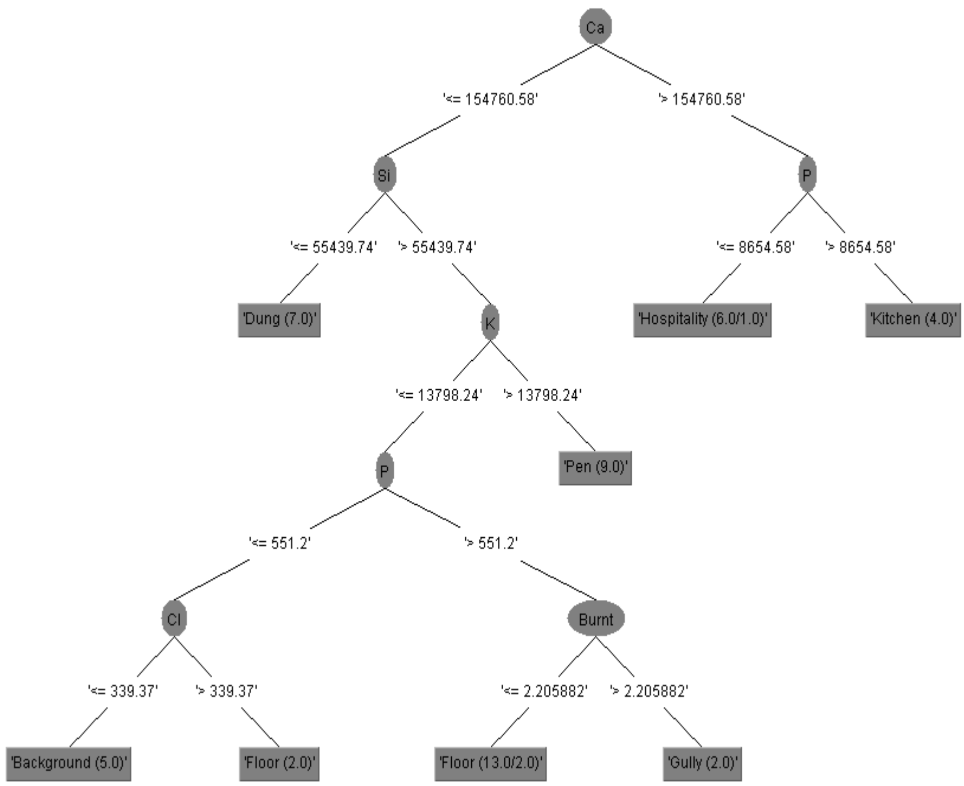


Figure 8.1. Decision tree combining variables from the geochemical and phytolith analyses for the ethnographic sites, 60% of cases correctly classified.

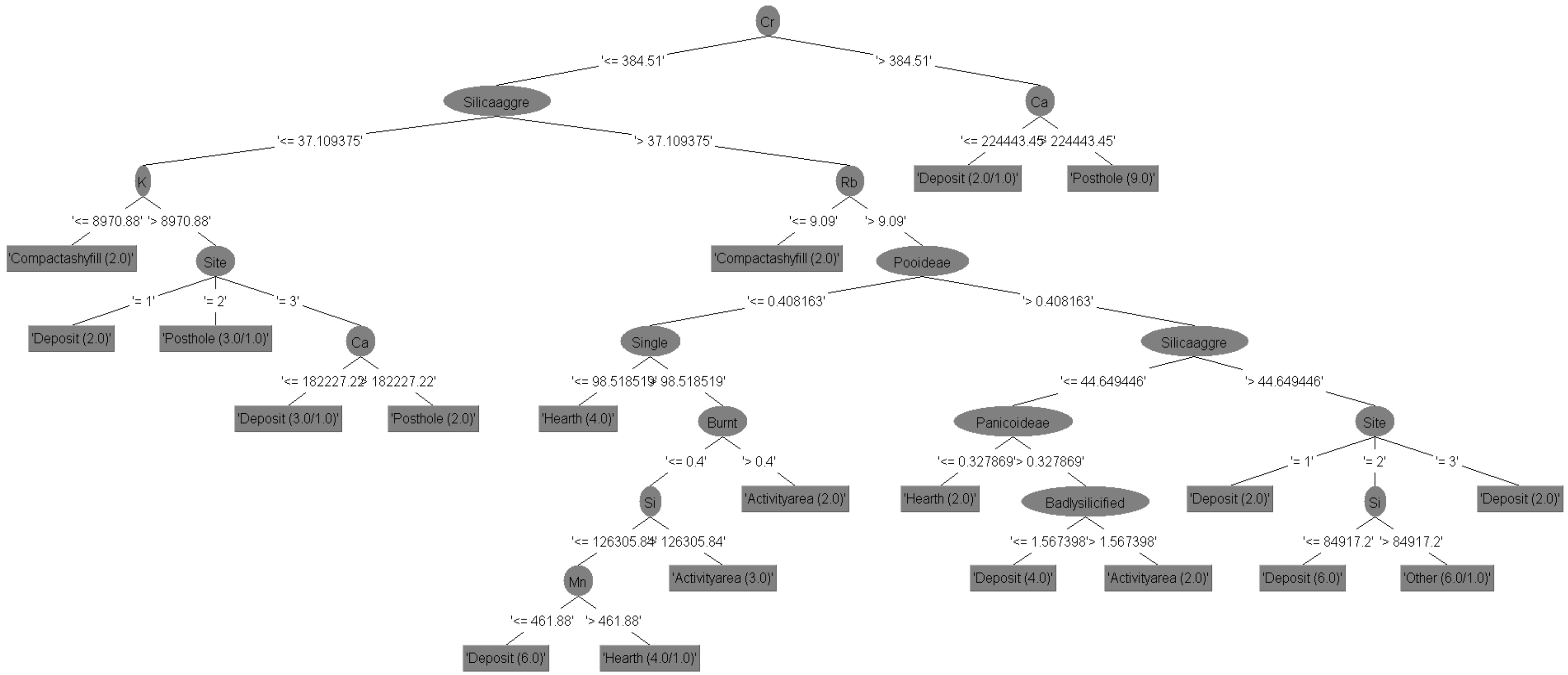


Figure 8.2. Decision tree combining variables from the geochemical and phytolith analyses for the Neolithic sites, 41% of cases correctly classified.

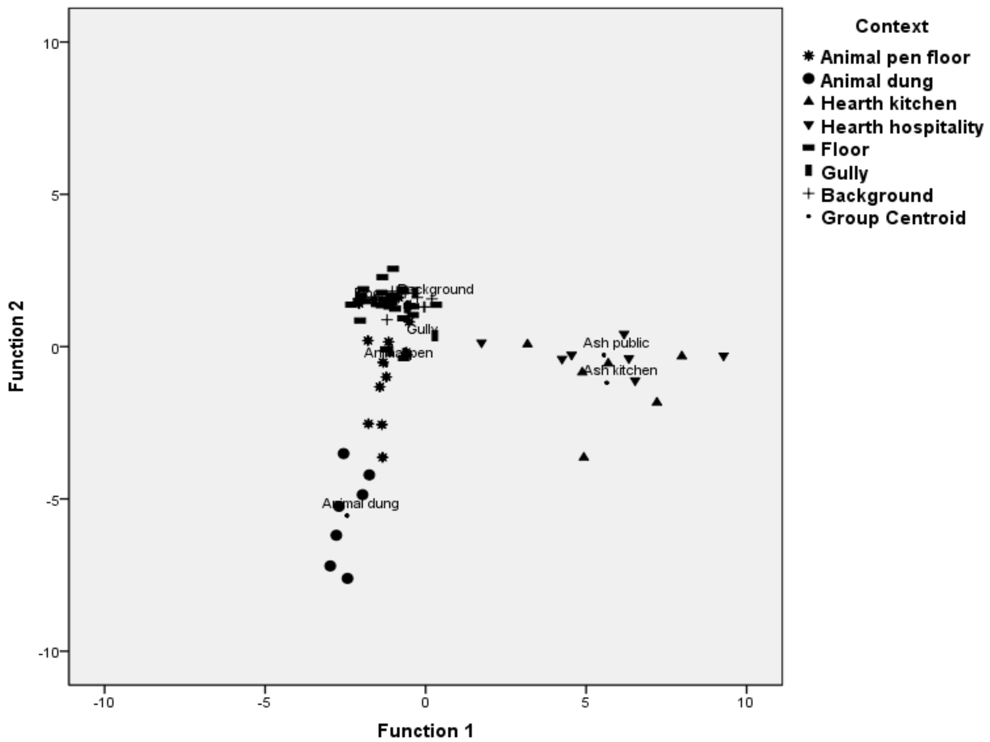


Figure 8.3. Discriminant function analysis scatterplot for ethnographic sites based on results of the geochemical analysis, 78% of original grouped cases and 58% of cross-validated grouped cases correctly classified.

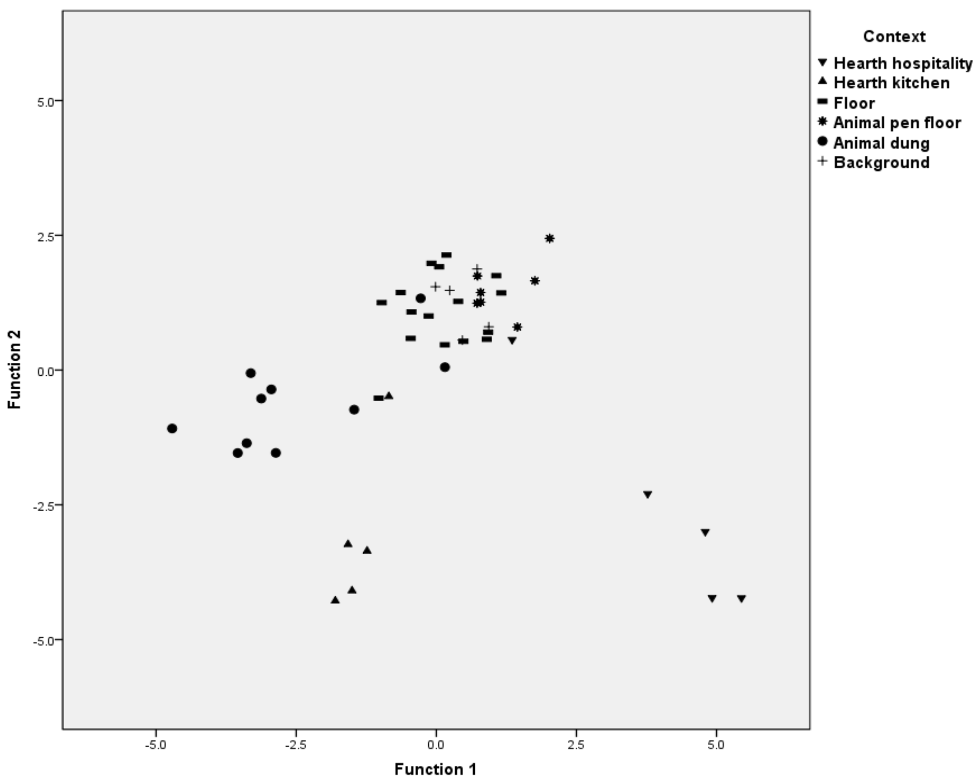


Figure 8.4. Discriminant function analysis scatterplot for ethnographic sites based on results of the phytolith analysis, 73% of original grouped cases and 33% of cross-validated grouped cases correctly classified.

8.2.2. Is there a correlation between geochemical and phytolith soil signatures?

In order to understand how the two analysis techniques can work together to indicate activity areas it is necessary to first estimate the degree of correlation between geochemical and phytolith soil signatures. In the case of a strong correlation one could realise specific, combined geochemical and phytolith signatures for each activity. A partial correlation would mean that some of the patterns of enrichment and depletion within the geochemical and phytolith assemblages occur together. A third scenario is the lack of correlation, where geochemical and phytolith trends are unrelated.

A two tailed Pearson correlation test revealed no strong correlations between any of the geochemical and phytolith variables for the Neolithic sites (Appendix 6). No correlation between geochemical and phytolith trends were observed across the Neolithic sites through the examination of the context categories in Chapter 8 either. This could either mean that there is no correlation between geochemical and phytolith soil signatures at the Neolithic sites, or that preservation, taphonomic issues or site specific trends (reflecting a substantial difference in the period and nature of occupation) have influenced the test results.

	Monocots	**Multi-cell**	**Poorly silicified**	**Pooideae**	**Husk**	**Leaf/husk**	**Leaf**
P	.798*	.663			.677	.714	
Zn	.687	.807*	.807	.656	.630		
Sr			.818*	.792			.646
Mg			.807*				
S	.671				.618		.661
Ca			.690				
Ti	-.707	-.628			-.620	-.619	
Si	-.643						

Table 8.1. Overview of correlations between geochemical and phytolith variables significant at the 0.01 level according to a two-tailed Pearson correlation test for the ethnographic data (the complete table can be found in Appendix 6). Very strong correlations are highlighted with *.

These correlations fit in well with the patterns observed in the chapters dealing with the results and observed patterns in regard to the context categories; Chapters 6-8. The first six geochemical variables in table 8.1. are considered to reflect the anthropogenic input at Wadi Faynan; P, Zn, Sr, Mg, S and Ca. They show strong to very strong significant correlations with the two phytolith context categories considered to reflect anthropogenic input as well, monocots and multi-cell, and a few additional contexts categories representing plant parts, a state of preservation (poorly silicified) and a grass subfamily (Pooideae). These phytolith variables are negatively correlated to two chemical elements considered to reflect the background geochemistry, Ti and Si. It is important to keep in mind the relationship between the categories monocots and multi-cell phytoliths, the latter are mainly derived from monocots, representing a conjoined sequence of single cells. This might either indicate a good state of preservation or large quantities of monocot material.

The correlation of variables from the geochemical and phytolith analysis results helps to identify the variables that reveal anthropogenic activity. However, although many variables considered to reflect anthropogenic input in both methods seem to be correlated, this association does not necessarily help us further in defining specific activity areas. We have already seen in Chapters 6 and 7 that there are two groups of context categories showing similar patterns of soil signatures, one comprising areas influenced by anthropogenic activity and others not affected, or affected to a very low degree, by this activity. The use of dung cakes for fuel means that the context categories showing a large anthropogenic input, the dung and hearths, will be similar in many aspects. As the discriminant analysis graphs for the ethnographic data show (section 8.2.), the differences between the two hearths for example, can be better explored within each of the analysis methods. Reviewing the trends seen within the geochemical and phytolith analyses separately and combining the two interpretations later allows for a better characterisation of activity areas than trying to combine variables of both sources of information.

8.3. Hearths

Fire installations are probably the most distinguishable features geochemically in anthropogenic deposits, and according to previous geochemical studies are associated with high concentrations of Mg, Ca, K, and P (Middleton 2004; Vyncke et al. 2011; Wilson et al. 2008). In contrast, when it comes to phytoliths signals from fire installations are not uniform. It seems that while geochemical signatures related to burning activities are fairly uniform across sites, phytolith signatures are more variable, depending on the type of fuel used which appears to be site dependent (see section 2.2.4.2.). It is also important to keep in mind that the composition of the ash derived from hearths represents the most recent fuel type used at the time of abandonment or sampling, and not necessarily the only source of fuel that was used at a site.

8.3.1. Hearths at Wadi Faynan

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 (figures 8.6. – 8.10). concentrations of K and Cl are elevated as well, probably because of the use of dung cakes for fuel since dung samples contain the highest readings for these elements (figures 8.23. ,8.24.). P levels are elevated in most sites, mainly in the kitchen hearth samples, and so are possibly linked to cooking, or alternatively to the preference for dung cakes in these hearths (figure 8.11.). The decision tree created for the ethnographic sites, based on the geochemistry, shows a first step split between hearths and the rest of the samples based on Sr levels, followed by a second step differentiating the two hearth types according to Zn (figure 8.5.). Zn is considered to be less affected by site conditions and more directly correlated to activities, and is associated with mineral grains and bone fragments and is often elevated in hearths (Wilson et al. 2008, 416-8). It is therefore not surprising that kitchen hearths, where food is cooked, contain higher levels of Zn than hospitality hearths which are used for making tea.

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 (figures 8.12. – 8.14.). 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, but in JTS this is probably related to an input of wheat from bread preparation. In WF953 and JTS hearth deposits contained the highest concentrations of phytolith material, but in WF916 dung deposits contained the highest concentration of phytoliths (figure 8.15.). This slightly confusing pattern might be related to preferences in fuel, but it can also simply reflect a build-up of dung or plant material in the sampling localities. If woody material was preferred at WF916 the hearths might comprise lower phytolith concentrations than the dung deposits since dicots produce less phytoliths than monocots, and the amount of dung was not reduced as a result of the production of dung cakes.

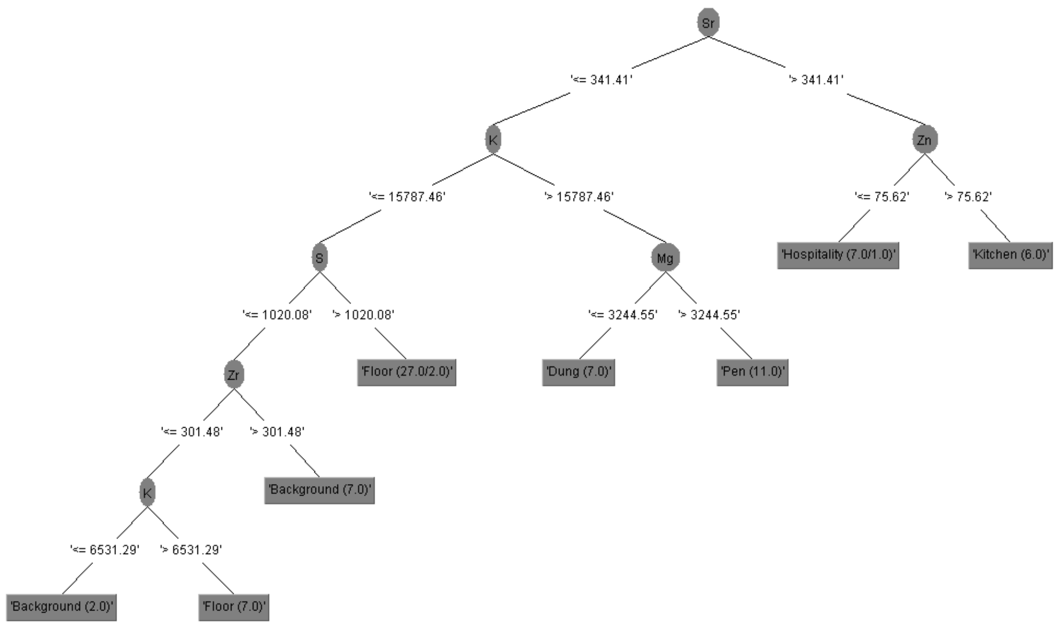


Figure 8.5. Decision tree created for the JT and WF sites based on geochemistry, 77% of cases correctly classified.

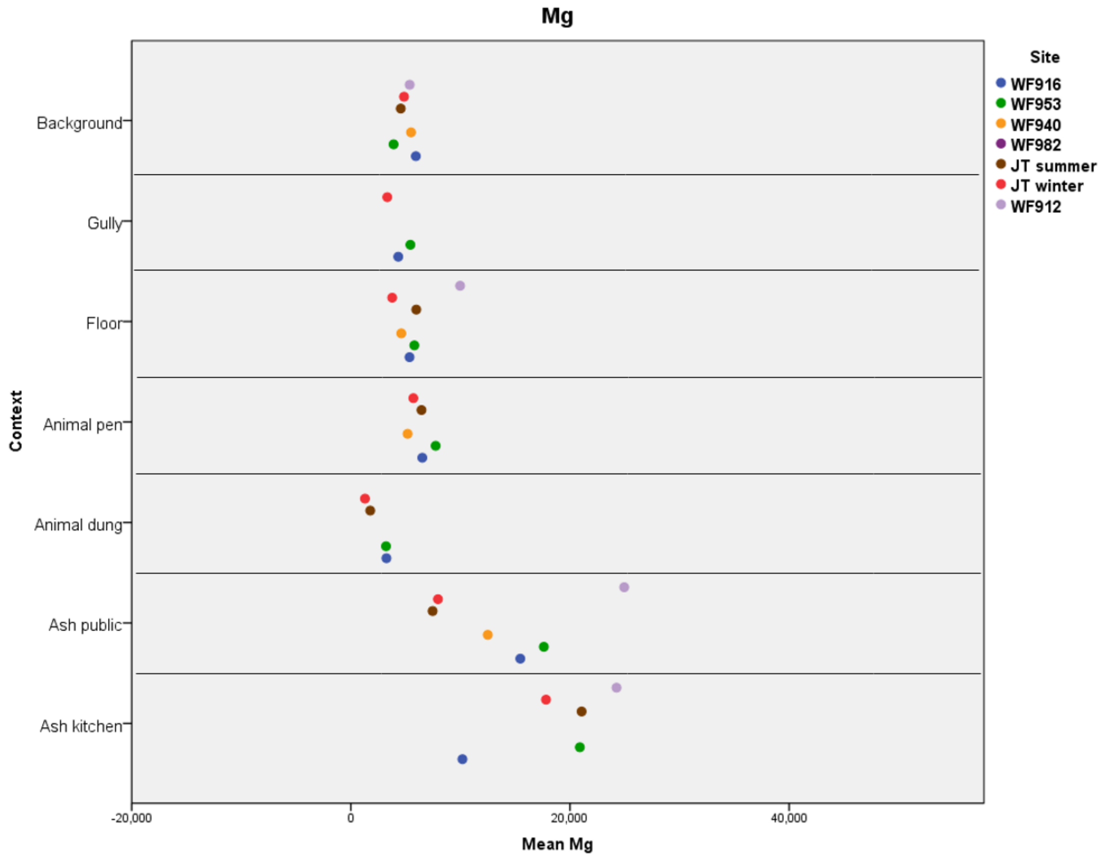


Figure 8.6. Magnesium levels in PPM per context, JT and WF sites.

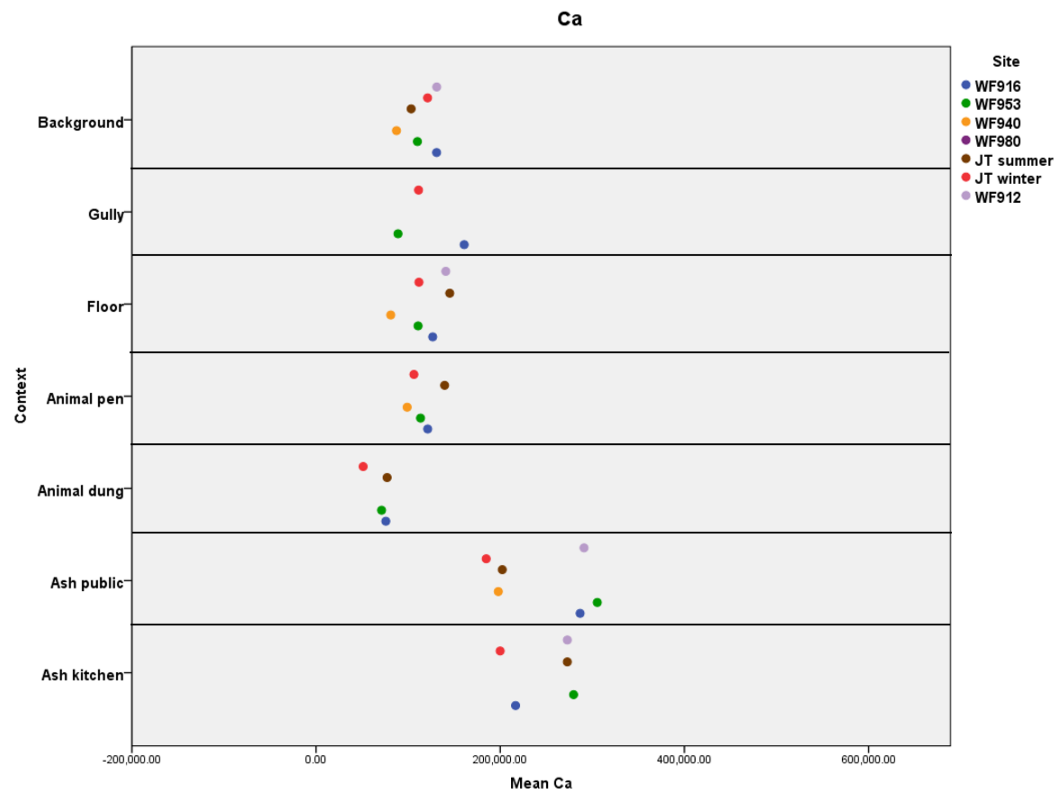


Figure 8.7. Calcium levels in PPM per context, JT and WF sites.

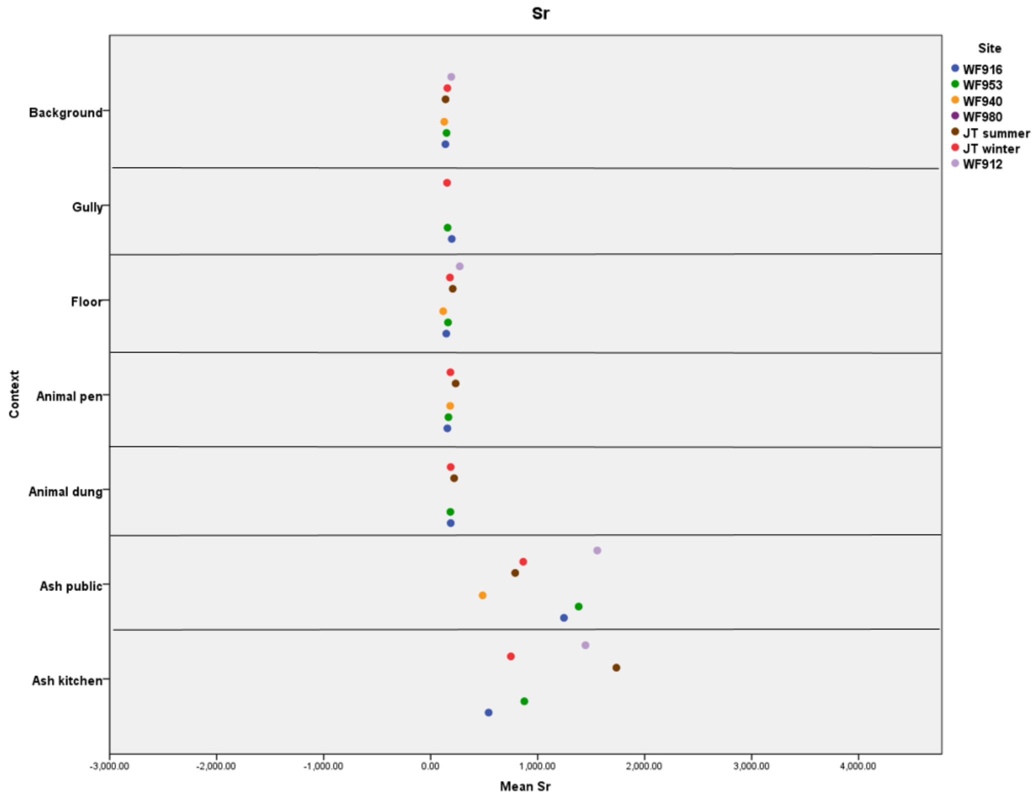


Figure 8.8. Strontium levels in PPM per context, JT and WF sites.

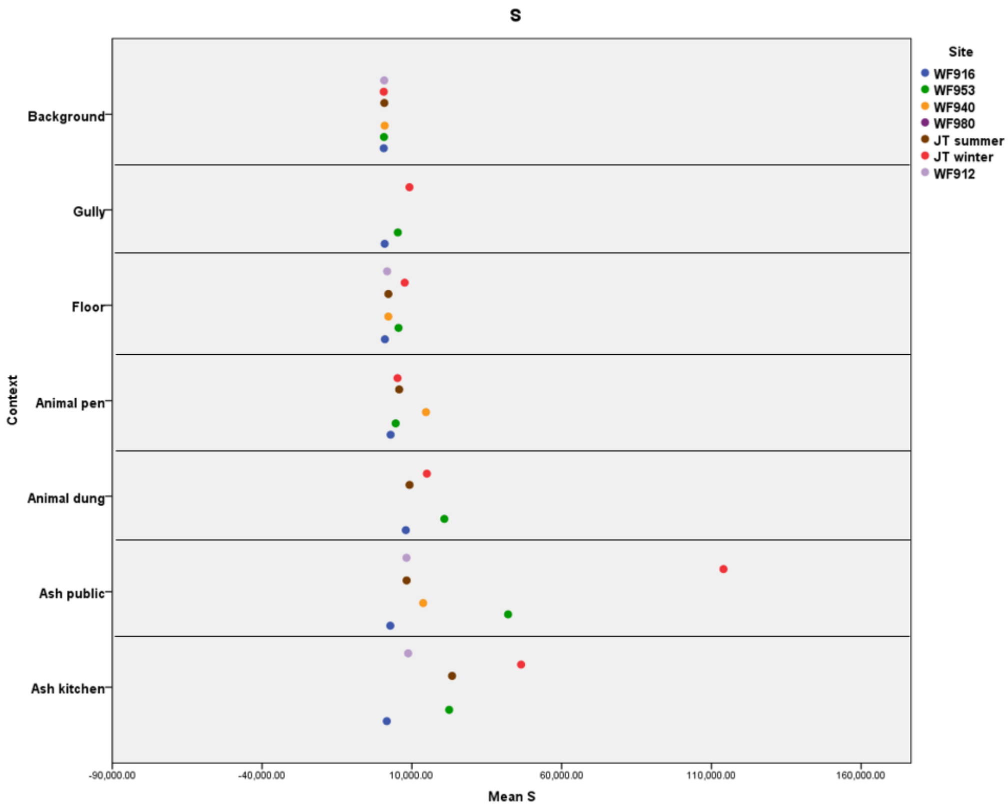


Figure 8.9. Sulphur levels in PPM per context, JT and WF sites.

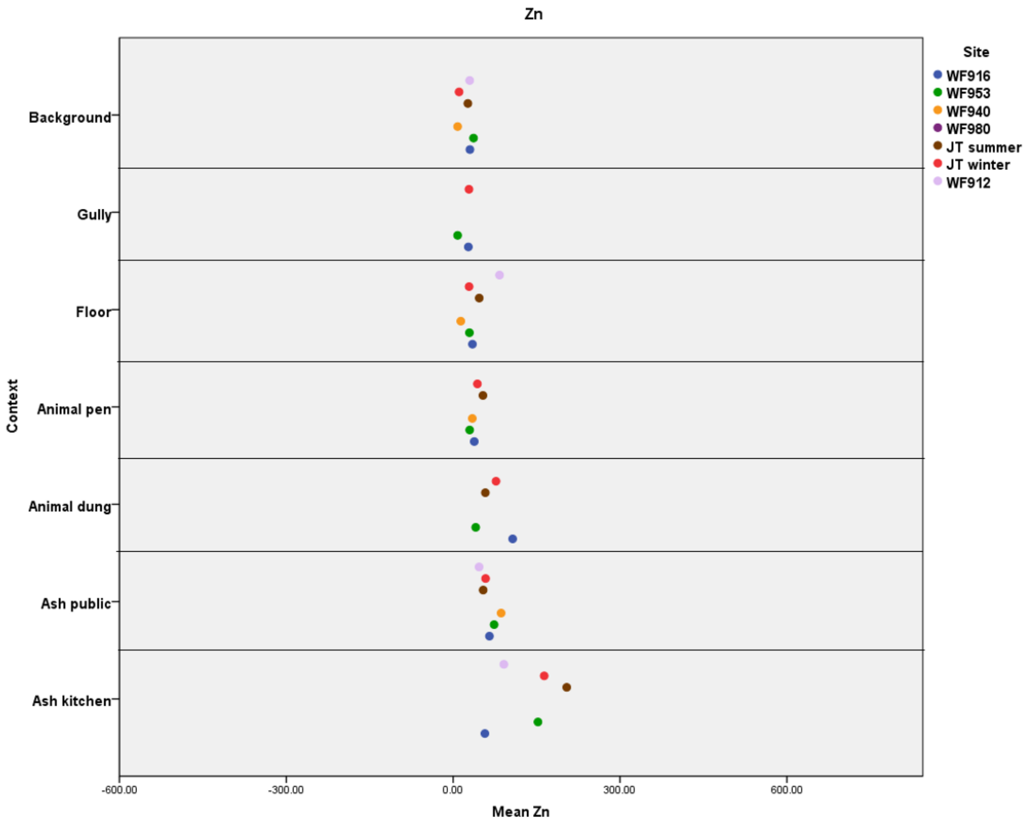


Figure 8.10. Zinc levels in PPM per context, JT and WF sites.

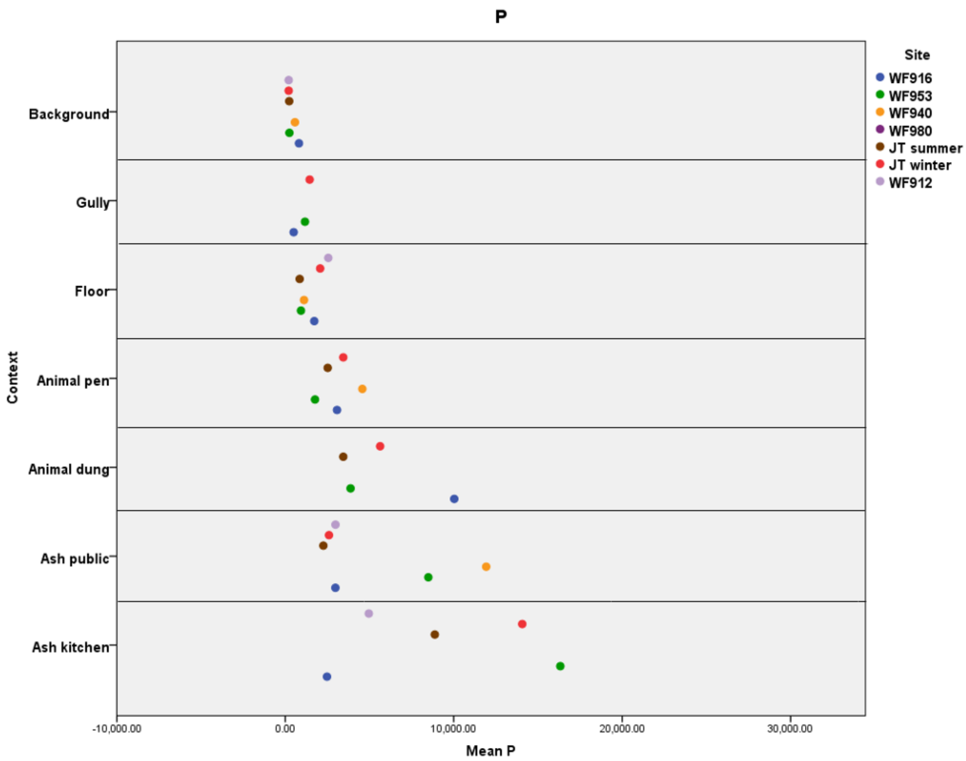


Figure 8.11. Phosphorus levels in PPM per context, JT and WF sites.

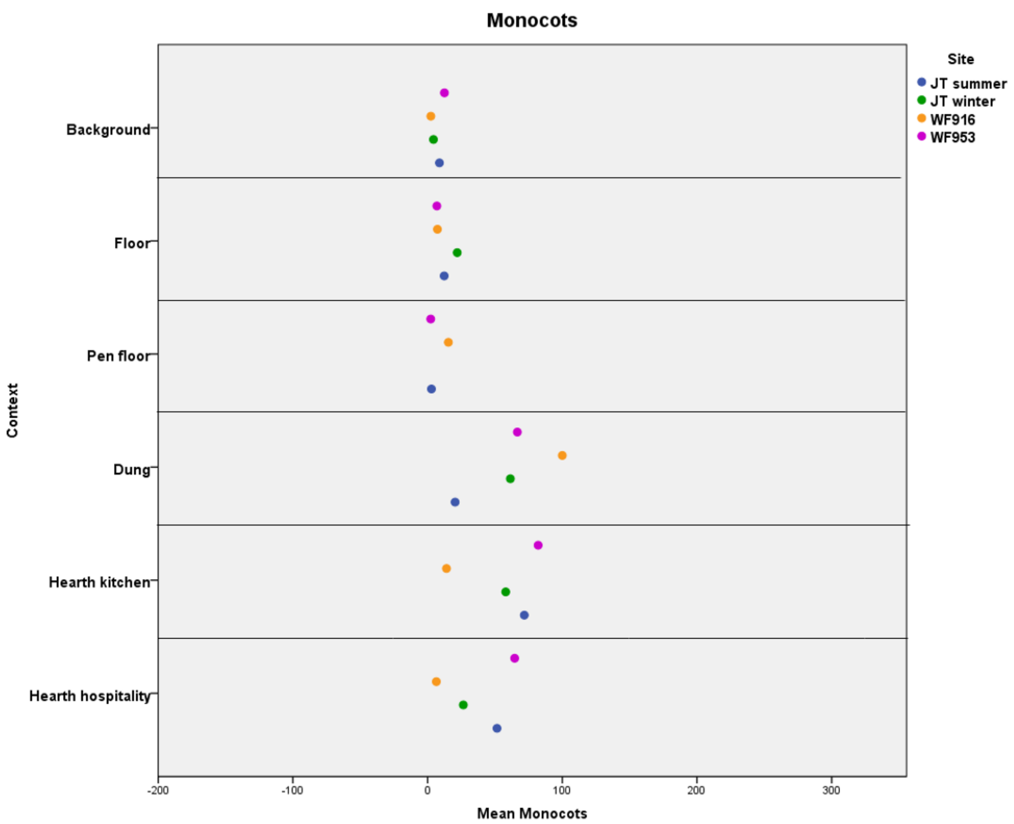


Figure 8.12. Proportions of monocots per context, JT and WF sites.

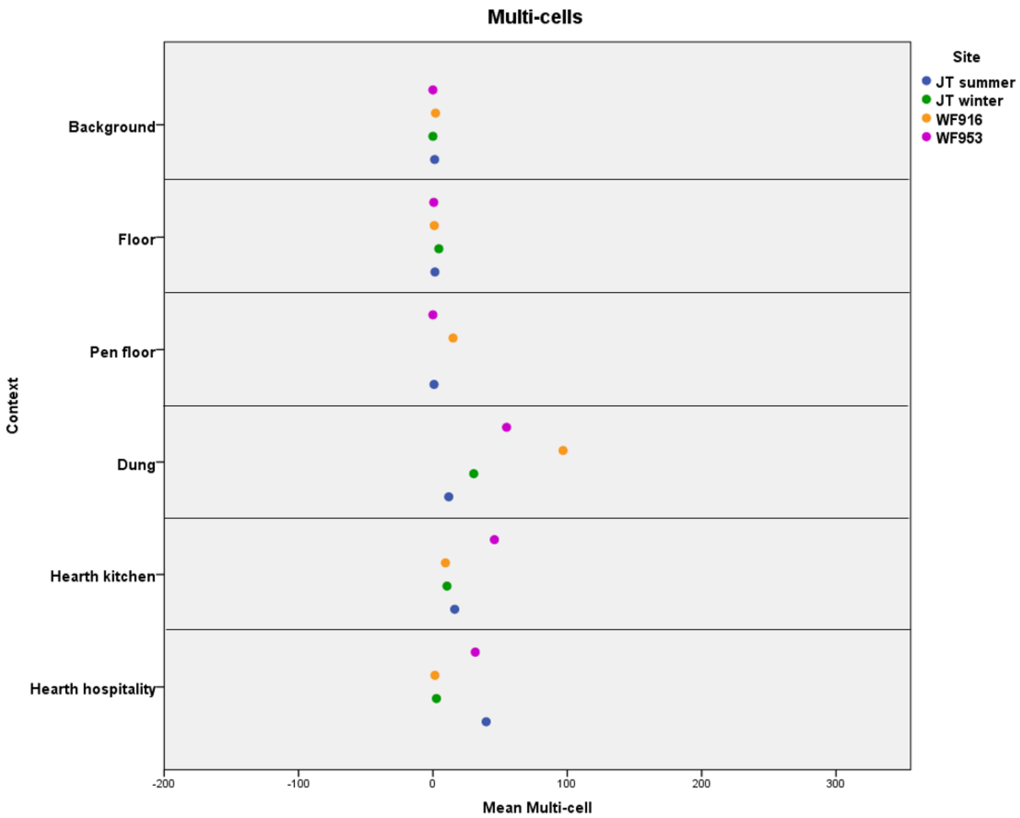


Figure 8.13. Proportions of multi-celled phytoliths per context, JT and WF sites.

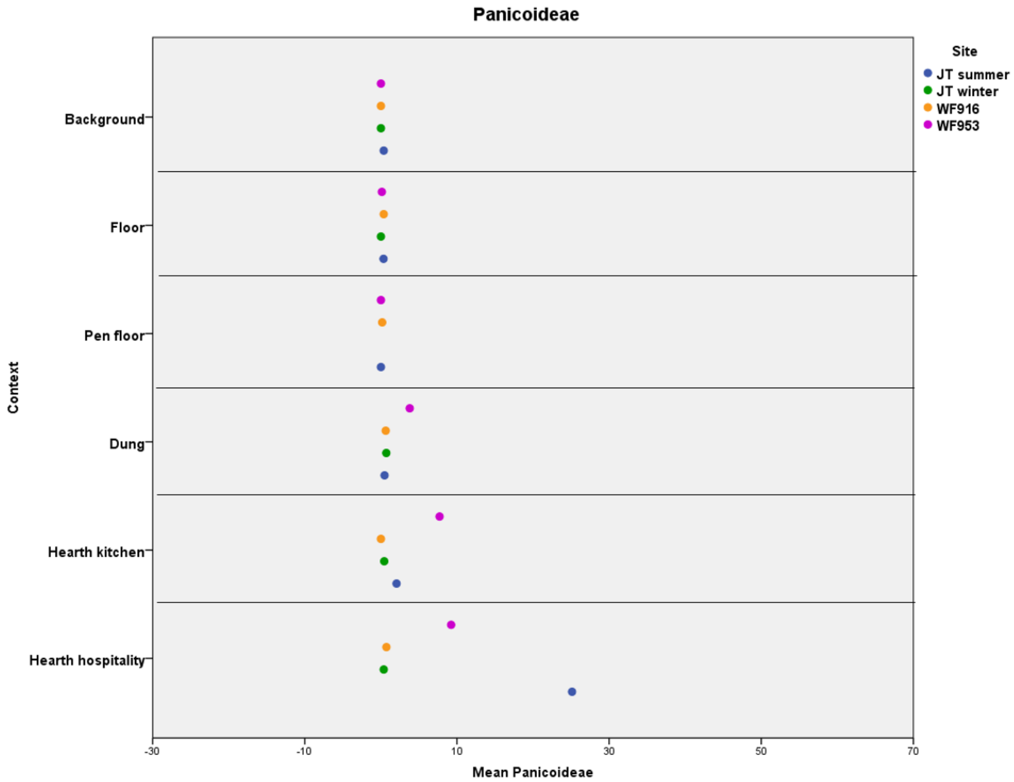


Figure 8.14. Proportions of Panicoideae grasses per context, JT and WF sites.

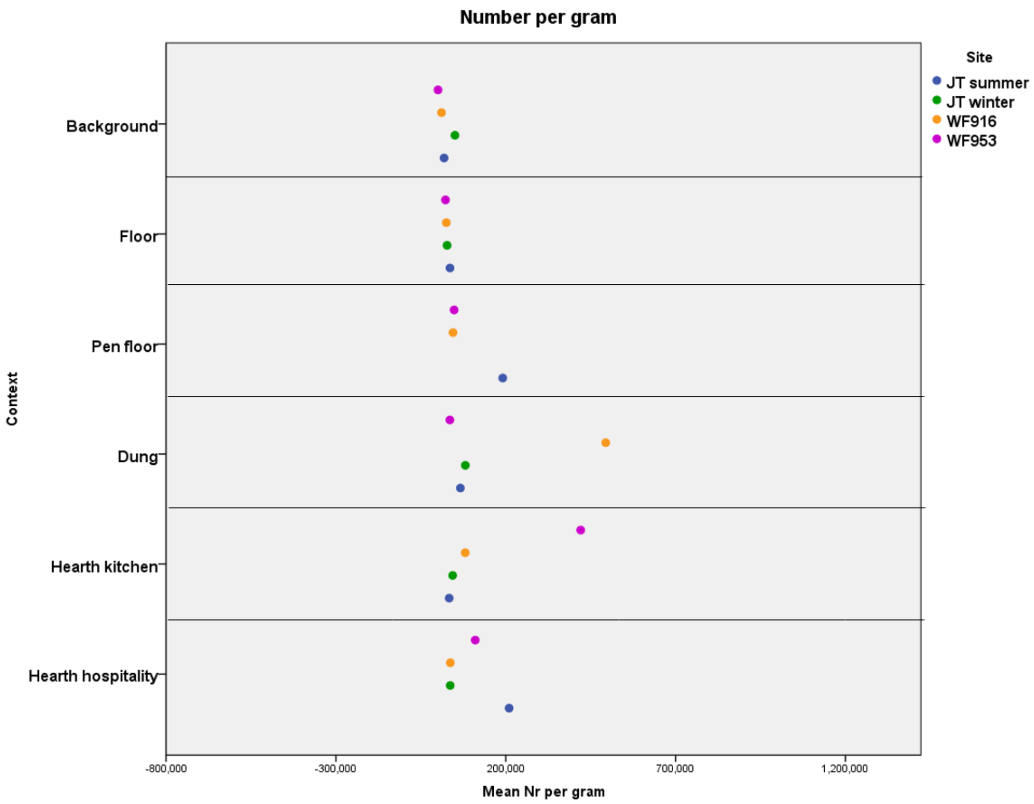


Figure 8.15. Average number of phytoliths per gram for each context, JT and WF sites.

8.3.2. Hearths at Wadi el-Jilat

The results of the geochemical analysis of the Neolithic sites does not conform to the expected trends observed in the literature and in the ethnographic case studies outlined above, with the exception of the hearths at WJ13, which show higher concentrations of Mg and K (see section 7.3.1.). It is likely that the length of time since abandonment, sampling methodology at Wadi el-Jilat, and perhaps the activities that took place within the buildings have affected the ability to identify activity specific soil signatures in these samples. In addition, whereas ethnographic settlements provide certainty regarding the spatial use of the site, identification of features in archaeological sites is more problematic. Another issue that complicates the interpretation of activity areas at Wadi el-Jilat is the difference between the three sites, which is responsible for some of the variation between the context categories.

When geochemistry decision trees were produced for each site (which carries the disadvantages of analysing a small sample size) it became clear that the hearth samples behave differently even within sites. Some plot similarly to general deposits, others to postholes. WJ26 comprises three sites that are different from each other, which is reflected in the sample clustering (figure 8.17.). Two of these sites (area E and area C) contain hearths, and at these two sites the hearths do cluster together. Those from WJ26 area E are differentiated from the postholes by their P concentrations, and those from WJ26 area C are differentiated from the other fills by their Mn concentrations. In WJ13 the hearths do not form a coherent cluster, one group being split by Cl concentrations and the other differentiated from the fills by Mn and Mg (figure 8.18.). The decision tree for the geochemical trends in WJ7 is purer, with Si used to distinguish between fills and hearths (figure 8.19.). Hearths at WJ7 are also associated with high concentrations of S, which are found in the posthole category as well (see section 7.3.2.).

When plotting phytolith decision trees for each WJ site, similar branching complexities can be seen. The one created for WJ7 produced the purest divisions, Panicoideae and diatoms used to differentiate between the background, deposit and posthole categories (figure 8.19.). The tree that was visualised for WJ26 shows a spread of the same categories across multiple nodes, which as with the geochemistry is caused by the differences between the three areas (figure 8.20.). According to the diagram, ash fills (representing hearths) are separated from other context categories mainly based on a greater weight percent, which reflects a higher concentration of phytoliths. Looking at individual trends, hearths in WJ7 and WJ13 contain the highest concentrations of monocots and multi-celled phytoliths (figures 8.21, 8.22.), but this trend is not observed at WJ26.

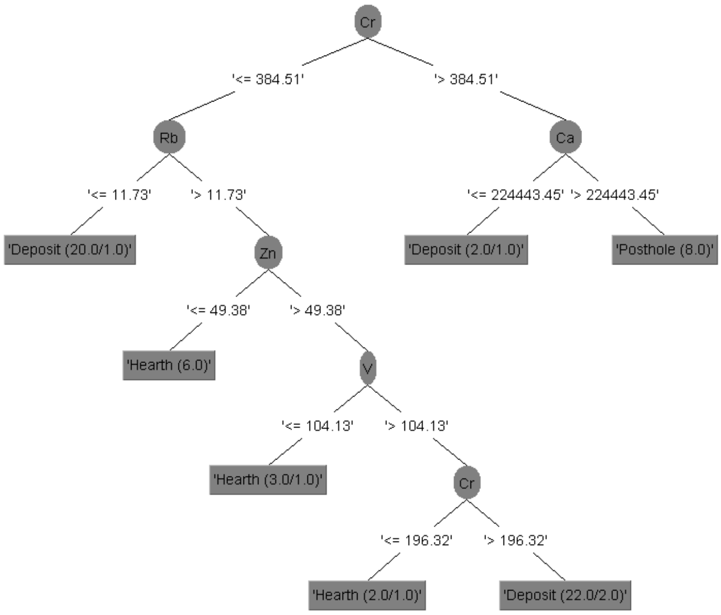


Figure 8.16. Decision tree for all Wadi el-Jilat sites based on the geochemical analysis (70% of cases correctly classified).

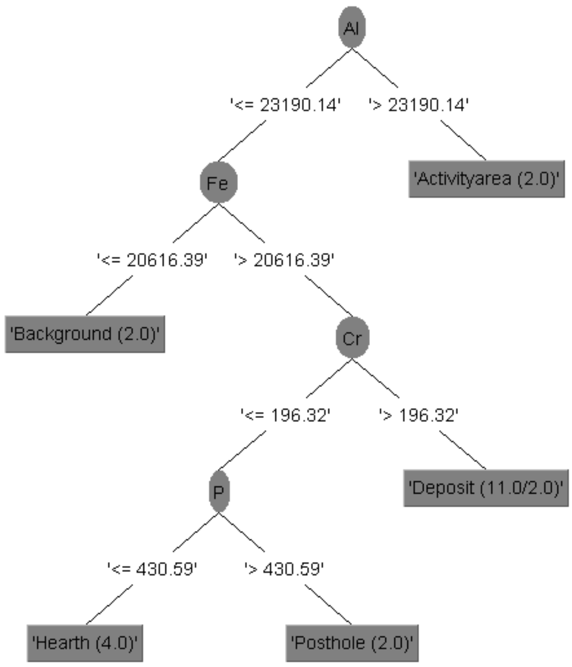


Figure 8.17. Decision tree created for WJ26 based on the geochemical analysis (only 33% of cases correctly classified).

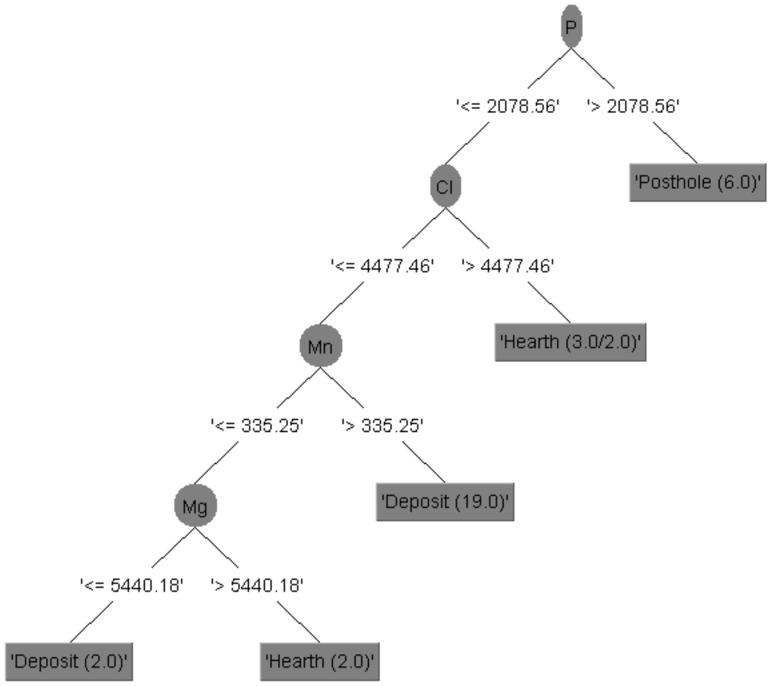


Figure 8.18. Simplified decision tree created for WJ13 based on the geochemical analysis, with the data grouped into three context categories: Deposits, hearths and postholes, adding the categories activity area and fills to the general deposits category (72% of cases correctly classified).

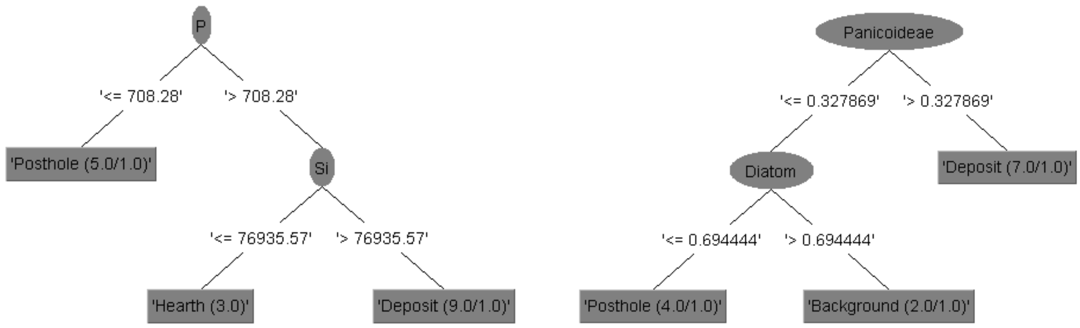


Figure 8.19. Decision trees created for WJ7 based on the geochemical analysis (left) and phytolith counts (59% and 46% of cases correctly classified, respectively).

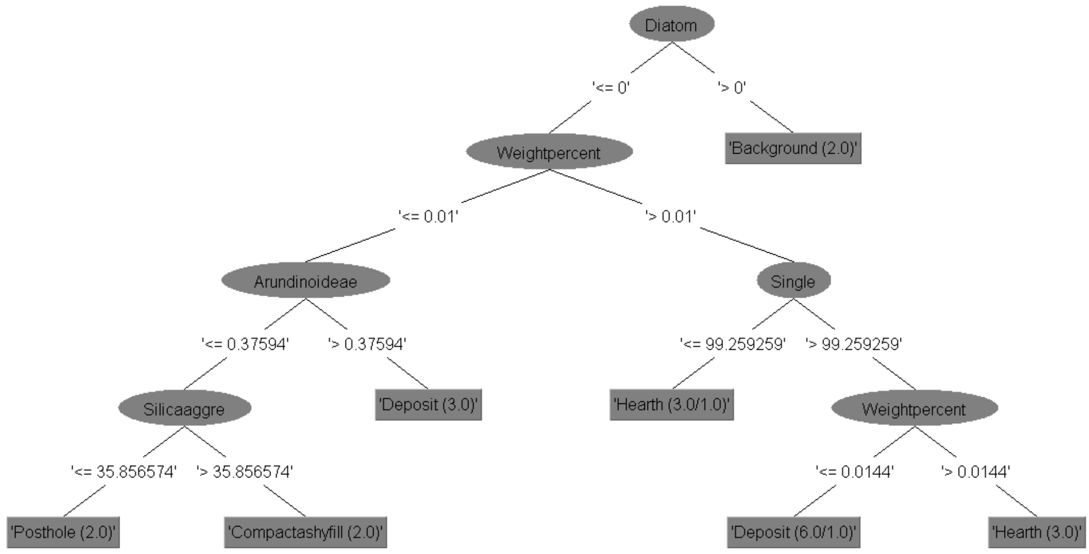


Figure 8.20. Decision tree created for WJ26 based on the phytolith analysis (29% of cases correctly classified).

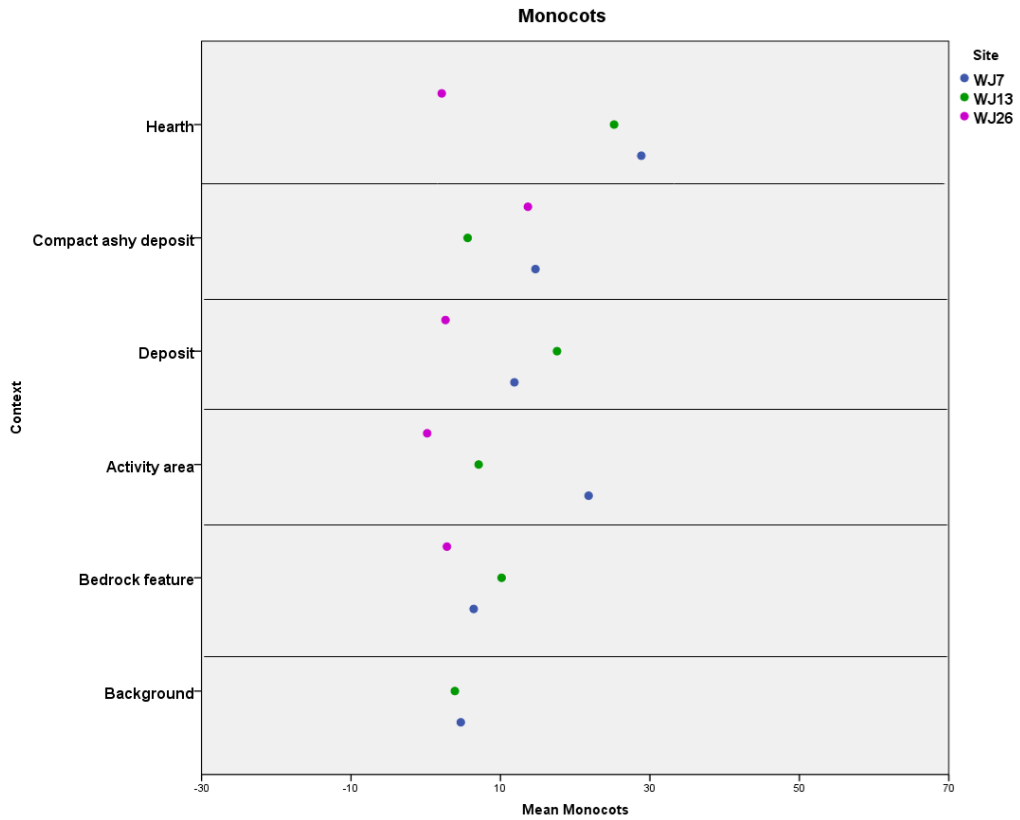


Figure 8.21. Proportion of phytolith types indicating monocots per context at Wadi el-Jilat.

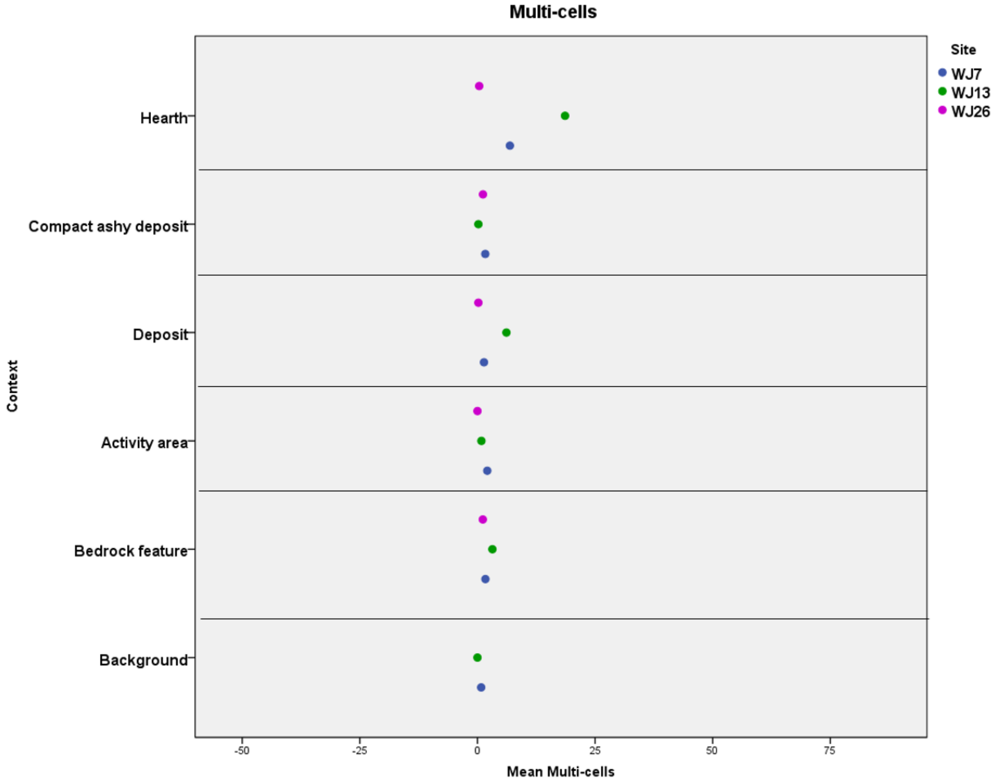


Figure 8.22. Proportion of multi-celled phytoliths per context at Wadi el-Jilat.

8.4. Dung related deposits at Wadi Faynan

The geochemistry of dung deposits is considered more susceptive to site effects than other context categories, such as hearths (Wilson et al. 2008, 418). High levels of phosphorus are often associated with dung (Pető et al. 2015; Wilson 2008), while phytolith samples from dung are often related to high concentrations of grass phytoliths (Shahack-Gross et al. 2003; Shahack-Gross et al. 2004). 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). A more secure way of identifying dung is by quantifying faecal spherulites, but these are not always present (Portillo et al. 2009).

Dung deposits at Wadi Faynan were rich in grass phytoliths, and contained high proportions of conjoined phytolith material (figures8.12., 8.13.). However, unlike the cases described above, the dung samples did not contain higher phytolith concentrations with the exception of the samples from WF916 (figure 8.15.). As described in section 8.2.1., 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. 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. Animal pen floors fall in between the floor and dung samples, with elevations of Cl, P and K in relation to the background and floor samples (figures 8.11., 8.23., 8.24.).

Variability in the length of abandonment of the campsites allows for observations about its influence on the availability of different elements to be made (see section 7.2.8.1.). A clear effect can be seen in the concentrations of Cl, which seems to dissolve relatively rapidly, the depletion in dung sediments is the greatest (figure 8.25.). Cl is strongly associated with animal dung at Wadi Faynan and is present to a lesser degree in hearth contexts when dung cakes are used (notice the lower levels of Cl in WF916 hearths) and animal pen floors, and is virtually absent in the background samples. Cl does not appear in its free elemental state in nature, but is commonly found within compounds such as the common salt (NaCl). The relatively rapid depletion in Cl concentrations at the Wadi Faynan sites is not surprising considering its highly reactive nature. It is a strong oxidising proxy and easily decomposes on exposure to sunlight and water (Petrucci 2007; Sconce 1962).

A loss of K through time can also be observed at the Wadi Faynan sites (figure 8.26.), with the most significant depletion occurring in the dung sediments. Although the mobility of K in soils is often studied in relation to moisture (Kuchenbuch et al. 1986; Zeng and Brown 2000), its depletion in the herbivore dung related sediments at Wadi Faynan is probably also related to their organic and microbial setting. The decomposition of accumulations of organic residues can release large quantities of organic acids, which may interfere with chemical processes leading to the release and mobilisation of cations in the soil. When contained in vegetable residues, K is easily released as it does not make part of any organic compound and is dependent on microbial action for decomposition (Brito et al. 2014). The decomposition of organic residues of animal fodder present in dung, exposure to sunlight and moisture from rain, household activities (and animal urine in dung areas), may all be contributing factors to the loss of Cl and K over time in the dung and other sediments of the Wadi Faynan campsites.

A similar trend can be seen when plotting the concentrations of Zn in the hearth contexts across the Wadi Faynan sites (figure 8.26.). At WF916 the levels of Zn are higher within the dung samples, which might indicate that this element is introduced into hearths at Wadi Faynan through the use of dung cakes (which are probably not used to fuel hearths at WF916). On the other hand, Zn could be introduced into the kitchen hearths, which show the largest concentrations, through the cooking of meat (Tripathi et al. 1997). If meat preparation is the largest enrichment factor it could be that more meat is consumed in the JT and WF953 tents, which are most recently abandoned but were also occupied by the same family. In that case the pattern seen in this graph would reflects changes in meat consumption rather than degradation of Zn. This is a likely scenario, since the degradation of Cl can be seen in all contexts, while lower concentrations of Zn in the older sites is only related to the kitchen hearths.

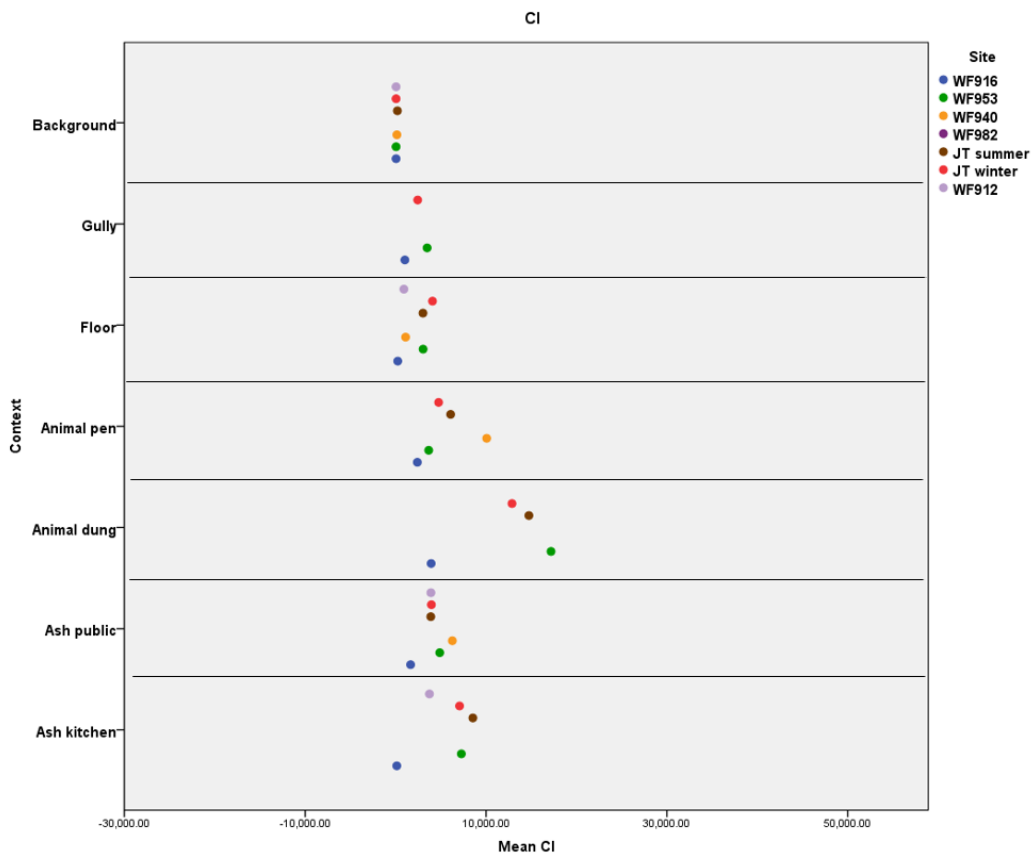


Figure 8.23. Chlorine concentrations in PPM per context, JT and WF sites.

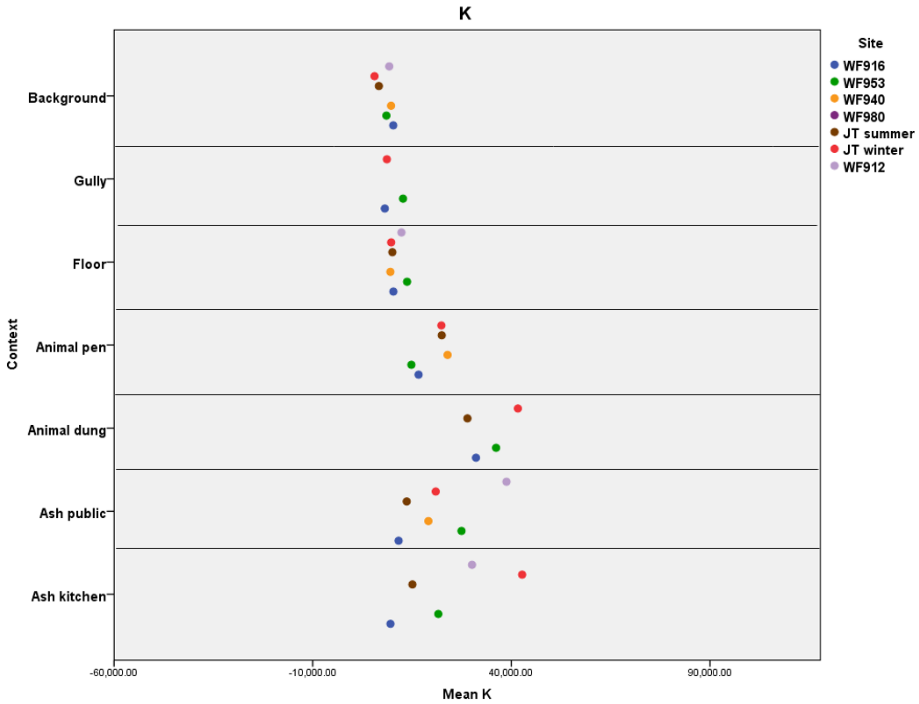


Figure 8.24. Potassium concentrations in PPM per context, JT and WF sites.

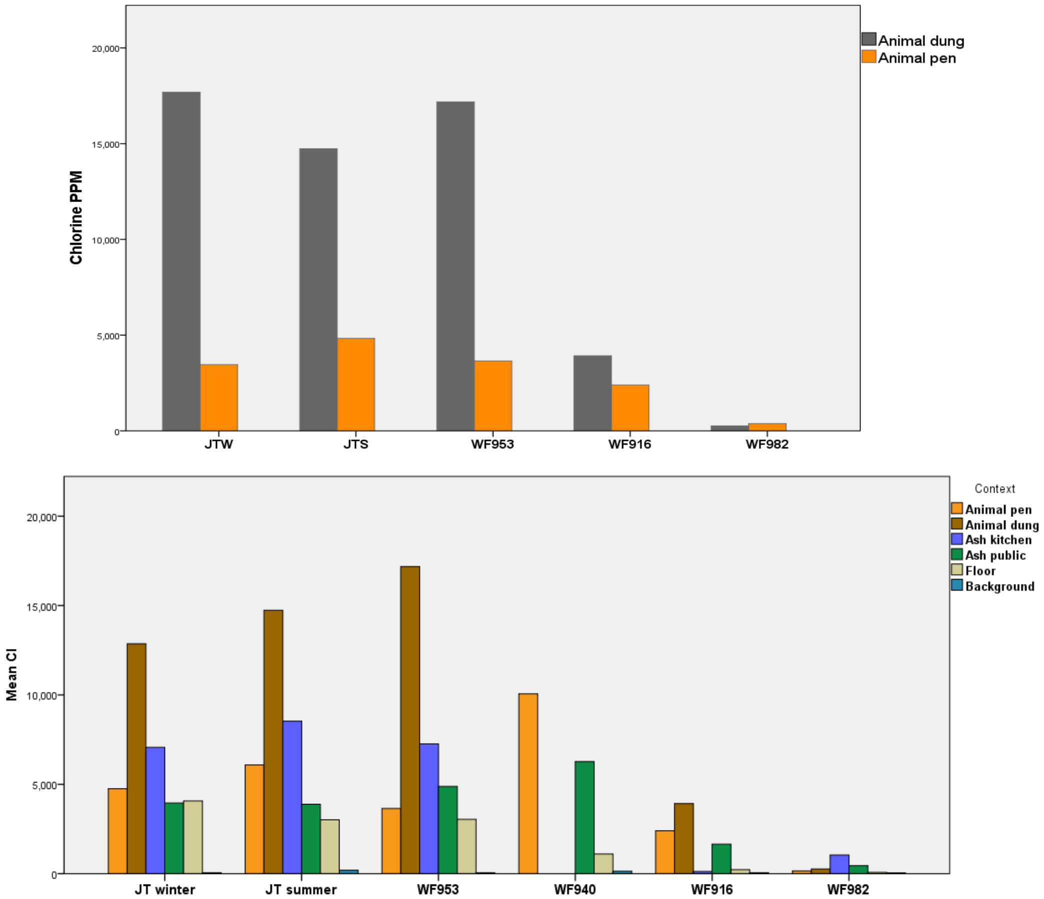
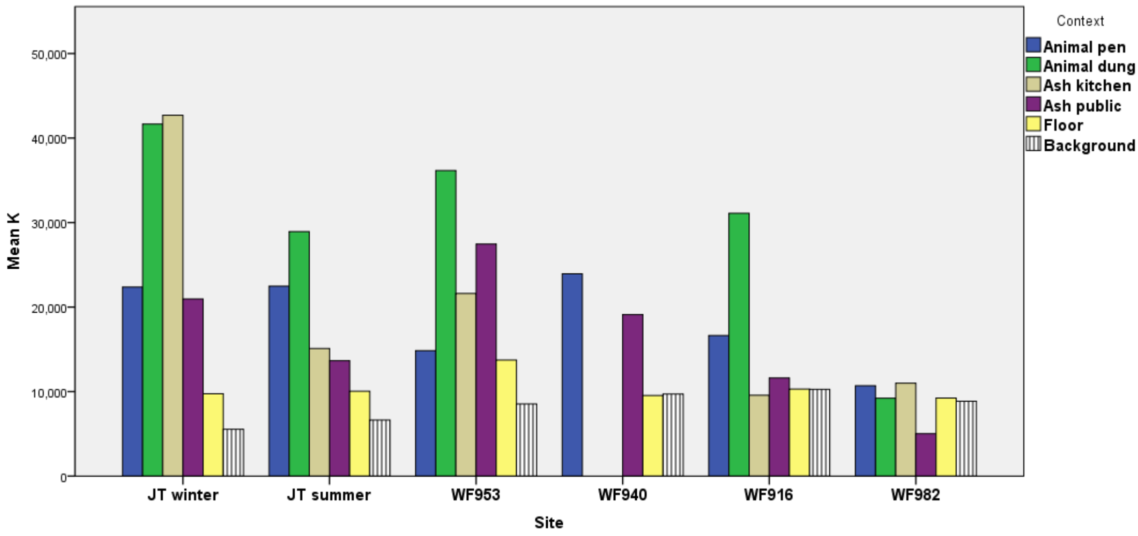


Figure 8.25. Average chlorine concentrations in PPM within dung samples, animal pen floor sediments, and background samples (top graph) and in all context categories (bottom graph) at the Wadi Faynan sites. JTW was occupied during sampling, JTS had been abandoned for 6 months, WF953 and WF940 for a year, WF916 for three years and WF982 for 10-15 years.



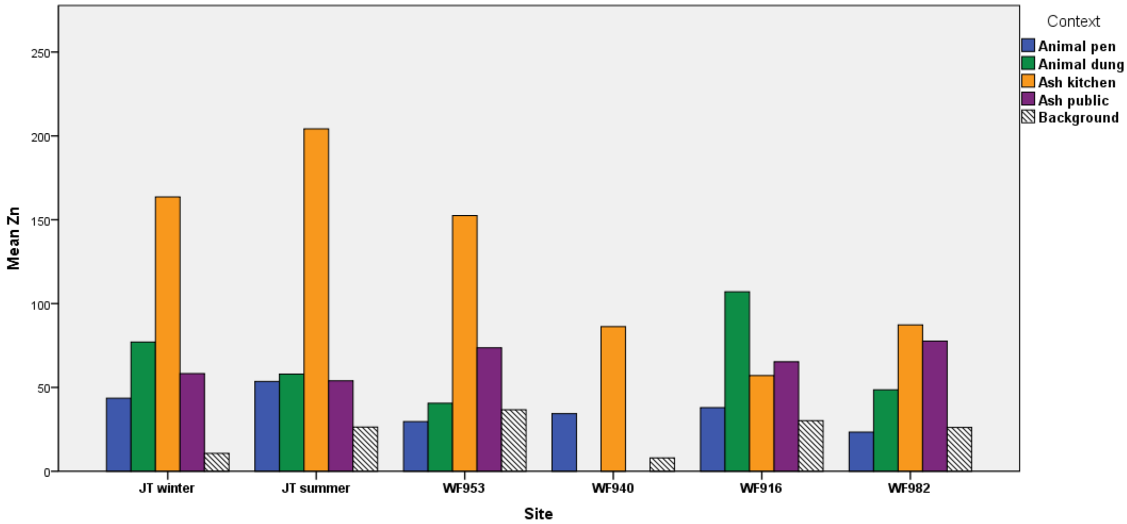


Figure 8.26. Average potassium and zinc concentrations in PPM within all context categories. JTW was occupied during sampling, JTS had been abandoned for 6 months, WF953 and WF940 for a year, WF916 for three years and WF982 for 10-15 years.

8.5. Floors, deposits and gullies

Floor surfaces, both in ethnographic and in archaeological contexts, do not usually contain specific chemical or phytolith enrichment signatures but rather the lack of these. They will generally comprise lower readings of anthropogenic related chemical elements and phytoliths than other activity areas (see section 2.3.2.). However, secondary activities that take place on floors such as food processing, storage or craft activities may create exceptions (Shahack-Gross et al. 2004; Tsartsidou et al. 2008; Tsartsidou et al. 2009). In some cases floors can be identified by a lower concentrations of chemical elements than control samples, with floors being referred to by Middleton (2004, 56) as ‘high traffic zones’.

8.5.1. Floors and gullies at Wadi Faynan

Floors and gullies display similar patterns to each other and to the background samples in all of the Wadi Faynan sites. They contain no elevations in the anthropogenic chemical markers described in sections 8.2.1. and 8.3. such as Mg, P, K, Mn, Sr, Ca (figures 8.6. - 8.11), or the phytolith categories related to anthropogenic input such as high levels of monocots and multi-cells (figures 8.12., 8.13.), although slight Cl enrichments can be seen in floor and gully samples from the majority of sites (figure 8.23.). Unlike floor areas that have been described as high traffic zones, 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.

8.5.2. Deposits, activity areas and compact ashy deposits at Wadi el-Jilat

The deposits of the Neolithic sites at Wadi el-Jilat do not form a coherent category and it is difficult to estimate what type of activities were involved in the creation of these anthropogenic sediments. The description of these features is not straightforward, and the mixing of material during the 8,000 years or so since abandonment could have diminished any clear signatures of specific activities. Perhaps if these were available at Wadi el-Jilat, they remained very local as with Wadi Faynan (see discussion of floors and gullies above). In that case it would be very difficult to sample specific locations without prior knowledge of activity areas.

The geochemistry based decision trees produced for the Wadi el-Jilat sites as a whole and individually distinguish several categories (nodes) of deposits (figure 8.16. – 8.19.). Samples taken from surfaces that were described as ‘activity areas’, often including high concentrations of flint or bone, and are similar to general deposits in some aspects and to hearths or the background samples in other (see overview for Wadi el-Jilat sites in chapters 6 and 7). At WJ13 they contain the highest concentrations of Mn, but activity areas do not stand out otherwise. Units described as ‘compact ashy deposits’ did not plot differently to the other deposits in most aspects and were incorporated into the general deposits category. Some of the deposits plot closer to the hearths, others to bedrock features (see overview for Wadi el-Jilat sites in chapters 6 and 7). Perhaps burning activities that were not detected archaeologically either within or in the vicinity of some of the deposits affected them so that they plot closer to hearths.

8.6. Bedrock cut features at Wadi el-Jilat

Bedrock cut features (henceforth bedrock features) have not been incorporated into spatial studies of archaeological or ethnographic sites using geochemical or phytolith analyses to date. This is unfortunate, as studying soil signatures derived from these areas may enable us to differentiate between, for example, postholes and bedrock mortars, and even identify what the latter were used for. Generally, postholes at the Wadi el-Jilat sites can be distinguished from the other context categories, and although as a group they do not portray the exact same geochemical or phytolith trends there are some similarities between them. In the geochemistry decision tree created for all Wadi el-Jilat sites the postholes are separated using Cr and Ca (figure 8.16.). P levels are highest in postholes at WJ13, and Cr is elevated in postholes at WJ13 and WJ7 (figures 8.28. – 8.29.). Postholes at WJ7 also contain high concentrations of S, similarly to the hearth contexts at this site. The two 'postholes' found at WJ26 are differentiated from the other samples by both Cr and P in the geochemistry decision tree created for this site (figure 8.17.). The phytolith decision tree for all the Wadi el-Jilat sites shows a strong site effect for this context category, the variables used to separate them from other deposits are husk, weight percent and silica aggregate (figure 8.27.).

The high levels of phosphorus in the postholes of WJ13 are an interesting detail. One possible explanation for this phenomenon is that phosphorus had leached down through the sediments over time and became concentrated in these bedrock features. However, if this is the case we would expect to see high concentrations of phosphorus in all bedrock features at Wadi el-Jilat, but this is not the case. Postholes at WJ26 show a slight elevation in this element, and at WJ7 the bedrock features contain the lowest concentrations of phosphorus apart from the background samples. It is therefore plausible that the enrichment in phosphorus is related to human activity, indicating the use of organic materials during a construction process, or the use of bedrock features at this site as mortars for food processing or craft activities. In this regard the phytolith analysis might add to the geochemical interpretation, as the posthole fills of WJ13 contained a higher weight percent and the largest amount of silica aggregate (associated with woody plant material) of all context categories (see section 6.3.1.).

The high concentration of silica aggregate could indicate the presence of wooden poles, and their absence at the other Wadi el-Jilat sites might reflect a secondary use of wood at WJ7 and WJ26 and not at WJ13. If the interpretation of wooden poles is correct, some of the bedrock features at WJ13 could represent a construction for cooking or craft activities as many of them are in close proximity to each other, which would not make sense in case of a roof support structure. The interpretation of these features is complicated by the difference between most of the postholes and a single one found in area A, covered by a stone. This hollow contained low amounts of silica aggregates but a relative high concentration of conjoined phytoliths. Is this discrepancy dictated by a better preservation due to the rock cover? Or was there a difference in use among the bedrock features? Another possible interpretation for these features is a use as mortars. Repeated pounding and grinding of organic material could explain the high levels of phosphorus, silica aggregate, conjoined phytoliths in the covered hole, and associated weight percent.

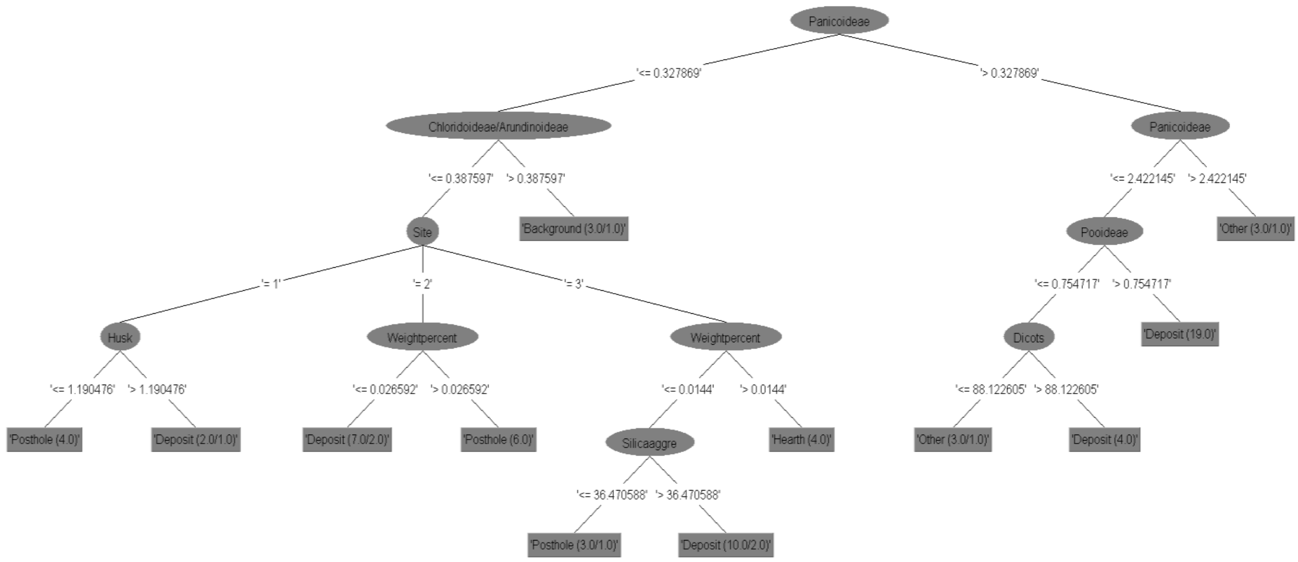


Figure 8.27. Decision tree based on phytolith analysis for Wadi el-Jilat sites, 45% of cases correctly classified. The variable site distinguishes between WJ7 (1), WJ13 (2) and WJ26.

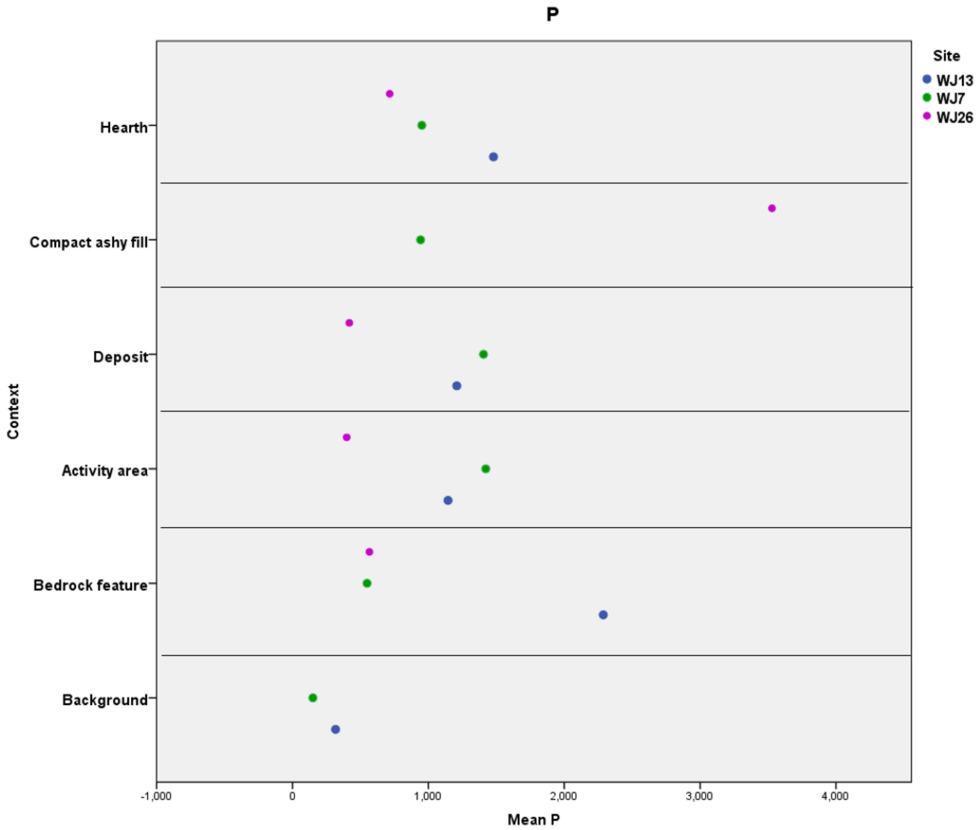


Figure 8.28. Phosphorus concentrations in PPM per context in Wadi el-Jilat sites.

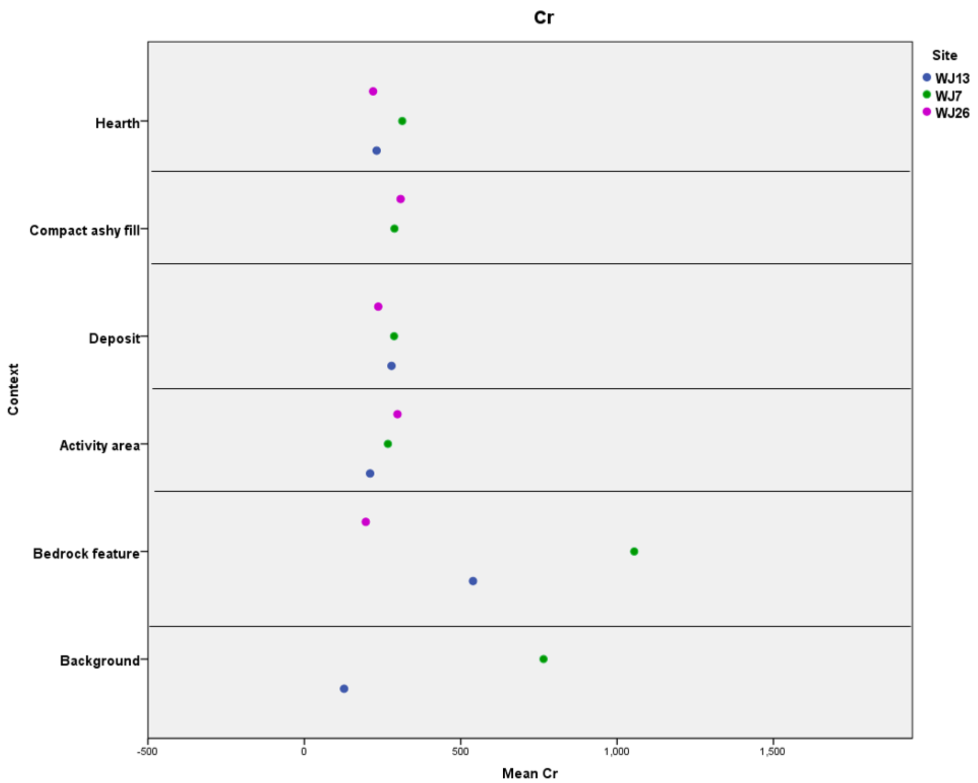


Figure 8.29. Cr readings per context in PPM, Wadi el-Jilat sites.

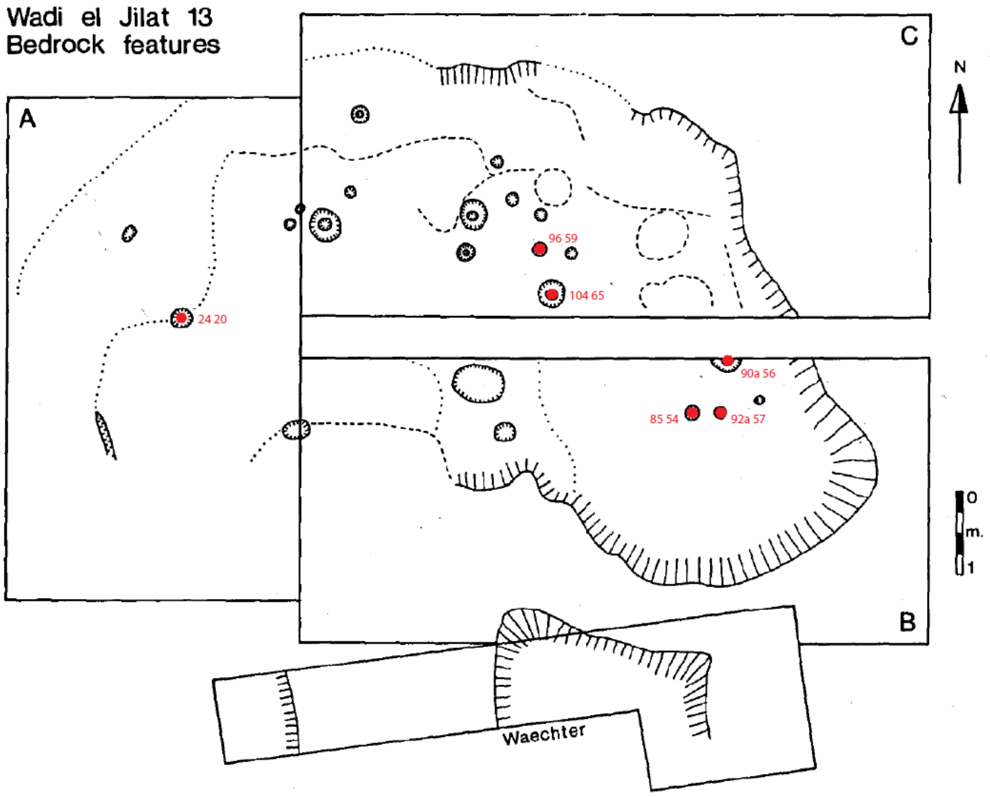


Figure 8.30. Plan of WJ13 showing the location of the bedrock features or postholes identified in the field. The red polygons represent the location of samples (adjusted from Garrard et al. 1994, 80).

8.7. A Bayesian model for increasing the probability of the identification of activity areas

The previous sections discussed in what way individual trends seen within the geochemical and phytolith analysis relate to certain contexts categories, and how decision trees can help visualise how well the data can be split into the pre-defined context categories through the different variables. This section will discuss a way in which the identification of activity areas in the field can be tested and aided by adding or subtracting to its probability through the results of the phytolith and geochemical analysis. In this way the two methods are combined through the probabilities of identification of context categories derived from their results.

In order to test the ability to increase or decrease the probability of the accurate identification of specific soil samples, a model loosely based on Bayesian belief networks will be applied to the samples of WJ13 using the decision trees created for the geochemical and phytolith results (figures 8.31., 8.32.). Bayesian networks are probabilistic models which look at the relationships between inter-dependent events or attributes. The network model defines various events, identifies dependencies between them and the conditional probabilities involved in these. The starting point of a Bayesian belief network is called the Prior Probability, which is a subjective estimate of the probability of the initial hypothesis regardless of the evidence. In archaeology Bayesian statistics have so far mainly been used for predictive modelling, a tool utilised by archaeologists and government planners to make predictions about the occurrence of archaeological sites (Canning 2005; Judge and Sebastian 1988).

The Bayesian based model used in this section is adopted from an ecology study by Stafford et al. (2015), who successfully applied it to a UK rocky shore community in order to predict increase and decline patterns in populations sizes of species within this ecosystem. The model in this study used known interactions between species which can lead to the increase or decrease of other species in order to make predictions about the growth or decline of each species. The nature of this technique is suitable for archaeological purposes as it includes a subjective Prior Probability, in our case the interpretation of a context in the field, and can enhance or deduct from this probability based on the attributes of the archaeological data.

The suitability of this model to aid the interpretation of activity areas in archaeological sites will be tested on WJ13. This site provides a suitable case study for the application of this model to archaeological data based on the geochemical and phytolith results because it does not show a clear division to context categories as is the case with WJ7 and therefore requires additional support for the identification of activity areas. The site also contains enough a large enough sample size to allow for a characterisation of activity areas to be made through decision trees in order to determine the general characteristics of the various context categories which will be used for the analysis, which could not be done with the data from WJ26 as the differences between its three areas are too great.

Each sample is given a starting value between 0 and 1, which indicates the Prior Probability; i.e. the belief that the related identification of the activity or context of this area in the field is either true or false [P(Xi) and P(Xd) respectively]. This probability estimate gives an indication of the likelihood of a correct or incorrect initial identification in the field. Within this belief network the sum of the probability of the original identification to be true or false must equal 1. If there is no reason to assume that the identification in the field is truthful, then the prior probability of a correct characterisation of the sample is the same as the prior probability of an incorrect identification, both set as 0.5. The results of the geochemical and phytolith analyses are considered to be independent of each other within the belief system, but are dependents of the soil samples.

The following equation was used in the study of the rock shore community by Stafford et al. (2015) to estimate the probability of each species increasing (what in our case would be a correct identification of context in the field) given species interactions (in our case this will be based on the results of the geochemical and phytolith analyses):

$$P(X_i|Y)=[P(X_i|Y_i)^* P(Y_i) + P(X_i|Y_d)^* P(Y_d)]$$

In this equation, X represents the sample under consideration, and Y is the result of the geochemical or phytolith analyses. Subscripts i and d indicate agreement or disagreement with the initial interpretation, respectively.

This equation was used as an excel function to calculate the probability of a correct identification of activity for each of the WJ13 samples. The Prior Probability for the samples was set at 0.5. The amount of increase or decrease in probability was chosen for the geochemical and phytolith analysis results based on the probability of a correct classification into context categories within the Weka decision trees. For the geochemical results 38% of cases were correctly classified, and for the phytolith results 21% of cases were correctly classified. An increase or decrease of probability was therefore set at 0.38 for the geochemistry and 0.21 for the phytolith analysis. The geochemical and phytolith results for each sample were individually manually checked against the decision tree diagrams in order to determine if it fell within the correct classified instances. If both methods agreed with the original interpretation the probability of a correct classification increased from 0.5 to 0.59, if both disagreed the probability decreased to 0.42. In case both results disagreed, the results were used to determine in which classification category the sample would fit using the decision trees, and an alternative identification was realised.

Appendix 7 contains a list of the results of the application of the Bayesian probability model to the samples from WJ13. The PCA scatterplots below (figure 8.33.) visually illustrate the change in classification for some of the samples based on the model. While there is little difference between the two graphs comparing information for the first two components, the scatterplots showing the second, third and fourth components (described in section 7.3.1.) portray clearer clusters of activity areas.

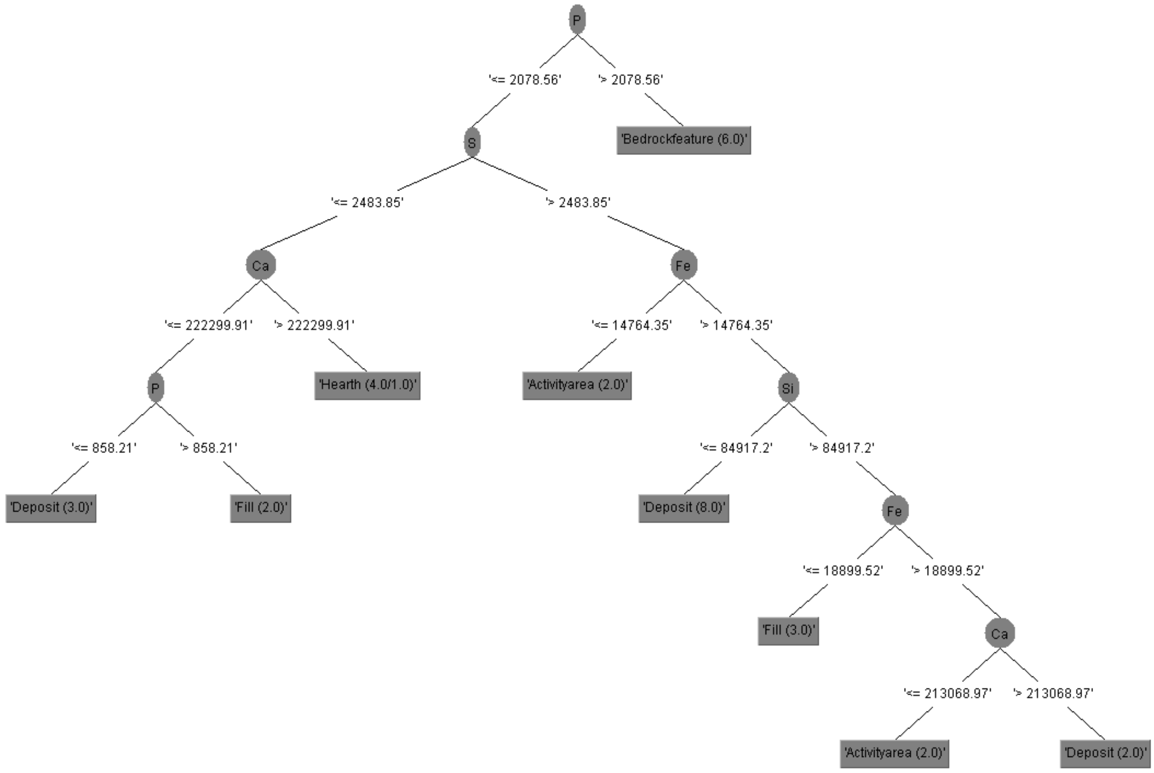


Figure 8.31. Decision tree created for WJ13 based on the geochemical results, including the categories: deposit, hearth, bedrock feature, activity area, fill and background. 38% of cases were correctly classified.

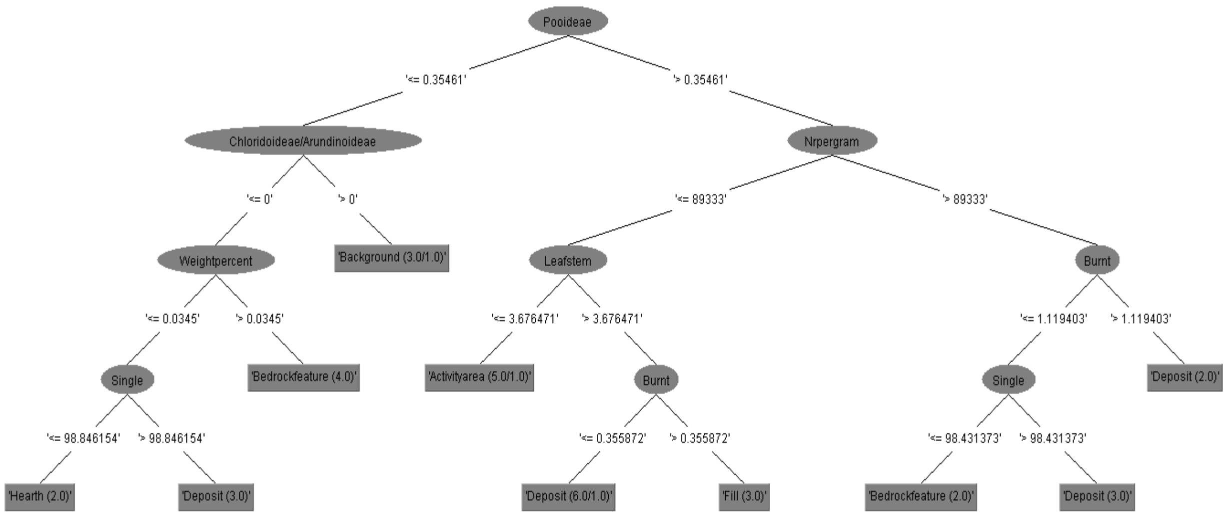


Figure 8.32. Decision tree created for WJ13 based on the phytolith results, including the categories: deposit, hearth, bedrock feature, activity area, fill and background. 21% of cases were correctly classified.

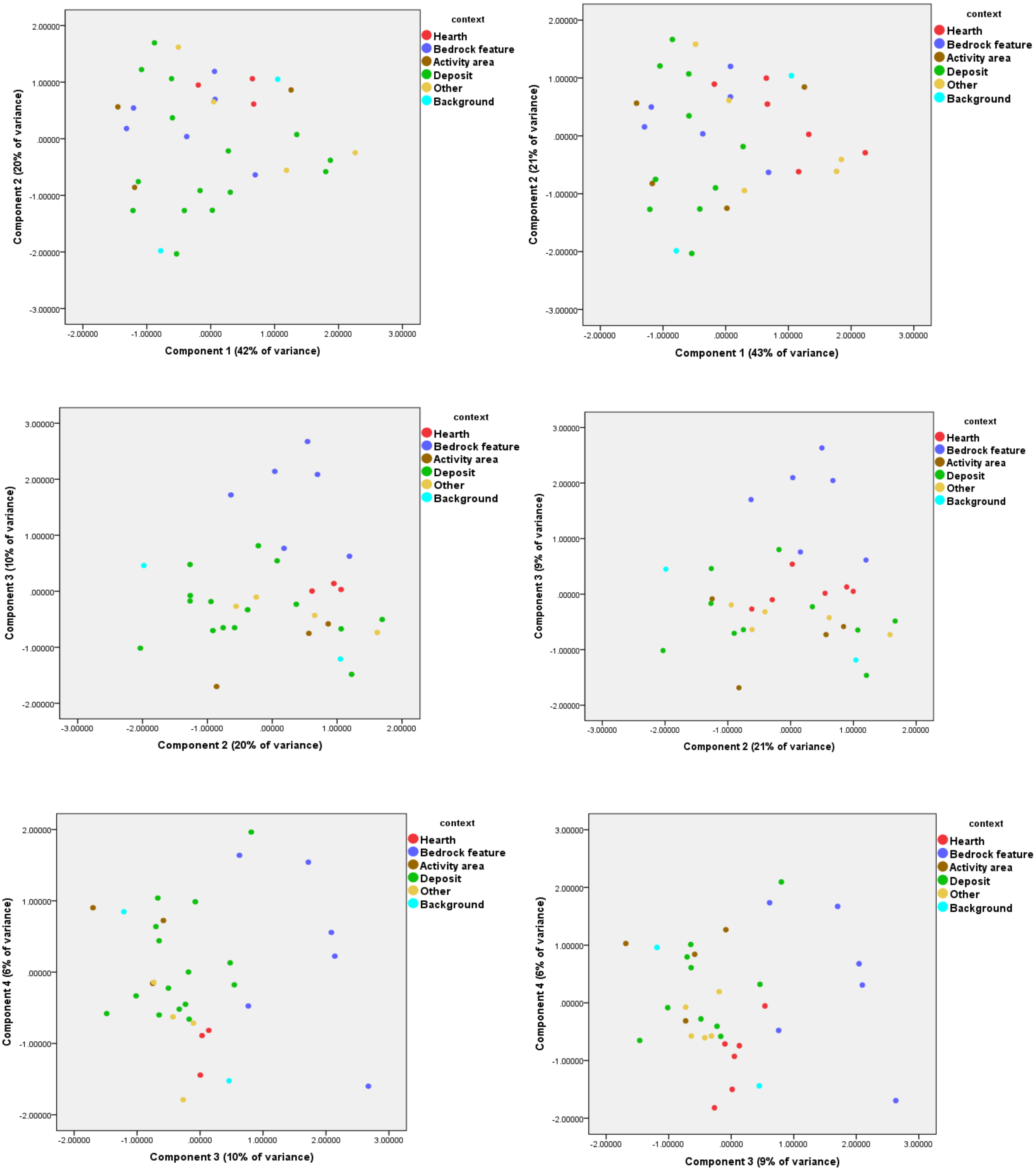


Figure 8.33. PCA scatterplots for WJ13 based on the geochemical analysis results. The graphs on the left represent the original context categories, the graphs on the right represent the change in the categories of some of the samples after the application of the Bayesian based model.

Aiding the interpretation of activity areas at anthropogenic sites can also be done on the basis of decision trees alone. In the case of the ethnographic data, the identification of activity areas in most sites was secure, but some of the Bedouin campsites, which were abandoned for a longer period, contained more ambiguity about some of the samples. This concerns mainly the identification of the kitchen and hospitality hearths at the sites WF940 (including one hearth – WF940 820) and 982 (including two hearths – WF982 873 and WF982 875). The geochemistry decision tree for the ethnographic data uses Zn to differentiate between the two types of hearths, while the phytolith one relied on the categories Panicoideae and multi-cell. According to these trends WF940 820 falls within the kitchen hearth category; its concertation of Panicoideae and multi-cell phytoliths resembles that of the dung sample, although the levels of Zn fall in between the two categories. At WF982 sample 873 falls within the hospitality hearth group while sample 875, which has higher concentrations of Zn, Panicoideae and multi-cell phytoliths than WF873, fits within the kitchen hearth category.

8.8. Discussion

The PCA scatterplots in chapters six and seven suggest that the main elements indicating difference between the context categories in the Neolithic sites are different from the clear markers of anthropogenic activities seen in the ethnographic data of Wadi Faynan and previous studies. This could indicate a variation in the background or parent material, other activities being represented at these sites, or be the result of taphonomic processes that have taken place during the 8,000 or so years after abandonment of the Wadi el-Jilat sites. Formation processes can influence the concentrations of certain elements to a large degree, as the example of the differences in Cl levels in dung related samples from the Wadi Faynan sites that had been abandoned for varying durations of time has revealed. It is also clear that more than a few elements are affected by anthropogenic activities, which led to general depletion and enrichment patterns (see chapter seven). In this sense, anomalies resulting from anthropogenic input could still be seen even if the original "main" elements (such as P or Mg) playing a role in these activities no longer show elevated concentrations due to mixing, dissolution or leaching. The "secondary" anthropogenic markers (such as Cr and Rb) that are of chief importance within the decision trees created for the Neolithic sites might be good indicators of past activities, and their role should be further explored in future studies.

The clarity of the anthropogenic signatures for the ethnoarchaeological context categories suggests that daily activities at ephemeral sites are highly visible within limited localities. However, prior knowledge of the use of space at these sites was necessary in order to interpret some of the observed patterns. The archaeological data contained weaker signatures of anthropogenic activity, the length of time since abandonment and the more general sampling strategy probably affecting the visibility of past activity areas. Nevertheless, even with only slight trends for some of the variables, statistical means were able to distinguish between broad categories of past activities. The use of a Bayesian based probability model in section 8.7. illustrates how this could allow for an improvement of the interpretation of spatial patterning made in the field. Even though the percent of correct classification of the geochemistry and phytolith analyses were low, the information from the results of both of these analyses aided the initial interpretation of context categories. This manner of combining information from various sources therefore carries much potential for aiding archaeological interpretation, and each additional analysis technique added to the Bayesian model would add strength to the interpretation.

9 Discussion

9.1. Introduction

This research set out to explore the potential of a dual phytolith and geochemical methodology for the identification of activity areas in ephemeral archaeological sites, and to contribute to our understanding of the formation of anthropogenic soil signatures. Studies of spatial activity patterns in archaeological and ethnographic sites using geoarchaeological methods are uncommon, and those combining information from geochemistry and phytolith analyses are even rarer. Testing the application of these techniques on ephemeral sites in an arid, dynamic environment contributed to questions concerning both the application of geoarchaeological methods for spatial analysis and taphonomic processes involved in the creation and preservation of anthropogenic soil signatures. In addition, through testing the application of the dual methodology on ephemeral sites, this study may also contribute to our understanding of prehistoric periods, which are often characterised by ephemeral occupation patterns. The following sections will discuss the findings of this research in relation to the aims outlined in section 1.5., which were:

1) To evaluate the potential of a dual phytolith and geochemical methodology to identify activity areas in ephemeral ethnographic and Neolithic occupation areas. This aim includes the assessment of each of the analysis techniques and exploring statistical means to combine the two sources of information in the most effective way.

2) To achieve a better understanding of how soil signatures are degraded through time in highly dynamic environments by examining taphonomic trends at the ethnographic sites that had been abandoned for varying durations of time, and through observations made about the preservation of soil signatures at the Neolithic sites.

The following two sections (9.2. and 9.3.) will evaluate the application of the dual methodology for the ethnographic and archaeological case studies and discuss the results obtained by the geochemistry and phytolith analysis for each type of site. Then, in section 9.4., the potential and compatibility of the two techniques and statistical approaches for their integration and result interpretation will be addressed. Section 9.5. will discuss the applicability of the dual methodology to other sites, and address issues encountered during this research. Finally, each of the research questions presented in section 1.5. will be addressed in section 9.6., summarising the findings of this study in relation to these.

9.2. The application of the dual methodology to the ethnoarchaeological sites

9.2.1. Evaluation of the efficacy of the dual methodology

The dual methodology was applied to ethnoarchaeological data in order to test its applicability on ephemeral anthropogenic sites in a controlled setting, where information about the use of space was available. Previous ethnoarchaeological spatial studies of geochemical and phytolith soil signatures indicate that specific (groups of) chemical elements are correlated to certain human activities, and that anthropogenic anomalies can be seen through phytolith analysis as well, although these will be more site specific (see Chapter 2). There are no universal concentrations of phytolith or chemical elements related to activities, the anomalies can only be observed through a comparison of samples within the context of a site. Previous publications also suggest that the use of multiple geoarchaeological techniques is beneficial for such studies (Canti and Huisman 2015).

The results of the ethnoarchaeological analysis in this research supports the observations made through the examination of previous studies, and the geochemical and phytolith analyses were found to provide a useful dual methodology for studying activity areas at the Bedouin campsites in 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. For example, the correlation of relative concentrations of chlorine to distinguish between hearths and dung samples, or the presence of wheat husk material in kitchen hearths (see Chapters 6, 7 and 8 for an overview of individual trends).

9.2.2. Geochemical patterns

The geochemical analysis of the Wadi Faynan sites provided insights into the associations between certain activities and particular chemical elements, or groups of these. The highest concentrations of the chemical elements Mg, Ca, Mn, S and Sr among the context categories were consistently found in hearths, and Zn was selected by the Weka decision trees as the best distinguishing factor between kitchen and hospitality hearths. High concentrations of K, P and Zn were characteristic of both hearths and animal dung. However, while the highest concentrations of K were either associated with hearths or dung, depending on the site, P and Zn were highest in the fireplaces of all sites except for WF916 where dung samples contain higher elevations of these elements. The discrepancy between WF916 and the rest of the campsites is probably related to a preference for other fuel sources above dung cakes at this site. This also indicates that hearths at the other campsites were enriched with K and P through the use of dung cakes. Animal dung at the Wadi Faynan sites also contained the highest concentrations of Cl, followed by the enrichment in hearths in all sites but WF916. The concentrations of this element, however, were found to diminish over time. Ti, Al and Fe were abundant in the background and floor related samples, the latter containing slightly higher concentrations of Cl which allowed to distinguish them from the natural sediment. These observations fit in well with the findings of earlier investigations. Table 9.1. summarises the associations between chemical elements and anthropogenic activities found in previous studies and in this research.

The geochemical analysis of the Bedouin campsites at Wadi Faynan added to the group of ethnoarchaeological geochemical studies of spatial patterning, of which there are not many. This is a unique ethnographic study of geochemical patterns at ephemeral sites in the Near East, allowing for another manner of spatial distribution of activities to be explored in a novel setting. One of the important additions to current understanding of geochemical trends in anthropogenic sites is the differentiation between hearths which were used for cooking and others which were not. Zn was found in this study to be the best chemical element to differentiate between the two types of burning signals, although further analysis is needed in order to determine if this only applied for the hearths at Wadi Faynan or represents a more wide-ranging trend. Including the site WF916, which unlike the other sites did not heavily rely on the use of dung cakes for fuel, allowed this study to identify the chemical elements within the hearths associated with burning and those which were derived from the dung. The association between chemical elements and activities found in this research match the findings of previous studies, suggesting that geochemical signals of activity have a universal nature. Findings regarding the associations between activities and certain chemical elements in ethnoarchaeological studies can therefore be applied to understand the use of space at other sites.

9.2.2.1. Patterns of enrichment and depletion in the geochemical analysis

Geochemical studies of activity areas in archaeological and ethnographic sites focus on elevations found in the concentrations of chemical elements considered to reflect anthropogenic input (see overview in section 2.3.2.). This research brings to light not only elevations of anthropogenic signatures but also a reduction in the natural occurring elements due to the anthropogenic input, which is readily observed through a PPM measurement level (figure 9.1.). The depletion in natural elements is compatible with the introduction of new material, which would dilute the background substances within the overall context matrix. An example of this can be seen in section 7.2.8.1., in the high concentrations of P and lower amounts of Al at JTW compared to the other sites. It is likely that a depletion of the 'natural' chemical elements will be noticeable in areas or sites with a strong anthropogenic input.

In order to get a comprehensive understanding of the processes that are involved in the creation of anthropogenic anomalies it is best to look at geochemical patterns within a suite of elements as a whole, rather than only focusing on enrichment of specific elements. It is also important to note that trends of enrichment and depletion only make sense within a site context containing the same parent material, where the readings can be compared to those of other samples and to the background samples. Individual measurements of geochemical elements cannot be understood independently, and there can be no universal framework of absolute measurements reflecting specific activities.

Chemical element	*Associated activity in previous studies*	*Associated activity in this study*
P	Food preparation and consumption (Fernandez et al. 2002; Parnell et al. 2002; Vyncke et al. 2011), burning and food storage (Middleton 2004), refuse areas (Fernandez et al. 2002), excrements (Vyncke et al. 2011), Byres (Wilson et al. 2008), Meat (da Costa and Kern 1999)	Hearths, animal dung
Mg	Wood ash (Middleton and Price 1996), cooking hearths, food preparation and consumption (Fernandez et al. 2002), Meat (da Costa and Kern 1999)	Hearths, animal dung
Ca	Cooking hearths (Fernandez et al. 2002), food storage and preparation (Middleton 2004; Vyncke 2011), lime use? (Middleton and Price 1996)	Hearths
K	Wood ash (Middleton and Price 1996), cooking hearths, food preparation and consumption (Fernandez et al. 2002)	Hearths, animal dung
Mn	Burning (Middleton 2004), vegetable (da Costa and Kern 1999)	Hearths
S	Not measured in previous studies	Hearths, animal dung
Sr	Hearths (Wilson et al. 2008), excrements and food preparation (Vyncke et al. 2011), Lime use? (Middleton and Price 1996)	Hearths
Zn	Hearths and Byres (Wilson et al. 2008), refuse areas (Fernandez et al. 2002), vegetable (da Costa and Kern 1999), meat (Tripathi et al. 1997)	Hearths (higher concentrations in kitchen hearths) and animal dung
Cl	Not measured in previous studies	Animal dung, hearths, animal pens
Fe	Craft production (high levels in combination with burning, Middletn 2004), burning (Vyncke et al. 2011)	Background
Ti	Background (Middleton 2004)	Background
Al	Background (Middleton 2004)	Background

Table 9.1. Associations between chemical elements and anthropogenic related activities found in earlier studies and in the analysis of the site of Wadi Faynan.

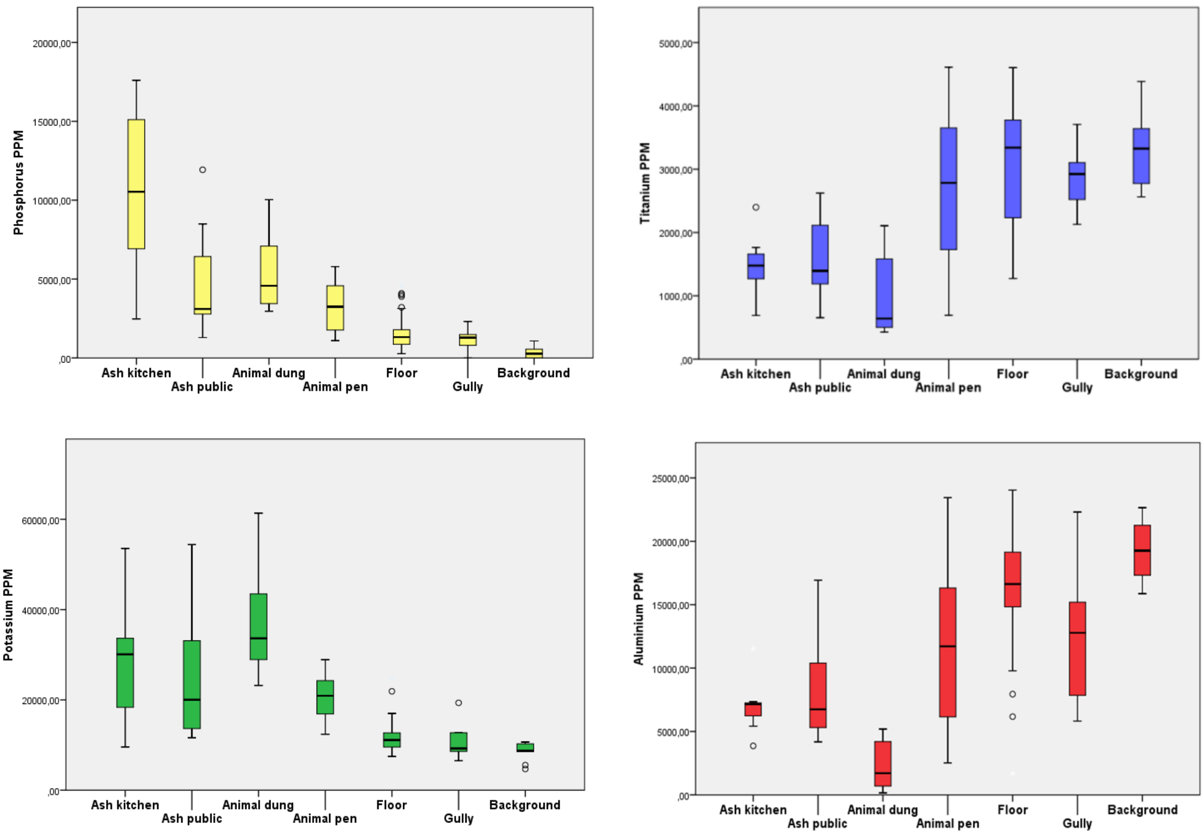


Figure 9.1. Examples of elements showing patterns of enrichment and depletion in the contexts influenced by anthropogenic inputs; ash kitchen, ash public and animal dung. Potassium and phosphorus show elevated concentrations in these context categories while aluminium and titanium are reduced.

9.2.2.2. Degradation of anthropogenic geochemical input

The variation in abandonment episodes among the Bedouin campsites allowed this study to explore patterns of short term dissolution (sections 6.2.8.1. and 7.2.8.1.). The only geochemical elements which were found to suffer from a reduction in their concentrations within the 15 years of difference in duration of abandonment which is captured through the studied sites at Wadi Faynan are chlorine and potassium (see sections 7.2.8.1. and 8.4.). The clearest deterioration effect can be seen within in dung samples. The depletion of chlorine and potassium through time could reflect the effects of exposure to sunlight and rain, mainly affecting outdoor animal pens but also indoor areas after abandonment and removal of the tent, and also anthropogenic inputs of decomposing organic matter and urine through animal dung, and water from household activities such as cleaning. It is difficult to estimate which changes would occur in the other chemical elements and phytolith attributes measured in this study over longer durations of abandonment than the 15 years represented through the Wadi Faynan campsites. Geochemical taphonomic processes are generally slow, although anthropogenic impact can speed up these processes (Mulder and Cresser 1994).

9.2.3. Phytolith patterns

As mentioned in section 8.2., the trends seen within the phytolith analysis results are more variable and site specific than the geochemical patterns. This fits in well with the evidence from previous phytolith studies of spatial patterning (see overview of phytolith studies in section 2.2.4.2.). Nevertheless, some general observations can be made regarding the nature of anthropogenic input at the Wadi Faynan sites through the phytolith analysis. The correlations discussed in section 8.2.2. show a strong association between chemical elements characteristic of anthropogenic enrichment and, among others, the phytolith analysis categories monocot and multicell phytoliths. High ratios of these two variables in relation to the opposed variables dicot and single-cell (respectively), and occasionally higher levels of weight percent or number of phytoliths per gram, are associated with the hearths and dung samples in most sites. These trends reflect the input of plant material, in particular derived from monocots, through grazing and fuel, to the contexts mostly affected by anthropogenic behaviour. In addition to elevations of monocots and conjoined phytoliths, occasional enrichment in specific plant material may allow for specific activity areas to be distinguished, such as the kitchen hearth at WF953 which contained a high concentration of *Triticum* sp.

This research adds to the limited number of ethnoarchaeological studies applying phytolith analysis to the study of spatial activity patterning, and confirms many of the findings in earlier publications. For example, high concentrations of phytolith material have been found to be associated with hearth and dung contexts in previous studies as well (see section 2.2.4.2.). Other patterns, related to phytolith morphologies, depend on the type of vegetation used for fodder and fuel at individual sites. The findings of this study can therefore not contribute to the application of universal associations between phytolith types and activities to archaeological sites, as these cannot be achieved through phytolith analysis. However, this research does provide insights into the nature of spatial information derived from phytolith material and the relationship between the direct and indirect input of plant material in hearths through dung and other fuel.

9.3. The application of the dual methodology to the archaeological sites

9.3.1. Evaluation of the efficacy of the dual methodology

The dual phytolith-geochemical methodology for identifying activity areas was applied to the Neolithic sites of Wadi el-Jilat in order to test its application on archaeological data. The trends observed in this study within the Neolithic sites are therefore not meant to be used directly in order to interpret other sites, but to inform us about the applicability of this method to study them. Unlike the ethnographic sites analysed in this research, the Neolithic sites probably represent different kinds of occupation, periods, and subsistence strategies. It is possible that the only aspects shared by these sites are their proximity to each other, their environmental setting and the method of their excavation. The unearthed deposited were described using the same terms, and by studying the geochemical and phytolith soil signatures associated with these the consistency of the categories across the sites could be determined.

The successful application of the dual phytolith-geochemical methodology was more site dependent at Wadi el-Jilat than with the ethnographic sites. While the identification of activity areas at WJ13 was fruitful to a limited degree, the multiple areas represented by WJ26 did not provide a coherent enough set of samples, and neither did a combination of the Wadi el-Jilat sites. The application of the dual methodology on WJ7 alone, on the other hand, provided clear differentiation of activity signals and a profound clustering of context categories within the PCA scatterplots and decision trees. It is likely that the individual buildings at Wadi el-Jilat were too different from each other to be studied as a whole according to the predefined context categories. An investigation into spatial patterning should therefore be restricted to an individual site context, which contains a large enough sample size to establish general trends for each context category. The application of the Bayesian model to WJ13 in section 8.7. was able to improve the geochemical and phytolith identification of activity areas at this site.

The period and duration of occupation, function of the buildings and types of activities that took place within them, use of different plant materials for fuel and construction, and taphonomic conditions could have all affected the comparability of the sites. WJ26 contained three areas, and was the most difficult to interpret due to the small sample size available for this site (see section 5.1.2.). WJ13 had a long sequence of occupation and reuse, 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 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 a structured occupation sequence of WJ7, contributed to the ease of its interpretation. As mentioned in section 1.3.1., 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 speculate that ephemeral archaeological sites with a straightforward stratigraphic sequence and a fixed, structured, spatial use of activity areas can benefit from the dual phytolith-geochemical method to a greater degree than sites with a complex stratigraphy which have been regularly modified.

This study represents the first combined application of geochemical and phytolith analyses of spatial activity patterns to ephemeral archaeological sites, and included the testing of statistical methods to obtain the most out of these. By doing so, this research contributes to future studies of ephemeral sites in highly dynamic environments. Previous applications of phytolith and/or geochemical analyses for the reconstruction of spatial activity patterns were conducted on large sites that contained substantial remains, with the exception of the phytolith study of Ayn Abū Nukhayla, a Neolithic site in Jordan representing seasonal occupation (see overview in section 2.2.4.2.). While all of these studies are important, and have managed to aid the archaeological interpretation of spatial patterning, it was unclear how well such methods would work on ephemeral sites. The analysis of the Neolithic sites of Wadi el-Jilat provided insights regarding the presence of geochemical and phytolith soil signatures at prehistoric ephemeral sites, their efficacy in interpreting activity areas within different sites, and the need for various statistical techniques to utilise the results of geoarchaeological methods in order to capture the variation in evidence of spatial trends available at these ancient ephemeral and dynamic sites.

9.3.2. Geochemical patterns

The geochemical variables that were found to be the most useful in distinguishing the anthropogenic input within the Neolithic sites are not the same ones that were found in the analysis of the Wadi Faynan sites or earlier studies (see Table 9.1.). The Weka decision trees created for the geochemistry results show a reliance on Cr, Rb, Ca, Zn and V in reflecting the clusters of the context categories, and the PCA scatterplots exhibited far better clustering when plotted according to the second and third components. An exception to this was the PCA scatterplot created for WJ7, which explained 82% of variance and included the first and second components. 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 this site enabled us to distinguish between context categories based on geochemical variables considered to reflect anthropogenic activity, the individual elements did not seem to correlate with the same activities that were associated with each element in previous studies. This however was the case with the site of WJ13, where Mg and K concentrations were highest for the hearths.

The geochemical analysis of the Neolithic sites suggests that there is great potential in identifying, or at least distinguishing between categories of activity areas at ephemeral sites. Although WJ13 and WJ7 have the same environmental and historical setting, and are adjacent to one another, the dual methodology worked differently with each site. WJ7 exhibits distinguishable context categories when examined through a PCA scatterplot - mainly due to the geochemical input, while the geochemical and phytolith analysis of WJ13 hints towards very subtle trends. The decision trees and descriptive analysis identified the best distinguishing factors to study the context categories within and across the sites.

9.3.3. Phytolith patterns

The results of the phytolith analysis at Wadi el-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. The bedrock features at WJ13 contained very low counts of phytoliths and most of them were associated with large amounts of silica aggregate material. In addition, the weight percent of this context category was much

Chemical element	*Associated activity in previous studies and at Wadi Faynan*	*Associated activity in this study*
P	Hearths, animal dung (WF), food preparation and consumption (Fernandez et al. 2002; Parnell et al. 2002; Vyncke et al. 2011), burning and food storage (Middleton 2004), refuse areas (Fernandez et al. 2002), excrements (Vyncke et al. 2011), Byres (Wilson et al. 2008), Meat (da Costa and Kern 1999)	General anthropogenic occupation (all sites), bedrock features (WJ13)
Mg	Hearths and animal dung (WF), wood ash (Middleton and Price 1996), cooking hearths, food preparation and consumption (Fernandez et al. 2002), Meat (da Costa and Kern 1999)	Hearths (WJ13)
Ca	Hearths (WF), cooking hearths (Fernandez et al. 2002), food storage and preparation (Middleton 2004; Vyncke 2011), lime use? (Middleton and Price 1996)	General occupation (all sites)
K	Hearths and animal dung (WF), wood ash (Middleton and Price 1996), cooking hearths, food preparation and consumption (Fernandez et al. 2002)	Hearths (WJ13)
Mn	Hearths (WF), burning (Middleton 2004), vegetable (da Costa and Kern 1999)	Activity areas (WJ13)
S	Hearths and animal dung (WF)	Hearths and bedrock features (WJ7)
Sr	Hearths (WF; Wilson et al. 2008), excrements and food preparation (Vyncke et al. 2011), Lime use? (Middleton and Price 1996)	Slight elevations in hearths (all sites)
Zn	Hearths and animal dung (WF), hearths and Byres (Wilson et al. 2008), refuse areas (Fernandez et al. 2002), vegetable (da Costa and Kern 1999), meat (Tripathi et al. 1997)	Hearths (WJ26)
Cr	Not measured in previous studies	Bedrock features (WJ7, WJ26)

Table 9.2. Associations between chemical elements and anthropogenic related activities found in earlier studies and in the analysis of the site of Wadi el-Jilat.

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 among the Neolithic sites. While all contexts show an increase of monocots in relation to the background samples, the categories "activity area" and "compact ashy fill" contained the highest concentrations of these. These two categories plot similarly when it comes to plant parts, containing the largest amounts of husk material in relation to the other context categories. Interestingly, the background sample is devoid of husks, but contains larger amounts of silica aggregates. The only clear observed pattern at WJ26 is a high number of phytoliths per gram for the category "compact ashy fill" in relation to the other context categories, which are associated with a far lower number per gram (the background samples are ignored here as they were collected from the vicinity of WJ7 and WJ13 and so might not provide a suitable comparative means for this site).

All in all, it appears that the same phytolith variables indicate a strong anthropogenic input at the Wadi el-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. 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 anthropogenic enrichment within two context categories at WJ7 that appear to reflect high activity, the activity areas and compact ashy deposits (which probably reflect hearths), strengthen 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. These results are encouraging considering the general sampling strategy, 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.

9.4. Evaluating the dual geochemical and phytolith methodology

9.4.1. The efficacy of geochemistry and phytolith analysis for studying activity areas

This research has shown that both phytolith analysis and geochemistry can be used to reveal patterns in the use of space at ephemeral sites (see discussion of the results in sections 9.2. and 9.3.). However, the use of these two sources of information within the dual methodology applied in this study was tied to an initial interpretation of context categories in the field during sampling or excavation, and its success depended on the structured use of the sites and the simplicity of the sequence of occupation within the Neolithic sites (see section 9.3.1.). The combination of data from geochemistry and phytolith analysis worked well for identifying activity areas in the ethnographic sites because the two types of results informed us about different forms, and aspects, of activities that were carried out at the sites. Much overlap exists within the categories of anthropogenic enrichment due to the use of vegetal material in many activities which also produce chemical signals, such as burning, which leaves phytolith indications of the type of plant used for fuel and an enrichment in chemical elements such as Mg and Ca. However, each of the methods can still provide detail in cases where the other technique does not allow a distinction to be made between two types of activities. This is illustrated in the ability to differentiate between kitchen and hospitality hearths within the ethnographic data based on the phytolith analysis, while the geochemical results grouped these two categories together (see section 8.2.1.).

The efficacy of the geochemistry was found to be greater than that of the phytolith analysis. The PCA scatterplots and decision trees in Chapters 6-8 produced better outcomes for the geochemical results than for the phytolith analysis, allowing for a more distinct and consistent division between context categories to be made. The geochemistry decision trees for both ethnographic and archaeological sites had higher rates of correctly classified instances than the decision trees based on the phytolith analysis. Similarly, the PCA scatterplots based on the geochemical results explained a greater amount of variance and showed a higher degree of clustering than those base on the phytolith results.

This having been said, the results of the analysis in Chapter 8 make it clear that a combination of the two methods is valuable. Although the geochemistry might explain the largest amount of variation within the data, it does not explain all of it. The strength of the phytolith analysis results lies within site specific trends, where they can be used to fine-tune the more general interpretation provided by initial definition of context categories in combination with the geochemical analysis. The identification of the ash sample at the ethnographic site WF940 as derived from a kitchen hearth was only possible by incorporating the two methods, since the geochemical indication alone was indecisive (see section 8.7.). The use of a dual methodology was found to be a strong tool for the interpretation of space at ephemeral sites despite, and perhaps even by virtue, of the differences between the two techniques.

9.4.2. The compatibility of phytolith analysis and geochemistry

By exploring the results of the two analysis methods it became clear that they are different in the nature of the trends they represent, in their degree of universality and in their competency in identifying activity areas (see Chapter 8). While geochemical patterns are more universal, representing the same activities across sites, phytolith trends are more site specific, although some similarities across sites can be observed (see Chapters 2 and 8). In addition, differences in the form the results take for both types of proxy influences their degree of compatibility. The measurement level of chemical elements was PPM. This allowed for one type of comparison within the geochemical data, one that is based on the concentrations of elements in the soil. The phytolith assemblages, on the other hand, could be compared through counts of phytolith types, taxonomic identifications, related attributes such as silica aggregate material or weight percent, and also through exploring ratios between related categories based on the phytolith counts such as multi-celled to single-celled phytoliths, or plant parts. This means that there are different levels of comparison within the phytolith data. The differences in measurement levels of the two methods used affect the way in which their results can be combined (see section 9.4.3.).

9.4.3. Combining the two sources of information to identify activity areas

The results of this research suggest that in the case of geochemical and phytolith analyses both methods carry the most value by being integrated in a serial or parallel analysis (see Chapter 8). This is due to their degree of compatibility; differences in the measurement level, efficacy, and universality of the geochemistry and phytolith analysis, which make the integration of their results within a single statistical test unfruitful. For example, when variables from both geochemistry and phytolith analysis were combined to create one decision tree, it did not provide a better classification nor was it able to classify more cases correctly than the geochemistry decision tree alone (section 8.2.1.). Nevertheless, the differences between the two sources of data are what make their integration worth while pursuing – each one can provide information about activities not captured with the other.

In addition, while some activity areas can be distinguished through using one method and others through the other, each technique can also be used to strengthen or fine-tune an interpretation achieved by another means of analysis or observation in the field. This can be done by considering trends in both types of data individually, or by combining the results in a model where they are considered independently such as the Bayesian belief network based model which was tested in section 8.7. The application of this model to the samples from WJ13 revealed that the use of even one soil analysis technique can aid the original interpretation of the use of space at a site, but that the certainty of the new identification increases when another method is added. In this sense, the difference in the type of data achieved from the two analysis techniques makes the identification of activity areas more convincing. The phytolith analysis reflects patterns of plant use, while the geochemistry is related to signals of activities such as burning and animal husbandry. If both of these different sources point towards a confirmation or rejection of the initial interpretation of a context category, it is more compelling than is the case with related sources of information.

9.4.4. Evaluating methods for data manipulation and interpretation

This work has explored new ways to visualise and examine pre-defined context categories using decision trees in addition to commonly used statistical techniques such as PCA scatterplots and bar charts. Previous spatial studies based on geochemistry and phytolith analyses used multivariate correlation (Middleton 2004; Parnell and Terry 2002; Vyncke et al. 2011), cluster analysis (Dirix 2013), PCA (Dirix 2013), nearest neighbour analysis through Pearson's correlation index (Portillo et al. 2009); descriptive statistics and associated graphs (Shahack-Gross et al. 2004; Portillo et al. 2014; Oonk et al. 2009c), an index for phytolith difference (Tsartsidou et al. 2008), and in the case of grid sampling plans of the sites with interpolated values of the concentrations of chemical elements or phytoliths (Fernandez et al. 2002; Middleton et al. 2004; Vyncke et al. 2011; Wells et al. 2000).

While these methods of data exploration and visualisation remain valuable, none of them combine information from multiple sources to render an interpretation of activity areas. Incorporating decision trees for spatial analysis at anthropogenic sites opens up new possibilities for analysis and can increase our certainty of the designation of samples to specific context categories. The Weka decision trees created for the geochemical and phytolith data in this study provided an overview of how successful each method was in identifying the predefined context categories, how well these describe the data, and identified the key variables that distinguished activity areas. In addition, they allowed for the identification of "typical" signatures for specific activity areas. This enabled the division of each sample into a context category based on the results of the soil analysis. The Bayesian belief network based model explored in section 8.7. utilised the information from the decision trees to provide probabilities for the identification of activity areas, and could potentially incorporate any number of additional methods for spatial analysis in future studies.

Alongside the new statistical methods tested in this research, the traditional data exploration techniques used in this study proved vital in establishing the trends of spatial activities. The PCA scatterplots and discriminant analysis provided a better understanding of how the different variables drive the variance within the data, and established the chemical elements characterising the natural versus the anthropogenic essences within the soil samples. Bar charts for each geochemical and phytolith variable allowed us to explore trends in relation to the various context categories and sites. These small scale statistical analyses through visualisation enabled associations between soil signatures and activity areas to be made, which shed light on the more general patterns observed through the PCA, discriminant analysis and decision trees. The three methods of data exploration complemented each other and provided an understanding of general trends within the data, aided the assessment of the application of the geochemical and phytolith analyses, and established individual correlations between anthropogenic activities and soil signatures and their development through time.

By finding new ways to use the information from geochemical and phytolith data, this research contributed to applying these techniques to archaeological case studies. Rather than trying to find "hard" archaeological evidence, the approach taken in this study was to bridge the gap between the scientific methods used and the ambiguity of archaeological data. This required fitting, or scaling down, hard methods to soft data, which was enabled by the use of decision trees and a Bayesian based probability model.

9.5. Recommendations for future studies and limitations

9.5.1. Applicability of the dual methodology to ephemeral archaeological sites

While the geochemical and phytolith signatures at WJ7 provided straightforward clusters of activity areas, this was not the case for WJ13 and WJ26 (section 9.3.1). Based on the results of the analysis in relation to the different conditions at these sites, it is assumed that ephemeral archaeological sites with a straightforward stratigraphic sequence which had a fixed, structured, spatial use of activity areas in the past can benefit from the dual phytolith-geochemical method to a greater degree than sites with a complex stratigraphy which have been regularly modified (section 9.3.1.). Naturally, the dual methodology will not be useful in sites which did not contain differentiated activity areas in the first place. The difficulty in correlating trends in the data across sites demonstrates the non-analogous nature of this approach, which will be most successful when studying a significant sample size (an estimation of n>20 can be provided considering the sample sizes used in the study of the Neolithic sites) within the context of a single structure or habitation area, preferably within a single episode of occupation.

The use of the dual methodology for the sites WJ13 and WJ26 was tied to the initial interpretation of activity areas in the field, and the use of decision trees and the Bayesian belief network based model to adjust this initial identification. In this sense, the evidence from the phytolith analysis and geochemistry can be used to aid the initial interpretation in the field by either confirming it, adjusting it or ruling out certain designations. This in turn allows for an (re)assessment of the archaeological interpretation of space. As mentioned above, the extent to which the combination of geochemical and phytolith studies, or the integration of other techniques, will be useful for distinguishing activity areas in other archaeological ephemeral sites depends on the nature of their habitation. The dual methodology might not be suitable for ephemeral sites which do not allow for an initial interpretation of context units to be made in the field, which could be necessary to guide the sampling strategy and provide the basis for additional statistical analysis.

The variable success of the application of a dual phytolith-geochemical method to the archaeological sites in this study may also be related to limitations set by the length of time since abandonment, difficulty in targeted sampling activity of areas in the field, or even reflect discrepancies between the activities taking place at the Neolithic sites and our expectations or modern analogies for these. It is not surprising that the previous knowledge about the Bedouin campsites and an accurate sampling strategy allowed for a more straightforward interpretation of the results of the ethnoarchaeological data. Perhaps some of the sites of Wadi el-Jilat had non-domestic functions that we are not aware of, producing soil signatures that we cannot interpret due to the lack of modern analogies. It is difficult to know what to expect from an archaeological (or any other anthropogenic) site in advance, and each case has different potential when it comes to phytolith and geochemical analysis of soil samples. The dual methodology proposed here can aid the identification of activity areas in any site where such soil signatures have been preserved, but might need to rely on an initial archaeological identification of these.

9.5.2. Recommendations for sampling

Sampling strategies are vital when studying soil signatures of anthropogenic activities, and need to be considered carefully. The sampling at Wadi Faynan was guided by previous knowledge on the use of the Bedouin campsites, and each activity area that was thought to be relevant for the spatial analysis was sampled. However, it is important to keep in mind that the last activities taking place before abandonment will strongly influence the results. For example, a fresh kitchen hearth sample collected from JTW might only reflect the most recent addition to this feature, which in this case seems to have been fuel as no wheat remains were retrieved from this sample.

The use of a grid sampling method could have been argued for at Wadi Faynan, as such a strategy often allows for an overview of the gradients of concentrations. However, the results of the ethnoarchaeological analysis in this research suggest that the increase of samples would have created more work while providing similar results because the anthropogenic soil signature were restricted spatially to limited localities at these sites. Floor samples that were collected from the edge of hearths, in sleeping areas, kitchens and gullies, which could have potentially revealed activity-specific signatures, ended up showing no variation in relation to other floor samples and the natural sediment. It is therefore likely that most samples on a sampling grid system, other than the ones falling within hearths or dung layers, would have provided similar results to the background and floor samples. Soil signatures of anthropogenic input appear to be very local at these sites, perhaps in part due the use of matting within the tents which could have prevented the spread of signs of activity throughout the area. These findings could also indicate a difference between the spread of soil signatures and artefacts, which did portray gradients of concentrations at Wadi Faynan (Palmer et al. 2007). In the case of the ethnographic case studies analysed in this research, a feature directed sampling strategy was probably the most efficient way to provide an overview of the characteristics of activity areas. Nevertheless, while this sampling strategy worked well for the Wadi Faynan sites, grid or other sampling strategies might reflect concentrations of activity better at other sites.

The sampling of the Wadi el-Jilat sites was performed without prior knowledge of the use of these sites, or even the future purpose of the soil samples. In some cases, such as hearths or bedrock features, the soil was collected from specific features. In other cases, the soil samples were collected from a randomly selected locality within a context. If the soil signatures reflecting anthropogenic input were very local, as was the case at Wadi Faynan, a precise sampling strategy would be needed in order to retrieve clear signals of activity. It is perhaps for this reason that the soil samples from the archaeological sites show the strongest division into three categories; deposits and other contexts, hearths, and bedrock features. The specific sampling of the last two categories could mean that they show distinctive patterns, while the more general sampling of the other contexts could have made them difficult to distinguish from each other. It is also possible that many of the more general deposits represented layers which similarly to the floor surfaces at the campsites of Wadi Faynan did not contain strong signals of activity detectable by the methods used in this analysis. As mentioned above, geochemical and phytolith soil signatures could be very local, in which case they would not be captured through a random sampling location within a large sediment unit. The effect of specific and informed versus general and ambiguous sampling strategies on the analysis of soil samples needs to be considered for future studies of spatial activity patterning.

Recommendations for future sampling strategies involve the full consideration of a large sample size (see section 9.5.1.) within each area of habitation, including both indoor and outdoor areas, which could portray anthropogenic enrichment. How this is achieved for each site depends on the way in which it was used in the past. Therefore, the best sampling strategy for each individual site is best determined and adjusted during fieldwork, while considering the suitability of the techniques chosen for analysis and consulting the preliminary readings of these. The results of this analysis support the use of field equipment such as the P-XRF, and even field laboratories during excavation. The use of micromorphology could help identify the nature of occupation phases and taphonomic processes which could influence the applicability of phytolith, geochemical or other techniques, and advise on the preservation of sources of information, and is recommended for future studies. Performing as much of the analysis in the field as possible enables more flexibility, finding the most suitable methods for analysis during excavation, which can lead to better targeted sampling allowing for more fruitful results.

9.5.3. Recommendations for the statistical synthesis of multiple proxies

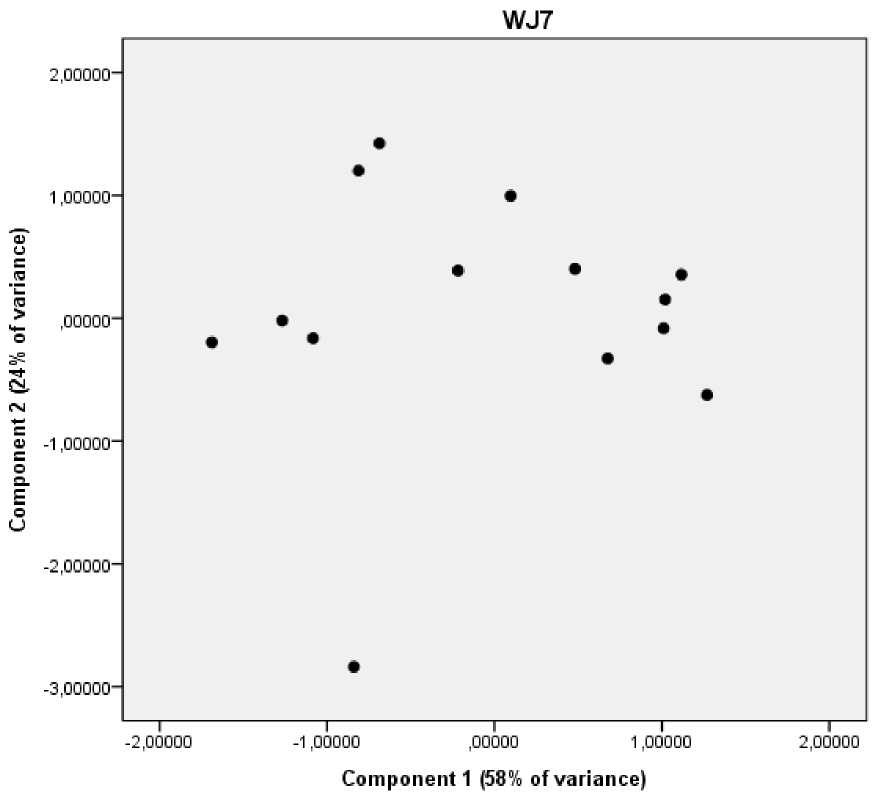
The statistical analysis of the results of the geochemical and phytolith analyses in this study suggests that a serial or parallel, rather than combined, synthesis between various geoarchaeological analysis techniques is advisable. This is due to the compatibility of the methods of analysis and differences in the types of data produced by these (see sections 9.4.2. and 9.4.3.). This work explored the use of PCA, discriminant analysis, decision trees and a model loosely based on Bayesian belief networks as means to achieve an overview of the clustering of data according to each analysis method and combine the two for aiding the interpretation of space within sites. Other statistical methods for achieving a serial or parallel application of the results of a number of geoarchaeological or additional proxies for past activities may carry value for archaeological interpretations of space, and should be explored in future studies.

While the analysis of the geochemical and phytolith results in the study of the Neolithic sites required the use of a probability model and relied on the initial interpretation of the context categories in the field, this might not always be necessary. Another option for the identification of activity areas would be to identify these from the clustering of data, in a 'blind' manner, which does not rely on the interpretation and identification of these features in the field. The advantages of such an approach is that it provides a more objective means to identify activity areas, and could enable this even within sites where a differentiation of context categories cannot be achieved in the field. However, the nature of occupation in early ephemeral sites, especially where 'industrial' craft activities and the processing of metal do not occur, produces an anthropogenic enrichment which is weaker than that of later, or more substantial sites. Reaching good results independently from archaeological expert opinion is therefore less likely in such sites. Figure 9.2. demonstrates that in the case of the sites of Wadi el-Jilat, this approach is not always feasible. While clustering to some degree can be seen within the geochemistry PCA scatterplot created for WJ7, the one created for WJ13 would only enabling distinguishing a weak cluster of bedrock features on the right. The interpretation of space at ephemeral sites, which often contain weak levels of anthropogenic input, might need to rely more heavily on expert opinion than is the case with more substantial occupation deposits, such as the sites discussed in chapter 2.

9.5.4. Further work

This study has shown the potential of a dual phytolith-geochemical methodology to identify activity areas at ephemeral sites. The methodology worked well for the ethnographic sites and at one of the Neolithic sites, WJ7, but to a lesser degree at the other two archaeological case studies. One of the possible reasons why the methodology did not work as well for the other Neolithic sites could be the nature of their occupation, which was not necessarily domestic. An important way of increasing our ability to interpret a variety of archaeological sites and past scenarios in future studies would be to focus on non-domestic activities when conducting additional ethnoarchaeological and experimental work on the distribution of activity areas. This will aid the interpretation of occupation which had a non-domestic function in the past, by identifying attributes, or the lack of these, which are typical for other kinds of occupation. Searching for soil signatures of non-domestic activities might also enable us to better interpret types of anthropogenic enrichment which is currently unidentified, such as the presence of chemical elements not currently associated with any human activities (see section 2.3).

Addressing sources of information which potentially represent different inputs from anthropogenic activities, in our case plant material and chemical elements, provides a comprehensive approach for identifying various spatial divisions (see section 9.4.1.). Additional multi-proxy applications of different geoarchaeological techniques are needed in order to establish the value of a range of methods for identifying different aspects of human activity. Geoarchaeological analyses of activity areas are a fairly recent development, and further studies looking into the compatibility and integration of such techniques will help determine the best approach for studying sites of different scale, date, nature of habitation, and taphonomic disturbance.



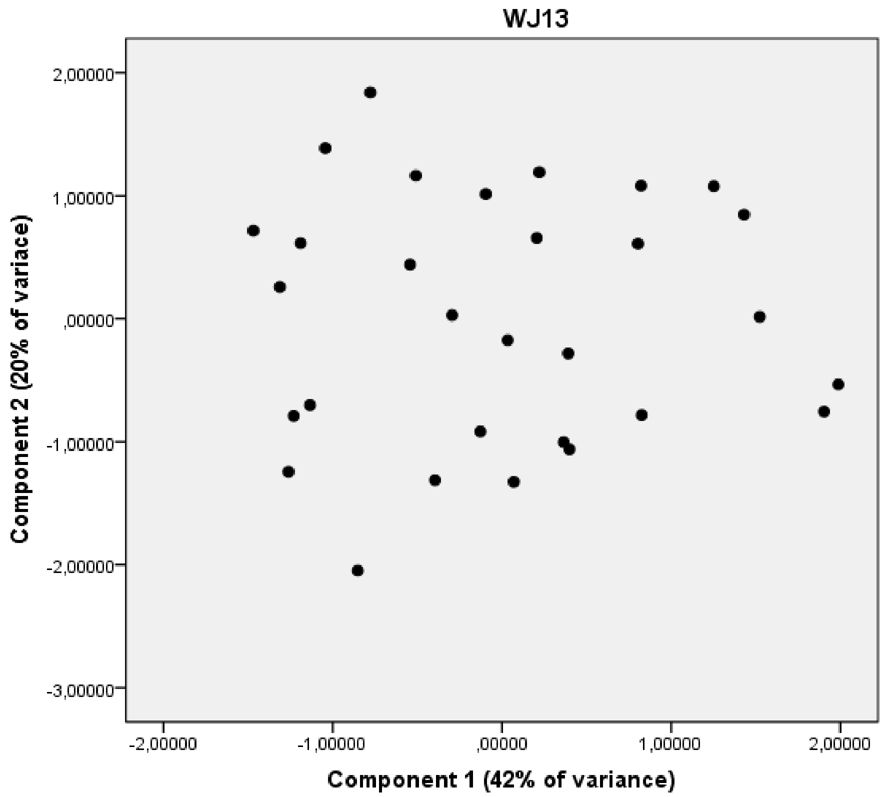


Figure 9.2. PCA scatterplots based on the results of the geochemical analysis for the sites WJ13 and WJ7.

9.5.5. Problems of equifinality

The use of dung cakes and the burning of dung sediments within animal pens at the Bedouin campsites create similar soil signatures from different sources of activity. However, the specific activities can be easily separated by considering a combination of variables and the differences in concentrations of these. In addition, each type of activity will include chemical elements that are not found in the other, such as chlorine or manganese. The two types of hearths can be distinguished using Zn levels at Wadi Faynan, and in some cases by the presence of wheat derived from bread making. It is difficult to carry these observations to future analyses of other sites, yet it is important to keep in mind that similar results could represent different activities. The likelihood of discovering small differences within larger context categories increases with the use of additional scientific and statistical methods.

9.5.6. Issues related to the interpretation of variance in concentrations

A similar problem to that of equifinality is establishing the likelihood of other scenarios in explaining differences in the levels of concentrations of anthropogenic soil signatures, which are relied upon in order to distinguish between activity areas. Do shifts in concentration of chemical elements or phytoliths reflect intensity of use, breakdown through time or individual preferences? WF916 is an important case study in this respect, as it provides an example of different preferences to other campsites. Unfortunately, the 15 years of difference in abandonment periods represented by the Wadi Faynan campsites do not provide a long enough time frame to explore related taphonomic processes in depth. Additional research into the breakdown of elements and mechanisms of concentration needs to take place in order to properly examine this issue, which is vital for the interpretation of anthropogenic soil signatures that are often left exposed to the elements in ephemeral sites.

The observed trends of activity areas in the sites where the application of the dual method was successful portray a simple divide into few categories of activity. One of the things that could not be observed through the geochemical and phytolith analysis of the Wadi Faynan campsites, for example, was the flexible use of spaces at different moments of the day relating to hospitality needs on the one hand, and cultural requirements on the other.

It could be that we are missing out on signals for other activities, but it is plausible that ephemeral sites represent a simplified habitation model in comparison to larger and more complex sites. While this can only be speculated for the archaeological sites, prior knowledge of the Bedouin campsites illustrate that household activities at a specific domestic site leave traces of agricultural and food preparation related activities. These provide important insights to the practical aspects of sustainability, although they could never truly reflect the richness of the social and cultural world it supports.

9.7. Addressing the research questions guiding the aims of this research

So far, the aims of this research were addressed through summarising the outcomes of this investigation. This section will consider the findings in light of the research questions outlined in section 1.5., providing a concise overview of the issues addressed in this and the first chapters.

- ❖ Can activity areas at ephemeral anthropogenic sites be distinguished through the use of geochemical and phytolith analyses?

The use of the dual phytolith-geochemical methodology was found useful for distinguishing between activity areas in ephemeral sites. The results of the ethnoarchaeological analysis support the notion that geochemical and phytolith signatures can be found in the soil at the locations where activities took place. The results of the archaeological analysis suggest that many of these signatures are present in the soil at ephemeral sites even after a substantial length of abandonment.

- ❖ How do the two methods compare in terms of their efficacy and type of information they provide?

The measurement level of chemical elements was PPM, parts per million. This allowed for one type of comparison within the geochemical data, one that is based on the concentrations of elements in the soil. The phytolith assemblages, on the other hand, could be compared through counts of phytolith types, taxonomic identifications, related attributes such as silica aggregate material or weight percent, and also through exploring ratios between related categories based on the phytolith counts such as multi-cell to single-cell phytoliths, or plant parts. This meant that there are different levels of comparison within the phytolith data. Another aspect related to the nature of both methods of analysis is their universal applicability. Although some tendencies were present across sites, phytolith trends were generally found to be site specific, while the relation between specific geochemical patterns and certain human activities was found to be more universally applicable.

The efficacy of the geochemical analysis was higher than that of the phytolith analysis when it came to identifying activity areas. Decision trees and PCA scatterplots created for the geochemical results of both ethnographic and archaeological data provided a higher percent of correctly identified instances and explained a higher percent of variance within the data. This having been said, adding information from both methods was found more useful in identifying activity areas than only one. While geochemistry may explain more variance within the data than the phytolith results, the two methods complement each other and provide information about different aspects of activities.

❖ How can the two methods of soil analysis be combined in order to achieve the best understanding of the use of space at ephemeral sites?

This study maintains that the best approach for combining the results of the geochemical and phytolith analyses is a parallel or serial, rather than an integrated manner. Decision trees created for the geochemical, phytolith and a combination of the two show that the combined decision trees do not provide a better classification of context categories than the geochemical results alone. The limited value of integrating the results of both analyses is due to the differences between the nature and type of information provided by each of the methods. By using the two techniques alongside each other, they can help fine tune the interpretation of the use of space at archaeological sites, and tackle issues of equifinality and equivocality.

- ❖ Do soil signatures of activities preserve in ephemeral sites well enough to enable the interpretation of activity areas?

The results of the soil analysis in this dissertation suggest that soil signatures at ephemeral sites can be preserved under the harsh conditions of dynamic environments, in our case those of the Near East. While the surfaces of the Bedouin campsites studied in this research were left exposed to wind erosion and rain after the tents covering them were moved to a different location, they retained phytolith and geochemical soil signatures for at least 15 years. The ephemeral occupation of the Neolithic sites of Wadi el-Jilat left traces of activity in the soil as well, which were detected through geochemical and phytolith analysis 8,000 or so years after abandonment.

- ❖ What observations about the taphonomic processes involved in element retention in soils can be made when the geochemical signatures of Bedouin campsites, which were abandoned for varying lengths of time, are compared?

The majority of chemical elements and phytoliths measured in this research do not appear to suffer from taphonomic processes within the short span of time differentiating the periods of abandonment of the Bedouin campsites. However, chlorine and potassium concentrations drop over time, more rapidly within dung deposits than with other context categories. This could be in part due to the organic nature of the dung and dung related sediments they are found in, but probably also as a result of exposure to moisture and sunlight.

- ❖ What can the analysis of the ethnographic and archaeological soil samples in this research inform us about sampling strategies for phytolith and geochemical spatial studies at ephemeral sites?

The sampling of the ethnographic and archaeological sites analysed in this study was guided by observed features in the field. Rather than a grid sampling system, which would provide a spread of random points across the sites, the sampling of the Wadi Faynan and

Wadi el-Jilat sites tried to represent activities or units of activity in the most precise manner. This was more easily achieved for the ethnoarchaeological sampling, which was guided by prior knowledge about the spatial use of the Bedouin campsites. It is estimated that soil signatures of activity, at least in the case of the ethnographic data, remain confined in space. Samples taken in close proximity to activity areas such as hearths or dung samples did not differ from the floor or background samples at these sites. This suggests that a grid sampling system would not have provided additional benefit to this study since soil signatures showing signs of anthropogenic anomalies would be limited to the activity areas that have already been sampled. An attempt should therefore be made to sample as precisely as possible in order to capture signatures of activity. This having been said, sampling strategies should be tailored to the needs of each individual site, and recommendations for sampling strategies in future studies are only that these should be carefully considered in relation to both indoor and outdoor activities.

By addressing these research questions, this study has contributed to future applications of phytolith and geochemical methods for spatial analysis of archaeological sites, in particular ephemeral ones situated in dynamic environments. In addition, it contributed to our understanding of formation and taphonomic processes influencing soil signatures related to anthropogenic anomalies at these sites. Previous studies of spatial patterning at anthropogenic sites using a number of geoarchaeological techniques did not address approaches for the combination of data from various sources. By exploring ways to do so, this research contributes to future studies wishing to combine information attained from multiple proxies.

10 Conclusions

The aims of this research were to establish the potential of a dual phytolith-geochemical methodology to identify activity areas in ephemeral archaeological sites and to add to our understanding of the formation and taphonomic processes influencing phytolith assemblages and geochemical signatures. This research has established the value of the dual phytolith-geochemical methodology to understanding the use of space at ephemeral sites, and developed novel statistical applications that enable the use of geoarchaeological techniques to aid archaeological interpretation. In addition, this study added to our knowledge of formation and taphonomic processes involved in fire installations and animal husbandry at ephemeral sites. By doing so it contributes to future geoarchaeological investigations, particularly those involving the study of ephemeral sites in dynamic environments. The key findings of this research can be summarised as follows:

- The dual phytolith and geochemical method tested in this study was successful in identifying activity areas at the ethnoarchaeological sites.

- Differences between activity areas within the Neolithic case studies were less straightforward than within the ethnographic ones, and the dual methodology was not able to define activity areas independently from field observations in all of the sites. The dual methodology was successful in identifying activity areas at WJ7, and aided the interpretation of activity areas at WJ13 through changing the definition of some of the pre-defined context categories.

- The use of the dual methodology is most suited to ephemeral sites which portray a simple occupation sequence, with a significant sample size achieved by targeted sampling. The success of the dual methodology in identifying activity areas in prehistoric ephemeral sites may be tied to the structured use of space in the past, and could suffer from episodes of reuse and unstructured distribution of activities within the occupation sequence. The use of statistical methods such as the Bayesian based model applied to WJ13 in this study may improve the applicability of geoarchaeological spatial studies.

- This research indicates that phytolith patterns relating to the distribution of activity areas are more site specific than the geochemical patterns. The latter encompass a more universal application and was found to carry more potential in distinguishing between activity areas.

- The phytolith and geochemical analyses were found to work well together as part of a parallel or serial analysis, rather than conjointly. A statistical analysis integrating variables from both methods was found to be ineffective due to differences in the measurement levels of the analysis techniques and the nature of the data produced by these.

- The dual methodology works as a comparative tool, where different activity or context categories are compared within a single site environment in relation to background samples. An investigation into spatial patterning should be restricted to an individual site context, which contains a large enough sample size to establish general trends for each context category.

- The results of the analysis in this research suggest that geochemical and phytolith soil signatures at ephemeral sites can be spatially confined rather than being reflected in gradual transitions, necessitating targeted sampling in order to be explored in detail. Undertaking as much of the laboratory analysis in the field, and adjusting the sampling strategy according to preliminary results of these, is recommended for future studies.

- The patterns observed within the geochemical analysis of the ethnoarchaeological data suggest that anthropogenic enrichment of soils is linked to a depletion in the natural signature of the parent material. This is assumed to reflect the addition of new material, diluting the present soil matrix, which is reflected in PPM measurements.

- This research identified the role of chlorine as an indicator of animal dung. This addition to a known set of associations between geochemical elements and anthropogenic related activities suggests that experimental and ethnoarchaeological studies should seek to cover a larger range of geochemical elements than is currently the case.

- The geochemical analysis of the ethnoarchaeological sites has found that some soil signatures, such as chlorine and potassium, can have a rapid rate of breakdown depending on local conditions and might not be visible in the archaeological record in the same form.

- Future ethnoarchaeological studies of non-domestic activity areas are needed in order to be able to identify soil signatures associated with these, or perhaps the lack of these, in archaeological sites.

- Future spatial studies of ephemeral sites can benefit from the application of multiple geoarchaeological techniques, but their efficacy will depend on the preservation of such soil signatures, and in many cases also on an initial interpretation of units of activity in the field.

References

Abu Jaber, K. A., Gharaibeh, F. A. and Hill, A., 1987. *The Badia of Jordan: the process of change*. University of Jordan.

Albert, R. M., Weiner, S., Bar-Yosef, O. and Meignen, L., 2000. Phytoliths in the Middle Palaeolithic deposits of Kebara Cave, Mt Carmel, Israel: Study of the plant materials used for fuel and other purposes. *Journal of Archaeological Science*, 27 (10), 931-947.

Arrhenius, O., 1929. Die phosphatfräge. Zeitschrift für Pflanzenernährung, Dungung, und Bodenkunde, Teil B B, 10, 185–194.

Audouze, F., 1988. Des modèles et des faits: Les modèles de A. Leroi-Gourhan et de L. Binford confrontés aux résultats récents. *Bulletin de la Société Préhistorique Française*, 84, 343-352.

Baird, D., Garrard, A., Martin, L. and Wright, K., 1992. Prehistoric environment and settlement in the Azraq Basin: An interim report on the 1989 excavation season. *Levant*, 24, 1-31.

Banerjea, R. Y., Bell, M., Matthews, W. and Brown, A., 2015. Applications of micromorphology to understanding activity areas and site formation processes in experimental hut floors. *Archaeological and Anthropological Sciences*, 7, 89-112.

Banning, E. B. and Köhler-Rollefson, I., 1983. Ethnoarchaeological survey in the Beidha area, southern Jordan. *Annals of the Department of Antiquities of Jordan*, 27, 375-384.

Banning, E. B. and Köhler-Rollefson, I., 1986. Ethnoarchaeological survey in the Beda area, southern Jordan. *Sonderdruck aus der Zeitschrift des Deutschen Palästina-Vereins*, 102, 152-l 70.

Banning, E. B. and Köhler-Rollefson, I., 1992. Ethnographic lessons for the pastoral past: camp locations and material remains near Beidha, Southern Jordan. *Bar-Yosef y Khazanov*, 181-204.

Banning, E. B., Siggers, J. and Rahimi, D., 1994. The Late Neolithic of the Southern Levant: hiatus, settlement shift or observer bias? The perspective from Wadi Ziqlab. *Paléorient* 20 (2), 151-164.

Barber, D. A. and Shone, M. G. T., 1966. The absorption of Silica from aqueous solutions by plants. *Journal of Experimental Botany*, 17 (3), 569-578.

Barker, G., 2000. Farmers, herders and miners in the Wadi Faynan, southern Jordan: a 10,000-year landscape archaeology. *In:* Barker, G. and Gilbertson, D., eds., *The Archaeology of drylands*. London: Routledge, 63–85.

Bar-Oz, G., 2004. *Epipaleolithic subsistence strategies in the Levant: A zooarchaeological perspective*. Brill Academic Publication.

Bar-Yosef, O., 1998. The Natufian culture in the Levant. *Evolutionary Anthropology*, 6, 159–177.

Bar-Yosef, O., 2002. The upper paleolithic revolution. *Annual Review of Anthropology*, 363-393.

Bar-Yosef, O., 2003. The Natufian culture and the early Neolithic: social and economic trends in southwestern Asia. *In*: Bellwood P. and Renfrew C., eds. *Examining the farming/language dispersal hypothesis*. Cambridge: McDonald Institute for Archaeological Research, 113–126.

Bar-Yosef, O. and Belfer-Cohen, A., 1989. The origins of sedentism and farming communities in the Levant. *Journal of World Prehistory*, 3(4), 447-498.

Bar-Yosef, O. and Valla, F. R., eds., 2013. *Natufian foragers in the Levant: Terminal Pleistocene social changes in Western Asia*. Ann Arbor: International Monographs in Prehistory, 185-192.

Bartoli, F. and Wilding, L. P., 1980. Dissolution of biogenic opal as a function of its physical and chemical properties. *Soil Science Society of America Journal*, 44 (4), 873-878.

Belfer-Cohen, A. and Goring-Morris, A.N., 2011. Becoming farmers. *Current Anthropology*, 52 (S4), 209-220.

Bienkowski, P., 2007. Tribes, borders, landscapes and reciprocal relations: The Wadi Arabah and its meaning. *Journal of Mediterranean Archaeology*, 20 (1), 33-60.

Bienkowski, P. and Chlebik, B., 1991. Changing places: Architecture and spatial organization of the Bedul in Petra. *Levant*, 23, 147-180.

Binford, L. R., 1977. *For theory building in archaeology*. New York: Academic Press.

Binford, L. R., 1978. Dimensional analysis of behavior and site structure: Learning from an Eskimo hunting stand. *American Antiquity*, 45, 255-273.

Binford., L. R., 1983. *In pursuit of the past: Decoding the archaeological record*. New York: Academic Press.

Bocco, R., 2006. The settlement of pastoral nomads in the Arab Middle East: International organizations and trends in development policies, 1950–1990. *Nomadic societies in the Middle East and North Africa: entering the 21st century*, 81, p.302.

Bolle, H.-J., ed. 2003. Mediterranean climate: Variability and trends. Berlin.

Bourdieu, P., 1984. *Distinction: A social critique of the judgement of taste*. London: Routledge.

Bourdieu, P., 1990. Appendix: The Kabyle House or the World Reversed. *In: The Logic of Practice*. Cambridge: Polity Press, 271-283.

Boyd, B., 2005. Transforming food practices in the Epipaleolithic and Pre-Pottery Neolithic in the Levant. *In:* Clarke, J., ed. *Archaeological perspectives on the transmission and transformation of culture in the eastern Mediterranean*. Oxford: Oxbow Books, 106-112.

Boyd, B., 2006. On sedentism in the later Epipalaeolithic (Natufian) Levant. *World Archaeology*, 38 (2), 164-178.

Bradely, R. and Small, C., 1985. Looking for circular structures in post hole distributions: Quantitative analysis of two settlements from Bronze Age England. *Journal of Archaeological Science*, 12, 285-297.

Brevik, E. C. and Hartemink, A. E., 2010. Early soil knowledge and the birth and development of soil science. *Catenai,* 83, 23-33.

Brito, O. R., Telles, T. S., Schnitzer, J. A., Gaspar, G. G. and Guimarães, M., 2014. The influence of crop residues in vertical soil mobility of potassium. *Semina: Ciências Agrárias* 35 (6), 3043-3051.

Bruins, H. J., 2006. Desert environment and geoarchaeology of the Wadi Aravah. *In*: Bienkowski, P. and Galor, K., eds. *Crossing the Rift: resources, settlement patterns and interaction in the Wadi Aravah*. Oxford: 29–44.

Bulliet, R. W., 1975. *The camel and the wheel*. Cambridge, Mass: Harvard University Press.

Byrd, B. F., 2005. Reassessing the emergence of village life in the Near East. *Journal of Archaeological Research*, 13 (3), 231-290.

Cabanes, D., Gadot, Y., Cabanes, M., Finkelstein, I., Weiner, S. and Shahack-Gross, R., 2012. Human impact around settlement sites: A phytolith and mineralogical study for assessing site boundaries, phytolith preservation, and implications for spatial reconstructions using plant remains. *Journal of Archaeological Science*, 39, 2697-2705.

Cabanes, D., Mallol, C., Expósito, I. and Baena, J., 2010. Phytolith evidence for hearths and beds in the late Mousterian occupations of Esquilleu cave (Cantabria, Spain). *Journal of Archaeological Science*, 37, 2947-2957.

Cameron, C. M. and Tomka, S. A., 1993. *Abandonment of settlements and regions: Ethnoarchaeological and archaeological approaches.* Cambridge: Cambridge University Press.

Canning, S., 2005. 'Belief' in the past: Dempster-Shafer theory, GlS and archaeological predictive modelling. *Australian Archaeology* 60, 6-15.

Canti, M. and Huisman, D. J., 2015. Scientific advances in geoarchaeology during the last twenty years. *Journal of Archaeological Science*, 56, 96-108.

Carnelli, A. L., Madella, M. and Theurillat, J. P., 2001. Biogenic silica production in selected alpine plant species and plant communities. *Annals of botany*, 87 (4), 425-434.

Carr, C., 1991. Left in the dust: Contextual information in model-focused archaeology. *In:* Kroll, E. M. and Price, T. D., eds. *The interpretation of archaeological spatial patterning*. New York: Plenum Press: 221-256.

Chase, M. W., 2004. Monocot relationships: An overview. *American Journal of Botany*, 91 (10), 1645-1655.

Childe, V. G., 1936. *Man makes himself.* London: Watts.

Clark, D. J., 1977. *Spatial archaeology*. New York: Academic Press.

Coinman, N., Clark, G. A. and Lindly, J., 1988. A diachronic study of Paleolithic and early Neolithic site placement patterns in the southern tributaries of the Wadi el Hasa. *In:* McDonald, B., ed. *The Wadi el Hasa srchaeological survey, 1979-1983, West Central Jordan*. Waterloo, Canada: Wilfred Laurier University Press: 48-86.

Colledge, S., 2001. *Plant exploitation on epipalaeolithic and early Neolithic sites in the Levant*. Oxford: British Archaeological Reports.

da Costa, M.L. and Kern, D.C., 1999. Geochemical signatures of tropical soils with archaeological black earth in the Amazon, Brazil. *Journal of Geochemical Exploration*, 66 (1), 369-385.

Coward, F., 2013. Grounding the net: Networks, environments and material culture in the epipalaeolithic and early Neolithic of the Near East. *In:* Knappett, C., ed. *Network analysis in archaeology: New approaches to regional integration*. Oxford: Oxford University Press, 247-280.

Cronquist, A., 1981. *An integrated system for classification of flowering plants*. New York: New York Botanical Garden.

David, N. and Kramer, C., 2001. *Ethnoarchaeology in action*. Cambridge: Cambridge University Press.

Denbow, J. R., 1986. A new look at the later Prehistory of the Kalahari. *Journal of African History*, 27, 3-28.

Dickau, R., 2005. *Resource use, crop dispersals, and the transition to agriculture in prehistoric Panama: evidence from starch grains and macroremains*. Unpublished Ph.D. Dissertation, Temple University, Philadelphia.

Dirix, K., Muchez, P., Degryse, P., Kaptijn, E., Mušič, B., Vassilieva, E. and Poblome, J., 2013. Multi-element soil prospection aiding geophysical and archaeological survey on an archaeological site in suburban Sagalassos (SW-Turkey). *Journal of Archaeological Science*, 40, 2961-2970.

Durkheim, E., 1915. *The elementary forms of the religious life*. New York: Macmillan.

Entwistle, J. A., 2000. The geoarchaeological significance and spatial variability of a range of physical and chemical soil properties from a former habitation site, Isle of Skye. *Journal of Archaeological Science*, 27, 287–303.

Entwistle, J. A. and Abrahams, P. W., 1997. Multi-element analysis of soils and sediments from Scottish historical sites. The potential of inductively coupled plasma-mass spectrometry for rapid site investigation. *Journal of Archaeological Science*, 24, 407–416.

Evans-Pritchard, E. E., 1949. *The Sanusi of Cyrenaica*. Oxford: Oxford University Press.

Evershed, R. P., Payne, S., Sherratt, A. G., Copley, M. S., Coolidge, J., Urem-Kotsu, D., Kotsakis, K., Özdoğan, M., Özdoğan, A.E., Nieuwenhuyse, O. and Akkermans, P.M., 2008. Earliest date for milk use in the Near East and southeastern Europe linked to cattle herding. *Nature*, 455 (7212), 528-531.

Fernandez, F. G., Terry, R. E., Inomata, T. and Eberl, M., 2002. An ethnoarchaeological study of chemical residues in the floors and soils of Q'eqchi' Maya houses at Las Pozas, Guatemala. *Geoarchaeology*, 17, 487-519.

Fewster, K. J., 2006. The potential of analogy in post-processual archaeologies: A case study from Basimane Ward, Serowe, Botswana. *Journal of Royal Anthropological Institute*, 12, 61-87.

Foucault, M., 1982. The subject and power: afterword to M. Foucault, *Beyond structuralism and hermeneutics*. Chicago: University of Chicago Press.

Frahm, E. and Doonan, R., 2013. The technological versus methodological revolution of portable XRF in Archaeology. *Journal of Archaeological Science*, 40, 1425-1434.

Fredlund, G.G. and Tieszen, L.T., 1994. Modern phytolith assemblages from the North American great plains. *Journal of Biogeography*, 21, (3), 321-335.

Fuller, D.Q., 2007. Contrasting patterns in crop domestication and domestication rates: recent archaeobotanical insights from the Old World. *Annals of Botany*, 100 (5), 903-924.

Gardiner, D. T. and Miller, R. W., 2004. *Soils in Our Environment, 10th edition*. New Jersey: Pearson Education Inc.

Garrard, A.N., Baird, D., Colledge, S., Martin, L. and Wright, K., 1994. Prehistoric environment and settlement in the Azraq Basin: an interim report on the 1987 and 1988 Excavation Season. *Levant*, 26, 73–109.

Gauss, R.K., Bátora, J., Nowaczinski, E., Rassmann, K. and Schukraft, G., 2013. The early Bronze Age settlement of Fidvár, Vráble (Slovakia): reconstructing prehistoric settlement patterns using portable XRF. *Journal of Archaeological Science*, 40 (7), 2942-2960.

Gibbs, K., 2013. Late Neolithic pottery and ambiguous symbols in the Southern Levant. *Paléorient* 39, 69-84.

Gifford, D., 1977. Observations of contemporary human settlements as an aid to archaeological interpretation. Thesis (PhD) *University of California, Berkeley.*

Goldberg, P. and Whitbread, I., 1993. Micromorphological study of a Bedouin tent floor. *In:* Goldberg, P., Nash, T. D. and Petraglia, M. D., eds. *Formation Processes in Archaeological Context*. Madison: Prehistory Press, 165-188.

Gopher, A. and Orelle, E., 1995. New data on burials in the Pottery Neolithic period (Sixth-Fifth Millennium BC) in Israel. In: Campbell, S. and Green, E., eds. *The archaeology of death in the Ancient Near East, Oxbow Monograph 51*. Oxford: Oxbow Press, 24-28.

Goring-Morris, A. N. and Belfer-Cohen, A., 2008. A roof over one's head: Developments in Near Eastern residential architecture across the epipalaeolithic – Neolithic transition. *In:* Bocquet-Appel, J. P. and Bar-Yosef O. eds. *The Neolithic demographic transition and its consequences*. New York: Spinger, 239-286.

Goring-Morris, A. N. and Belfer-Cohen, A., 2010. Different ways of being, different ways of seeing: Changing worldviews in the Near East. *In*: Finlayson, B. and Warren G. eds. *Landscapes in transition: Understanding hunter-gatherer and farming landscapes in the Early Holocene of Europe and the Levant*. Levant Supplementary Series & CBRL, London, 9-22.

Goring-Morris, A. N. and Belfer-Cohen, A., 2011. Neolithization processes in the Levant. *Current Anthropology*, 52 (S4), 195-208.

Goring-Morris, A. N., Hovers, E. and Belfer-Cohen, A., 2009. The dynamics of Pleistocene and Early Holocene settlement patterns and human adaptations in the Levant: An overview. *In:* Shea, J. J. and Lieberman, D. E. eds. *Transitions in prehistory: Essays in honor of Ofer Bar-Yosef.* Oxford: Oxbow Books, 185-252.

Gosselain, O. P., 1998. Social and technical identity in a clay crystal ball. *In:* Stark, M. T. ed. *The archaeology of social boundaries*. Washington DC: Smithsonian Institution Press, 78-106.

Grattan, J. P., Huxley, S. I. and Pyatt, F. B., 2003. Modern Bedouin exposures to copper contamination: An imperial legacy? *Ecotoxicology and Environmental Safety*, 55 (1), 108-115.

Grosman, L., Munro, N. D., Abadi, I., Boaretto, E., Shaham, D., Belfer-Cohen, A. and Bar-Yosef, O., 2016. Nahal Ein Gev II, A late Natufian community at the Sea of Galilee. *PLoS ONE*, 11 (1), e0146647. doi:10.1371/journal.pone.0146647.

Guan, Y., Gao, X., Wang, H., Chen F., Pei, S., Zhang, X. and Zhou, Z., 2011. Spatial analysis of intra-site use at a Late Palaeolithic site at Shuidonggou, Northwest China. *Chinese Science Bulletin*, 56 (32), 3457-3463.

Hall, M., 1986. The role of cattle in Southern African agropastoral societies: More than bones alone can tell. *Southern African Archaeological Society Goodwin Series*, 5, 83-87.

Hardy-Smith, T. and Edwards, P. C., 2004. The garbage crisis in Prehistory: Artefact discard patterns at the early Natufian site of Wadi Hammeh 27 and the origins of household refuse disposal strategies. *Journal of Anthropological Archaeology*, 23, 253-289.

Harvey, E.L. and Fuller, D. Q. 2005. Investigating crop processing through phytolith analysis: The case of rice and millets. *Journal of Archaeological Science*, 32, 739-752.

Haslam, R. and Tibbett, M., 2004. Sampling and analyzing metals in soils for archaeological prospection: a critique. *Geoarchaeology*, 19, 731-751.

Hauptmann, A., Begemann, F., Heitkemper, E., Pernicka, E. and Schmitt-Strecker, S., 1992. Early copper produced at Feinan, Wadi Araba, Jordan: The composition of ores and copper. *Archaeomaterials*, 6, 1-33.

Hayes, K., 2013. Parameters in the use of pXRF for archaeological site prospection: a case study at the Reaume Fort Site, Central Minnesota. *Journal of Archaeological Science*, 40 (8), 3193-3211.

Heidegger, M., 1971. *Poetry, language, thought*. New York: Harper & Row.

Heider, K., 1961. Archaeological assumptions and ethnographic fact: A cautionary tale from New Guinea. *Southwestern Journal of Anthropology*, 23, 52-64.

Helms, S.W., 1990. *Early Islamic architecture of the desert: a Bedouin station in eastern Jordan*. Edinburgh University Press.

Hemsley, J. H. and George, M., 1966. Azraq Desert National Park, Jordan. *Draft Management Plan. London: International Biological Programme, Conservation of Terrestrial Communities*.

Hillman, G., 1984. Interpretation of archaeological plant remains: the application of ethnographic models from Turkey. *Plants and ancient man. Balkema, Rotterdam*, 1-41.

Hodder, I., 1979. Economic and social stress and material culture patterning. *American Antiquity*, 44, 446-454.

Hodder, I., 1982. *The present past: An introduction to anthropology for archaeologists*. London: Batsford.

Hodder, I. and Orton, C., 1979. *Spatial analysis in archaeology*. Cambridge: Cambridge University Press.

Hjulström, B. and Isaksson, S., 2009. Identification of activity area signatures in a reconstructed Iron Age house by combining element and lipid analyses of sediments. *Journal of Archaeological Science*, 36, 174-183.

Hull, K. L., 1987. Identification of cultural site formation processes through microdebitage analysis. *American Antiquity*, 52, 774-783.

Husserl, E., 1990. *On the phenomenology of the consciousness of internal time (1893-1917)*, trans. J. B. Brough. Dordrecht: Kluwer.

Hutson, S. R. and Terry, R. R., 2006. Recovering social and cultural dynamics from plaster floors: chemical analyses at ancient Chunchucmil, Yucatan, Mexico. *Journal of Archaeological Science*, 33, 391-404.

Hutton, J. T. and Norrish, K., 1974. Silicon content of wheat husks in relation to water transpired. *Australian Journal of Agricultural Research*, 25, 203-212.

Jabbūr, J. S., Jabbūr, S. J. and Conrad, L. I., 1995. *The Bedouins and the desert: aspects of nomadic life in the Arab East*. State University of New York Press.

Jenny, H., 1980. *The soil resource: Origin and behavior*. New York: Springer-Verlag.

Jenkins, E. L., 2009. Phytolith taphonomy: A comparison of dry ashing and acid extraction on the breakdown of conjoined phytoliths formed in Triticum durum. *Journal of Archaeological Science*, 36, 2402-2407.

Jenkins, E. L., Baker, A. and Elliott, S., 2011. Past plant use in Jordan as revealed by archaeological and ethnoarchaeological phytolith signatures. *In:* Mithen, S. J. and Black, E., eds.

Water, life and civilisation: climate, environment and society in the Jordan Valley. Cambridge: Cambridge University Press, 381-399.

Jones, L. H. P. and Handreck, K. A., 1967. Silica in soils, plants and animals. *Advances in Agronomy*, 19, 107-149.

Jones L. H. P. and Milne, A. A., 1963. Studies of silica in the oat plant: I. Chemical and physical properties of silica. *Plant and Soil*, 18, 207-220.

Judge, J. W. and Sebastian, L., 1988. *Quantifying the present and predicting the past: Theory, method and application of archaeological predictive modelling*. Denver: U.S. Department of the Interior, Bureau of Land Management.

Kalnicky, D. J. and Singhvi, R., 2001. Field portable XRF analysis of environmental samples. *Journal of Hazardous Materials*, 83, 93-122.

Kent, S., 1984. *Analyzing activity areas: an ethnoarchaeological study of the use of space*. University of New Mexico Press.

Khan, F., 1994. The potential of ethnoarchaeology with special reference to recent archaeological work in Bannu district, Pakistan. *In*: Allchin, B. ed. *Living traditions: Studies in the ethnoarchaeology of South Asia*. New Delhi: Oxford and IBH Publishing. 83-99.

Khazanov, A. M., 1994. *Nomads and the outside world* (No. Ed. 2). University of Wisconsin Press.

King, S. M., 2008. The spatial organization of food sharing in Early Postclassic households: an application of soil chemistry in Ancient Oaxaca, Mexico. *Journal of Archaeological Science*, 35, 1224-1239.

Knauf, E. A., 1992. *Bedouin and Bedouin states*. ABD.

Koetje, T. A., 1994. Intrasite Spatial structure in the European upper Paleolithic: Evidence and patterning from the SW of France. *Journal of Anthropological Archaeology*, 13, 161-169.

Köhler-Rollefson, I., 1992. A model for the development of nomadic pastoralism on the Transjordanian Plateau. *In:* Bar-Yosef, O. and Khazanov, A. M., eds. *Pastoralism in the Levant. Archaeological materials in anthropological perspectives*. Monographs in World Archaeology, 10. Madison, 11–18.

Kuchenbuch, R., Claassen, N. and Jungk, A., 1986. Potassium availability in relation to soil moisture. *Plant and Soil* 95 (2), 233-243.

Kuijt, I. and Finlayson, B., 2009. Evidence for food storage and predomestication granaries 11,000 years ago in the Jordan Valley. *Proceedings of the National Academy of Sciences*, 106 (27), 10966-10970.

Kuijt, I. and Goodale, N., 2009. Daily practice and the organization of space at the dawn of Agriculture: A Case Study from the Near East. *American Antiquity*, 74 (3), 403-422.

Kuijt, I. and Goring-Morris, N., 2002. Foraging, farming, and social complexity in the Pre-Pottery Neolithic of the southern Levant: a review and synthesis. *Journal of World Prehistory*, 16 (4), 361-440.

Kürschner, H., 1986. A physiognomical-ecological classification of the vegetation of southern Jordan. *Contributions to the vegetation of South West Asia, H. Kruschner (ed.) Beihefte Tubinger Atlas Voedere Orient, Rihe A (Naturwisseneschaften), Weisbaden (Dr. L. Reischert)*, 45-79.

Layne, L., 1987. Village-Bedouin: Patterns of change from mobility to sedentism in Jordan. *Method and theory for activity area research: An ethnoarchaeological approach*, 345-373.

Leroi-Gourhan, A. and Brézillon, M., 1966. L'habitation Magdalénienne no. 1 de Pincevent près Montereau (Seine-et-Marne). *Galia Préhistoire* 9, 263-385.

Lin, J., Performance of the thermo scientific Niton XRF analyzer: The effects of particle size, length of analysis, water, organic matter, and soil chemistry.

López Varela, S. and Dore, C., 2010. Social spaces of daily life: A reflexive approach to the analysis of chemical residues by multivariate spatial analysis. *Journal of Archaeological Method and Theory*, 17, 249-278.

Madella, M., Alexandre, A. and Ball, T., 2005. International code for phytolith nomenclature 1.0. *Annals of Botany* 96, 253-260.

Madella, M., Jones, M. K., Echlin, P., Powers-Jones, A. and Moore, M., 2009. Plant water availability and analytical microscopy of phytoliths: Implications for ancient irrigation in arid zones. *Quaternary International*, 193, 32-40.

Madella, M. and Lancelotti, C., 2012. Taphonomy and phytoliths: A user manual. *Quaternary International*, 275, 76-83.

Maher, L.A., Richter, T., Macdonald, D., Jones, M.D., Martin, L. and Stock, J.T., 2012. Twenty thousand-year-old huts at a hunter-gatherer settlement in eastern Jordan. *PloS one*, 7 (2), p.e. 31447.

Manzanilla, L., 1996. Corporate groups and domestic activities at Teotihuacan. *Latin American Antiquity*, 7 (3), 228-246.

Manzanilla, L. and Barba, L., 1990. The study of activities in classic households: Two case studies from Coba and Teotihuacan. *Ancient Mesoamerica*, 1, 41-49.

Martin, L., 1999. Mammal remains from the eastern Jordanian Neolithic, and the nature of caprine herding in the steppe. *Paléorient*, 1999, vol. 25, n°2. 87-104.

Matschullat, J., Ottenstein, R. and Reimann, C., 2000. Geochemical background – can we calculate it? *Environmental Geology*, 39, 990-1000.

Middleton, W. D., 2004. Identifying chemical activity residues on Prehistoric house floors: A methodology and rationale for multi-elemental characterisation of a mild acid extract of anthropogenic sediments. *Archaeometry*, 46 (1), 47-65.

Middleton, W. D. and Price, T. D., 1996. Identification of activity areas by multi-element characterization of sediments from modern and archaeological house floors using inductively coupled plasma-atomic emission spectroscopy. *Journal of Archaeological Science*, 23, 673-687.

Milek, K. B. and Roberts, H. M., 2013. Integrated geoarchaeological methods for the determination of site activity areas: a study of a Viking Age house in Reykjavik, Iceland. *Journal of Archaeological Science*, 40, 1845-1865.

Montague, R., Hunt, G., Colledge, S. and Garrard, A. N., 1988. Environment and subsistence during the Late Pleistocene and Early Holocene in the Azraq Basin. *Paléorient*, 14 (2),40-49.

Mulder, J. and Cresser, M. S., 1994. Soil and soil solution chemistry. *In:* Moldan, B. and Cerny, J., eds. *Biochemistry of small catchments: A tool for environmental research*. New York: Wiley and Sons, 107-131.

Munro, N. D., 2009. Epipaleolithic subsistence intensification in the southern Levant: The faunal evidence. *In:* Richards, M. J. and Hublin, J. J., eds. *The evolution of hominid diets: integrating approaches to the study of Paleolithic subsistence*, 141-155.

Na'amneh, M., Shunnaq, M. and Tasbasi, A., 2008. The modern sociocultural significance of the Jordanian Bedouin tent. *Nomadic Peoples*, 12, Issue 1, 149–163.

Nahedh, M., 1989. *The sedentarization of a Bedouin community in Saudi Arabia*. Thesis (PhD) The University of Leeds, Department of Social Policy and Sociology.

Namdar, D., Zukerman, A., Maeir, A. M., Katz, J. C., Cabanes, D., Trueman, C., Shahack-Gross, R. and Weiner, S., 2011. The 9th century BCE destruction layer at Tell es-Safi/Gath, Israel: integrating macro- and microarchaeology. *Journal of Archaeological Science*, 38, 3471-3482.

Nelson, J.B., 1973. *Azraq: desert oasis*. Allen Lane, London.

Noy-Meir, I. (1975). Primary and secondary production in sedentary and nomadic grazing systems in the semi-arid region: Analysis and modelling. Research report, Ford Foundation/Department of Botany, Hebrew University, Jerusalem, Israel.

O'Connell, J. F., 1987. Alyawara site structure and its archaeological implications. *American Antiquity,* 52, 74-108.

Oonk, S., Slomp, C. P. and Huisman, D. J., 2009a. Geochemistry as an aid in archaeological prospection and site interpretation: Current issues and research directions. *Archaeological Prospection,* 16, 35–51.

Oonk, S., Slomp, C. P., Huisman, D. J. and Vriend, S. P., 2009b, Effects of site lithology on geochemical signatures of human occupation in archaeological house plans in the Netherlands. *Journal of Archaeological Science*, 36, 1215–1228.

Oonk, S., Slomp, C.P., Huisman, D. J. and Vriend, S.P., 2009c. Geochemical and mineralogical investigation of domestic archaeological soil features at the Tiel-Passewaaij site, The Netherlands. *Journal of geochemical exploration*, 101 (2), 155-165.

Orton, C., 1980. *Mathematics in archaeology*. Cambridge: Cambridge University Press.

Palmer, C., 2002. Milk and cereals: Identifying food and food identity among Fallahin and Bedouin in Jordan. *Levant*, 34, 173-195.

Palmer, C. and Daly, P., 2006. Jouma's Tent. Bedouin and digital archaeology. *In:* Evans, T.L. and Daly, P., eds. *Digital archaeology. Bridging method and theory*. London: Routledge, 97-127.

Palmer C., Gilbertson, D., el-Rishi, H., Hunt, C., Grattan, J., McLaren, S. and Pyatt, B., 2007. The Wadi Faynan today: Landscape, environment, people. *In:* Barker, G., Gilbertson, D. and Mattingly, D., eds. *Archaeology and desertification. The Wadi Faynan landscape survey, southern Jordan*. Oxford: Oxbow Books.

Palmer C., Smith, H. and Daly, P., 2007. Ethnoarchaeology. *In:* Barker, G., Gilbertson, D. and Mattingly, D., eds. *Archaeology and desertification. The Wadi Faynan landscape survey, southern Jordan*. Oxford: Oxbow Books.

Parnell, J. J. and Terry, R. E., 2002. Soil chemical analysis applied as an interpretive tool for ancient human activities in Piedras Negras, Guatemala. *Journal of Archaeological Science*, 29, 379–404.

Pearsall, D. M., 1978. Phytolith analysis of archaeological soils: evidence for maize cultivation in formative Ecuador. *Science*, 199, 177–178.

Pearsall, D. M., Chandler-Ezell, K. and Zeidler, J. A., 2004. Maize in ancient Ecuador: results of residue analysis of stone tools from the Real Alto site. *Journal of Archaeological Science*, 31, 423–442.

Pető, Á., Kenéz, Á., Prunner, A. C. and Lisztes-Szabo, Z., 2015. Activity area analysis of a Roman period semi-subterranean building by means of integrated archaeobotanical and geoarchaeological data. *Vegetation History and Archaeobotany*, 24, 101–120.

Petrucci, R. H., 2007. *General chemistry: principles and modern applications*. Upper Saddle River: Pearson Education International.

Piperno, D., 1988. *Phytolith Analysis, an archaeological and geological perspective*. San Diego: Academic Press.

Piperno, D., 2006. *Phytoliths: A comprehensive guide for archaeologists and palaeoecologists*. Oxford: Altimira Press.

Portillo, M., Albert, R. M. and Henry, D. O., 2009. Domestic activities and spatial distribution in Ain Abū Nukhayla (Wadi Rum, southern Jordan): The use of phytoliths and spherulites studies. *Quaternary International*, 193 (1-2), 174-183.

Portillo M., Kadowaki, S., Nishiaki, Y. and Albert R. M., 2014. Early Neolithic household behavior at Tell Seker al-Aheimar (Uppere Khabur, Syria): a comparison to ethnoarchaeological study of phytoliths and dung spherulites. *Journal of Archaeological Science*, 42, 107–118.

Rapp, G. R. Jr. and Hill, C. L., 1998. *Geoarchaeology: The Earth-Science Approach to Archaeological Interpretation*. New Haven: Yale University Press.

Richter, T., Garrard, A., Allcock, S. and Maher, L., 2011. Interaction before agriculture. *Cambridge Archaeological Journal* 21 (1), 95-114.

Rollefson, G., Rowan, Y. and Wasse, A., 2014. The Late Neolithic colonization of the Eastern Badia of Jordan. *Levant* 46 (2), 285 – 301.

Rondelli B., Lancelotti C., Madella M., Pecci, A., Balbo, A., Pérez, J. R., Inserra, F., Gadekar, C., Cau Ontiveros, M. Á. and Ajithprasad, P., 2014. Anthropic activity markers and spatial variability: an ethnoarchaeological experiment in a domestic unit of Northern Gujarat (India). *Journal of Archaeological Science,* 41, 482–492.

Rosen, A. M., 1986. *Cities of clay: The geoarchaeology of tells*. Chicago: University of Chicago Press.

Rosen, A. M., 1992. Preliminary identification of silica skeletons from Near Eastern archaeological sites: an anatomical approach. *In*: Rapp, G., Mulholland, S. C., eds. *Phytolith systematics: emerging issues.* Plenum Press, New York, 129–147.

Rosen, S. A. and Saidel, B. A., 2010. The camel and the tent: An exploration of technological change among early pastoralists. *Journal of Near Eastern Studies*, 69 (1), 63-77.

Rosen, A. M. and Weiner, S., 1994. Identifying ancient irrigation: A new method using opaline phytoliths from emmer wheat. *Journal of Archaeological Science*, 21, 125-132.

Saidel, B. A., 2001. Abandoned tent camps in southern Jordan. *Near Eastern Archaeology*, 64 (3), 150-157.

Saidel, B. A., 2009. Coffee, gender, and tobacco: Observations on the history of the Bedouin tent. *Anthropos,* 104, 179-186.

Salisbury, R. B., 2007. Introduction: Examining archaeology's spatial fabric. *In:* Salisbury, R. B. and Keeler, D., eds. Space – archaeology's final frontier? An intercontinental approach. Cambridge: Cambridge Scholars Publishing, 2-17.

Schiffer, M. B., 1988. The structure of archaeological theory. *American Antiquity*, 53 (3), 461-485.

Schiffer, M. B., 1995. *Behavioral archaeology: First principles*. Salt Lake City: University of Utah Press.

Sconce, J. S., 1962. *Chlorine, its manufacture, properties and uses. Editor-in-chief: J. S. Sconce*. New York: Reinhold Publishing Corporation.

Shackley, M.S., 2010. Is there reliability and validity in portable X-ray fluorescence spectrometry (PXRF). *The SAA Archaeological* Record, 10 (5), 17-20.

Shahack-Gross, R., Albert, R.-M., Gilboa, A., Nagar-Hillman, O., Sharon, I. and Weiner, S., 2005. Geoarchaeology in an urban context: the uses of space in a Phoenician monumental building at Tel Dor (Israel). *Journal of Archaeological Science*, 32, 1417-1431.

Shahack-Gross, R., Marshall, F., Ryan, K. and Weiner, S., 2004. Reconstruction of spatial organization in abandoned Maasai settlements: Implications for site structure in the pastoral Neolithic of East Africa. *Journal of Archaeological Science*, 31, 1395-1411.

Shahack-Gross, R., Marshall, F. and Weiner, S., 2003. Geo-ethnoarchaeology of pastoral sites: the identification of livestock enclosures in abandoned Maasai settlements. *Journal of Archaeological Science*, 30 (4), 439-459.

Shillito, L.-M., 2011. Taphonomic observations of archaeological wheat phytoliths from Neolithic Çatalhöyük, Turkey, and the use of conjoined phytolith size as an indicator of water availability. *Archaeometry*, 53, 3, 631–641.

Shillito, L.-M. and Ryan, P., 2013. Surfaces and streets: phytoliths, micromorphology and changing use of space at Neolithic Catalhöyük (Turkey). *Antiquity*, 87, 684-700.

Simek, J. F., 1987. Spatial order and behavioural change in the French Palaeolithic. *Antiquity* 61, 25-40.

Simms, S. R., 1988. The archaeological structure of a Bedouin camp. *Journal of Archaeological Science*, 15, 197-211.

Snir, A., Nadel, D. and Weiss, E., 2015. Plant-food preparation on two consecutive floors at Upper Paleolithic Ohalo II, Israel. *Journal of Archaeological Science*, 53, 61-71.

Soja, E. W., 1989. *Postmodern geographies: The reassertion of space in critical social theory*. New York: Verso.

Sorensen, M., 2008. Spatial analysis by dynamic technological classification: A case study from the Palaeolithic – Mesolithic transition in Scandinavia.

Speakman, R. J. and Shackley, M. S., 2013. Silo science and portable XRF in archaeology: a response to Frahm. *Journal of Archaeological Science*, 40 (2), 1435-1443.

Stafford, R., Williams, R. L. and Herbert, R. J., 2015. Simple, policy friendly, ecological interaction models from uncertain data and expert opinion. *Ocean & Coastal Management*, 118, 88-96.

Stutz, A. J., Munro, N. D. and Bar-Oz, G., 2009. Increasing the resolution of the broad spectrum revolution in the southern Levantine Epipaleolithic (19-12 ka). *Journal of Human Evolution*, 56 (3), 294-306.

Sulas, F. and Madella, M., 2012. Archaeology at the micro-scale: micromorphology and phytoliths at a Swahili stonetown. *Archaeological and Anthropological Sciences*, 4, 145-159.

Sullivan, K. A. and Kealhofer, L., 2004. Identifying activity areas in archaeological soils from a colonial Virginia house lot using phytolith analysis and soil chemistry. *Journal of Archaeological Science*, 31, 1659-1673.

Sylvia, D. M., Fuhrmann, J. J., Hartel, P. G. and Zuberer, D. A., 1998. *Principles and applications of soil microbiology*. New Jersey: Prentice Hall.

Terry, R. E., Fabian, G. Fernández, F. G., Parnella, J. J. and Inomata, T., 2004. The story in the floors: chemical signatures of ancient and modern Maya activities at Aguateca, Guatemala. *Journal of Archaeological Science*, 31, 1237-1250.

Tripathi, R. M., Raghunath, R. and Krishnamoorthy, T. M., 1997. Dietry intake of heavy metals in Bombay city, India. *The Science of the Total Environment*, 208, 149-159.

Tsartsidou, G., Lev-Yadun, S., Efstratiou, N. and Weiner, S., 2008. Ethnoarchaeological study of phytolith assemblages from an agro-pastoral village in Northern Greece (Sarakini): development and application of a Phytolith Difference Index. *Journal of Archaeological Science*, 35, 600-613.

Tsartsidou, G., Lev-Yadun, S., Efstratiou, N. and Weiner, S., 2009. Use of space in a Neolithic village in Greece (Makri): Phytolith analysis and comparison of phytolith assemblages from an ethnographic setting in the same area. *Journal of Archaeological Science*, 36, 2342-2352.

Twiss, K. C., 2007. The Neolithic of the Southern Levant. *Evolutionary Anthropology* 16, 24-35.

Ullah, I. I., Duffy, P. R. and Banning, E. B., 2015. Modernizing spatial micro-refuse analysis: New methods for collecting, analyzing, and interpreting the spatial patterning of micro-refuse from house-floor contexts. *Journal of Archaeological Method and Theory*, 22, 1238-1262.

Van Breemen, N. and Buurman, P., 1998. *Soil formation*. Dordrecht: Kluwer Academic Publishers.

Van der Veen, M., 2007. Formation processes of desiccated and carbonized plant remains – The identification of routine practice. *Journal of Archaeological Science*, 34, 968-990.

Vyncke, K., Degryse, P., Vassilieva, E. and Waelkens, M., 2011. Identifying domestic functional areas. Chemical analysis of floor sediments at the Classical-Hellenistic settlement at Düzen Tepe (SW Turkey). *Journal of Archaeological Science*, 38, 2274-2292.

Wagstaff, J. M., 1987. *Landscape and culture: Geographical and archaeological perspectives*. London: Basil Blackwell.

Wells, E. C., 2006. Cultural soilscapes. *In:* Frossard, E., Blum, W. E. H. and Warkentin, B. P., eds. *Function of soils for human societies and the environment*. Geological Society, London, Special Publications 266, 125-132.

Wells, E. C., Terry, R. E., Parnell, J. J., Hardin, P. J., Jackson, M. W. and Houston, S. D., 2000. Chemical analyses of ancient anthrosols in residential areas at Piedras Negras, Guatemala. *Journal of Archaeological Science*, 27, 449–462.

Whallon, R., 1973. Spatial analysis of occupation floors I: Application of dimensional analysis of variance. *American Antiquity*, 38, 266-278.

Wilson, C., Davidson, D. and Cresser, M., 2008. Multi-element soil analysis: an assessment of its potential as an aid to archaeological interpretation. *Journal of Archaeological Science*, 35, 412-424.

Wu, Y., Yang, Y., Wang, H. and Wang, C., 2013. The effects of chemical composition and distribution on the preservation of phytolith morphology. *Applied Physics A*, 114, 503-507.

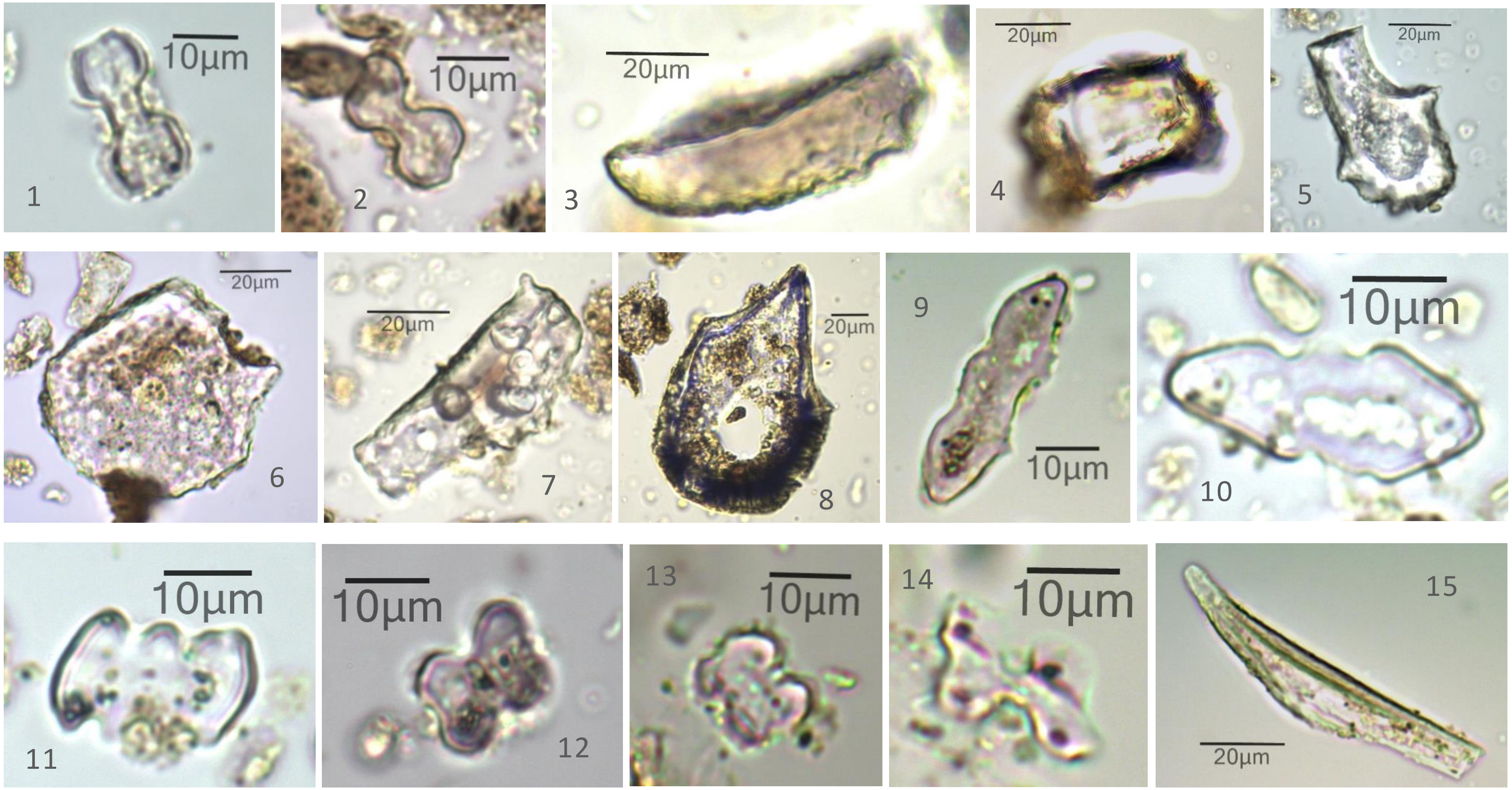
Wylie, A., 1985. The reaction against analogy. *In:* Schiffer, M. B., ed. *Advances in archaeological method and theory*, vol. 8. London: Academic Press, 63-111.

Yellen, 1977. *Archaeological approaches to the present*. New York: Academic Press.

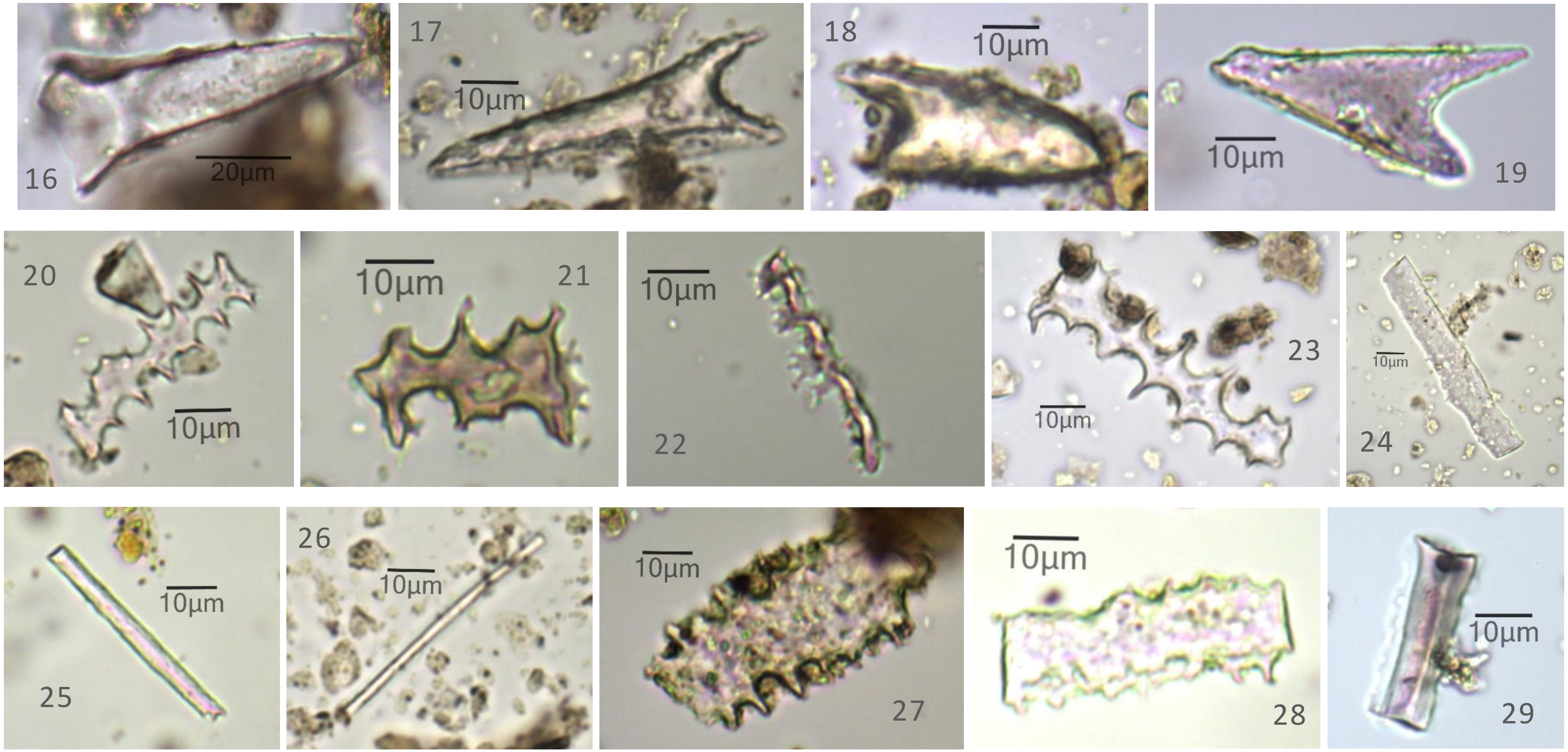
Zeder, M.A., 2011. The origins of agriculture in the Near East. *Current Anthropology*, 52 (S4), 221-235.

Zeng, Q. and Brown, P. H., 2000. Soil potassium mobility and uptake by corn under differential soil moisture regimes. *Plant and Soil* 221 (2), 121-134.

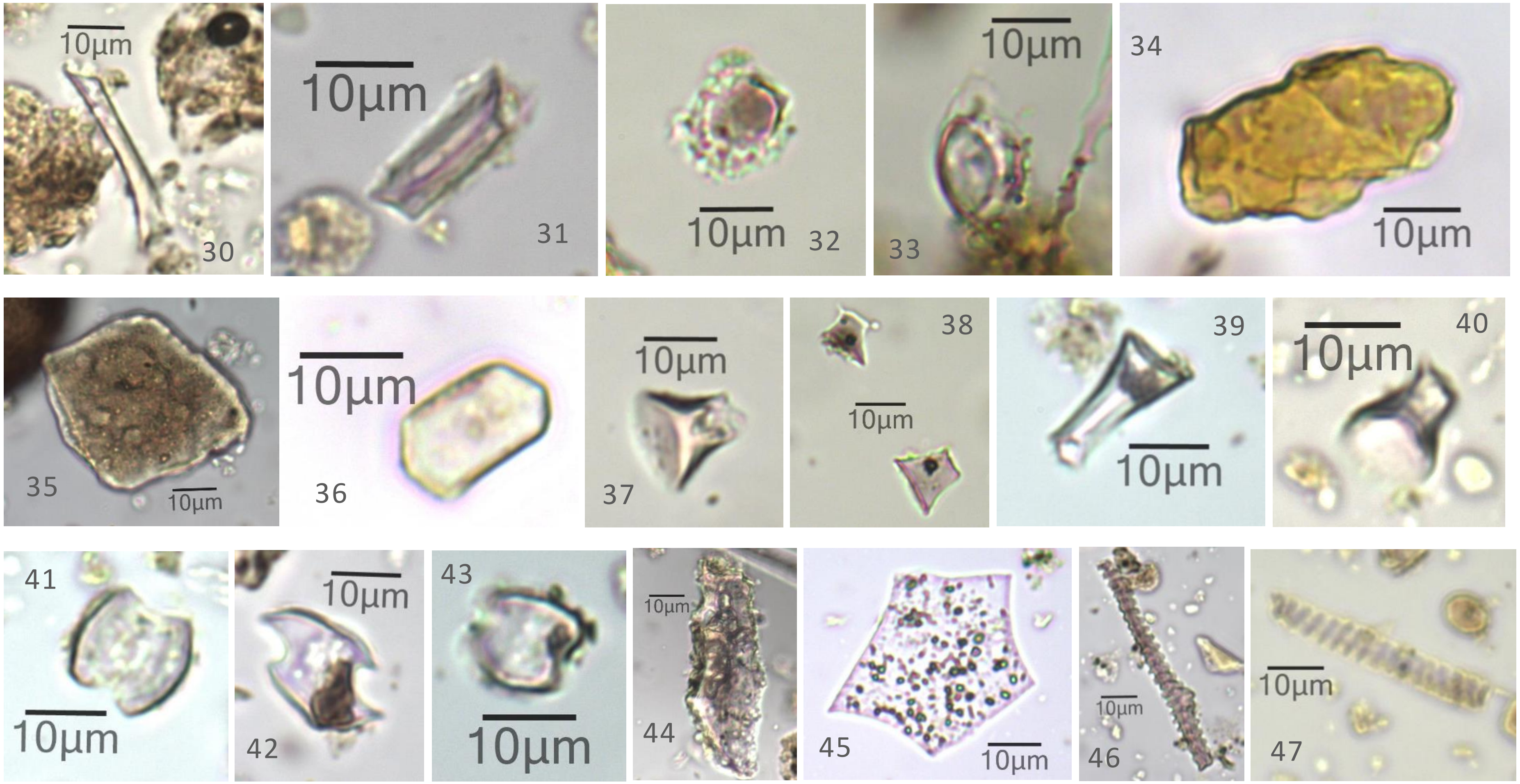
Appendix 1: Images of phytolith types identified in this study



Figures 1-2: bilobate short cell, figures 3-4: parallepipedal bulliform cell, figures 5-8: cuneiform bulliform cell, figures 9-11: ovate crenate, figures 12-14: cross, figure 15: hair cells.



Figures 16-19: hair cells, figures 20-23: elongate dendritic, figures 24-25: elongate psilate, figure 26: elongate psilate tenis, figures 27-28: elongate sinuate, figure 29: elongate trapezoid.



Figures 30-31: elongate trapezoid, figures 32-33: papillae, figures 34-35: tabular irregular, figure 36: polyhedral plain, figures 37-40: rondel, figures 41-43: saddle, figure 44: scalloped, figure 45: rectangular tabular, figures 46-47: cylindric sulcate tracheid.

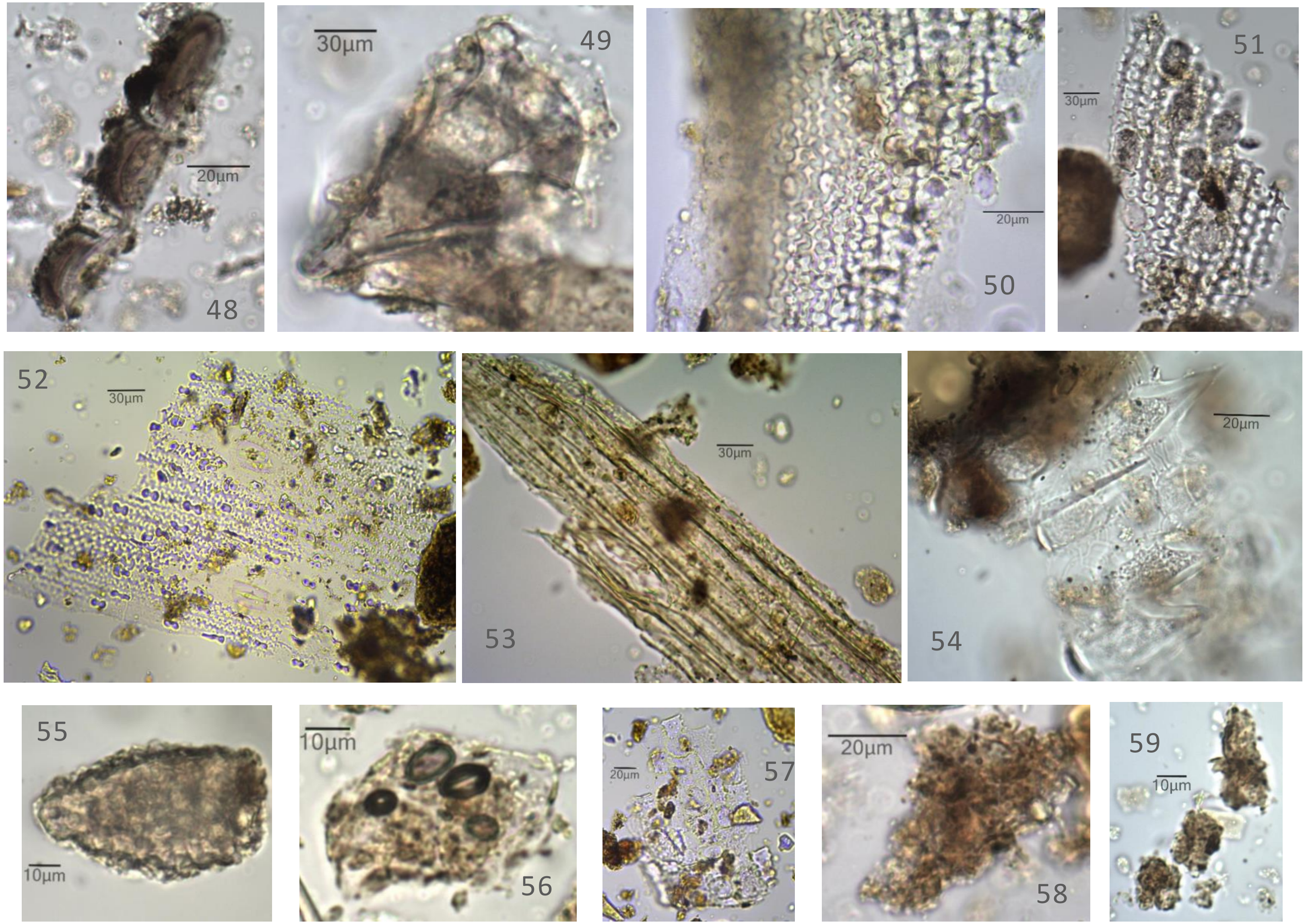


Figure 48: multi-cell parallepipedal bulliform cells, figure 49: multi-cell cuneiform bulliform cells, figure 50: wheat husk, figure 51: barley husk, figure 52: leaf multi-cell, figure 53: stem multi-cell, figure 54: conjoined hair cells, figure 55: degraded phytolith, figure 56: burnt phytolith, figure 57: poorly silicified husk, figures 58-59: silica aggregates.

Appendix 2: Example of site recording form and plan for JT sites

Site recording form

Project: JT 2014 Site: Jouma's tent winter (JTW) Date: 29-Apr-2014

Initials: DV Plan number: 1

Measurements:

Total length: 18.5 meter

Total width: ~ 4.6 meter (slightly variable along the length of the tent)

Shigg length: 7 meter

Site description:

Jouma's winter tent, occupied at the time of sampling. Family was about to move to summer location up the hill within one or two days after sampling. Living there at the time were Jouma Aly and Umm Ibrahim, their two older and one 11-year-old sons and 9-year-old daughter, with frequent visits from their other sons and daughter in law.

The winter tent includes a kitchen area, women activity area, women sleeping area, shigg. Outside is a goat/sheep pen and the remains of two older pens, two storage tents which were not sampled, an animal feeding station which was not sampled. The family has about 35 animals; the younger animals often wander around the tent and the older ones less frequently as they are herded or kept in the pen most of the day. There is one donkey and three guard dogs.

Umm Ibrahim will milk the goats in the morning, make bread, attend to other household activities such as making dairy products and making tea for visitors. The children leave to school/work in the morning and return in the afternoon.

The kitchen is used for cooking and contains a storage area, the floor is uncovered and has become compact during use. There is an entrance to the kitchen. The women activity area is used for various activities, butter was being made during our visit. Next to it is the women sleeping area, where mattresses are stored during the day. The floor areas in both the women activity and sleeping areas are covered by plastic matting. On the other side of a dividing cloth (mualad) is the shigg, the men's living area. Three mattresses are arranged in a U form with the opening towards the shigg entrance, with the middle being an exposed floor area which has become compact due to use. In the floor is the shigg hearth, used for making tea. Beyond the mattresses, in front of the entrance the floor is covered by plastic matting.

Features: Kitchen hearth, Shigg hearth, animal pens, women activity and sleeping areas, kitchen storage, two outdoor storage tents (?), animal feeding (including water) station.

Samples taken:

No.	Context description	Notes
201	Shigg hearth	Ash sample from middle and a bit towards edge of hearth, avoiding the fresh ash.
202	Shigg floor	Piece (chunk) of floor, which was broken up by Jouma using a pickaxe.
203	Main gully	Sample taken from gully floor in shigg area.
204	Shigg gully	Sample taken from small gully in shigg floor, its higher side was broken up by a pickaxe.
205	Sleeping area	Sample taken from edge of women's sleeping area, under the plastic matt, next to the walking path that runs between the two entrances.
206	Women activity area	Surface scraped from open floor area between two plastic matts.
207	Kitchen hearth, ash from centre	Ash was hot when taken, plastic bag started melting and was replaced. Goat dung was used as fuel on the day of sampling.
208	Kitchen hearth ash	Some of the older ash from the kitchen hearth was sampled (towards the side), might be a different fuel type?
209	Kitchen floor	Sample taken from floor, approx. 40 cm from hearth. The floor was broken by a pickaxe and a piece was taken.
210	Old goat + sheep pen	From June 2013, surface was scraped.
211	Current goat + sheep pen – dung	Dung sample taken from middle of pen.
212	Current goat + sheep pen – soil under + dung	Sample taken from middle of pen, includes soil under the dung (3 cm layer) and some dung.
213	Old sheep pen – dung	Sheep pen, used previously between October – February 2013. Dung sampled.
214	Old goat pen – dung	Goat pen, used previously between October – February 2013. Dung sampled.
215	Background III	Background sample taken near top of slope approx. 50 meters S of tent.

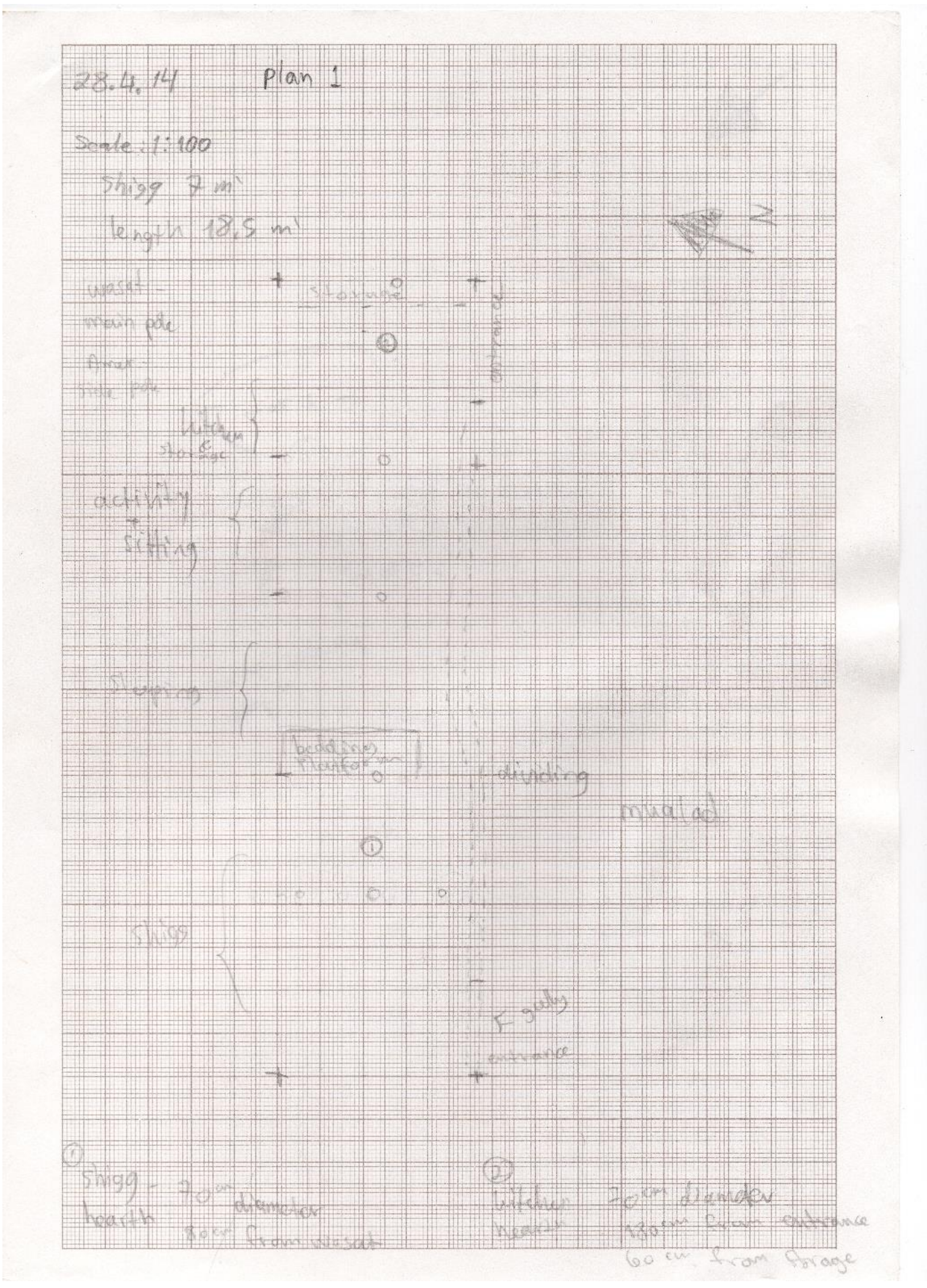
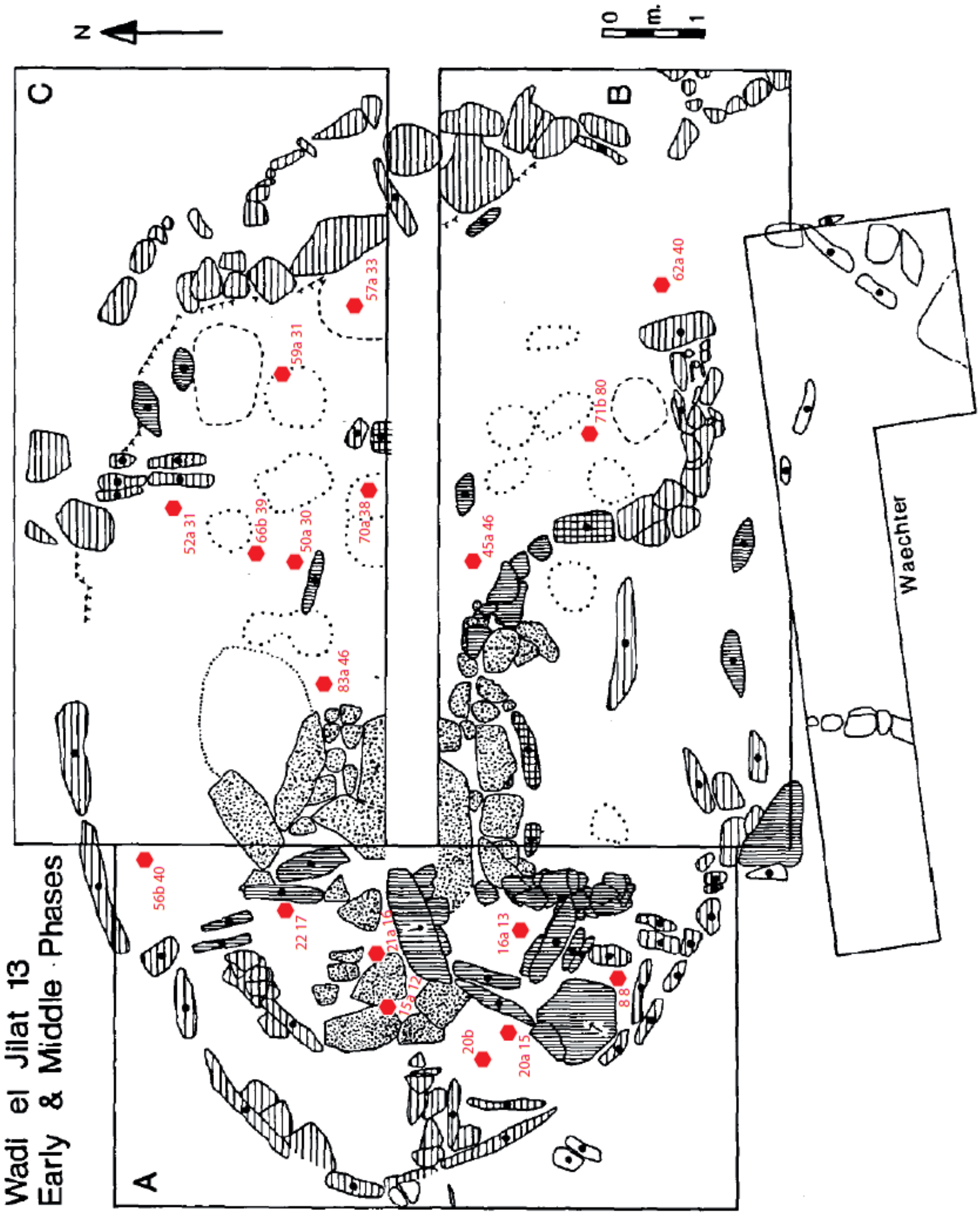
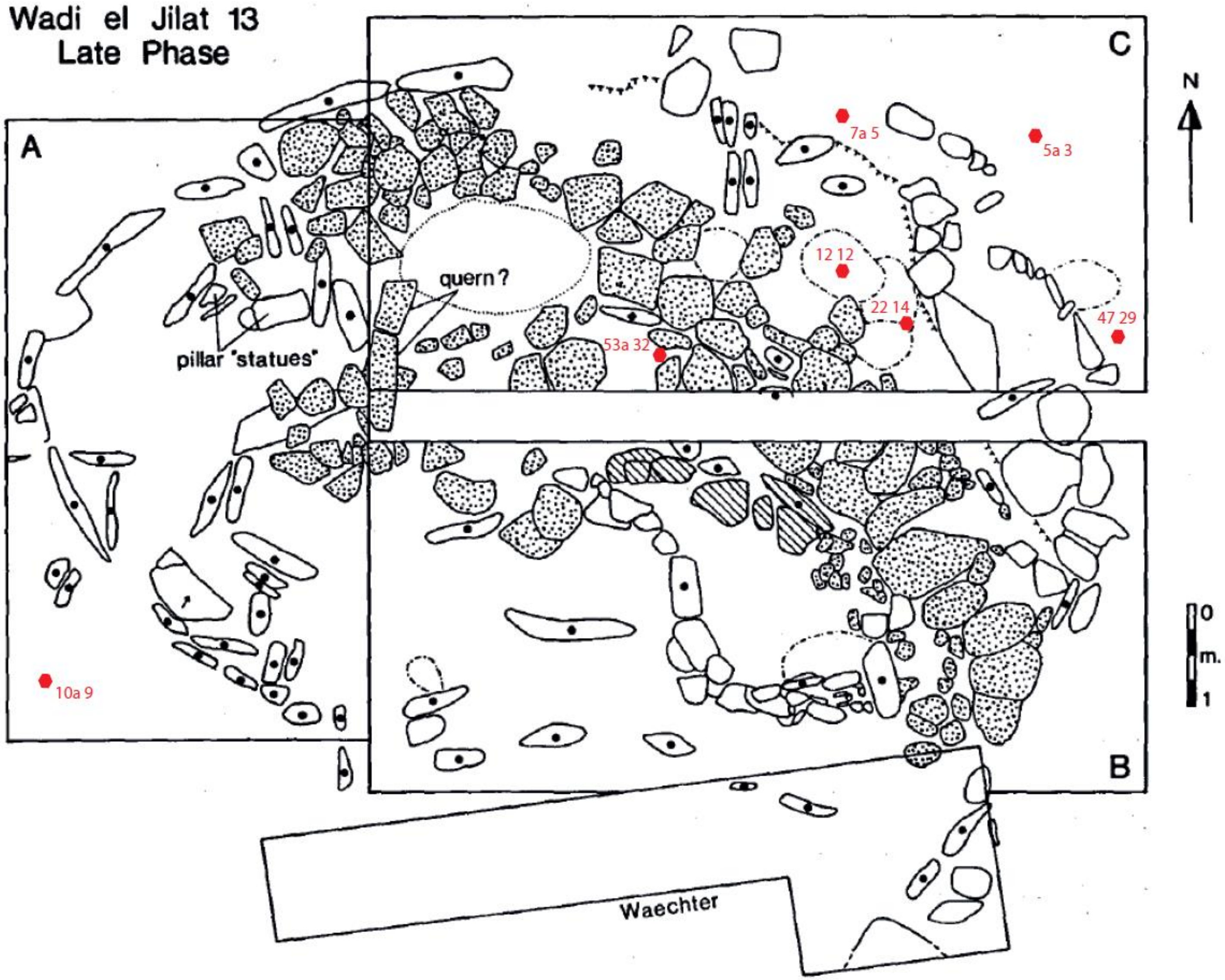


Figure *. Sketch of JTW made in the field by the author.

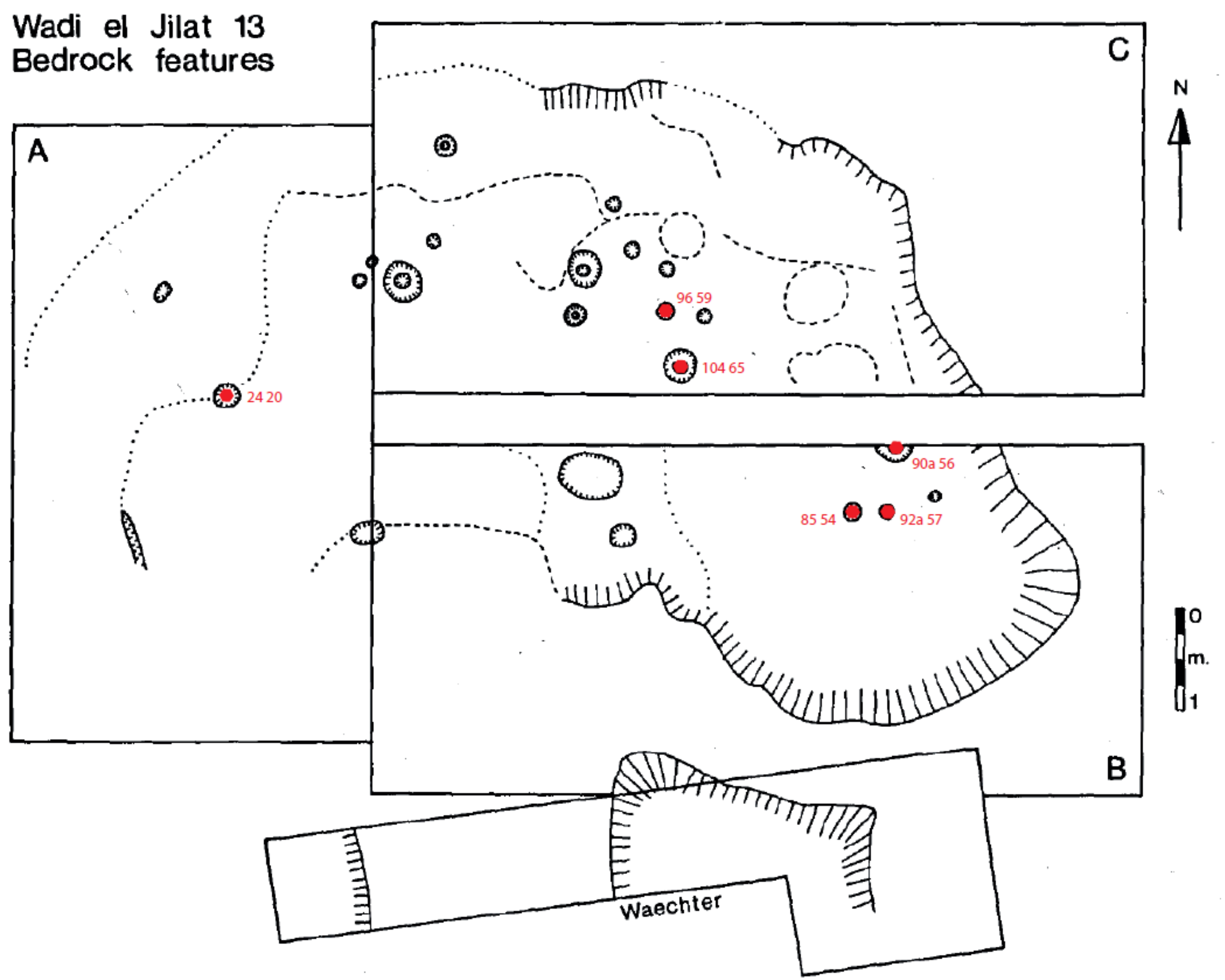
Appendix 3: Sample locations for the Wadi el-Jilat sites



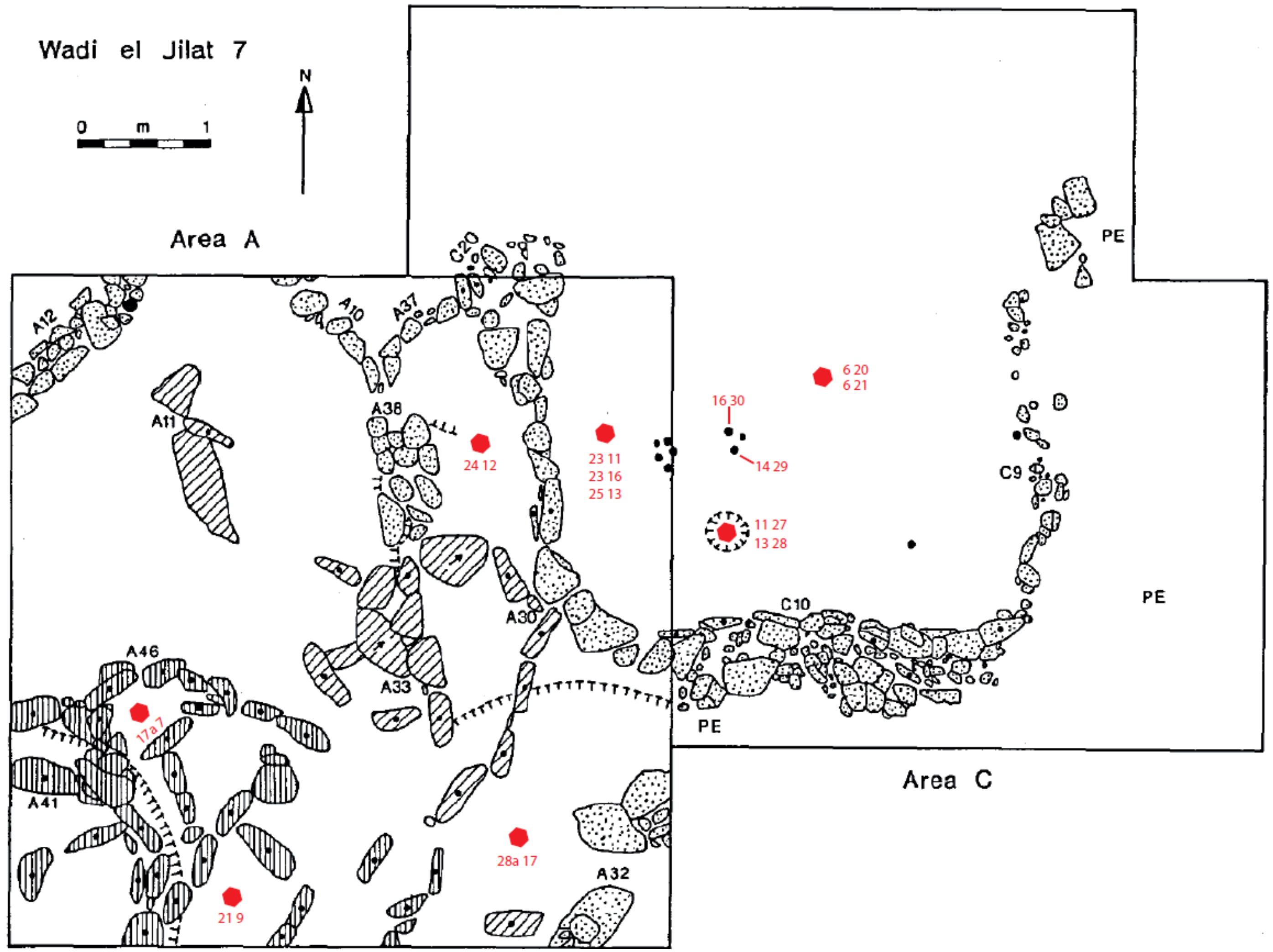
Plan of Wadi el-Jilat 13, early and middle phases. The red polygons represent the location of samples. The location of sediment samples was not provided for area B, where the polygons represent the centre of the relevant loci (adjusted from Garrard et al. 1994, 80).



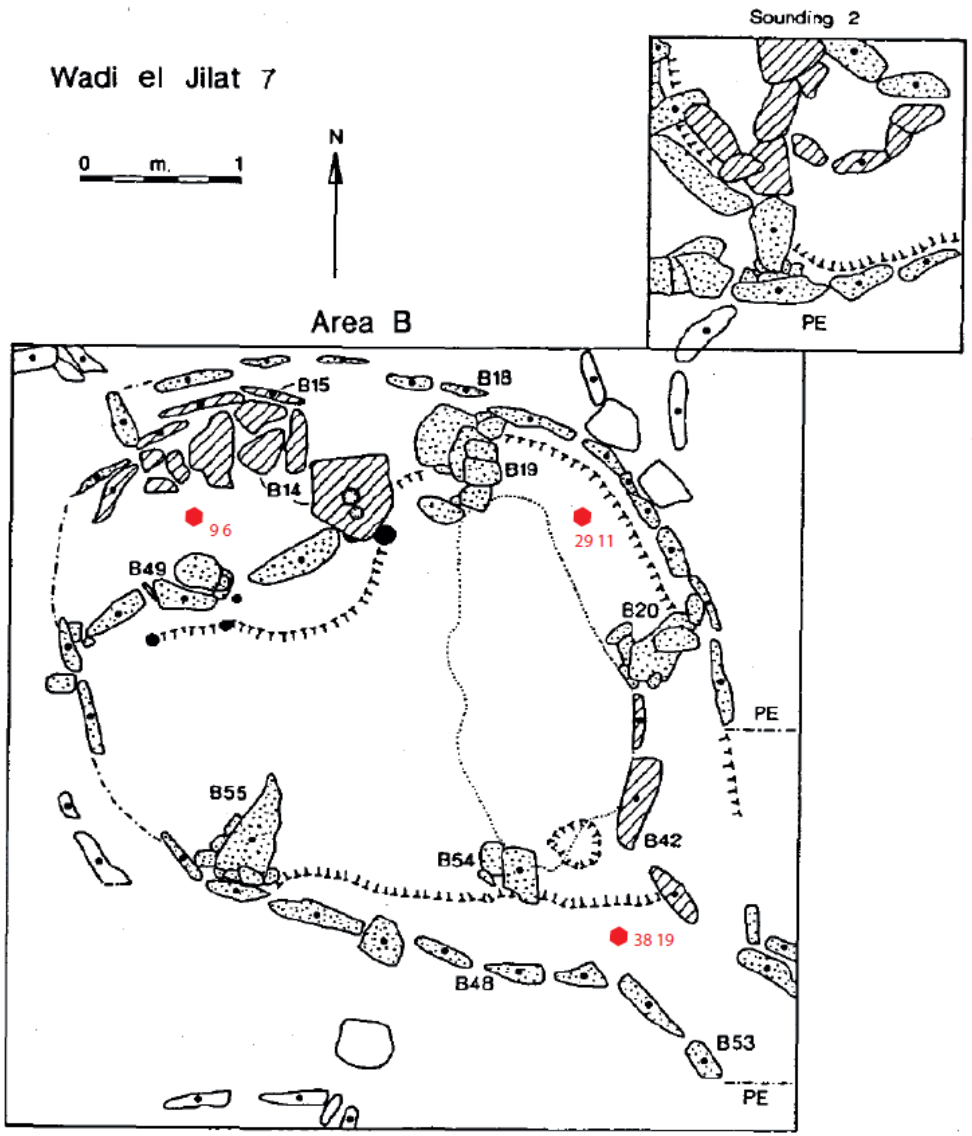
Plan of Wadi el-Jilat 13, late phase. The red polygons represent the location of samples (adjusted from Garrard et al. 1994, 80).



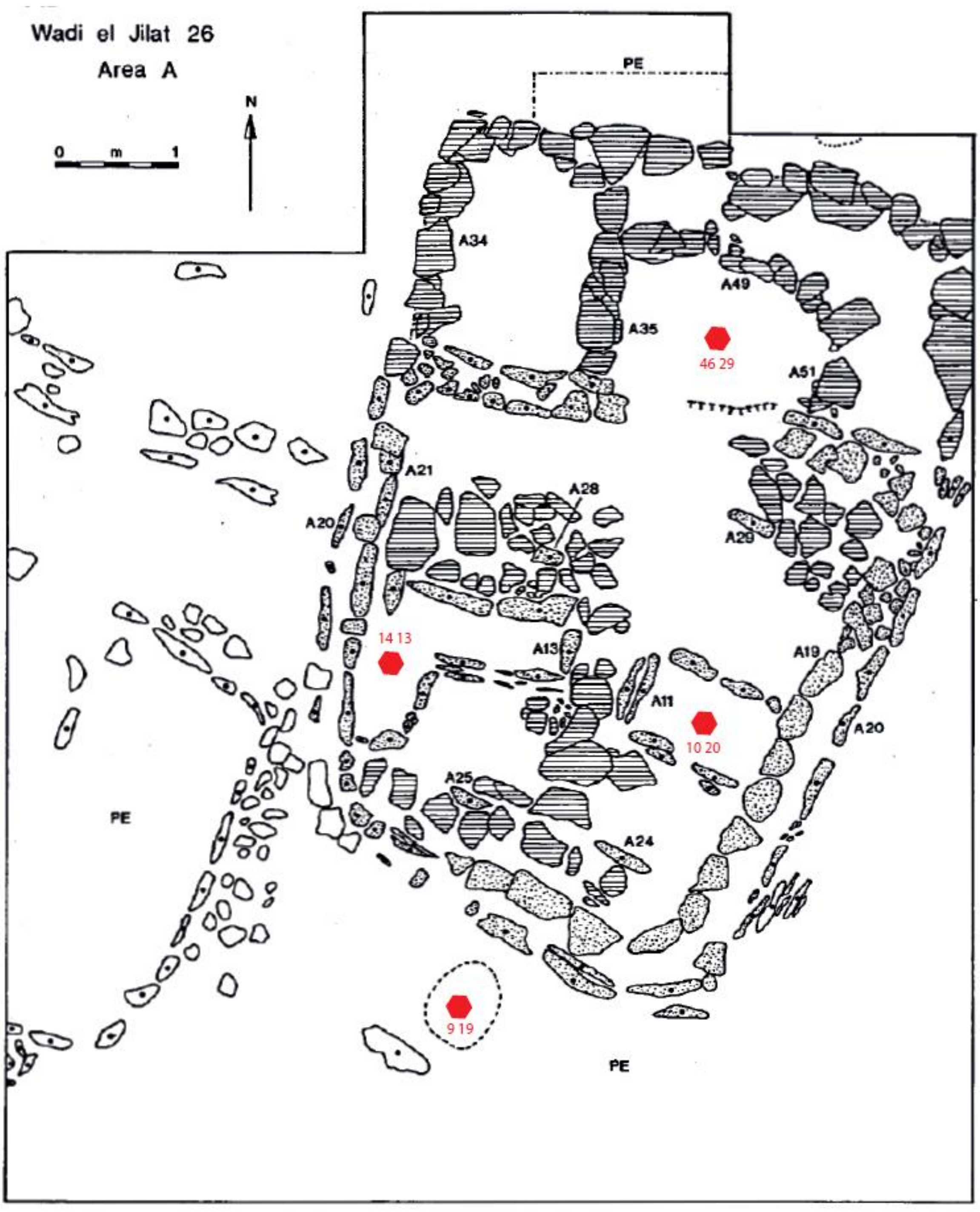
Plan of Wadi el-Jilat 13, bedrock features. The red polygons represent the location of samples (adjusted from Garrard et al. 1994, 80).



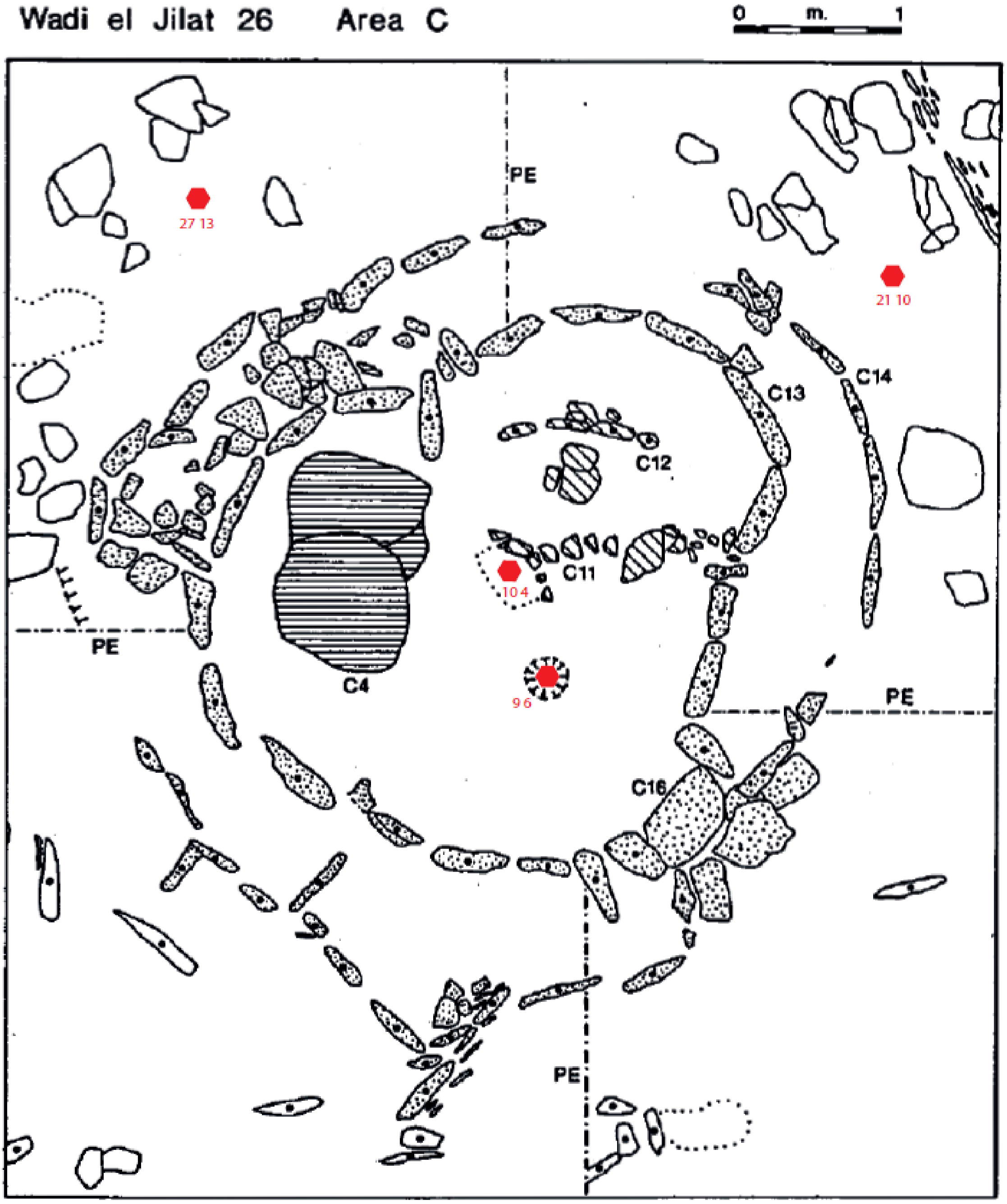
Plan of Wadi el-Jilat 7 areas A and C. The red polygons represent the location of samples (adjusted from Garrard et al. 1994, 74).



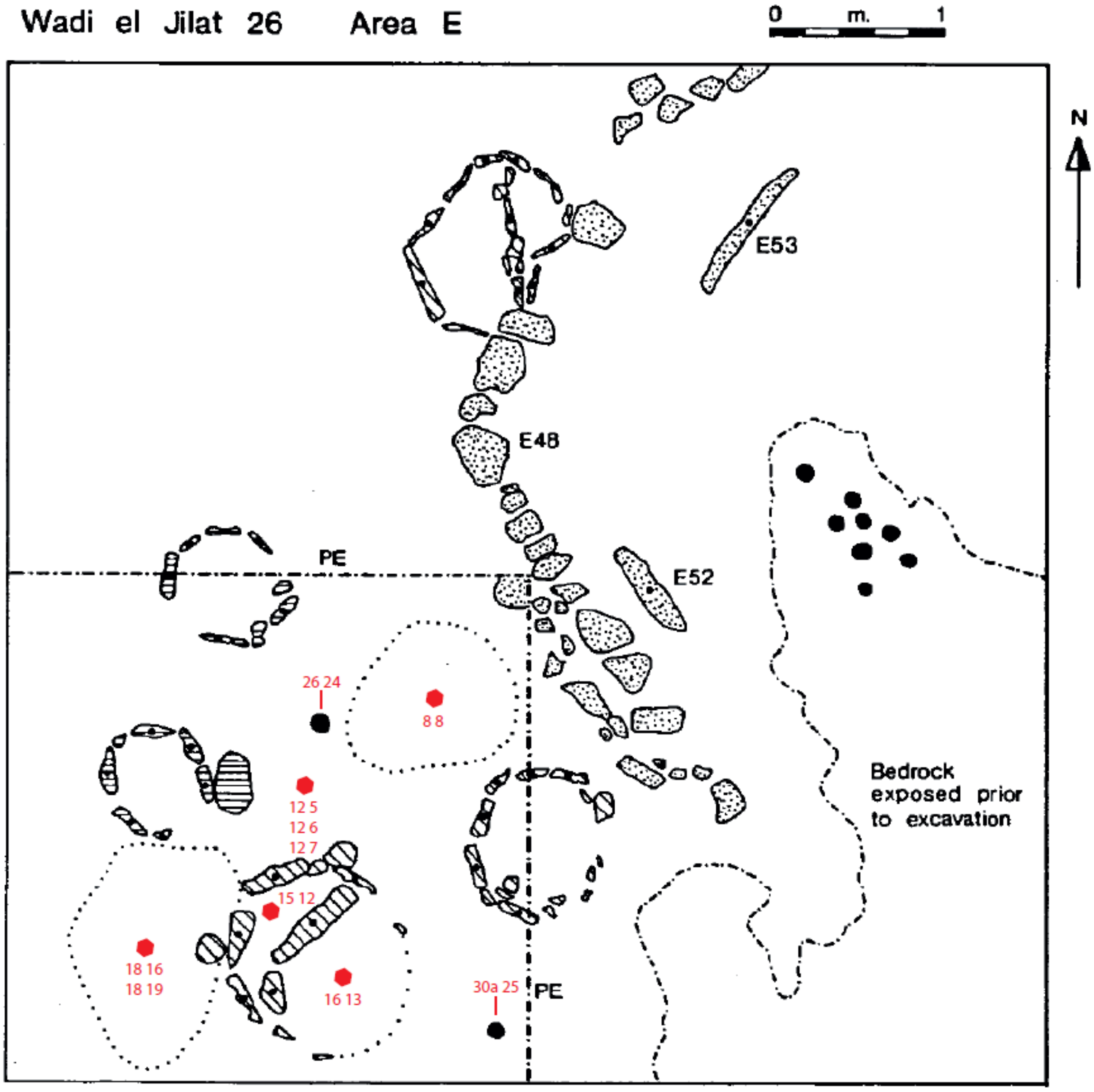
Plan of Wadi el-Jilat 7 area B. The red polygons represent the location of samples (adjusted from Garrard et al. 1994, 74).



Plan of Wadi el-Jilat 26 area A. The red polygons represent the location of samples (adjusted from Garrard et al. 1994, 78).



Plan of Wadi el-Jilat 26 area C. The red polygons represent the location of samples (adjusted from Garrard et al. 1994, 78).



Plan of Wadi el-Jilat 26 area E. The red polygons represent the location of samples (adjusted from Garrard et al. 1994, 78).

Appendix 4: Phytolith counting sheet

Sample #	Microscope	Co-ordinates counted				
Phytolith types						
Single cells						
bilobe						
blocks						
bulliform						
coarse verrucate						
cone						
cone						
cork cell						
crenate						
cross						
moon						
globular echinate						
globular granulate						
globular smooth						
hair base						
hair/trichome						
jigsaw piece						
keystone						
long dendritic						
long spiny dendritic						
long rod						
long sinuate						
long smooth						
long trapeziform						
oval						
papillae						
platey						
polyhedrol granulate						
polyhedrol plain						
polylobe						
rondel						
saddle						
scalloped						
sheet						
tracheid						
Unidentified short cell						
Unidentified long cell						
Unidentified single						
Unidentifiable						
Badly silicified conjoined						
silica aggregte						
FIELDS OF VIEW						
TOTAL						
badly silicified						
diatom						
Burnt						
Degraded						
Sponge spicule						

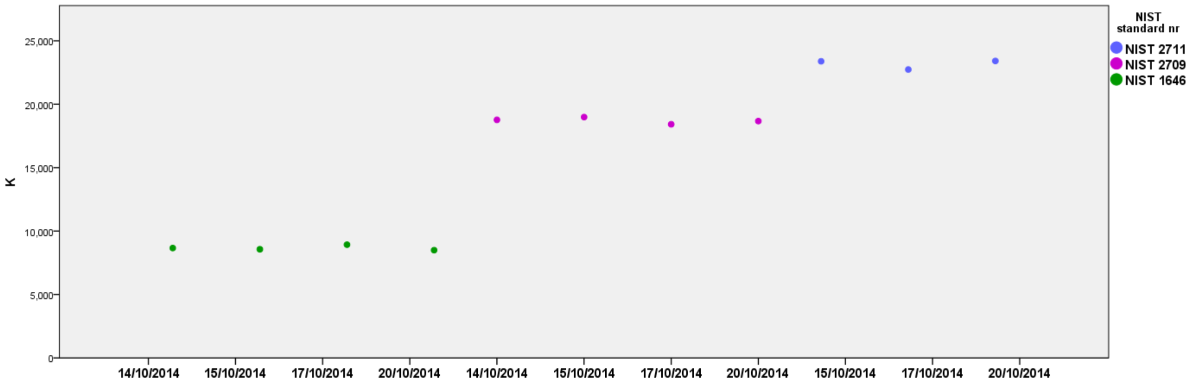
Multicells						
awn	**Multicell total:**					
Long cell						
Short cell						
Barley husk	**Multicell total:**					
Long cell						
Cork cell						
Papillae						
bulliforms	**Multicell total:**					
Bulliform						
Cyperaceae cones	Cone					
Cyperaceae rods	Rod					
Rods						
jigsaw puzzle	Jigsaw puzzle					
leaf-stem	**Multicell total:**					
Long cell smooth						
Long cell sinuate						
mesophyll						
Tracheid						
Phragmites leaf	**Multicell total:**					
Stomata						
Long cell						
short cell						
Phragmites stem	**Multicell total:**					
Long cell						
Short cell						
cf Phragmites	**Multicell total:**					
Long cell						
Short cell						
polyhedrol granulate						
polyhedrol plain	**Multicell total:**					
polyhedrol plain						
unid conjoined	**Multicell total:**					
Dendritics						
Short cells/papillae						
unidentifiable husk	**Multicell total:**					
Long cell						
Cork cell						
Papillae						
Wheat husk	**Multicell total:**					
Long cell						
Cork cell						
Papillae						
Wild Grass husk						
Long cell						
Cork cell						
Papillae						
cf Barley	**Multicell total:**					
Long cell						
Cork cell						
Papillae						
cf. Setaria husk	Multicell total:					
Long cell						
short cell						
Melted multi-cell						
Unidentifiable multicell						

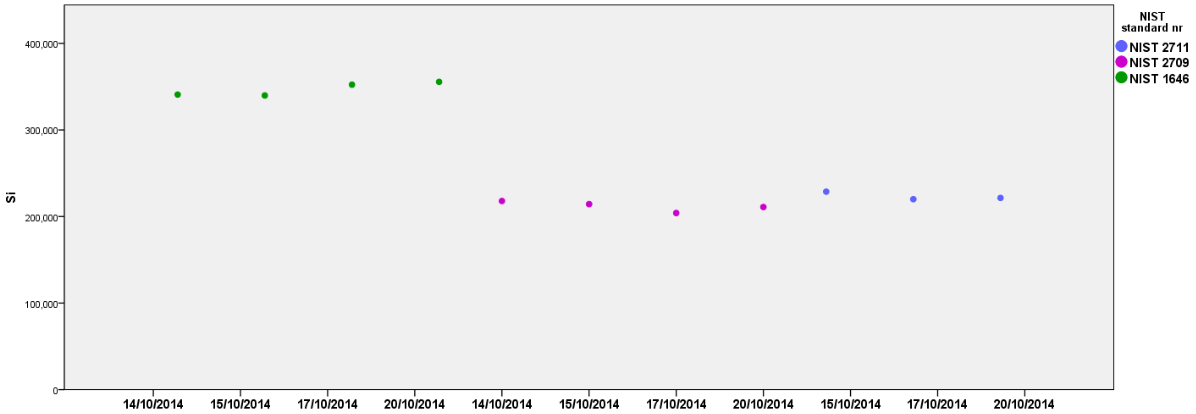
Name in phytolith counting sheet	Name according to the International Code for Phytolith Nomenclature
Bilobe	Bilobate short cell
Bulliform	Parallepipedal bulliform cell
Keystone	Cuneiform bulliform cell
Crenate	Ovate crenate
Cross	Cross
Globular echinate	Globular echinate
Globular smooth	Globular psilate
Hair base	Hair base
Hair / trichome	Unciform hair cell
Long dendritic	Elongate dendriform/dendritic
Long rod	Elongate psilate tenis
Long sinuate	Elongate sinuate
Long smooth	Elongate psilate
Long trapezoid	Trapeziform psilate
Papillae	Papillae cell
Platey	Tabular irregular
Polyhedral plain	Polyhedral plain
Polyhedral granulate	Polyhedral granulate
Rondel	Rondel
Saddle	Saddle
Scalloped	Scalloped
Sheet	Rectangle tabular
Tracheid	Cylindric sulcate tracheid
Silica aggregate	Silica aggregate

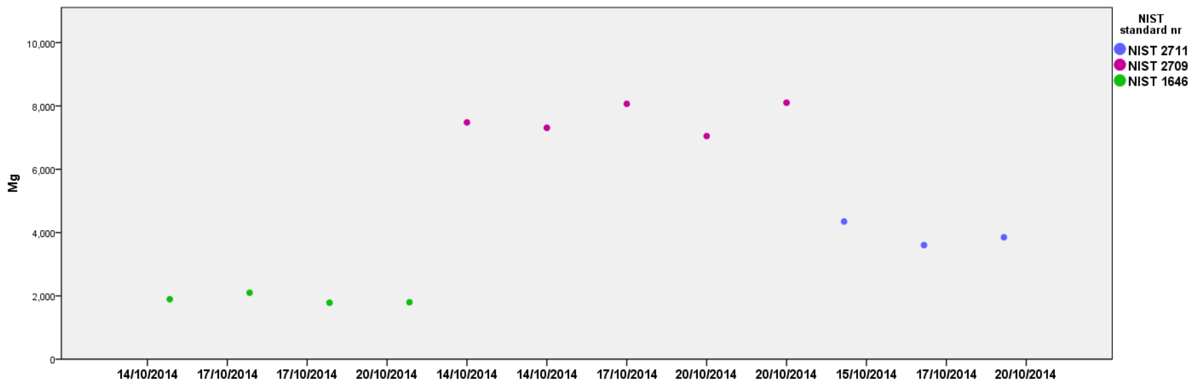
Table A3.1. Phytolith type names in the counting sheet and the adjusted names used in this research according to the International Code for Phytolith Nomenclature (Madella et al. 2005).

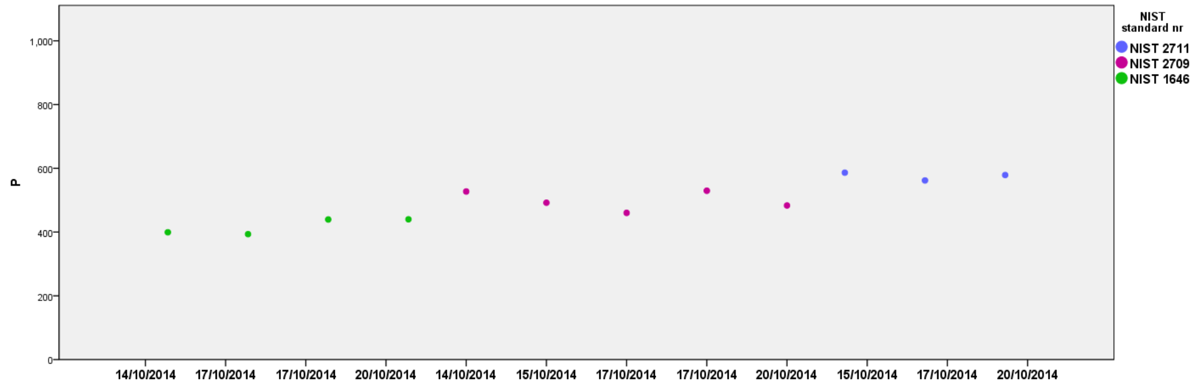
Appendix 5: NIST graphs

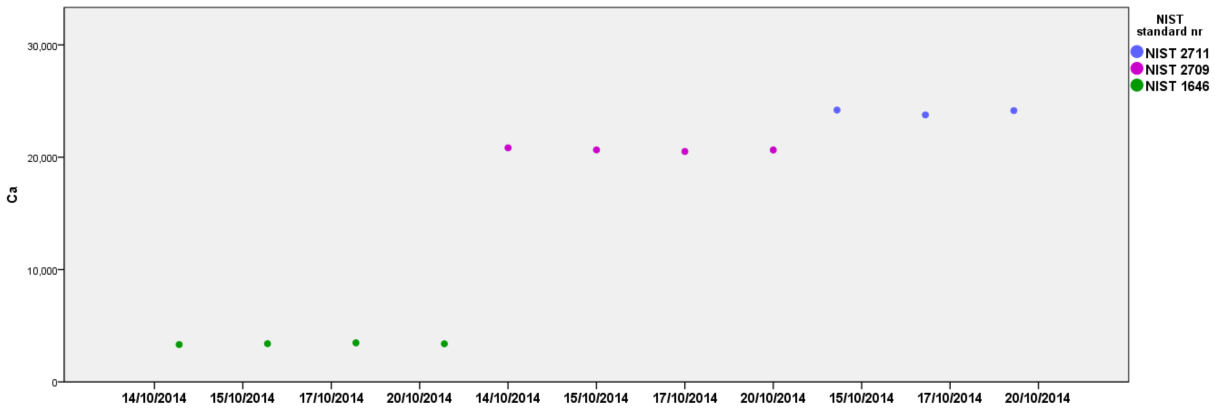
NIST standard nr 2711 was erroneously not used on 14/10/2014.

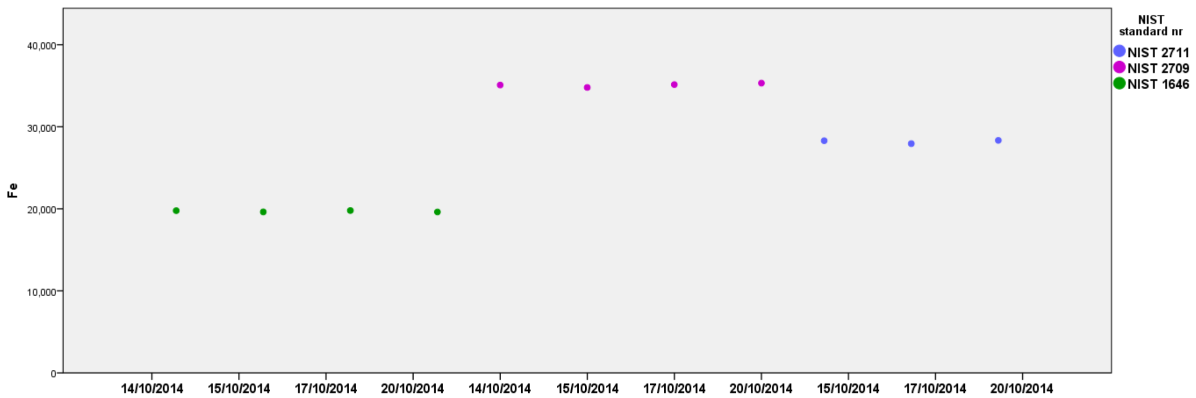


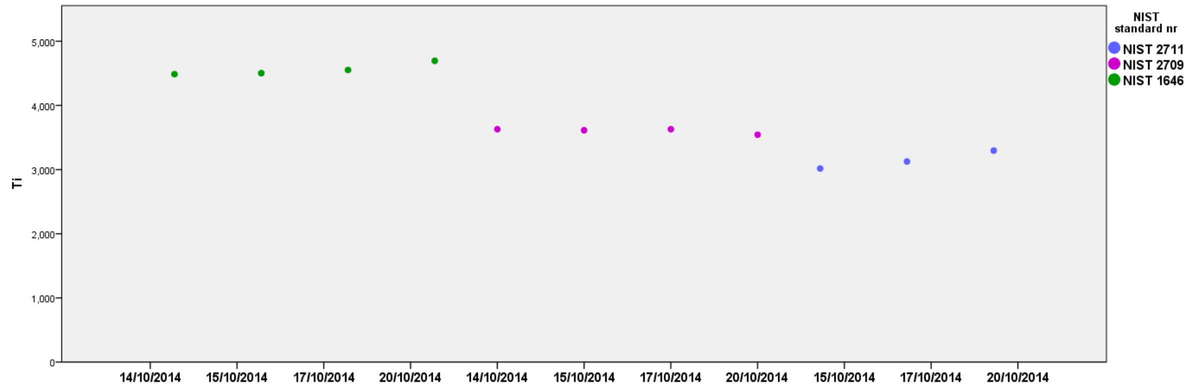


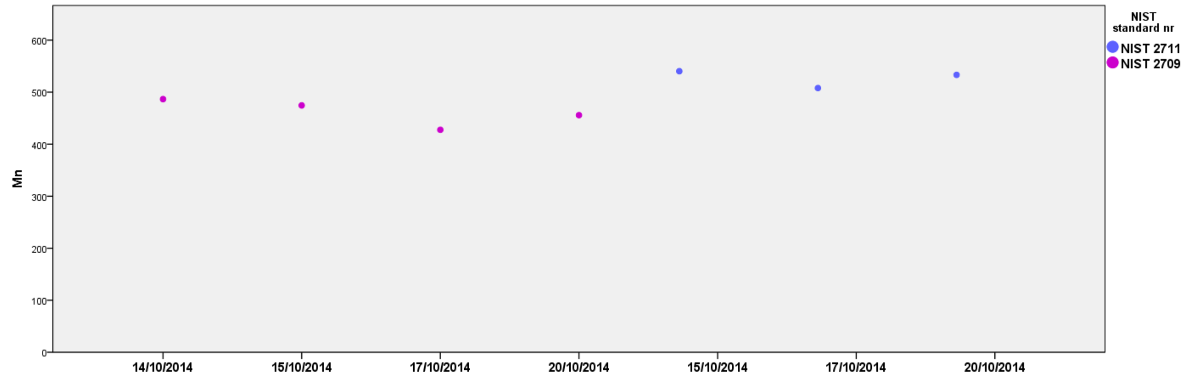


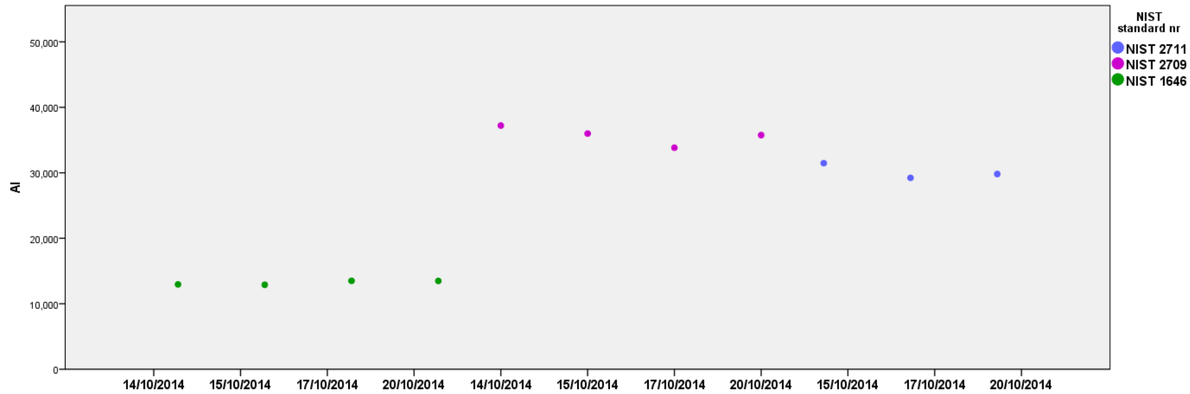

P
1,000
800
600
400
200
0
14/10/2014
17/10/2014
17/10/2014
20/10/2014
14/10/2014
15/10/2014
17/10/2014
17/10/2014
20/10/2014
15/10/2014
17/10/2014
20/10/2014
NIST standard nr
NIST 2711
NIST 2709
NIST 1646

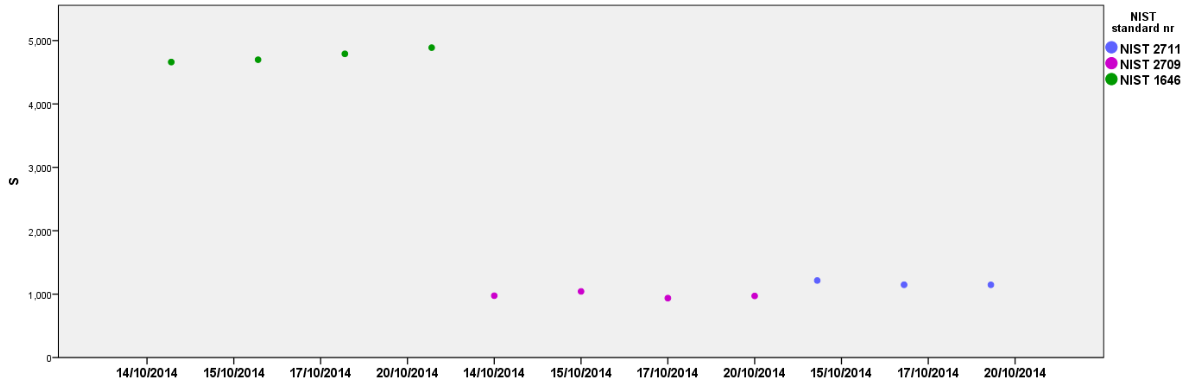

Ca
30,000
20,000
10,000
0
14/10/2014
15/10/2014
17/10/2014
20/10/2014
14/10/2014
15/10/2014
17/10/2014
20/10/2014
15/10/2014
17/10/2014
20/10/2014
NIST standard nr
NIST 2711
NIST 2709
NIST 1646

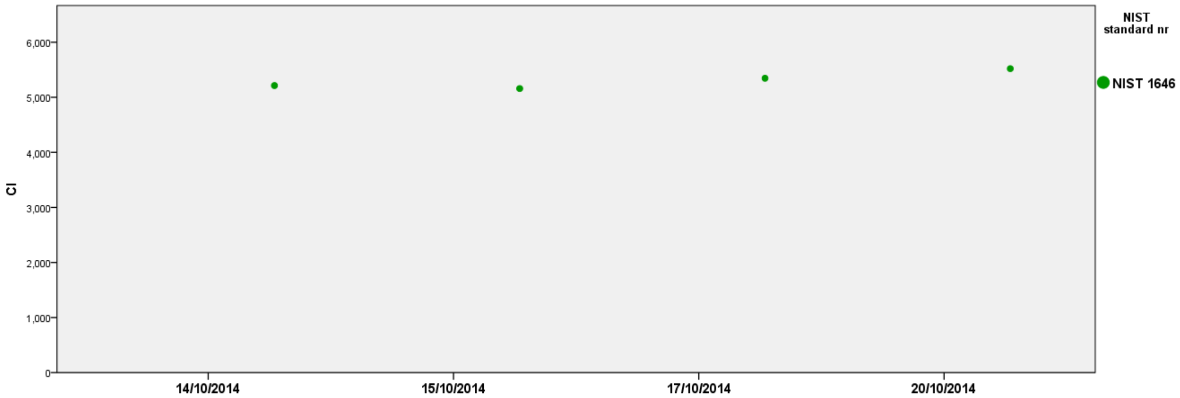

Fe
40,000
30,000
20,000
10,000
0
14/10/2014
15/10/2014
17/10/2014
20/10/2014
14/10/2014
15/10/2014
17/10/2014
20/10/2014
15/10/2014
17/10/2014
20/10/2014
NIST standard nr
NIST 2711
NIST 2709
NIST 1646

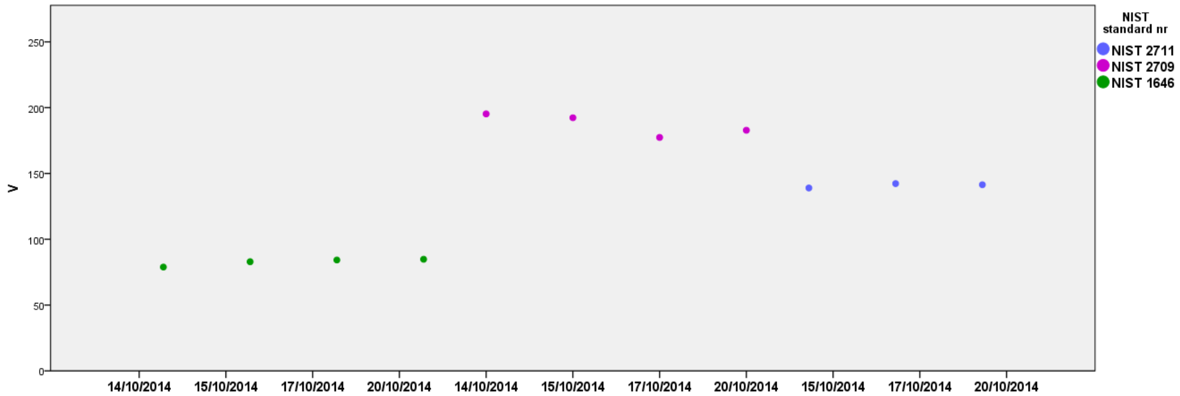

Ti
NIST standard nr
NIST 2711
NIST 2709
NIST 1646
14/10/2014
15/10/2014
17/10/2014
20/10/2014

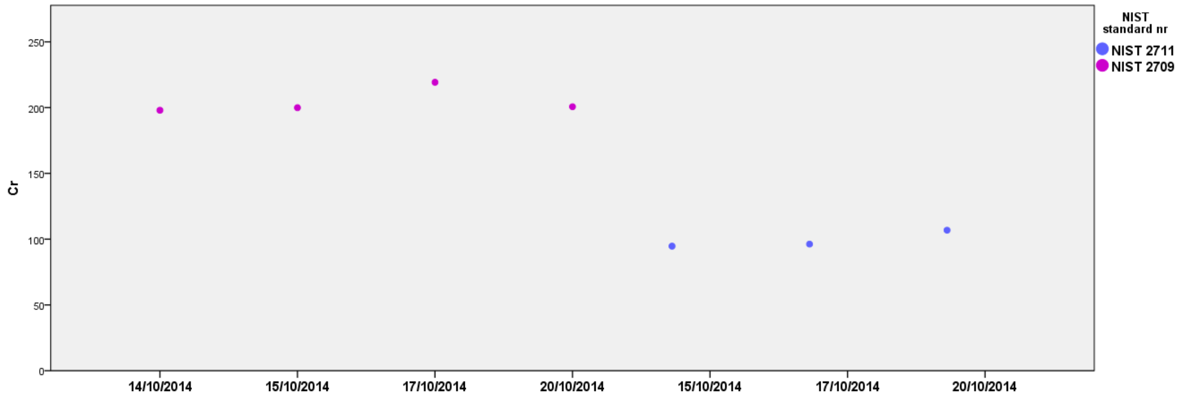

Mn
NIST standard nr
NIST 2711
NIST 2709
14/10/2014
15/10/2014
17/10/2014
20/10/2014

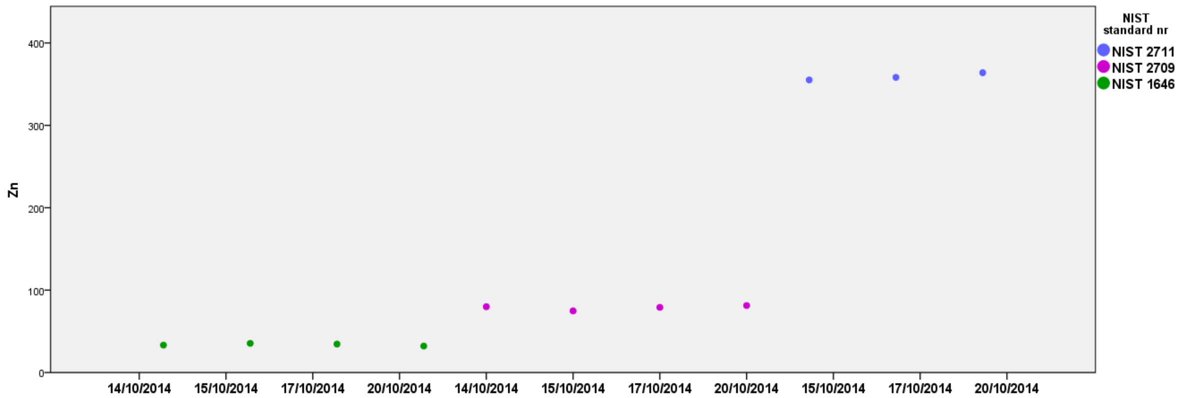

Al
NIST standard nr
NIST 2711
NIST 2709
NIST 1646
14/10/2014
15/10/2014
17/10/2014
20/10/2014

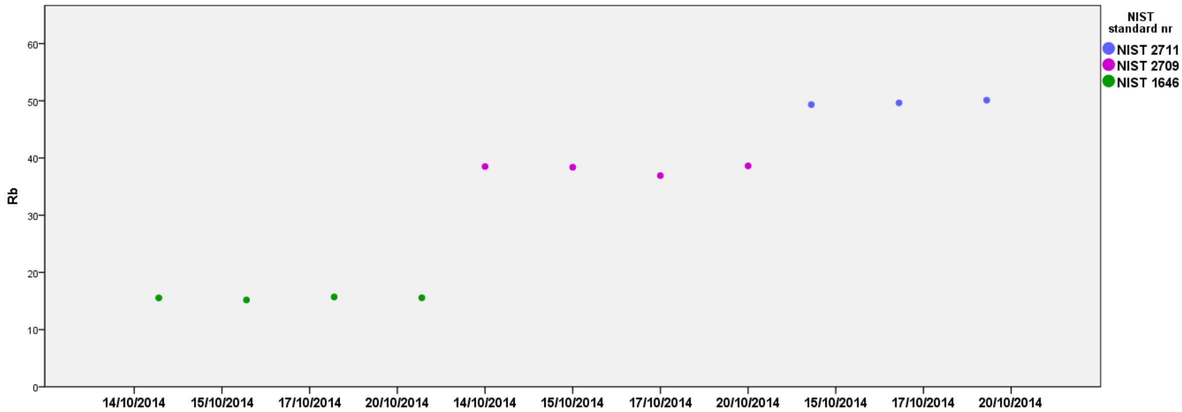

S
NIST standard nr
NIST 2711
NIST 2709
NIST 1646
14/10/2014
15/10/2014
17/10/2014
20/10/2014

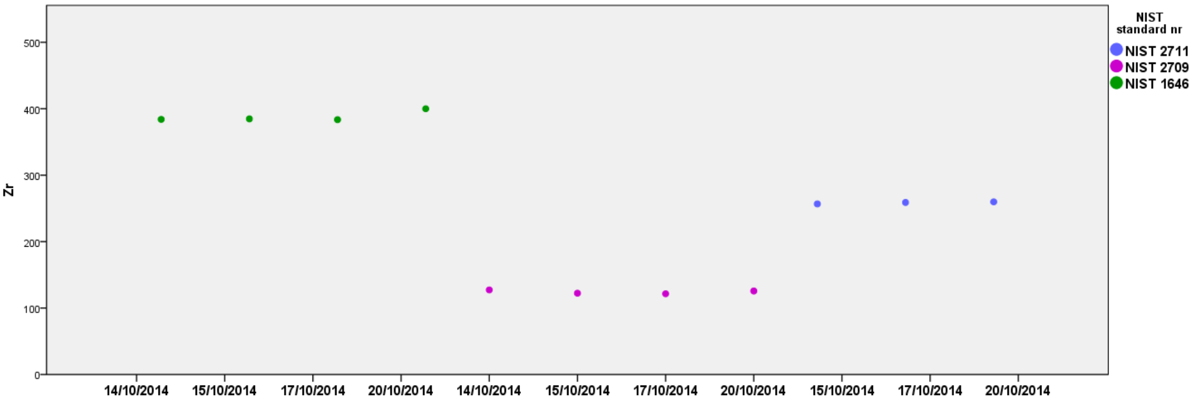

NIST standard nr
NIST 1646
Cl
0
1,000
2,000
3,000
4,000
5,000
6,000
14/10/2014
15/10/2014
17/10/2014
20/10/2014

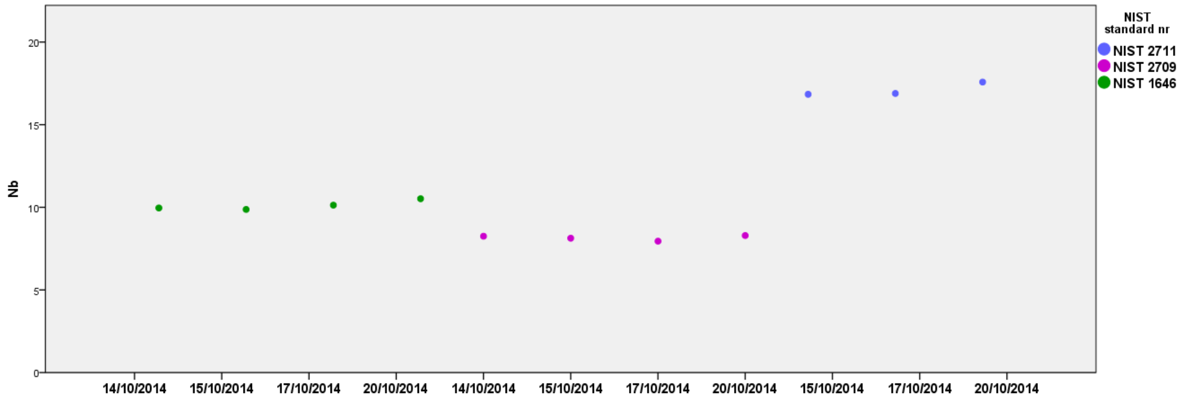

NIST standard nr
NIST 2711
NIST 2709
NIST 1646
V
0
50
100
150
200
250
14/10/2014
15/10/2014
17/10/2014
20/10/2014
14/10/2014
15/10/2014
17/10/2014
20/10/2014
15/10/2014
17/10/2014
20/10/2014


NIST standard nr
NIST 2711
NIST 2709
Cr
0
50
100
150
200
250
14/10/2014
15/10/2014
17/10/2014
20/10/2014
15/10/2014
17/10/2014
20/10/2014


NIST standard nr
NIST 2711
NIST 2709
NIST 1646
Zn
0
100
200
300
400
14/10/2014
15/10/2014
17/10/2014
20/10/2014
14/10/2014
15/10/2014
17/10/2014
20/10/2014
15/10/2014
17/10/2014
20/10/2014


NIST standard nr
NIST 2711
NIST 2709
NIST 1646
Rb
14/10/2014
15/10/2014
17/10/2014
20/10/2014
14/10/2014
15/10/2014
17/10/2014
20/10/2014
15/10/2014
17/10/2014
20/10/2014


NIST standard nr
NIST 2711
NIST 2709
NIST 1646
Zr
14/10/2014
15/10/2014
17/10/2014
20/10/2014
14/10/2014
15/10/2014
17/10/2014
20/10/2014
15/10/2014
17/10/2014
20/10/2014


NIST standard nr
NIST 2711
NIST 2709
NIST 1646
Nb
14/10/2014
15/10/2014
17/10/2014
20/10/2014
14/10/2014
15/10/2014
17/10/2014
20/10/2014
15/10/2014
17/10/2014
20/10/2014

Appendix 6: Two tailed Pearson correlation test results

Wadi Faynan and Dana sites

		Monocots	Dicots	Single	Multicell	Pooideae	Chloridoideae	Arundinoideae	Panicoideae
Monocots	Pearson Correlation	1	-.957**	-.887**	.907**	.603**	.373*	.335	.468**
	Sig. (2-tailed)		.000	.000	.000	.000	.032	.057	.006
	N	33	33	33	33	33	33	33	33
Dicots	Pearson Correlation	-.957**	1	.941**	-.862**	-.744**	-.396*	-.262	-.649**
	Sig. (2-tailed)	.000		.000	.000	.000	.023	.140	.000
	N	33	33	33	33	33	33	33	33
Single	Pearson Correlation	-.887**	.941**	1	-.938**	-.582**	-.149	-.199	-.673**
	Sig. (2-tailed)	.000	.000		.000	.000	.409	.266	.000
	N	33	33	33	33	33	33	33	33
Multicell	Pearson Correlation	.907**	-.862**	-.938**	1	.366*	.055	.276	.448**
	Sig. (2-tailed)	.000	.000	.000		.036	.763	.121	.009
	N	33	33	33	33	33	33	33	33
Pooideae	Pearson Correlation	.603**	-.744**	-.582**	.366*	1	.597**	.121	.721**
	Sig. (2-tailed)	.000	.000	.000	.036		.000	.501	.000
	N	33	33	33	33	33	33	33	33
Chloridoideae	Pearson Correlation	.373*	-.396*	-.149	.055	.597**	1	-.034	-.030
	Sig. (2-tailed)	.032	.023	.409	.763	.000		.849	.868
	N	33	33	33	33	33	33	33	33
Arundinoideae	Pearson Correlation	.335	-.262	-.199	.276	.121	-.034	1	.108
	Sig. (2-tailed)	.057	.140	.266	.121	.501	.849		.550
	N	33	33	33	33	33	33	33	33
Panicoideae	Pearson Correlation	.468**	-.649**	-.673**	.448**	.721**	-.030	.108	1
	Sig. (2-tailed)	.006	.000	.000	.009	.000	.868	.550	
	N	33	33	33	33	33	33	33	33
Palmaceae	Pearson Correlation	-.126	.115	.152	-.162	-.088	-.030	-.096	-.114
	Sig. (2-tailed)	.486	.524	.400	.369	.626	.867	.596	.527
	N	33	33	33	33	33	33	33	33
Hordeum	Pearson Correlation	.277	-.400*	-.350*	.192	.377*	.204	-.037	.460**
	Sig. (2-tailed)	.119	.021	.046	.286	.030	.255	.839	.007
	N	33	33	33	33	33	33	33	33
Triticum	Pearson Correlation	.614**	-.489**	-.587**	.750**	-.015	-.010	-.067	-.001
	Sig. (2-tailed)	.000	.004	.000	.000	.935	.954	.712	.997
	N	33	33	33	33	33	33	33	33
Leaf	Pearson Correlation	.572**	-.568**	-.297	.239	.640**	.596**	.589**	.257
	Sig. (2-tailed)	.001	.001	.094	.180	.000	.000	.000	.150
	N	33	33	33	33	33	33	33	33
Leafhusk	Pearson Correlation	.657**	-.572**	-.421*	.464**	.449**	.175	.564**	.391*
	Sig. (2-tailed)	.000	.001	.015	.007	.009	.331	.001	.024
	N	33	33	33	33	33	33	33	33
Leafstem	Pearson Correlation	.488**	-.652**	-.682**	.494**	.644**	-.015	.101	.838**
	Sig. (2-tailed)	.004	.000	.000	.003	.000	.932	.576	.000
	N	33	33	33	33	33	33	33	33
Husk	Pearson Correlation	.665**	-.589**	-.436*	.455**	.422*	.520**	.310	.183
	Sig. (2-tailed)	.000	.000	.011	.008	.015	.002	.079	.308
	N	33	33	33	33	33	33	33	33
Awn	Pearson Correlation	.493**	-.369*	-.402*	.575**	.020	-.157	.513**	.057
	Sig. (2-tailed)	.004	.035	.021	.000	.914	.382	.002	.752
	N	33	33	33	33	33	33	33	33
Silicaagregate	Pearson Correlation	-.227	.267	.190	-.118	-.259	-.196	.001	-.209
	Sig. (2-tailed)	.205	.134	.289	.514	.146	.274	.997	.244
	N	33	33	33	33	33	33	33	33
Nrpergram	Pearson Correlation	.549**	-.521**	-.619**	.647**	.235	-.027	-.019	.355*
	Sig. (2-tailed)	.001	.002	.000	.000	.188	.880	.916	.043
	N	33	33	33	33	33	33	33	33
Indet	Pearson Correlation	.233	-.251	.036	-.117	.480**	.752**	.042	-.050
	Sig. (2-tailed)	.193	.158	.840	.518	.005	.000	.815	.783
	N	33	33	33	33	33	33	33	33
Degraded	Pearson Correlation	-.094	.094	.291	-.316	.093	.295	-.137	-.194
	Sig. (2-tailed)	.604	.603	.101	.073	.606	.095	.448	.279
	N	33	33	33	33	33	33	33	33
Burnt	Pearson Correlation	.030	-.082	.021	-.098	.285	.199	-.099	.123
	Sig. (2-tailed)	.869	.650	.907	.588	.108	.268	.585	.494
	N	33	33	33	33	33	33	33	33
Badlysilicified	Pearson Correlation	.456	-.440	-.162	.111	.654	.768	.269	.079
	Sig. (2-tailed)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	N	33	33	33	33	33	33	33	33
Diatom	Pearson Correlation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Sig. (2-tailed)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	N	33	33	33	33	33	33	33	33
Mg	Pearson Correlation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Sig. (2-tailed)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	N	33	33	33	33	33	33	33	33
Si	Pearson Correlation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Sig. (2-tailed)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	N	33	33	33	33	33	33	33	33
K	Pearson Correlation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Sig. (2-tailed)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	N	33	33	33	33	33	33	33	33
Ca	Pearson Correlation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Sig. (2-tailed)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	N	33	33	33	33	33	33	33	33
P	Pearson Correlation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Sig. (2-tailed)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	N	33	33	33	33	33	33	33	33
Fe	Pearson Correlation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Sig. (2-tailed)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	N	33	33	33	33	33	33	33	33
Ti	Pearson Correlation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Sig. (2-tailed)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	N	33	33	33	33	33	33	33	33
Mn	Pearson Correlation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Sig. (2-tailed)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	N	33	33	33	33	33	33	33	33
Al	Pearson Correlation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Sig. (2-tailed)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	N	33	33	33	33	33	33	33	33
Sr	Pearson Correlation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Sig. (2-tailed)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	N	33	33	33	33	33	33	33	33
S	Pearson Correlation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Sig. (2-tailed)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	N	33	33	33	33	33	33	33	33
Cl	Pearson Correlation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Sig. (2-tailed)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	N	33	33	33	33	33	33	33	33
Zn	Pearson Correlation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Sig. (2-tailed)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	N	33	33	33	33	33	33	33	33
Zr	Pearson Correlation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Sig. (2-tailed)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	N	33	33	33	33	33	33	33	33

		Palmaceae	Hordeum	Triticum	Leaf	Leafhusk	Leafstem	Husk	Awn	Silicaagregate
Monocots	Pearson Correlation	-.126	.277	.614**	.572**	.657**	.488**	.665**	.493**	-.227
	Sig. (2-tailed)	.486	.119	.000	.001	.000	.004	.000	.004	.205
	N	33	33	33	33	33	33	33	33	33
Dicots	Pearson Correlation	.115	-.400*	-.489**	-.568**	-.572**	-.652**	-.589**	-.369*	.267
	Sig. (2-tailed)	.524	.021	.004	.001	.001	.000	.000	.035	.134
	N	33	33	33	33	33	33	33	33	33
Single	Pearson Correlation	.152	-.350*	-.587**	-.297	-.421*	-.682**	-.436*	-.402*	.190
	Sig. (2-tailed)	.400	.046	.000	.094	.015	.000	.011	.021	.289
	N	33	33	33	33	33	33	33	33	33
Multicell	Pearson Correlation	-.162	.192	.750**	.239	.464**	.494**	.455**	.575**	-.118
	Sig. (2-tailed)	.369	.286	.000	.180	.007	.003	.008	.000	.514
	N	33	33	33	33	33	33	33	33	33
Pooideae	Pearson Correlation	-.088	.377*	-.015	.640**	.449**	.644**	.422*	.020	-.259
	Sig. (2-tailed)	.626	.030	.935	.000	.009	.000	.015	.914	.146
	N	33	33	33	33	33	33	33	33	33
Chloridoideae	Pearson Correlation	-.030	.204	-.010	.596**	.175	-.015	.520**	-.157	-.196
	Sig. (2-tailed)	.867	.255	.954	.000	.331	.932	.002	.382	.274
	N	33	33	33	33	33	33	33	33	33
Arundinoideae	Pearson Correlation	-.096	-.037	-.067	.589**	.564**	.101	.310	.513**	.001
	Sig. (2-tailed)	.596	.839	.712	.000	.001	.576	.079	.002	.997
	N	33	33	33	33	33	33	33	33	33
Panicoideae	Pearson Correlation	-.114	.460**	-.001	.257	.391*	.838**	.183	.057	-.209
	Sig. (2-tailed)	.527	.007	.997	.150	.024	.000	.308	.752	.244
	N	33	33	33	33	33	33	33	33	33
Palmaceae	Pearson Correlation	1	-.078	-.078	.020	-.111	-.019	-.121	-.143	-.127
	Sig. (2-tailed)		.667	.665	.913	.538	.918	.504	.427	.482
	N	33	33	33	33	33	33	33	33	33
Hordeum	Pearson Correlation	-.078	1	-.051	.328	.005	.376*	.178	-.093	-.106
	Sig. (2-tailed)	.667		.779	.062	.980	.031	.323	.607	.555
	N	33	33	33	33	33	33	33	33	33
Triticum	Pearson Correlation	-.078	-.051	1	-.100	.146	.023	.148	.277	-.177
	Sig. (2-tailed)	.665	.779		.580	.417	.901	.410	.118	.323
	N	33	33	33	33	33	33	33	33	33
Leaf	Pearson Correlation	.020	.328	-.100	1	.609**	.242	.573**	.217	-.238
	Sig. (2-tailed)	.913	.062	.580		.000	.175	.000	.226	.182
	N	33	33	33	33	33	33	33	33	33
Leafhusk	Pearson Correlation	-.111	.005	.146	.609**	1	.307	.649**	.483**	-.153
	Sig. (2-tailed)	.538	.980	.417	.000		.082	.000	.004	.396
	N	33	33	33	33	33	33	33	33	33
Leafstem	Pearson Correlation	-.019	.376*	.023	.242	.307	1	.014	.222	-.056
	Sig. (2-tailed)	.918	.031	.901	.175	.082		.938	.215	.756
	N	33	33	33	33	33	33	33	33	33
Husk	Pearson Correlation	-.121	.178	.148	.573**	.649**	.014	1	.273	-.108
	Sig. (2-tailed)	.504	.323	.410	.000	.000	.938		.125	.549
	N	33	33	33	33	33	33	33	33	33
Awn	Pearson Correlation	-.143	-.093	.277	.217	.483**	.222	.273	1	.159
	Sig. (2-tailed)	.427	.607	.118	.226	.004	.215	.125		.376
	N	33	33	33	33	33	33	33	33	33
Silicaagregate	Pearson Correlation	-.127	-.106	-.177	-.238	-.153	-.056	-.108	.159	1
	Sig. (2-tailed)	.482	.555	.323	.182	.396	.756	.549	.376	
	N	33	33	33	33	33	33	33	33	33
Nrpergram	Pearson Correlation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Sig. (2-tailed)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	N	33	33	33	33	33	33	33	33	33
Indet	Pearson Correlation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Sig. (2-tailed)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	N	33	33	33	33	33	33	33	33	33
Degraded	Pearson Correlation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Sig. (2-tailed)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	N	33	33	33	33	33	33	33	33	33
Burnt	Pearson Correlation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Sig. (2-tailed)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	N	33	33	33	33	33	33	33	33	33
Badlysilicified	Pearson Correlation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Sig. (2-tailed)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	N	33	33	33	33	33	33	33	33	33
Diatom	Pearson Correlation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Sig. (2-tailed)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	N	33	33	33	33	33	33	33	33	33
Mg	Pearson Correlation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Sig. (2-tailed)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	N	33	33	33	33	33	33	33	33	33
Si	Pearson Correlation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Sig. (2-tailed)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	N	33	33	33	33	33	33	33	33	33
K	Pearson Correlation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Sig. (2-tailed)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	N	33	33	33	33	33	33	33	33	33
Ca	Pearson Correlation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Sig. (2-tailed)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	N	33	33	33	33	33	33	33	33	33
P	Pearson Correlation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Sig. (2-tailed)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	N	33	33	33	33	33	33	33	33	33
Fe	Pearson Correlation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Sig. (2-tailed)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	N	33	33	33	33	33	33	33	33	33
Ti	Pearson Correlation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Sig. (2-tailed)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	N	33	33	33	33	33	33	33	33	33
Mn	Pearson Correlation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Sig. (2-tailed)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	N	33	33	33	33	33	33	33	33	33
Al	Pearson Correlation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Sig. (2-tailed)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	N	33	33	33	33	33	33	33	33	33
Sr	Pearson Correlation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Sig. (2-tailed)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	N	33	33	33	33	33	33	33	33	33
S	Pearson Correlation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Sig. (2-tailed)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	N	33	33	33	33	33	33	33	33	33
Cl	Pearson Correlation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Sig. (2-tailed)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	N	33	33	33	33	33	33	33	33	33
Zn	Pearson Correlation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Sig. (2-tailed)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	N	33	33	33	33	33	33	33	33	33
Zr	Pearson Correlation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Sig. (2-tailed)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	N	33	33	33	33	33	33	33	33	33

		Nrpergram	Indet	Degraded	Burnt	Badlysilicified	Diatom	Mg	Si	K	Ca	P	Fe	Ti	Mn	Al	Sr	S	Cl	Zn	Zr
Monocots	Pearson Correlation	.549**	.233	-.094	.030	.456	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Sig. (2-tailed)	.001	.193	.604	.869	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	N	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33
Dicots	Pearson Correlation	-.521**	-.251	.094	-.082	-.440	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Sig. (2-tailed)	.002	.158	.603	.650	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	N	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33
Single	Pearson Correlation	-.619**	.036	.291	.021	-.162	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Sig. (2-tailed)	.000	.840	.101	.907	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	N	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33
Multicell	Pearson Correlation	.647**	-.117	-.316	-.098	.111	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Sig. (2-tailed)	.000	.518	.073	.588	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	N	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33
Pooideae	Pearson Correlation	.235	.480**	.093	.285	.654	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Sig. (2-tailed)	.188	.005	.606	.108	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	N	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33
Chloridoideae	Pearson Correlation	-.027	.752**	.295	.199	.768	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Sig. (2-tailed)	.880	.000	.095	.268	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	N	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33
Arundinoideae	Pearson Correlation	-.019	.042	-.137	-.099	.269	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Sig. (2-tailed)	.916	.815	.448	.585	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	N	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33
Panicoideae	Pearson Correlation	.355*	-.050	-.194	.123	.079	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Sig. (2-tailed)	.043	.783	.279	.494	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	N	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33
Palmaceae	Pearson Correlation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Sig. (2-tailed)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	N	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33
Hordeum	Pearson Correlation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Sig. (2-tailed)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	N	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33
Triticum	Pearson Correlation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Sig. (2-tailed)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	N	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33
Leaf	Pearson Correlation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Sig. (2-tailed)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	N	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33
Leafhusk	Pearson Correlation	.305	.171	-.102	.020	.448	-.096	.635	-.566	.367	.602	.714	-.573	-.619	.051	-.535	.602	.894	.232	.473	-.544
	Sig. (2-tailed)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	N	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33
Leafstem	Pearson Correlation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Sig. (2-tailed)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	N	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33
Husk	Pearson Correlation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Sig. (2-tailed)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	N	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33
Awn	Pearson Correlation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Sig. (2-tailed)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	N	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33
Silicaagregate	Pearson Correlation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Sig. (2-tailed)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	N	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33
Nrpergram	Pearson Correlation	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Sig. (2-tailed)		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	N	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33
Indet	Pearson Correlation	[illegible]	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Sig. (2-tailed)	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	N	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33
Degraded	Pearson Correlation	[illegible]	[illegible]	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Sig. (2-tailed)	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	N	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33
Burnt	Pearson Correlation	[illegible]	[illegible]	[illegible]	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Sig. (2-tailed)	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	N	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33
Badlysilicified	Pearson Correlation	[illegible]	[illegible]	[illegible]	[illegible]	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Sig. (2-tailed)	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	N	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33
Diatom	Pearson Correlation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Sig. (2-tailed)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	N	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33
Mg	Pearson Correlation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Sig. (2-tailed)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	N	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33
Si	Pearson Correlation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Sig. (2-tailed)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	N	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33
K	Pearson Correlation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Sig. (2-tailed)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	N	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33
Ca	Pearson Correlation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Sig. (2-tailed)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	N	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33
P	Pearson Correlation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Sig. (2-tailed)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	N	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33
Fe	Pearson Correlation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Sig. (2-tailed)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	N	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33
Ti	Pearson Correlation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Sig. (2-tailed)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	N	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33
Mn	Pearson Correlation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Sig. (2-tailed)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	N	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33
Al	Pearson Correlation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Sig. (2-tailed)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	N	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33
Sr	Pearson Correlation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	[illegible]	[illegible]	[illegible]	[illegible]
	Sig. (2-tailed)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]
	N	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33
S	Pearson Correlation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	[illegible]	[illegible]	[illegible]
	Sig. (2-tailed)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]
	N	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33
Cl	Pearson Correlation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	[illegible]	[illegible]
	Sig. (2-tailed)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]
	N	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33
Zn	Pearson Correlation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	[illegible]
	Sig. (2-tailed)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
	N	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33
Zr	Pearson Correlation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1
	Sig. (2-tailed)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
	N	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Wadi el-Jilat sites

		Silicaaggre	Monocots	Dicots	Single	Multiple	Husk	Leafhusk	Leaf	Leafstem	Indet	Degraded	Burnt	Badlysilicified	Diatom	Mg	Si	K	Ca	P	Fe	Mn	Al	Sr	S	Cl	Cr	Zn	Rb
Silicaaggre	Pearson Correlation	1	.039	-.038	-.158	.160	-.163	-.123	-.067	-.103	-.003	.186	-.080	-.017	-.132	-.114	-.106	-.120	.096	.288	-.087	.104	-.087	.058	.065	.115	.113	.082	-.043
	Sig. (2-tailed)		.750	.757	.199	.192	.184	.318	.587	.405	.981	.128	.517	.894	.283	.356	.391	.331	.435	.017	.478	.400	.481	.641	.600	.352	.357	.506	.728
	N	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68
Monocots	Pearson Correlation	.039	1	-1.000	-.784	.783	.498	.410	.687	.796	.408	.584	.395	.362	.292	-.178	-.260	-.341	.299	.290	-.317	-.199	-.359	.277	.067	-.116	-.130	-.040	-.166
	Sig. (2-tailed)	.750		.000	.000	.000	.000	.001	.000	.000	.001	.000	.001	.002	.016	.147	.033	.004	.013	.016	.009	.104	.003	.022	.585	.346	.292	.743	.175
	N	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68
Dicots	Pearson Correlation	-.038	-1.000	1	.784	-.783	-.497	-.412	-.688	-.795	-.407	-.585	-.394	-.360	-.294	.177	.260	.344	-.303	-.294	.319	.198	.360	-.279	-.067	.116	.129	.041	.165
	Sig. (2-tailed)	.757	.000		.000	.000	.000	.000	.000	.000	.001	.000	.001	.003	.015	.149	.032	.004	.012	.015	.008	.106	.003	.021	.588	.348	.294	.742	.180
	N	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68
Single	Pearson Correlation	-.158	-.784	.784	1	-1.000	-.073	-.003	-.152	-.427	-.004	-.208	-.414	-.142	-.033	.055	.170	.210	-.187	-.226	.218	.192	.246	-.266	-.028	-.057	.080	.017	.081
	Sig. (2-tailed)	.199	.000	.000		.000	.553	.980	.216	.000	.973	.089	.000	.248	.791	.658	.167	.086	.126	.064	.074	.117	.043	.028	.820	.647	.515	.892	.509
	N	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68
Multiple	Pearson Correlation	.160	.783	-.783	-1.000	1	.073	.005	.151	.420	.006	.205	.397	.146	.035	-.051	-.167	-.208	.189	.230	-.218	-.188	-.245	.269	.024	.059	-.080	-.016	-.082
	Sig. (2-tailed)	.192	.000	.000	.000		.556	.968	.218	.000	.964	.094	.001	.235	.777	.679	.172	.089	.123	.060	.075	.125	.044	.027	.847	.635	.514	.900	.509
	N	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68
Husk	Pearson Correlation	-.163	.498	-.497	-.073	.073	1	.493	.602	.471	.329	.334	.177	.230	.195	-.323	-.296	-.287	.117	.053	-.228	-.094	-.321	.042	.240	-.096	-.083	-.114	-.192
	Sig. (2-tailed)	.184	.000	.000	.553	.556		.000	.000	.000	.006	.005	.149	.059	.110	.007	.014	.018	.341	.665	.062	.444	.008	.735	.049	.438	.502	.354	.116
	N	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68
Leafhusk	Pearson Correlation	-.123	.410	-.412	-.003	.005	.493	1	.616	.306	.159	.316	.071	.137	.268	-.154	-.091	-.161	.069	.078	-.126	.109	-.163	-.058	.031	-.183	-.154	-.020	-.110
	Sig. (2-tailed)	.318	.001	.000	.980	.968	.000		.000	.011	.195	.009	.566	.264	.027	.209	.460	.189	.577	.526	.307	.374	.184	.640	.804	.136	.209	.874	.371
	N	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68
Leaf	Pearson Correlation	-.067	.687	-.688	-.152	.151	.602	.616	1	.693	.608	.719	.105	.415	.360	-.161	-.196	-.272	.230	.277	-.207	.003	-.287	.192	-.020	-.169	-.134	.039	-.151
	Sig. (2-tailed)	.587	.000	.000	.216	.218	.000	.000		.000	.000	.000	.396	.000	.003	.191	.110	.025	.060	.022	.090	.981	.018	.117	.874	.167	.276	.753	.219
	N	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68
Leafstem	Pearson Correlation	-.103	.796	-.795	-.427	.420	.471	.306	.693	1	.582	.679	.426	.426	.417	-.157	-.261	-.320	.333	.199	-.304	-.295	-.305	.249	.127	-.214	-.025	-.065	-.138
	Sig. (2-tailed)	.405	.000	.000	.000	.000	.000	.011	.000		.000	.000	.000	.000	.000	.201	.031	.008	.006	.103	.012	.015	.012	.041	.303	.079	.841	.601	.261
	N	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68
Indet	Pearson Correlation	-.003	.408	-.407	-.004	.006	.329	.159	.608	.582	1	.580	-.041	.477	.459	-.043	-.173	-.204	.318	.278	-.209	-.085	-.181	.267	.007	-.077	-.059	.032	-.177
	Sig. (2-tailed)	.981	.001	.001	.973	.964	.006	.195	.000	.000		.000	.743	.000	.000	.730	.159	.095	.008	.021	.087	.489	.140	.028	.952	.530	.632	.795	.148
	N	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68
Degraded	Pearson Correlation	.186	.584	-.585	-.208	.205	.334	.316	.719	.679	.580	1	.222	.452	.342	-.073	-.215	-.276	.305	.298	-.279	-.103	-.277	.238	.022	-.098	-.015	.067	-.160
	Sig. (2-tailed)	.128	.000	.000	.089	.094	.005	.009	.000	.000	.000		.068	.000	.004	.554	.078	.023	.011	.013	.021	.404	.022	.051	.860	.428	.904	.587	.193
	N	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68
Burnt	Pearson Correlation	-.080	.395	-.394	-.414	.397	.177	.071	.105	.426	-.041	.222	1	-.055	-.078	-.169	-.237	-.262	.089	-.019	-.198	-.235	-.229	.090	.272	-.086	-.142	-.020	-.129
	Sig. (2-tailed)	.517	.001	.001	.000	.001	.149	.566	.396	.000	.743	.068		.653	.529	.168	.051	.031	.473	.878	.105	.054	.060	.466	.025	.484	.249	.869	.296
	N	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68
Badlysilicified	Pearson Correlation	-.017	.362	-.360	-.142	.146	.230	.137	.415	.426	.477	.452	-.055	1	.256	-.053	-.151	-.229	.117	.106	-.206	-.006	-.175	.124	.150	-.071	-.020	.062	-.139
	Sig. (2-tailed)	.894	.002	.003	.248	.235	.059	.264	.000	.000	.000	.000	.653		.035	.666	.218	.061	.340	.390	.092	.964	.154	.315	.222	.565	.873	.615	.258
	N	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68
Diatom	Pearson Correlation	-.132	.292	-.294	-.033	.035	.195	.268	.360	.417	.459	.342	-.078	.256	1	-.003	.040	-.141	.208	-.026	-.083	-.030	.021	-.042	-.026	-.313	-.053	-.131	.096
	Sig. (2-tailed)	.283	.016	.015	.791	.777	.110	.027	.003	.000	.000	.004	.529	.035		.982	.745	.252	.089	.835	.499	.807	.862	.732	.836	.009	.670	.288	.437
	N	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68
Mg	Pearson Correlation	-.114	-.178	.177	.055	-.051	-.323	-.154	-.161	-.157	-.043	-.073	-.169	-.053	-.003	1	.730	.668	-.241	.011	.565	.449	.703	-.047	-.763	.204	-.548	.531	.011
	Sig. (2-tailed)	.356	.147	.149	.658	.679	.007	.209	.191	.201	.730	.554	.168	.666	.982		.000	.000	.048	.928	.000	.000	.000	.701	.000	.095	.000	.000	.929
	N	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68
Si	Pearson Correlation	-.106	-.260	.260	.170	-.167	-.296	-.091	-.196	-.261	-.173	-.215	-.237	-.151	.040	.730	1	.836	-.696	-.190	.897	.474	.960	-.612	-.818	.047	-.446	.472	.272
	Sig. (2-tailed)	.391	.033	.032	.167	.172	.014	.460	.110	.031	.159	.078	.051	.218	.745	.000		.000	.000	.121	.000	.000	.000	.000	.000	.702	.000	.000	.025
	N	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68
K	Pearson Correlation	-.120	-.341	.344	.210	-.208	-.287	-.161	-.272	-.320	-.204	-.276	-.262	-.229	-.141	.668	.836	1	-.642	-.353	.789	.376	.798	-.507	-.773	.106	-.431	.309	.152
	Sig. (2-tailed)	.331	.004	.004	.086	.089	.018	.189	.025	.008	.095	.023	.031	.061	.252	.000	.000		.000	.003	.000	.002	.000	.000	.000	.391	.000	.010	.215
	N	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68
Ca	Pearson Correlation	.096	.299	-.303	-.187	.189	.117	.069	.230	.333	.318	.305	.089	.117	.208	-.241	-.696	-.642	1	.387	-.860	-.263	-.730	.831	.353	-.190	.197	-.283	-.316
	Sig. (2-tailed)	.435	.013	.012	.126	.123	.341	.577	.060	.006	.008	.011	.473	.340	.089	.048	.000	.000		.001	.000	.030	.000	.000	.003	.121	.108	.019	.009
	N	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68
P	Pearson Correlation	.288	.290	-.294	-.226	.230	.053	.078	.277	.199	.278	.298	-.019	.106	-.026	.011	-.190	-.353	.387	1	-.233	.023	-.247	.462	-.005	.107	.101	.425	-.253
	Sig. (2-tailed)	.017	.016	.015	.064	.060	.665	.526	.022	.103	.021	.013	.878	.390	.835	.928	.121	.003	.001		.056	.854	.042	.000	.970	.383	.414	.000	.037
	N	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68
Fe	Pearson Correlation	-.087	-.317	.319	.218	-.218	-.228	-.126	-.207	-.304	-.209	-.279	-.198	-.206	-.083	.565	.897	.789	-.860	-.233	1	.411	.921	-.683	-.684	.186	-.360	.515	.298
	Sig. (2-tailed)	.478	.009	.008	.074	.075	.062	.307	.090	.012	.087	.021	.105	.092	.499	.000	.000	.000	.000	.056		.000	.000	.000	.000	.128	.003	.000	.014
	N	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68
Mn	Pearson Correlation	.104	-.199	.198	.192	-.188	-.094	.109	.003	-.295	-.085	-.103	-.235	-.006	-.030	.449	.474	.376	-.263	.023	.411	1	.432	-.188	-.517	.213	-.389	.491	-.127
	Sig. (2-tailed)	.400	.104	.106	.117	.125	.444	.374	.981	.015	.489	.404	.054	.964	.807	.000	.000	.002	.030	.854	.000		.000	.125	.000	.082	.001	.000	.303
	N	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68
Al	Pearson Correlation	-.087	-.359	.360	.246	-.245	-.321	-.163	-.287	-.305	-.181	-.277	-.229	-.175	.021	.703	.960	.798	-.730	-.247	.921	.432	1	-.660	-.701	.095	-.355	.477	.302
	Sig. (2-tailed)	.481	.003	.003	.043	.044	.008	.184	.018	.012	.140	.022	.060	.154	.862	.000	.000	.000	.000	.042	.000	.000		.000	.000	.441	.003	.000	.012
	N	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68
Sr	Pearson Correlation	.058	.277	-.279	-.266	.269	.042	-.058	.192	.249	.267	.238	.090	.124	-.042	-.047	-.612	-.507	.831	.462	-.683	-.188	-.660	1	.213	.002	.030	-.039	-.364
	Sig. (2-tailed)	.641	.022	.021	.028	.027	.735	.640	.117	.041	.028	.051	.466	.315	.732	.701	.000	.000	.000	.000	.000	.125	.000		.081	.985	.811	.751	.002
	N	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68
S	Pearson Correlation	.065	.067	-.067	-.028	.024	.240	.031	-.020	.127	.007	.022	.272	.150	-.026	-.763	-.818	-.773	.353	-.005	-.684	-.517	-.701	.213	1	-.100	.568	-.494	-.094
	Sig. (2-tailed)	.600	.585	.588	.820	.847	.049	.804	.874	.303	.952	.860	.025	.222	.836	.000	.000	.000	.003	.970	.000	.000	.000	.081		.417	.000	.000	.447
	N	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68
Cl	Pearson Correlation	.115	-.116	.116	-.057	.059	-.096	-.183	-.169	-.214	-.077	-.098	-.086	-.071	-.313	.204	.047	.106	-.190	.107	.186	.213	.095	.002	-.100	1	-.015	.312	-.073
	Sig. (2-tailed)	.352	.346	.348	.647	.635	.438	.136	.167	.079	.530	.428	.484	.565	.009	.095	.702	.391	.121	.383	.128	.082	.441	.985	.417		.904	.009	.556
	N	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68
Cr	Pearson Correlation	.113	-.130	.129	.080	-.080	-.083	-.154	-.134	-.025	-.059	-.015	-.142	-.020	-.053	-.548	-.446	-.431	.197	.101	-.360	-.389	-.355	.030	.568	-.015	1	-.366	.147
	Sig. (2-tailed)	.357	.292	.294	.515	.514	.502	.209	.276	.841	.632	.904	.249	.873	.670	.000	.000	.000	.108	.414	.003	.001	.003	.811	.000	.904		.002	.233
	N	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68
Zn	Pearson Correlation	.082	-.040	.041	.017	-.016	-.114	-.020	.039	-.065	.032	.067	-.020	.062	-.131	.531	.472	.309	-.283	.425	.515	.491	.477	-.039	-.494	.312	-.366	1	-.339
	Sig. (2-tailed)	.506	.743	.742	.892	.900	.354	.874	.753	.601	.795	.587	.869	.615	.288	.000	.000	.010	.019	.000	.000	.000	.000	.751	.000	.009	.002		.005
	N	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68
Rb	Pearson Correlation	-.043	-.166	.165	.081	-.082	-.192	-.110	-.151	-.138	-.177	-.160	-.129	-.139	.096	.011	.272	.152	-.316	-.253	.298	-.127	.302	-.364	-.094	-.073	.147	-.339	1
	Sig. (2-tailed)	.728	.175	.180	.509	.509	.116	.371	.219	.261	.148	.193	.296	.258	.437	.929	.025	.215	.009	.037	.014	.303	.012	.002	.447	.556	.233	.005	
	N	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Appendix 7: Results of application of Bayesian model to the samples from WJ13

Sample	*Context*	*Prior*	*Geochem weight*	*Phyto weight*	*Both agree*	*Geochem not agree*	*Phyto not agree*	*Neither agree*	*Alternative category*
WJ13 5a 3	Deposit	0.5	0.38	0.21		0.47875			Other
WJ13 7a 5	Deposit	0.5	0.38	0.21				0.42625	Background/hearth
WJ13 8 8	Deposit	0.5	0.38	0.21		0.47875			Deposit2/other
WJ13 16a 13	Deposit	0.5	0.38	0.21	0.57375				
WJ13 20b	Deposit	0.5	0.38	0.21				0.42625	Other/bedrock feature
WJ13 25 19	Deposit	0.5	0.38	0.21				0.42625	Deposit2/activity area/hearth
WJ13 50a 30	Deposit	0.5	0.38	0.21	0.57375				
WJ13 53a 3	Deposit	0.5	0.38	0.21	0.57375				
WJ13 56b 40	Deposit	0.5	0.38	0.21	0.57375				
WJ13 62a 40	Deposit	0.5	0.38	0.21	0.57375				
WJ13 70a 38	Deposit	0.5	0.38	0.21	0.57375				
WJ13 71b 80	Deposit	0.5	0.38	0.21	0.57375				
WJ13 83a 46	Deposit	0.5	0.38	0.21			0.52125		Deposit2/hearth
WJ13 10a 9	Other	0.5	0.38	0.21		0.47875			Other2/deposit2/hearth
WJ13 22 17	Other	0.5	0.38	0.21			0.52125		Deposit
WJ13 47 29	Other	0.5	0.38	0.21		0.47875			Other2/deposit2/hearth
WJ13 52a 31	Other	0.5	0.38	0.21	0.57375				
WJ13 57a 33	Other	0.5	0.38	0.21			0.52125		Activity area
WJ13 15a 12	Activity area	0.5	0.38	0.21	0.57375				Deposit
WJ13 45a 46	Activity area	0.5	0.38	0.21	0.57375				Deposit
WJ13 59a 31	Activity area	0.5	0.38	0.21	0.57375				Deposit
WJ13 66b 39	Activity area	0.5	0.38	0.21	0.57375				Deposit
WJ13 12 12	Hearth	0.5	0.38	0.21	0.57375				
WJ13 18 13	Hearth	0.5	0.38	0.21	0.57375				
WJ13 22 14	Hearth	0.5	0.38	0.21			0.52125		Deposit
WJ13 24 20	Posthole	0.5	0.38	0.21			0.52125		Deposit/bedrock 2
WJ13 85 54	Posthole	0.5	0.38	0.21	0.57375				
WJ13 90a 56	Posthole	0.5	0.38	0.21	0.57375				
WJ13 92a 57	Posthole	0.5	0.38	0.21			0.52125		Deposit/bedrock 2
WJ13 96 59	Posthole	0.5	0.38	0.21	0.57375				
WJ13 104 65	Posthole	0.5	0.38	0.21	0.57375				

Appendix 8: phytolith counts

Wadi el-Jilat sites

Slide	Bilobate	Par.bulliform	Ov.crenate	Globular.smoo	Hair.base	Hair.cell	Keystone	El.dend	El.tenis	El.sinuate	El.psi	Trapez.
WJ7C 6 21	1	3	19	0	0	2	0	7	1	0	16	11
WJ7B 29 11	0	0	8	0	0	1	1	0	0	1	1	4
WJ7B 9 6	3	4	9	1	0	0	2	8	2	2	14	4
WJ7A 21 9	1	3	19	0	0	1	3	4	1	4	14	6
WJ7A 23 11	1	1	2	0	0	0	0	1	0	1	8	2
WJ7A 23 16	4	1	2	2	0	2	0	1	0	1	11	2
WJ7A 25 13	0	1	1	11	0	0	0	7	0	1	6	1
WJ7A 24 12	0	0	1	27	0	0	0	2	1	0	5	1
WJ7B 38 19	2	1	4	6	0	0	0	0	1	0	7	5
WJ7C 11 27	0	1	3	1	0	1	0	3	1	0	8	2
WJ7C14 29	0	1	0	0	0	4	3	1	2	1	9	0
WJ7C 13 28	0	1	0	1	0	0	0	1	0	0	2	0
WJ7 backgr	0	1	4	2	0	0	0	0	0	0	2	1
WJ7Ab 17a 7	2	1	5	0	0	1	3	7	0	2	9	5
WJ7C 6a 20	3	0	0	2	1	0	0	3	0	3	4	2
WJ7A 28a 17	2	2	2	2	0	2	0	4	0	3	9	2
WJ7C 16 30	0	0	1	0	0	0	0	1	0	0	0	1
WJ13 5a 3	0	2	2	0	0	3	2	1	0	1	6	3
WJ13 7a 5	0	0	0	0	0	0	0	0	1	0	1	0
WJ13A 8 8	1	3	4	0	0	0	0	1	0	1	7	0
WJ13 10a 9	10	15	5	3	0	6	1	4	2	1	18	5
WJ13 12 12	4	5	0	1	0	4	1	1	2	1	5	2
WJ13A 15a 12	2	0	4	0	0	2	1	0	0	1	4	2
WJ13A 16a 13	4	4	1	0	0	1	0	7	1	0	4	2
WJ13 18 13	0	4	1	0	0	1	2	1	0	2	10	8
WJ13A 20a 15	1	3	0	0	0	1	0	3	1	1	0	2
WJ13 20b	2	5	0	0	0	2	0	3	1	1	8	0
WJ13 22 14	0	0	0	0	0	0	0	0	0	0	0	0
WJ13A 22 17	1	5	4	1	0	3	1	3	0	1	7	4
WJ13A 24 20	7	4	3	26	0	4	0	8	1	1	11	3
WJ13 25 19	0	0	0	0	0	0	0	0	0	0	0	0
WJ13B 45a 46	2	5	0	1	0	2	4	5	0	1	7	0
WJ13 47 29	0	4	5	0	0	1	1	1	1	3	9	2
WJ13C 50a 30	1	10	7	12	1	1	1	4	0	2	6	1
WJ13 52a 31	2	0	1	0	0	0	0	0	0	0	6	0
WJ13C 53a 32	1	6	2	0	0	3	3	2	1	2	11	2

Slide	Bilobate	Par.bulliform	Ov.crenate	Globular.smoo	Hair.base	Hair.cell	Keystone	El.dend	El.tenis	El.sinuate	El.psi	Trapez.
WJ13C 56b 40	0	2	1	0	0	4	3	4	5	1	18	1
WJ13 57a 33	0	0	0	0	0	1	0	0	1	1	3	0
WJ13 59a 31	1	2	0	0	0	1	0	0	0	0	1	1
WJ13B 62a 40	7	21	5	20	0	1	1	7	0	1	19	2
WJ13 66b 39	1	0	0	0	0	0	0	1	0	0	4	1
WJ13C 70a 38	0	2	4	0	0	0	1	0	0	0	2	0
WJ13B 71b 80	1	0	2	0	0	0	0	1	0	2	4	0
WJ13 83a 46	0	2	1	0	0	2	0	0	0	0	5	2
WJ13 85 54	0	1	0	0	0	0	0	0	0	0	0	0
WJ13 90a 56	0	0	0	0	0	0	0	0	0	0	0	0
WJ13 92a 57	0	3	0	0	0	2	0	0	0	0	3	0
WJ13 96 59	0	2	0	0	0	0	0	0	0	0	3	0
WJ13 104 65	0	0	0	4	0	0	0	0	0	0	0	0
WJ13 backgr	0	0	5	4	0	1	2	1	0	0	0	0
WJ26C 27 13	0	0	0	0	0	0	0	0	0	0	0	0
WJ26E 12 6	0	0	0	0	0	0	0	0	0	0	1	0
WJ26E 12 7	0	0	0	3	0	0	0	0	0	0	2	0
WJ26E 15 12	0	1	4	1	0	2	0	0	0	0	0	0
WJ26E 18 16	0	0	0	0	0	0	0	0	0	0	0	0
WJ26E 12 36	0	2	0	0	0	0	0	0	0	0	0	0
WJ26A 46 29	0	0	0	0	0	0	0	0	0	0	0	0
WJ26E 12 5	0	0	1	1	0	1	0	2	0	0	2	0
WJ26E 18 19	0	0	0	1	0	1	0	0	0	0	0	0
WJ26E 16 13	0	1	0	0	1	0	1	0	0	0	2	0
WJ26C 10 4	0	0	2	0	0	0	0	4	0	0	2	2
WJ26A 10 20	0	1	2	0	1	1	1	2	2	0	2	1
WJ26A 14 13	0	1	0	0	0	1	0	0	1	0	0	1
WJ26E 8 8	0	0	0	0	0	0	0	0	0	0	0	0
WJ26C 9 6	1	3	1	4	0	1	0	2	0	6	8	1
WJ26C 21 10	0	0	0	0	0	0	0	0	0	0	1	0
WJ26Ed 30a 25	0	1	0	0	0	1	0	2	0	1	2	0
WJ26A 9 19	1	2	3	2	0	0	0	0	0	0	2	3
WJ26E 26 24	0	0	0	0	0	0	0	0	0	1	0	0

Slide	Papillae	Tabular.irreg	Polyhedral.plain	Polyhedral.gran	Rondel	Saddle	Scalloped	Rectan.tabular	Tracheid	Total
WJ7C 6 21	2	229	0	0	8	5	0	3	0	319
WJ7B 29 11	1	243	0	0	13	1	0	2	0	282
WJ7B 9 6	1	221	0	0	9	1	0	1	0	289
WJ7A 21 9	0	215	0	0	11	0	2	0	0	305
WJ7A 23 11	0	235	0	1	2	0	0	0	0	260
WJ7A 23 16	0	230	0	0	2	0	0	4	0	262
WJ7A 25 13	0	225	0	0	2	0	0	1	0	260
WJ7A 24 12	0	221	1	0	2	1	0	0	0	263
WJ7B 38 19	0	229	0	0	2	1	0	3	0	261
WJ7C 11 27	0	240	0	0	0	1	0	2	0	271
WJ7C14 29	0	250	0	0	1	0	0	5	0	288
WJ7C 13 28	0	249	0	0	2	0	0	1	0	257
WJ7 backgr	0	240	1	0	0	2	0	1	0	256
WJ7Ab 17a 7	0	227	1	0	9	0	0	2	0	274
WJ7C 6a 20	0	230	0	0	4	0	0	0	0	252
WJ7A 28a 17	1	211	0	0	10	0	0	1	0	268
WJ7C 16 30	0	252	0	0	1	0	0	0	0	256
WJ13 5a 3	0	202	0	0	3	1	0	20	0	258
WJ13 7a 5	0	250	0	0	0	0	0	3	0	255
WJ13A 8 8	0	226	4	1	2	0	0	6	0	263
WJ13 10a 9	0	188	0	0	12	0	0	0	0	275
WJ13 12 12	0	225	0	0	0	0	0	4	0	261
WJ13A 15a 12	0	239	0	0	4	0	0	5	1	272
WJ13A 16a 13	0	228	0	0	6	0	0	2	0	262
WJ13 18 13	0	237	0	0	1	2	0	3	0	282
WJ13A 20a 15	0	255	2	0	0	0	0	6	0	281
WJ13 20b	0	231	0	0	1	0	0	3	0	260
WJ13 22 14	0	1	0	0	0	0	0	0	0	2
WJ13A 22 17	0	229	0	0	2	0	0	2	0	266
WJ13A 24 20	2	167	1	0	16	3	0	3	1	295
WJ13 25 19	0	2	0	0	0	0	0	0	0	2
WJ13B 45a 46	1	205	1	3	1	0	0	7	0	245
WJ13 47 29	0	225	0	0	3	0	0	2	0	260
WJ13C 50a 30	0	165	1	0	3	1	0	10	0	281
WJ13 52a 31	0	228	0	0	2	0	0	1	0	265
WJ13C 53a 32	0	173	0	2	7	0	0	14	0	269
WJ13C 56b 40	0	138	0	0	6	0	0	4	0	296
WJ13 57a 33	0	178	0	0	3	0	0	3	0	195
WJ13 59a 31	0	240	0	0	1	0	0	3	0	253

Slide	Papillae	Tabular.irreg	Polyhedral.plain	Polyhedral.gran	Rondel	Saddle	Scalloped	Rectan.tabular	Tracheid	Total
WJ13B 62a 40	0	174	0	0	10	6	0	7	0	289
WJ13 66b 39	0	256	0	1	1	0	0	3	0	268
WJ13C 70a 38	0	244	0	0	2	0	0	1	0	256
WJ13B 71b 80	0	241	0	0	7	0	0	1	0	260
WJ13 83a 46	0	236	0	0	0	0	1	1	0	251
WJ13 85 54	0	97	0	0	0	0	0	1	0	99
WJ13 90a 56	0	5	0	0	0	0	0	0	0	5
WJ13 92a 57	0	239	0	0	3	0	0	1	0	255
WJ13 96 59	0	14	0	0	0	0	0	4	0	23
WJ13 104 65	0	300	2	0	0	0	0	2	0	340
WJ13 backgr	0	242	0	0	0	1	0	1	0	257
WJ26C 27 13	0	250	0	0	0	0	0	3	0	253
WJ26E 12 6	0	250	0	0	0	0	0	0	0	251
WJ26E 12 7	0	248	0	0	1	0	0	0	0	254
WJ26E 15 12	0	241	0	0	2	0	0	3	0	254
WJ26E 18 16	0	240	0	0	0	0	0	10	0	250
WJ26E 12 36	0	250	0	0	0	0	0	0	0	252
WJ26A 46 29	0	249	0	0	0	0	0	3	0	252
WJ26E 12 5	0	240	0	0	3	0	0	0	0	250
WJ26E 18 19	0	245	1	0	0	0	0	1	0	249
WJ26E 16 13	0	255	1	0	0	1	0	4	0	270
WJ26C 10 4	0	255	1	0	2	0	0	0	0	270
WJ26A 10 20	1	234	0	0	2	0	0	4	0	258
WJ26A 14 13	1	242	0	0	0	0	1	5	0	253
WJ26E 8 8	0	251	0	0	0	0	0	1	0	252
WJ26C 9 6	0	217	0	0	9	0	0	0	0	256
WJ26C 21 10	0	260	0	0	0	0	0	0	0	261
WJ26Ed 30a 25	0	242	0	0	1	0	0	10	0	266
WJ26A 9 19	0	243	0	0	2	1	0	0	0	259
WJ26E 26 24	0	250	0	0	0	0	0	0	0	251

Slide	Barley husk	Multi-bull	Multi-el.tenis	Leaf-stem	Ind.-dendritic	Wheat-husk	Ind.-husk	Multi-hairs	Multi-tracheid
WJ13C 56b 40		2		52	49				
WJ13C 61a 35				6					
WJ13 52a 31				8					
WJ13 47 29									
WJ13 83a 46									

Slide	Barley husk	Multi- bull	Multi- el.tenis	Leaf- stem	Ind.- dendritic	Wheat- husk	Ind.- husk	Multi- hairs	Multi- tracheid
WJ13 59a 31									
WJ13 5a 3		2		9					
WJ13C 53a 32		4		32					
Wj13C 50a 30				17	20				
WJ13B 62a 40	6								
WJ13 20b				3					
WJ13 10a 9			3	2					
WJ13 66b 39									
WJ13 85 54									
WJ13 92a 57		4							
WJ13 12 12									
WJ13 25 19									
WJ13 90a 56									
WJ13 18 13		2		6					
WJ13 22 14									
WJ13 104 65				28					
WJ13A 8 8						6			
WJ13A 15a 12									
WJ13A 24 20				16					
WJ13A 22 17									
WJ13A 20a 15					5				
WJ13 96 59									
WJ13B 45a 46									
WJ13A 16a 13					2				
WJ13C 70a 38									
WJ13B 71b 80									
WJ13 background									
WJ13 7a 5									
WJ13 57a 33		2			3				
WJ7C 6 21				2			9		
WJ7B 29 11				5					
WJ7B 9 6				3					3
WJ7A 21 9				19				2	
WJ7A 23 11				6					
WJ7A 23 16									
WJ7A 25 13				4					
WJ7A 24 12									

Slide	Barley husk	Multi-bull	Multi-el.tenis	Leaf-stem	Ind.-dendritic	Wheat-husk	Ind.-husk	Multi-hairs	Multi-tracheid
WJ7B 38 19									
WJ7C 11 27				8					
WJ7C14 29				11					
WJ7C 13 28									
Background WJ7				2					
WJ7Ab 17a 7									
WJ7C 6a 20									
WJ7A 28a 17				15					
WJ7C 16 30									
WJ26C 27 13									
WJ26E 12 6									
WJ26E 12 7									
WJ26E 15 12									
WJ26E 18 16									
WJ26E 12 36									
WJ26A 46 29									
WJ26E 12 5									
WJ26E 18 19									
WJ26E 16 13				4					
WJ26C 10 4				2					
WJ26A 10 20				4					
WJ26A 14 13									
WJ26E 8 8									
WJ26C 9 6		3							
WJ26C 21 10									
WJ26Ed 30a 25				6					
WJ26A 9 19									
WJ26E 26 24									

Slide	Silica.aggr	Monocots	Dicots	Single	Multiple	Husk	Leaf/husk	Leaf	Leaf/stem
WJ7C 6 21	115	87	232	308	11	18	1	17	49
WJ7B 29 11	109	37	245	277	5	1	0	16	18
WJ7B 9 6	128	63	226	283	6	9	3	17	32
WJ7A 21 9	121	88	217	284	21	4	1	17	59
WJ7A 23 11	102	25	236	254	6	1	1	3	18
WJ7A 23 16	162	26	236	262	0	1	4	3	15

Slide	Silica.aggr	Monocots	Dicots	Single	Multiple	Husk	Leaf/husk	Leaf	Leaf/stem
WJ7A 25 13	139	23	237	256	4	7	0	3	12
WJ7A 24 12	80	14	248	263	0	2	0	4	8
WJ7B 38 19	181	23	238	261	0	0	2	4	17
WJ7C 11 27	121	28	243	263	8	3	0	2	22
WJ7C14 29	114	33	255	277	11	1	0	5	22
WJ7C 13 28	148	6	251	257	0	1	0	3	2
Background WJ7	254	12	243	254	2	0	0	3	9
WJ7Ab 17a 7	116	44	229	274	0	7	2	13	19
WJ7C 6a 20	154	20	232	252	0	3	3	4	6
WJ7A 28a 17	99	54	214	253	15	4	2	14	28
WJ7C 16 30	159	4	252	256	0	1	0	1	2
WJ13 5a 3	129	36	222	246	12	1	0	10	20
WJ13 7a 5	93	2	253	255	0	0	0	0	2
WJ13A 8 8	104	30	233	257	6	7	1	6	11
WJ13 10a 9	158	84	191	270	5	4	10	28	35
WJ13 12 12	273	28	230	255	6	1	4	6	9
WJ13A 15a 12	110	27	245	265	7	0	2	5	10
WJ13A 16a 13	368	32	230	260	2	7	4	10	8
WJ13 18 13	231	42	240	272	10	1	0	11	25
WJ13A 20a 15	195	19	261	275	6	3	1	3	3
WJ13 20b	206	26	234	257	3	3	2	6	12
WJ13 22 14	101	1	1	1	1	0	0	0	0
WJ13A 22 17	227	34	232	263	3	3	1	8	15
WJ13A 24 20	68	98	197	262	33	10	7	24	34
WJ13 25 19	258	0	2	2	0	0	0	0	0
WJ13B 45a 46	180	29	216	245	0	6	2	10	7
WJ13 47 29	259	33	227	257	3	1	0	8	17
WJ13C 50a 30	259	94	187	226	55	4	1	15	31
WJ13 52a 31	387	35	229	241	24	0	2	2	15
WJ13C 53a 32	364	80	189	230	39	2	1	21	48
WJ13C 56b 40	358	154	142	188	103	4	0	14	77
WJ13 57a 33	272	14	181	190	5	0	0	5	4
WJ13 59a 31	506	9	243	251	2	0	1	4	2
WJ13B 62a 40	155	88	201	281	8	13	7	38	26
WJ13 66b 39	443	8	260	268	0	1	1	1	5
WJ13C 70a 38	188	11	245	256	0	0	0	5	6

Slide	Silica.aggr	Monocots	Dicots	Single	Multiple	Husk	Leaf/husk	Leaf	Leaf/stem
WJ13B 71b 80	111	18	242	259	1	1	1	7	6
WJ13 83a 46	223	12	238	251	0	0	0	2	8
WJ13 85 54	689	1	98	99	0	0	0	1	0
WJ13 90a 56	278	0	5	5	0	0	0	0	0
WJ13 92a 57	364	11	240	251	4	0	0	6	3
WJ13 96 59	1310	5	18	23	0	0	0	2	3
WJ13 104 65	920	34	306	308	32	0	0	0	28
WJ13 background	49	10	247	257	0	1	0	3	5
WJ26C 27 13	320	0	253	253	0	0	0	0	0
WJ26E 12 6	114	1	250	251	0	0	0	0	1
WJ26E 12 7	161	3	251	254	0	0	0	1	2
WJ26E 15 12	110	9	245	254	0	0	0	3	4
WJ26E 18 16	392	0	250	250	0	0	0	0	0
WJ26E 12 36	126	2	250	252	0	0	0	2	0
WJ26A 46 29	142	0	252	252	0	0	0	0	0
WJ26E 12 5	115	9	241	250	0	2	0	3	3
WJ26E 18 19	173	1	248	249	0	0	0	0	0
WJ26E 16 13	133	10	260	266	4	0	0	3	6
WJ26C 10 4	61	14	256	268	2	4	0	2	8
WJ26A 10 20	120	20	238	254	4	3	0	4	11
WJ26A 14 13	51	5	248	253	0	1	0	1	2
WJ26E 8 8	124	0	252	252	0	0	0	0	0
WJ26C 9 6	95	35	221	253	3	2	0	15	10
WJ26C 21 10	99	1	260	261	0	0	0	0	1
WJ26Ed 30a 25	53	14	252	260	6	2	0	2	8
WJ26A 9 19	85	14	245	259	0	0	0	5	8
WJ26E 26 24	90	1	250	251	0	0	0	0	0

Slide	Indet	Degraded	Burnt	Poor.silicified	Diatom	Weightpercent	Nrpergram	Panicoideae	Pooideae	Chloridoidea.	Arundinoidea.
WJ7C 6 21	36	33	0	5	2	0.035064935	263193	2	8	5	3
WJ7B 29 11	43	26	0	4	4	0.03956044	137305	1	13	1	0
WJ7B 9 6	41	24	0	5	2	0.032209663	114567	4	9	1	4
WJ7A 21 9	54	43	0	9	5	0.031790463	161602	1	11	0	3
WJ7A 23 11	10	7	1	0	0	0.036610983	195259	1	2	0	1
WJ7A 23 16	13	4	2	0	0	0.047943149	223309	4	2	0	1
WJ7A 25 13	9	2	2	1	0	0.026592022	184371	0	2	0	1
WJ7A 24 12	10	3	0	1	0	0.04569543	400597	1	2	1	0
WJ7B 38 19	19	13	1	0	3	0.025594881	100834	2	2	1	1
WJ7C 11 27	18	2	0	11	0	0.022204441	171926	0	0	1	1
WJ7C14 29	10	8	1	0	2	0.011009909	158543	0	1	0	1
WJ7C 13 28	4	5	0	0	0	0.027972028	155434	0	2	0	1
Background WJ7	3	2	0	0	2	0.092609261	301054	0	0	2	1
WJ7Ab 17a 7	17	9	0	0	1	0.023888056	227664	2	9	0	1
WJ7C 6a 20	17	9	2	1	0	0.015689018	71884	3	4	0	0
WJ7A 28a 17	25	12	2	1	2	0.032686925	259558	4	10	0	2
WJ7C 16 30	3	0	0	0	0	0.011994003	87728	0	1	0	0
WJ13 5a 3	21	20	0	9	5	0.004	9936	0	3	1	4
WJ13 7a 5	0	2	0	0	0	0.0345	117271	0	0	0	0
WJ13A 8 8	0	5	0	0	1	0.0045	39478	2	2	0	3
WJ13 10a 9	10	30	1	1	2	0.0049	31693	10	12	0	15
WJ13 12 12	10	21	1	0	2	0.01	61458	4	0	0	5
WJ13A 15a 12	15	0	0	12	0	0.0141	82990	2	4	0	0
WJ13A 16a 13	24	17	6	1	1	0.0158	114139	4	6	0	4
WJ13 18 13	6	30	1	2	1	0.0085	31924	0	1	2	6
WJ13A 20a 15	3	7	4	0	0	0.011	224890	1	0	0	3
WJ13 20b	15	16	0	12	3	0.0173	112153	2	1	0	5
WJ13 22 14	0	0	0	0	0	0.0125	318	0	0	0	0
WJ13A 22 17	17	21	0	9	1	0.0099	35711	1	2	0	5
WJ13A 24 20	9	34	0	10	1	0.0121	109886	8	16	3	4
WJ13 25 19	0	0	0	0	0	0.025	930	0	0	0	0
WJ13B 45a 46	4	16	6	8	0	0.0113	67162	2	1	0	5
WJ13 47 29	4	21	1	0	0	0.0186	26377	0	3	0	4
WJ13C 50a 30	14	31	1	15	0	0.0168	29207	1	3	1	10
WJ13 52a 31	2	11	1	1	3	0.0273	43442	2	2	0	0
WJ13C 53a 32	37	42	0	14	1	0.013	19714	2	7	0	10

Slide	Indet	Degraded	Burnt	Poor.silicified	Diatom	Weightpercent	Nrpergram	Panicoideae	Pooideae	Chloridoidea.	Arundinoidea.
WJ13C 56b 40	7	44	21	0	0	0.018	152210	0	6	0	4
WJ13 57a 33	17	0	0	0	0	0.0254	66000	51	3	0	2
WJ13 59a 31	7	9	0	7	0	0.0199	18378	1	1	0	2
WJ13B 62a 40	17	38	0	3	1	0.0136	53315	7	10	6	21
WJ13 66b 39	4	9	3	0	0	0.0138	89333	1	1	0	0
WJ13C 70a 38	0	2	0	0	0	0.0208	157819	0	2	0	2
WJ13B 71b 80	0	4	0	0	0	0.025	162484	1	7	0	0
WJ13 83a 46	4	0	0	4	0	0.0062	24107	0	0	0	2
WJ13 85 54	1	1	0	0	0	0.0494	52818	0	0	0	1
WJ13 90a 56	0	1	0	0	0	0.0793	7735	0	0	0	0
WJ13 92a 57	7	6	0	0	0	0.0289	184239	0	3	0	3
WJ13 96 59	5	6	0	1	0	0.097	21253	0	0	0	2
WJ13 104 65	2	0	0	0	0	0.0522	189446	0	0	0	0
WJ13 background	0	16	2	2	1	0.0021	15417	0	0	1	0
WJ26C 27 13	1	0	0	0	0	0.0077	6549	0	0	0	0
WJ26E 12 6	1	1	0	0	0	0.0122	98049	0	0	0	0
WJ26E 12 7	4	4	0	0	0	0.0144	55154	0	1	0	0
WJ26E 15 12	5	9	0	0	0	0.0162	73108	0	2	0	1
WJ26E 18 16	0	0	0	0	0	0.0237	18102	0	0	0	0
WJ26E 12 36	4	3	0	0	0	0.0118	40970	0	0	0	2
WJ26A 46 29	0	0	0	0	0	0.012	19338	0	0	0	0
WJ26E 12 5	14	8	1	1	0	0.0132	47100	0	3	0	0
WJ26E 18 19	4	0	0	0	0	0.0179	71364	0	0	0	0
WJ26E 16 13	2	0	0	0	0	0.0127	57116	0	0	1	1
WJ26C 10 4	6	1	2	1	0	0.0288	388412	0	2	0	0
WJ26A 10 20	22	2	1	0	0	0.0062	29075	0	2	0	1
WJ26A 14 13	10	2	1	0	0	0.0032	16182	0	0	0	1
WJ26E 8 8	2	1	0	0	0	0.0117	87325	0	0	0	0
WJ26C 9 6	22	12	0	0	0	0.031	453486	1	9	0	6
WJ26C 21 10	7	0	0	0	0	0.0096	66836	0	0	0	0
WJ26Ed 30a 25	3	1	2	10	0	0.0033	15601	0	1	0	1
WJ26A 9 19	9	3	1	1	0	0.0037	24725	1	2	1	2
WJ26E 26 24	2	2	0	0	0	0.01	64742	0	0	0	0

Wadi Faynan and Wadi Dana sites

Slide	Bilobate.s.c.	Par.bulliform	Ov.crenate	Cross	Glob.ech	Glob.smoo	Hair.base	Hair.cell	Cu.bulliform	El.dend	El.ps.tenis	El.sinuate
JT14 101	7	5	0	0	0	0	0	1	4	100	3	3
JT14 102	0	10	1	0	1	0	0	3	1	1	0	1
JT14 103	1	1	0	0	0	0	1	4	3	3	0	0
JT14 104	2	5	1	1	1	0	1	1	0	17	0	0
JT14 105	0	3	0	0	0	0	0	0	1	0	0	1
JT14 106	0	0	0	0	0	0	0	0	0	0	0	0
JT14 107	0	3	0	0	0	0	0	1	0	0	0	0
JT14 108	0	1	0	0	0	0	0	0	0	4	0	0
JT14 109	2	5	1	0	0	0	0	1	0	10	0	2
JT14 110	3	6	0	5	0	0	0	1	0	14	2	0
JT14 111	9	7	2	0	0	0	0	1	1	0	0	4
JT14 112	1	0	1	0	1	0	0	0	0	0	0	0
JT14 113	1	1	0	0	0	6	0	0	0	20	0	2
JT14 114	2	7	3	0	0	0	0	2	2	2	0	3
JT14 115	0	0	0	0	0	0	0	0	0	0	0	0
JT14 116	1	10	2	0	2	0	0	2	2	2	0	0
JT14 201	1	4	1	0	3	0	0	0	1	1	0	1
JT14 202	0	13	0	0	0	0	1	1	2	7	0	2
JT14 203	0	12	0	0	0	0	0	0	1	28	0	0
JT14 204	0	7	0	0	0	1	0	1	1	45	0	2
JT14 205	0	4	0	0	0	0	0	0	1	29	0	0
JT14 206	0	4	4	0	0	2	3	0	5	2	0	0
JT14 207	2	5	1	0	1	4	0	2	4	31	0	3
JT14 208	0	7	1	1	0	0	0	1	2	20	0	2
JT14 209	0	15	5	0	0	0	0	1	5	4	0	1
JT14 210	2	1	0	0	0	0	0	1	1	50	0	1
JT14 211	1	0	0	1	1	1	0	1	1	32	0	3
JT14 212	1	9	1	0	0	0	0	0	0	0	0	0

Slide	Bilobate.s.c.	Par.bulliform	Ov.crenate	Cross	Glob.ech	Glob.smoo	Hair.base	Hair.cell	Cu.bulliform	El.dend	El.ps.tenis	El.sinuate
JT14 213	1	3	0	0	0	0	0	0	0	0	0	0
JT14 214	3	3	0	0	0	0	0	0	0	0	0	0
JT14 215	0	7	0	0	0	0	0	0	0	0	0	0
WF916-1042	0	0	0	0	0	0	0	0	0	0	0	0
WF916-1009	2	1	0	0	0	0	0	0	2	0	4	0
WF916-1010	0	0	0	0	0	0	0	1	0	0	0	0
WF916-1012	0	3	0	0	0	0	0	2	0	1	0	0
WF916-1014	0	8	0	0	1	0	0	6	2	1	0	0
WF916-1015	0	22	1	1	0	0	1	5	6	0	0	0
WF916-1016	0	0	0	0	0	0	0	0	0	0	0	0
WF916-1017	1	0	0	0	0	0	0	0	0	0	0	0
WF916-1018	2	0	0	0	0	0	0	1	0	3	0	0
WF953-1019	28	3	3	0	0	0	1	16	0	6	0	1
WF953-1020	23	0	1	0	0	0	1	3	0	55	0	4
WF953-1027	0	1	0	0	0	0	0	1	1	0	0	0
WF953-1029	0	4	1	0	0	0	0	3	3	2	0	1
WF953-1030	2	8	0	0	0	0	0	2	1	16	0	1
WF953-1031	0	4	0	0	0	0	0	1	0	0	0	0
WF953-1032	1	8	0	0	0	0	0	0	3	3	0	0
WF953-1033	0	3	0	0	0	0	0	3	1	1	0	0
WF940 827	0	0	0	0	0	2	0	0	0	0	0	0
WF940 821	0	0	0	1	0	0	0	1	1	0	0	0
WF940 815	0	0	0	0	0	1	0	0	0	0	0	0
WF940 814	0	0	0	0	0	13	0	0	0	0	0	0
WF940 813	0	0	0	0	0	0	0	0	0	0	0	0
WF940 811	0	1	0	0	0	0	0	0	0	0	0	0
WF940 801	2	6	2	0	1	0	0	1	1	93	0	0
WF940 820	3	1	0	1	3	1	0	1	4	36	1	2
WF982 876	0	23	1	0	0	0	1	3	2	2	0	4

Slide	Bilobate.s.c.	Par.bulliform	Ov.crenate	Cross	Glob.ech	Glob.smoo	Hair.base	Hair.cell	Cu.bulliform	El.dend	El.ps.tenis	El.sinuate
WF982 875	0	4	2	1	0	12	0	1	0	8	2	0
WF982 901	1	25	7	0	1	0	2	2	6	4	0	2
WF982 900	1	2	2	1	0	7	0	0	2	57	0	3
WF982 912	1	4	1	0	0	3	0	0	0	82	0	4
WF982 971	1	15	1	0	0	0	0	0	3	2	0	3
WF982 873	0	0	1	1	0	6	0	0	0	0	0	0
WF982 902	0	27	2	1	0	0	0	8	6	3	0	2
WF982 903	0	15	0	0	0	19	0	1	5	0	0	1
WD1	6	0	0	0	1	0	0	0	0	18	1	0
WD2	5	0	3	2	0	0	0	2	0	22	1	4
WD3	1	2	1	0	0	0	0	3	1	11	1	1
WD4	0	2	2	0	0	0	0	2	1	29	0	0
WD5	3	0	1	0	0	0	0	1	0	65	0	0
WD6	1	0	0	0	0	1	1	1	1	79	2	1
WD7	1	0	4	0	1	0	0	1	0	150	3	22
WD8	0	0	0	0	0	0	0	0	1	25	1	0
WD9	7	0	0	0	0	0	0	2	0	26	2	2
WD10	2	2	0	0	0	0	0	2	2	15	0	0

Slide	El.psilate	Trapezi.ps	Papillae	Tabular.irreg	Polyh.gran	Polyh.plain	Rondel	Saddle	Scalloped	Rectangle.tab	Tracheid	Total
JT14 101	6	3	1	35	0	0	50	11	0	0	0	340
JT14 102	6	1	0	220	0	0	1	0	0	3	0	255
JT14 103	4	0	0	235	0	0	0	1	0	0	0	257
JT14 104	8	3	0	225	0	0	11	1	0	2	0	370
JT14 105	4	0	0	245	0	1	2	0	0	0	0	258
JT14 106	0	0	0	261	0	0	0	0	0	0	0	261
JT14 107	1	0	0	276	0	0	0	0	0	0	0	281
JT14 108	0	0	0	255	0	0	1	0	0	4	0	281
JT14 109	11	0	0	235	0	1	5	4	0	6	0	309

Slide	El.psilate	Trapezi.ps	Papillae	Tabular.irreg	Polyh.gran	Polyh.plain	Rondel	Saddle	Scalloped	Rectangle.tab	Tracheid	Total
JT14 110	11	0	0	88	0	0	28	0	0	1	0	486
JT14 111	7	1	0	16	0	0	10	0	0	0	0	446
JT14 112	0	1	0	247	0	0	0	0	0	0	0	261
JT14 113	5	1	1	170	0	0	10	4	0	5	0	396
JT14 114	6	5	0	215	0	0	8	1	0	2	0	272
JT14 115	0	0	0	228	0	0	0	0	0	60	0	288
JT14 116	14	2	0	237	0	0	3	1	0	2	0	286
JT14 201	2	1	0	240	0	0	2	1	0	1	0	268
JT14 202	8	0	0	242	0	0	5	2	2	0	0	268
JT14 203	7	0	0	166	0	0	14	5	0	5	0	276
JT14 204	6	2	0	45	0	0	75	6	0	1	0	270
JT14 205	12	4	0	171	0	0	32	0	0	0	0	276
JT14 206	10	1	1	209	0	0	12	1	0	1	0	268
JT14 207	5	1	2	66	0	0	92	9	0	3	0	228
JT14 208	0	0	2	17	0	0	8	13	0	0	0	270
JT14 209	5	1	0	225	0	0	5	1	0	0	0	272
JT14 210	3	0	0	87	0	0	45	2	0	0	0	316
JT14 211	8	0	0	127	0	0	41	4	0	0	0	275
JT14 212	3	0	0	209	0	0	0	0	0	32	0	263
JT14 213	0	0	0	0	0	0	0	0	0	0	0	274
JT14 214	0	0	0	0	0	0	0	0	0	0	0	280
JT14 215	0	0	0	0	0	0	0	0	0	0	0	252
WF916-1042	1	0	0	186	0	0	0	0	0	19	0	210
WF916-1009	4	0	0	260	0	0	1	0	0	0	0	278
WF916-1010	0	0	0	300	0	0	0	0	0	0	0	301
WF916-1012	4	0	1	275	1	1	0	0	0	0	0	321
WF916-1014	2	0	0	293	0	0	0	0	0	2	0	315
WF916-1015	9	0	0	298	0	0	1	0	0	10	0	365
WF916-1016	0	0	0	207	0	1	0	0	0	5	0	304

Slide	El.psilate	Trapezi.ps	Papillae	Tabular.irreg	Polyh.gran	Polyh.plain	Rondel	Saddle	Scalloped	Rectangle.tab	Tracheid	Total
WF916-1017	0	0	0	305	2	0	0	0	0	1	0	309
WF916-1018	2	0	0	0	0	0	2	0	0	0	0	314
WF953-1019	6	28	1	93	0	1	21	0	0	0	1	314
WF953-1020	3	2	5	33	0	1	18	3	0	0	0	363
WF953-1027	0	0	0	259	0	1	0	0	0	4	0	269
WF953-1029	7	0	1	189	0	0	0	0	0	0	0	211
WF953-1030	3	1	0	131	2	0	6	0	0	1	0	396
WF953-1031	0	0	0	252	1	3	0	0	0	1	0	262
WF953-1032	3	0	0	231	0	1	0	0	0	1	0	255
WF953-1033	3	0	0	72	0	0	0	0	0	5	0	88
WF940 827	0	0	0	33	1	0	0	0	0	2	0	38
WF940 821	4	1	0	236	1	0	4	0	0	0	0	252
WF940 815	0	1	0	250	0	0	1	0	0	0	0	253
WF940 814	0	0	0	1	0	0	0	0	0	0	0	14
WF940 813	0	0	0	1	0	0	0	0	0	0	0	1
WF940 811	0	0	0	249	0	0	0	0	0	15	0	265
WF940 801	7	1	0	102	0	0	17	0	1	3	0	384
WF940 820	7	2	0	9	0	0	25	2	0	0	0	271
WF982 876	2	1	1	210	0	0	5	0	0	8	0	263
WF982 875	3	2	0	174	0	0	5	0	0	2	1	267
WF982 901	18	5	1	184	0	0	22	1	0	2	0	283
WF982 900	6	1	1	157	0	0	58	1	0	0	0	307
WF982 912	4	2	2	107	0	0	36	5	0	0	0	263
WF982 971	7	7	0	209	0	0	7	2	0	7	0	265
WF982 873	0	0	0	235	0	0	3	0	0	0	0	272
WF982 902	11	1	0	195	0	0	2	0	0	2	0	261
WF982 903	4	0	0	212	0	0	0	0	0	3	0	260
WD1	11	0	0	46	0	0	2	0	0	1	0	1655
WD2	8	1	2	82	0	1	24	1	0	3	0	798

Slide	El.psilate	Trapezi.ps	Papillae	Tabular.irreg	Polyh.gran	Polyh.plain	Rondel	Saddle	Scalloped	Rectangle.tab	Tracheid	Total
WD3	3	1	0	220	0	0	1	0	0	6	0	273
WD4	2	1	0	202	0	1	7	0	0	0	0	342
WD5	3	3	0	160	0	1	11	0	0	0	0	312
WD6	2	0	1	101	0	0	9	0	0	2	0	373
WD7	9	0	0	36	0	3	53	2	0	0	0	496
WD8	4	1	0	272	0	0	3	0	0	3	0	343
WD9	11	0	0	97	0	1	16	1	0	0	0	261
WD10	5	1	1	235	0	2	2	0	0	6	0	397

Slide	Phrag. sp.	Multi-awn	Barley husk	Multi-p.bull	Multi-c.bull	Multi-el.teni	Multi-jigsaw	Leaf-stem	Meso-phyll	Polyhe-plain	Ind.-dendr.	Ind.-husk	Wheat-husk	Cf. Barley	Multi-rondel	Multi-hairs	Multi-cross	Multi. trach.	C4-bilobes
JT14 101	0	0	0	0	3	0	0	2	0	5	28	7	0	5	5	0	0	0	0
JT14 102	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
JT14 103	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
JT14 104	0	0	0	0	2	0	0	35	0	0	7	0	0	0	0	0	0	0	0
JT14 105	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
JT14 106	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
JT14 107	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
JT14 108	0	2	0	0	0	0	0	3	0	0	4	0	0	0	0	0	0	0	0
JT14 109	0	0	0	0	0	0	0	0	0	0	0	13	0	0	0	0	0	0	0
JT14 110	0	0	22	2	0	0	0	37	0	0	17	7	0	0	2	0	50	0	37
JT14 111	0	0	0	0	0	0	0	0	0	0	6	0	0	0	60	0	0	0	128
JT14 112	0	0	0	0	2	0	0	3	0	0	0	0	0	0	0	0	0	0	0
JT14 113	0	0	0	7	0	0	0	36	0	0	33	9	0	0	0	0	0	0	0
JT14 114	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0
JT14 115	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
JT14 116	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0
JT14 201	0	0	5	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
JT14 202	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0

Slide	Phrag. sp.	Multi-awn	Barley husk	Multi-p.bull	Multi-c.bull	Multi-el.teni	Multi-jigsaw	Leaf-stem	Meso-phyll	Polyhe-plain	Ind.-dendr.	Ind.-husk	Wheat-husk	Cf. Barley	Multi-rondel	Multi-hairs	Multi-cross	Multi. trach.	C4-bilobes
JT14 203	0	0	0	0	0	0	0	0	0	0	16	0	0	0	0	0	0	0	0
JT14 204	0	0	0	0	0	0	0	9	0	0	0	0	0	0	0	0	0	0	0
JT14 205	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
JT14 206	0	0	0	0	0	0	0	4	0	0	0	8	26	0	0	0	0	0	0
JT14 207	0	2	0	4	0	0	0	14	0	0	16	0	0	0	0	0	0	0	0
JT14 208	0	0	0	0	0	0	0	11	0	0	3	0	0	0	0	0	0	0	0
JT14 209	0	3	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
JT14 210	0	0	0	0	2	0	0	30	0	0	26	31	0	0	0	0	0	0	0
JT14 211	0	22	0	3	0	0	0	7	0	0	17	65	0	0	57	0	0	0	0
JT14 212	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
JT14 213	0	9	0	9	2	0	0	23	0	0	32	0	0	0	5	0	0	0	0
JT14 214	0	0	0	14	0	0	0	0	0	0	26	9	0	0	5	0	0	0	0
JT14 215	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
WF916-1042	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0
WF916-1009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0
WF916-1010	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
WF916-1012	0	0	0	30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
WF916-1014	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
WF916-1015	0	0	0	0	0	4	0	4	0	0	0	0	0	0	0	0	3	0	0
WF916-1016	0	2	0	0	0	0	0	80	0	0	9	0	0	0	0	0	0	0	0
WF916-1017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
WF916-1018	0	2	0	0	0	0	0	24	0	0	28	0	250	0	0	0	0	0	0
WF953-1019	0	3	0	29	0	0	14	32	0	0	16	0	0	0	0	0	0	0	0
WF953-1020	0	0	0	3	0	3	0	13	0	31	15	0	96	0	0	0	0	3	2
WF953-1027	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
WF953-1029	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
WF953-1030	0	4	0	27	0	0	0	6	0	0	148	0	0	0	0	13	0	6	13
WF953-1031	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
WF953-1032	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0

Slide	Phrag. sp.	Multi-awn	Barley husk	Multi-p.bull	Multi-c.bull	Multi-el.teni	Multi-jigsaw	Leaf-stem	Meso-phyll	Polyhe-plain	Ind.-dendr.	Ind.-husk	Wheat-husk	Cf. Barley	Multi-rondel	Multi-hairs	Multi-cross	Multi. trach.	C4-bilobes
WF953-1033	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
WF940 827	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
WF940 821	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0
WF940 815	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
WF940 814	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
WF940 813	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
WF940 811	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
WF940 801	0	0	0	14	0	0	0	9	1	0	51	15	32	0	26	0	0	0	0
WF940 820	0	0	0	13	0	0	11	7	1	73	39	0	0	22	8	0	0	2	0
WF982 876	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
WF982 875	0	0	0	30	0	0	0	14	1	0	5	0	0	0	0	0	0	0	0
WF982 901	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
WF982 900	0	0	0	0	0	0	0	7	1	0	0	0	0	0	0	0	0	0	0
WF982 912	0	0	0	0	0	0	0	0	0	0	12	0	0	0	0	0	0	0	0
WF982 971	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
WF982 873	0	0	0	0	0	0	0	4	0	0	2	20	0	0	0	0	0	0	0
WF982 902	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
WF982 903	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
WD1	950	5	0	0	0	0	0	451	0	0	40	0	0	0	0	0	0	0	122
WD2	0	6	0	3	0	0	0	91	0	0	37	0	85	0	0	0	0	0	407
WD3	0	0	0	0	0	0	0	0	0	0	20	0	0	0	0	0	0	0	0
WD4	0	0	30	0	0	0	0	47	0	0	14	0	0	0	0	0	0	0	0
WD5	0	0	32	0	0	0	0	10	0	0	13	0	0	0	0	8	0	0	0
WD6	0	7	0	0	0	0	0	47	0	0	85	0	24	0	0	0	0	0	0
WD7	0	11	0	0	0	6	0	2	0	0	189	0	0	0	0	0	0	0	0
WD8	0	0	0	0	0	0	0	0	0	0	31	0	0	0	0	0	0	0	0
WD9	0	0	0	0	0	0	0	11	41	9	32	0	0	0	0	0	0	0	42
WD10	0	3	0	0	0	0	0	0	0	0	115	0	0	0	0	0	0	0	0

Slide	Monocots	Dicots	Single	Multicell	Pooideae	Chloridoideae	Arundinoideae	Panicoideae	Palmaceae	Hordeum	Triticum
JT14 101	244	40	230	55	55	11	3	7	0	5	0
JT14 102	25	224	255	0	1	0	0	0	1	0	0
JT14 103	19	235	253	2	0	1	0	1	0	0	0
JT14 104	94	228	282	44	11	1	2	3	1	0	0
JT14 105	11	246	258	0	2	0	0	0	0	0	0
JT14 106	0	261	261	0	0	0	0	0	0	0	0
JT14 107	5	276	281	0	0	0	0	0	0	0	0
JT14 108	15	259	265	9	1	0	0	0	0	0	0
JT14 109	54	242	283	13	5	4	0	2	0	0	0
JT14 110	244	89	160	174	30	0	2	95	0	22	0
JT14 111	236	16	58	194	70	0	0	137	0	0	0
JT14 112	8	248	251	5	0	0	2	1	1	0	0
JT14 113	130	181	226	85	10	4	7	1	0	0	0
JT14 114	48	217	258	7	8	1	0	2	0	0	0
JT14 115	0	288	288	0	0	0	0	0	0	0	0
JT14 116	42	241	280	3	3	1	0	1	2	0	0
JT14 201	71	197	261	7	19	10	2	1	0	5	0
JT14 202	46	222	266	2	7	1	0	0	1	0	0
JT14 203	97	179	260	16	17	13	0	0	0	0	0
JT14 204	26	244	261	9	2	1	0	0	3	0	0
JT14 205	32	244	276	0	5	2	0	0	0	0	0
JT14 206	97	171	230	38	14	5	0	0	0	0	26
JT14 207	181	47	192	36	75	6	4	2	0	0	0
JT14 208	99	171	256	14	32	0	0	0	0	0	0
JT14 209	60	212	266	6	12	1	3	0	0	0	0
JT14 210	242	74	227	89	92	9	2	2	1	0	0
JT14 211	258	17	68	207	65	49	3	2	0	0	0
JT14 212	38	225	263	0	5	1	0	1	0	0	0
JT14 213	187	87	194	80	50	2	11	1	0	0	0

Slide	Monocots	Dicots	Single	Multicell	Pooideae	Chloridoideae	Arundinoideae	Panicoideae	Palmaceae	Hordeum	Triticum
JT14 214	151	129	226	54	46	4	14	4	1	0	0
JT14 215	11	241	252	0	0	0	0	0	0	0	0
WF916-1042	5	205	206	4	0	0	0	0	0	0	0
WF916-1009	18	260	274	4	1	0	0	2	0	0	0
WF916-1010	1	300	301	0	0	0	0	0	0	0	0
WF916-1012	45	276	288	30	0	0	30	0	0	0	0
WF916-1014	19	296	315	0	0	0	0	0	0	0	0
WF916-1015	57	308	354	11	1	0	0	4	0	0	0
WF916-1016	91	213	213	91	0	0	0	0	0	0	0
WF916-1017	3	306	309	0	0	0	0	1	0	0	0
WF916-1018	314	0	10	304	2	0	0	2	0	0	250
WF953-1019	203	108	215	99	21	0	29	29	0	0	0
WF953-1020	298	65	166	166	18	3	3	28	0	0	96
WF953-1027	5	264	267	2	0	0	0	0	0	0	0
WF953-1029	22	189	211	0	0	0	0	0	0	0	0
WF953-1030	264	132	179	217	6	0	27	15	0	0	0
WF953-1031	6	256	262	0	0	0	0	0	0	0	0
WF953-1032	22	233	252	3	0	0	0	1	0	0	0
WF953-1033	11	77	88	0	0	0	0	0	0	0	0
WF940 827	0	38	38	0	0	0	0	0	0	0	0
WF940 821	15	237	249	3	4	0	0	1	0	0	0
WF940 815	2	251	253	0	1	0	0	0	0	0	0
WF940 814	0	14	14	0	0	0	0	0	0	0	0
WF940 813	0	1	1	0	0	0	0	0	0	0	0
WF940 811	1	264	265	0	0	0	0	0	0	0	0
WF940 801	277	107	237	147	43	0	14	2	1	0	32
WF940 820	174	97	98	173	33	2	13	4	3	22	0
WF982 873	31	241	246	26	3	0	0	1	0	0	0
WF982 875	77	188	217	50	5	0	30	1	0	0	0

Slide	Monocots	Dicots	Single	Multicell	Pooideae	Chloridoideae	Arundinoideae	Panicoideae	Palmaceae	Hordeum	Triticum
WF982 876	45	218	263	0	5	0	0	0	0	0	0
WF982 900	142	164	299	8	58	1	0	2	0	0	0
WF982 901	96	187	283	0	22	1	0	1	0	0	0
WF982 902	63	197	261	0	2	0	0	1	0	0	0
WF982 912	153	110	251	12	36	5	0	1	0	0	0
WF982 971	48	216	265	0	7	2	0	1	0	0	0
WF982 903	26	234	260	0	0	0	0	0	0	0	0
WD1	1607	47	87	1568	2	0	0	128	0	0	0
WD2	712	86	169	629	24	1	0	417	0	85	0
WD3	47	226	253	20	1	0	0	2	0	0	0
WD4	139	203	251	91	7	0	0	2	0	0	30
WD5	151	161	249	63	11	0	0	4	0	0	32
WD6	269	103	210	163	9	0	0	2	0	24	0
WD7	456	39	288	208	53	2	0	5	0	0	0
WD8	68	275	312	31	3	0	0	0	0	0	0
WD9	153	98	166	94	16	1	0	49	0	0	0
WD10	154	243	279	118	2	0	0	2	0	0	0

Slide	Leaf	Leafhusk	Leafstem	Husk	Awn	Silica.ag	Weightpercent	Nrpergram	Indet	Degraded	Burnt	Poorlly.silicified	Diatom
JT14 101	73	7	19	113	0	56	0.0034	33569	76	20	2	30	0
JT14 102	13	0	8	1	0	110	0.0030	12138	24	18	2	1	1
JT14 103	5	1	4	3	0	44	0.0025	32699	19	14	1	0	2
JT14 104	21	2	47	17	0	48	0.0020	47385	19	16	2	6	6
JT14 105	6	0	4	0	0	47	0.0021	31393	11	9	0	2	4
JT14 106	0	0	0	0	0	96	0.0479	384674	1	1	0	0	0
JT14 107	3	0	1	0	0	80	0.0104	106269	6	3	3	0	2
JT14 108	2	0	3	4	2	82	0.0320	241876	4	1	0	0	4
JT14 109	14	2	12	23	0	25	0.0062	50932	17	6	1	0	4
JT14 110	41	3	139	43	0	64	0.0092	117082	24	3	1	3	0

Slide	Leaf	Leafhusk	Leafstem	Husk	Awn	Silica.agg	Weightpercent	Nrpergram	Indet	Degraded	Burnt	Poorly.silicified	Diatom
JT14 111	18	9	198	0	0	8	0.0090	302612	1	1	3	0	2
JT14 112	3	1	5	0	0	35	0.0027	78994	3	0	0	0	0
JT14 113	22	1	42	30	0	47	0.0056	73331	26	0	0	2	0
JT14 114	18	2	21	2	0	6	0.0013	32800	16	11	6	0	11
JT14 115	0	0	0	0	0	22	0.0052	4219	0	0	0	0	0
JT14 116	18	1	21	2	0	23	0.0024	48279	33	17	3	2	5
JT14 201	35	1	10	23	0	64	0.0020	36661	24	7	9	6	1
JT14 202	24	0	11	8	0	59	0.0011	29477	30	37	3	3	6
JT14 203	42	0	6	24	0	66	0.0010	27243	19	14	7	3	0
JT14 204	14	0	13	1	0	31	0.0011	22828	17	15	11	1	1
JT14 205	13	0	8	7	0	81	0.0012	24524	8	10	5	0	3
JT14 206	24	0	11	62	0	84	0.0016	37464	27	4	2	0	4
JT14 207	91	2	22	45	2	42	0.0084	72967	21	1	7	0	3
JT14 208	40	0	27	29	0	46	0.0017	14691	23	3	15	5	12
JT14 209	36	0	15	3	3	61	0.0011	22783	18	25	6	0	14
JT14 210	109	2	37	64	0	10	0.0057	130996	16	0	107	0	0
JT14 211	120	1	8	87	22	5	0.0046	112444	11	0	6	15	1
JT14 212	20	1	11	4	0	31	0.0014	28337	16	8	15	1	5
JT14 213	67	1	26	50	9	18	0.0022	80373	42	0	0	0	1
JT14 214	70	3	8	41	0	50	0.0025	53333	41	1	0	0	0
JT14 215	7	0	4	0	0	7	0.0010	50395	11	9	5	2	1
WF916-1042	0	0	5	0	0	215	0.0009	11047	16	0	0	0	0
WF916-1009	4	2	8	0	0	91	0.002	37063	0	0	0	7	1
WF916-1010	0	0	0	0	0	80	0.0017	30081	0	0	0	0	0
WF916-1012	33	0	4	2	0	120	0.0033	80668	8	4	0	5	0
WF916-1014	11	0	2	1	0	39	0.0012	29647	6	12	0	0	1
WF916-1015	30	4	18	0	0	48	0.0003	15789	22	24	0	3	3
WF916-1016	0	0	80	0	2	405	0.003	48664	1	0	0	0	0
WF916-1017	0	1	0	0	0	27	0.0006	41164	0	0	0	0	0

Slide	Leaf	Leafhusk	Leafstem	Husk	Awn	Silica.agg	Weightpercent	Nrpergram	Indet	Degraded	Burnt	Poorly.silicified	Diatom
WF916-1018	2	2	26	3	2	2	0.0197	494567	0	0	0	0	0
WF953-1019	54	28	69	26	3	74	0.0025	110142	24	4	1	11	0
WF953-1020	27	25	19	182	0	32	0.0087	420870	14	0	0	9	1
WF953-1027	2	0	2	0	0	363	0.0065	42392	6	3	0	0	0
WF953-1029	7	0	8	3	0	0	0.0037	1582	10	6	0	0	0
WF953-1030	42	15	10	169	4	186	0.0016	35546	4	2	0	0	0
WF953-1031	4	0	0	0	0	234	0.0062	48106	3	1	0	0	0
WF953-1032	11	1	3	7	0	227	0.0025	24009	7	5	0	0	0
WF953-1033	4	0	3	1	0	0	0.0024	523	5	3	0	0	0
WF940 827	0	0	0	0	0	0	0.0018	1330	5	0	0	0	0
WF940 821	2	0	5	0	0	53	0.0026	13830	0	2	2	0	0
WF940 815	0	0	1	0	0	16	0.0005	1964	0	0	0	0	0
WF940 814	0	0	0	0	0	0	0.0013	889	1	0	0	0	0
WF940 813	0	0	0	0	0	1	0.0045	69	0	0	0	0	0
WF940 811	1	0	0	0	0	2	0.0062	6307	15	2	0	2	0
WF940 801	22	2	19	140	0	25	0.0024	58982	8	2	0	5	0
WF940 820	24	3	17	58	0	7	0.0015	42213	0	3	4	4	2
WF982 873	4	0	5	20	0	0	0.0068	36258	12	3	1	3	0
WF982 875	40	0	23	8	0	0	0.0082	56552	10	8	10	11	0
WF982 876	30	0	4	3	0	0	0.0015	10288	22	32	7	0	0
WF982 900	64	1	16	58	0	0	0.003	34293	31	12	1	8	4
WF982 901	55	1	30	5	0	0	0.001	12002	29	35	20	0	10
WF982 902	36	0	14	3	0	0	0.0008	4000	28	34	13	3	1
WF982 912	45	1	7	84	0	0	0.0033	30184	23	8	3	1	2
WF982 971	27	1	15	2	0	0	0.0006	3839	27	37	5	1	5
WF982 903	20	0	4	0	0	0	0.0009	3040	16	17	8	0	0
WD1	3	128	463	59	5	0	0	0	0	0	0	0	0
WD2	30	412	108	156	6	0	0	0	0	0	0	0	0
WD3	4	1	7	32	0	0	0	0	0	0	0	0	0

Slide	Leaf	Leafhusk	Leafstem	Husk	Awn	Silica.agg	Weightpercent	Nrpergram	Indet	Degraded	Burnt	Poorly.silicified	Diatom
WD4	10	0	52	75	0	0	0	0	0	0	0	0	0
WD5	11	3	17	111	0	0	0	0	0	0	0	0	0
WD6	11	1	52	196	7	0	0	0	0	0	0	0	0
WD7	56	1	46	342	11	0	0	0	0	0	0	0	0
WD8	4	0	6	58	0	0	0	0	0	0	0	0	0
WD9	58	49	26	59	0	0	0	0	0	0	0	0	0
WD10	6	2	6	135	3	0	0	0	0	0	0	0	0

Appendix 9: Geochemical Analysis readings

Wadi el Jilat sites

Sample	Bal	Mg	Si	K	Ca	P	Fe	Ti	Mn	Al
WJ7C 6a 21	554280.25	4935.34	76935.57	8471.13	241959.84	1278.63	16001.17	2585.66	349.71	12737.08
WJ7B 29a 11	577152.81	6612.82	106528.7	10010.57	248019.73	2270.77	20085.86	3434.24	481.11	17332.01
WJ7B 9a 6	579489.38	6487.84	104872.58	11197.23	250331.23	1422.53	19053.89	3464.93	526.99	16622.03
WJ7A 21a 9	578410.44	5379.93	112666.66	11128.29	240193.7	952.31	20604.89	3831.17	376.41	18160.5
WJ7A 23a 11	581436.5	6298.32	112175.55	14457.92	238879.14	1370.51	20557.31	3441.02	374.38	17869.21
WJ7A 23d 16	579082.25	5523.81	108297.01	11466.95	246657.39	1733.33	20594.33	3203.59	481.92	17471.15
WJ7A 25a 13	530885	2789.54	51825.71	7596.49	251437.28	716.39	12277.18	1976.72	289.49	9274.45
WJ7A 24a 12	593627.06	4726.09	100675.2	12999.63	241995.05	1129.94	20083.58	3318.07	381.32	15531.33
WJ7B 38b 19	559043.56	4029.67	77055.66	7601.19	258354.42	1010.62	16229.95	2775.87	461.23	12561.39
WJ7C 11 27	543720.69	2528.31	58508.06	7024.78	233311.95	708.28	13302.19	2185.8	282.32	10005.42
WJ7 C 14 29	500070.16	4074.21	62130.38	7827.64	256877.31	499.96	14024.08	2365.49	279.44	11689.01
WJ7C 13 28	539473.06	1905.26	62553.43	7131.59	232109.34	523.63	13646.02	1938.78	420.1	11231.63
WJ7 background	553739.44	2965.23	90996.31	7266.75	220600.25	150	18534.05	2701.02	257.96	15729.92
WJ7A 17 7	570518.44	4050.97	78685.05	8970.88	250019.72	927.92	16776.1	2409.1	404.39	12800.68
WJ7C 6a 20	538484.44	3853.35	56941.2	7110.21	251737.42	832.69	12933.24	1915.9	475.22	9834.45
WJ7A 28a 17	573156.69	5457.7	98452.2	10135.54	249697.33	1399.89	18135.99	2898.85	517.2	15718.87
WJ7C 16 30	540062.5	750	46903.09	6244.57	233645.94	414.75	12473.65	1703.69	192.94	8566.84
WJ13 5a 3	603093.06	5862.29	128265.66	11991.31	197817.14	858.21	23724.26	4252.84	521.9	20970.25
WJ13C 7a 5	595382.06	5786.72	119207.11	11124.5	211841.28	738.93	22248.45	4022.92	421.33	19923.85
WJ13A 8 8	605689.75	6288.82	120013.91	10455.38	205299.34	753.61	23145.1	4324.35	430.14	20607.41
WJ13A 10a 9	592145.5	6921.77	135082.41	11737.04	197205.88	887.82	24097.64	4223.02	519.72	22899.09
WJ13 12 12	592840.31	6687.61	106763.38	11404.61	235779.64	1098.74	18899.52	3672	335.25	16154.6
WJ13A 15 12	580354.88	3630.75	91194.3	7927.21	192254.72	1212.78	19265	3008.08	402.29	15172.45
WJ13A 16a 13	556136.25	4739.26	70635.41	7393.84	224443.45	1771.2	15106.47	2668.42	333.78	11376.04
WJ13 18 13	582639.06	7335.58	114379.15	11615.68	233911.77	1292.7	20073.26	3651.69	334.83	17191.58
WJ13A 20b	539677.88	5341.77	94266.45	8708.52	220660.61	285.13	21228.2	3154.16	428.08	17976.26
WJ13 22 14	601857.75	5440.18	95736.04	9916.73	241541.59	2046.4	17117.27	3379.63	415.45	13366.9
WJ13A 22 17	582155.56	4001.49	88699.63	8493.36	213068.97	1211.29	18150.32	3369.78	585.75	14673.13
WJ13A 24 20	611185.25	3778.83	97053.67	9487.41	181711.78	2646.6	20839.45	3756.71	448.52	14050.07
WJ13A 25 19	562285.63	4223.52	94901.17	9378.86	215671.83	1877.73	21127.37	3462.95	577.83	17155.25
WJ13B 45a 4	549391.81	4252.65	66620.55	7219.21	246389.2	758.75	14764.35	2547.4	458.24	11105.5
WJ13 47 29	602643.75	5352.59	122648.96	12181.33	209070.73	1426.28	21700.22	3745.62	406.85	17739.17

Sample	Bal	Mg	Si	K	Ca	P	Fe	Ti	Mn	Al
WJ13C 50a 3	575433.31	6695.24	84436.71	8697.5	249511.55	1572.47	16049.05	2969.42	476.32	12797.31
WJ13 52a 31	563266.81	7078.92	97979.18	9666.52	250449.63	1319.88	18656.97	3288.34	430.57	16070.03
WJ13C 53a 3	580236.06	7925.03	75770.61	8612.14	264136.44	1825.7	16436.15	2662.24	393.63	12297.46
WJ13C 56b 4	569289.63	3357.29	64782.28	6250.54	227441.89	1009.71	15786.22	2574.02	262.84	10075.75
WJ13C 57a 33	568722.63	6241.57	90851.21	9265.83	265953.34	2078.56	16693.47	3238.67	408.55	13079.26
WJ13 59a 31	580366	7310.21	127610.4	11298.24	211911.48	1263.31	20025.92	4061.22	647.45	18967.89
WJ13B 62a 4	647939.81	1866.31	64411.42	9252.47	222299.91	513.35	18804.36	3517.86	521.62	7406.49
WJ13 66b 39	573132.38	5924.52	68565.12	7942.31	266912.25	1343.19	14090.19	2472.47	461.29	11188.31
WJ13C 70a 3	573521.31	6721.59	73422.88	8119.69	274170.25	1211.89	15002.61	2564.26	489.62	11075.25
WJ13B 71b 8	603962.56	2322.14	72091.21	8554.65	210006.16	988.93	18866.23	3416.67	388.08	10376.79
WJ13 83a 46	551292.56	6676.6	84917.2	9104.76	252600.02	1358.52	17449.66	2953.6	398.56	14705.62
WJ13B 85 54	572856.44	6128.91	92977.81	9557.58	241575.27	2848.53	18608.81	3332.23	432.68	15442.07
WJ13B 90a 5	562688.94	5144.32	83979.55	8801.93	242496.11	2115.05	17590.78	2957.01	460.75	13932.11
WJ13B 92a 5	560356.13	5959.62	95002.23	8913.08	248131.66	2686.21	18434.31	3564.59	580.16	16166.04
WJ13 96 59	589021.56	4669.88	71112.48	8687.71	252955.5	2366.02	15385.94	2425.15	334.37	11829.29
WJ13 104 65	567838.81	4999.5	70223.3	8801.35	259411.48	2609.06	16470.57	2746.65	392.27	12603.39
WJ13 background	570304.06	7097.09	122034.82	10637.02	235819.91	317.06	20616.39	3929.05	565.56	21394.58
WJ26Ce 27a	612812.44	7143.43	132596.13	14659.06	162041.25	394.99	30699.19	4898.39	468.31	24633.96
WJ26Ed 12 6	606951.31	7630.96	126305.84	16860.26	181269.08	509.47	25842.03	3924.37	451.93	21986.63
WJ26Ed 12b	606041.44	7100.25	116462.55	13986.97	197312.09	784.26	24056.06	3628.61	420.35	20682.53
WJ26Ed 15a	604021.5	7060.99	128222.73	13934.93	192434	327.2	24579.76	3785.52	477.03	22791.33
WJ26Ed 18a	634321.5	5005.94	99186.91	13376.1	199257.33	286.88	21457.62	3387.17	543.29	14787.19
WJ26Ec 12a	628320.69	5299.58	119046.7	14507.47	175207.64	176.06	25115.15	4121.54	430.71	19400.59
WJ26Ae 46a	605157.13	6498.31	125055.9	11438.75	171907.2	384.34	28708	4655.64	407.58	22153.93
WJ26Ea 12a	613897.25	7489.32	116299.87	15492.57	185585.8	689.2	25208.04	3753.21	470.15	20653.86
WJ26Ed 18a	608848.44	6980.52	120698.41	13052.22	193000.78	361.6	23506.47	4099.41	561.93	18773.03
WJ26Ed 16 1	599443.88	8534.24	131918.5	16178.88	186195.84	430.59	25095.01	4642.42	583.57	22101.91
WJ26C 10a 4	599750.44	5378.24	130246.82	10706.9	147289.91	2647.67	31436.7	4691.61	471.32	23190.14
WJ26A 10 20	616216.5	6165.32	120240.78	12127.62	182227.22	256.97	27698.64	3869.89	523.58	22529.96
WJ26Ac 14a	617061.31	7031.08	121760.57	13046.78	173686.45	266.25	27645.27	3942.47	580.86	22267.42
WJ26Ed 8a 8	609679.13	6902.91	119836.12	15921.53	187511.83	238.8	24668.24	4284.28	481.16	20708.06
WJ26C 9a 6	581599.88	6375.38	108565.92	8602	222677.75	3529.12	24195.29	3737.94	461.88	18560.56
WJ26Cd 21a	615515.5	7437.85	135331.2	14091.64	165507.61	403.05	28226.59	4588.74	393.04	23851.69
WJ26Ed 30a 25	609521.69	6860.9	130055.29	14760.29	191087.3	470.96	24268.6	3927.21	432.4	20777.92
WJ26A 9 19	617944.13	6183.63	132854.2	13883.1	169792.69	279.62	28103.63	4374	469.97	23071.42

Sample	Sr	S	Cl	V	Cr	Zn	Rb	Zr	Nb
WJ7C 6a 21	515.83	74886.71	3910.51	102.95	317.71	37.35	10.4	159.85	8.21
WJ7B 29a 11	538.04	5960.54	381.98	114.94	261.15	52.88	11.56	201.37	9.82
WJ7B 9a 6	490.93	2581.18	2254.85	124.9	267.31	52.07	11.79	202.53	10.69
WJ7A 21a 9	442.35	3319.61	3295.08	124.49	313.07	48.99	12.48	202.55	10.92
WJ7A 23a 11	456.35	1508.77	30	130.81	220.76	55.45	12.67	235.26	10.8
WJ7A 23d 16	456.3	2600.36	1248.97	116.97	277.39	56.46	11.38	191.91	10.47
WJ7A 25a 13	596.15	127503.05	1854.96	106.44	248.19	41.29	8.37	121.86	7.9
WJ7A 24a 12	486.6	2304.43	1583.09	112.21	318.73	48.86	11.55	183.46	10.43
WJ7B 38b 19	571.84	58652.99	622.52	118.14	269.23	56.02	9.49	175.89	9.05
WJ7C 11 27	464.91	122759.23	3316.51	96.61	1202.6	36.84	9.63	127.79	6.02
WJ7 C 14 29	477.8	135363.92	2974.55	117.76	694.34	38.69	10.93	141.84	8.76
WJ7C 13 28	429.42	123450.95	3241.15	112.43	1259.51	40.65	10.3	106.87	7.77
WJ7 background	344.7	84473.99	927.77	99.78	764.79	8	45.93	131.97	8.78
WJ7A 17 7	484.51	50045.71	2719.18	116.64	329.22	41.81	10.18	140.9	7.78
WJ7C 6a 20	570.87	111656.1	2590.76	104.44	298.31	42.67	9.09	123.99	5.85
WJ7A 28a 17	458.34	18601.59	4183.04	111.78	331.81	57.95	9.98	162.94	9.1
WJ7C 16 30	450.18	144196.88	2554.45	83.96	702.55	25.02	10.74	95.05	7.91
WJ13 5a 3	299.43	1104.37	38.8	118.19	237.52	56.1	13.17	318.1	11.36
WJ13C 7a 5	356.53	2321.5	5410	112.85	284.34	55.07	13.8	287.56	11.95
WJ13A 8 8	296.75	1251.22	219.2	151.25	236.54	54.05	13.66	320.7	12.09
WJ13A 10a 9	296.61	1317.22	1400.86	113.6	254.46	52.99	13.41	376.54	14.06
WJ13 12 12	491.67	1637.21	3109.13	94.59	236.47	56.27	12.7	255.88	11.65
WJ13A 15 12	313.4	80525.06	3540.2	138.49	271.86	50.21	12.76	253.78	8.76
WJ13A 16a 13	421.71	100414.91	3580.5	105.88	184.49	49.06	9.26	226.97	8.72
WJ13 18 13	536.81	1827.54	4015.29	100.79	238.13	62.3	12.04	256.25	10.19
WJ13A 20b	369.83	83319.28	3344.87	126.85	384.51	49.55	12.3	191.83	12.09
WJ13 22 14	593.98	2483.85	5004.65	79.15	219	47.03	11.79	234.37	9.24
WJ13A 22 17	420.41	60919.06	3167.16	126.67	265.81	62.08	11.84	234.33	10.36
WJ13A 24 20	315.83	49727.82	3829.09	103.72	299.45	63.12	13.59	289.48	11.41
WJ13A 25 19	378.78	63643.88	4121.46	111.23	336.5	62.43	11.73	206.48	10.32
WJ13B 45a 4	564.23	92625.53	2311.95	151.61	207.67	47.54	9.84	188.74	8.44
WJ13 47 29	386.15	1423.23	86.54	118.98	299.35	43.65	12.51	272.61	11.4
WJ13C 50a 3	643.55	35912.36	3743.73	113.27	199.63	66.3	10.31	216.5	8.19
WJ13 52a 31	514.16	26246.3	3900.76	95.96	226.05	51.79	11.1	232.93	10.41

Sample	Sr	S	Cl	V	Cr	Zn	Rb	Zr	Nb
WJ13C 53a 3	785.15	23532.21	4316.58	91.49	202.22	61.98	10.67	206.41	8.27
WJ13C 56b 4	486.74	95084.64	2592.62	79.14	260.99	48.01	11.07	215.07	9.54
WJ13C 57a 33	761.04	17618.99	3845.23	123.32	249.46	57.31	10.49	194.1	9.01
WJ13 59a 31	419.14	10871.47	4022.94	118.2	198.8	53.3	12.09	284.63	10.75
WJ13B 62a 4	478.7	18444.42	3367.12	121.71	275.82	45.81	10.85	259.01	11.43
WJ13 66b 39	738.4	43207.01	3173.76	75.85	162.74	54.27	10.07	165.25	7.54
WJ13C 70a 3	804.79	28940.44	2910.06	85.96	165.41	51.66	9.45	205.35	9.26
WJ13B 71b 8	401.86	64018.27	3335.34	104.13	469.94	47.69	11.57	206.93	10.03
WJ13 83a 46	490.91	52979.6	3911.02	91.85	336.23	52.68	9.98	172.1	9.73
WJ13B 85 54	530.78	29503.09	4531.95	124.8	767.84	61.38	13.08	222.77	10.44
WJ13B 90a 5	498.12	53649.47	3979.35	93.77	875.35	57.84	12.36	207.64	10.83
WJ13B 92a 5	511.65	34269.13	4066.88	110.27	416.89	65.74	10.84	236.89	9.98
WJ13 96 59	571.94	35481.71	4081.47	86.38	403.28	52.02	10.84	140.49	7.84
WJ13 104 65	637.87	47347.91	4477.46	10	728.24	50.31	11.96	170.11	9.17
WJ13 background	348.61	1158.02	4692.96	129.18	127.02	62.42	10.85	215.08	10.85
WJ26Ce 27a	310.63	2139.96	5917.24	172.84	298.33	67.41	16.98	282.84	13.9
WJ26Ed 12 6	371.73	1330.18	5380.58	145.59	202.39	58.01	14.92	274.29	12.19
WJ26Ed 12b	370.96	1991.08	6023.88	120.79	203.52	58.23	12.57	273.42	11.52
WJ26Ed 15a	324.35	834.63	30	148.44	190.87	55.14	14.37	288.75	11.94
WJ26Ed 18a	363.4	2188.35	4756.68	113.96	180.45	40.19	12.69	261.33	11.02
WJ26Ec 12a	325.06	3432.48	3485.12	104.93	231.22	51.33	12.93	252.46	12.23
WJ26Ae 46a	330.51	19659.89	2357.73	173.93	284.84	56.9	15.4	288.46	16.09
WJ26Ea 12a	361.21	1870.54	7136.42	130.92	216.59	60.82	13.77	246.4	13.52
WJ26Ed 18a	378.91	2347.01	6252.07	126.17	196.16	49.24	13.44	257.44	11.44
WJ26Ed 16 1	378.57	1871.91	1458.99	139.66	169.59	49.38	13.37	292.17	14.04
WJ26C 10a 4	323.97	36768.11	5735.99	209.19	369.31	88.73	12.57	238.13	13.19
WJ26A 10 20	329.42	1538.03	5185.09	126.51	252.14	61.78	14.61	185.81	11.98
WJ26Ac 14a	344.36	2564.58	8662.06	129.31	237.85	61.46	15.62	264.47	12.64
WJ26Ed 8a 8	352.36	3338.25	4927.96	127.08	211.98	48.4	14.39	274.31	11.53
WJ26C 9a 6	551.56	14195.98	5556.3	177.7	308.01	76.41	11.84	205.19	11.45
WJ26Cd 21a	303.79	1089.96	1984.32	157.57	297.39	58.25	14.46	271.49	13.39
WJ26Ed 30a 25	402.31	813.47	1056.99	154.42	153.93	57.17	12.77	254.35	13.06
WJ26A 9 19	324.98	1009.22	507.61	150.02	261.09	63.59	14.23	238.32	13.13
WJ26Ed 26a	413.33	12450.51	6234.1	144.18	196.32	49.5	12.87	255.74	10.34

Wadi Faynan and Wadi Dana sites

Sample	Bal	Mg	Si	K	Ca	P	Fe	Ti	Mn	Al	Sr	S	Cl	Zn	Zr
JT101	598894.19	21063.14	35480.34	15097.82	272782.5	8876.96	6416.31	1084.31	371.53	5420.24	1735.36	23437.44	8534.13	204.17	89.32
JT102	651726.13	6790.8	131586.2	10014.47	145805.34	307.88	23733.85	4189.36	367.75	20972.2	199.14	2200.79	1059.63	44.75	326.93
JT103	660073.06	5564.88	119958.41	11145.3	146910.67	412.26	25074.47	4389.29	313.33	19682.73	215.61	4208.11	897.01	43.5	394.43
JT104	675755.19	6110.47	111452.56	18058.84	138424.73	3245.32	18731.41	3254.1	241.52	14489.82	228.59	4097.1	4979.13	66.49	317.12
JT105	654911.94	8200.66	97471.88	28563.05	147003.28	2018.26	21835.43	3878.1	262.38	16002.36	248.6	6917.81	10932.85	52.5	328.07
JT106	664656	7643.95	97150.55	21863.57	154760.58	1247.96	20433.27	3651.35	262.62	16405.24	255.52	4740.81	5598.88	47.01	259.08
JT107	726175.31	6586.03	82445.91	24052.31	113074.73	4362.89	13511.86	2764.98	101.77	11717.61	197.65	8454.63	6066.58	41.55	188.28
JT108	711513.31	3693.7	77266.5	19836.34	144326.42	1712.02	18736.58	3451.34	256.16	10643.44	236.22	4601.38	2827.18	60.34	312.69
JT109	640401.13	6573.89	148423.64	9821.88	140441.16	1705.97	23151.07	4364.95	364.11	22312.93	206.5	973.15	118.55	56.79	282.86
JT110	645153.38	7868.4	106205.75	15036.6	174086.77	1292.41	17488.29	2621.17	199.87	16930.44	365.33	4900.89	6796.02	40.68	227.25
JT111	615568.06	7053.94	84926.81	12281.47	230407.67	3229.16	15866.25	2545.48	274.81	13111.2	1214.03	11608.11	965.89	67.3	202.86
JT112	780867.81	1651.49	54679.14	27045.54	90554.48	3160.64	12567.3	2105.71	60	5190.29	206.81	10500.68	10814.93	65.06	231.25
JT113	838955.31	1892.85	25650.81	30830.43	63741.19	3721.87	5864.76	719.98	60	1604.01	231.8	7939.04	18653.75	50.78	92.7
JT114	632996.81	5981.96	156660.27	8591.84	148727.45	200	19495.32	4387.04	300.76	19263.05	198.71	697.71	339.37	44.79	591.18
JT115	722184.75	3131.58	175682.58	4687.78	57722.49	267.56	10619.49	2818.89	60	21255.85	80.06	896.05	50	8	261.07
JT116	663292.94	4953.49	119549.09	9221.25	147671.36	982.41	21109.67	3990.75	341.38	16358.08	202.17	1300.67	9985.35	42.31	316.15
JT201	604574.5	7948.74	46117.15	20966.36	184768.67	2591.47	6812.73	1454.54	146.15	5147.01	864.87	114025.43	3954.13	58.27	221.71
JT202	707698.13	3202.89	80778.35	12405.15	136705.86	1564.41	14552.25	3052.1	283.86	9896.86	300.24	18002.93	10365.79	39.38	363.16
JT203	682248.38	4593.85	159327.69	8596.04	100858.85	1482.09	12160.02	2805.63	123.88	15200.03	164.96	9667.8	1937.24	31.9	446.66
JT204	736519	2061.76	87939.19	8719.31	121728.66	1406.76	13929.15	3104.92	200.82	11865.31	141	8729.16	2926.62	25.01	288.93
JT205	666153.88	5123.64	172086.06	9009.23	107219.39	957.58	12895.82	3433.32	193.13	18206.13	123.88	2692.21	1082.87	22.23	330.11
JT206	697015.38	3802.9	168286.44	8005.06	86350.09	1661.38	10205.55	2700.55	60	14857.66	123.85	4317.39	1932.15	17.56	350.58
JT207	581522.19	21682.91	50467.07	53543.06	207726.72	17599.66	9459.77	1451.94	412.05	7047.77	818.07	38779.25	8598.2	224.54	185.27
JT208	616903.75	13936.16	55439.74	31864.8	191969.97	10536.32	9209.14	1555.15	335.87	7179.35	680.8	54154.85	5541.26	102.71	182.03
JT209	739780.19	2979.47	90174.24	9553.43	116657.34	4087.91	14351.82	3186.94	146.02	9786.25	172.77	5386.58	2902.57	35.44	408.46
JT210	770170	5312.95	70763.1	28908.33	89283.77	5786.8	7633.71	1730.43	60	6150.63	223.04	7711.31	6041.75	59.14	100.79
JT211	796938.63	2768.52	22705.79	61363.82	64846.34	8654.58	3150.75	560.91	60	1034.53	221.07	19879.91	17686.38	88.78	66.16
JT212	675044.31	6088.84	134315.88	15846.08	123278.47	1099.6	15970.58	4064.4	235.46	16892.78	146.38	2729.28	3460.16	28.06	322.15

Sample	Bal	Mg	Si	K	Ca	P	Fe	Ti	Mn	Al	Sr	S	Cl	Zn	Zr
JT213	864629.88	588.55	9882.38	40413.13	40767.27	5270.96	2830.19	458.3	60	347.82	152.13	20914.23	13581.55	86.08	43.62
JT214	905021.31	500	6527.55	23188.42	47668.25	2957.78	2155.35	426.8	60	151.55	187.15	4259.31	7324.8	56.21	34.38
JT215	695948.13	4852.78	139154.86	5552.56	121081.2	200	11957.16	2656.52	73.88	17325.22	155.7	614.16	50	10.64	227.83
WF916 1012	648703.38	10186.62	77796.96	9563.23	216667.78	2473.54	16643.79	2398.72	622.57	11540.11	542.04	1648.63	125.44	57.06	243.79
WF916 1018	799571.56	3244.55	54677.98	31104.96	75709.21	10029.97	8500.44	1412.21	73.48	3308.52	187.29	7971.58	3921.24	107.04	115.3
WF916 1039	691161.56	1921.97	74328.23	6531.29	193912.72	200	16771.27	3040.28	160	7855.25	264.95	1085.55	1994.51	27.46	285.4
WF916 1009	609281.44	15461.57	47133.79	11616.22	286732.09	2975.5	9808.51	1682.21	953.61	7690.19	1245.67	2785.37	1650.12	65.29	185.04
WF916 1010	656383.5	6147.54	146662.56	10976.62	133405.33	973.27	18098.66	3569.06	358.73	19908.5	177.54	1840.35	730.49	39.71	286.48
WF916 1013	659121.25	5808.33	153702.89	12962.79	122771.18	568.12	18114.37	3827.3	324.25	21142.84	145.8	678.15	50	32.66	266.07
WF916 1014 l	676195.31	5418.08	149167.91	9521.32	117801.05	1438.82	16450.16	3567.08	82.42	19140.31	136.77	601.8	50	31.85	261.47
WF916 1015	664671.88	4033.53	152134.66	7723.38	132594.22	3892.09	14193.2	3513.56	219.2	14883.7	123.4	881.06	82.96	34.32	240.88
WF916 1016	697779.88	6458.14	121086.17	20882.81	109659.75	4631.63	13161.72	3065.53	176.09	14183.26	158.03	4345.01	3760.14	37.02	301.48
WF916 1017	641963.63	6581.79	153636.83	12399.79	132709.81	1506.97	19052.93	4611.83	342.27	23440.58	153.41	1445.13	1037.38	38.86	464.25
WF916 1041	654498	6736.7	155702.06	9778.28	127638.98	796.14	16838.66	3708.39	318.55	22305.52	129.33	731.12	50	27.12	298.22
WF916 1042	652052	5584.37	162404.59	10267.68	123598.28	551.2	17343.95	3602.61	317.64	22650.94	134.28	588.39	50	27.14	403.15
WF916 1043	641114.38	6276.46	157823.27	10279.32	138116.81	1074.65	17286.18	3640.25	382.42	22230.84	140.84	621.97	50	33.18	342.05
WF953 1028	701253.19	5166.71	115922.09	14709.8	116445.8	1382.26	14257.24	3570.12	125.61	14825.08	160.72	6393.33	5175.37	32.04	216.14
WF953 1030	816889.5	3206.32	25064.22	36155.23	71117.4	3876.76	3024.85	542.35	60	1816.02	184.25	20842.55	17181.12	40.55	20.56
WF953 1031	683899.44	7734.68	135660.19	14843.08	113403.63	1765.78	13957.64	2779.94	196.54	16671.48	165.94	4588.9	3649.25	29.6	257.17
WF953 1027	683691.56	4913.23	138814.27	13798.24	114479.34	1036.27	13818.14	3774.09	173.69	16300.24	158.27	5293.86	3022.07	27.67	261.06
WF953 1020	590898.19	20902.71	29679.5	21603.61	279571.22	16328.45	5038.2	690.1	329.12	3862.03	874.83	22455.02	7261.62	152.52	64.27
WF953 1019	556619.56	17614.52	25444.15	27458.04	305347.88	8489.47	5104.32	653.25	258.29	4177.69	1383.03	42117.72	4878.51	73.66	60.17
WF953 1023	672390.63	6722.63	150451.91	15787.46	107551.69	472.51	13917.27	2916.28	60	17300.88	188.13	9521.22	2131.18	31.34	210.06
WF953 1026	677540.81	5953.38	153996.2	12001.55	106258.84	867.04	14202.75	3245.76	60	19712.59	147.09	3639.93	1798.66	21.8	206.36
WF953 1029	684563.13	6233.13	142670.5	12414.56	108984.38	893.93	16220.19	3661.7	60	17689.25	155.25	2954.81	3060.27	33.2	214.99
WF953 1032	713269.88	5433.5	142224.47	12728.61	88909.41	1166.34	10621.04	2521.04	60	13688.66	157.63	5330.01	3480.5	8	189.2
WF953 1033	691636.94	3898.8	146527.31	8540.45	110014.94	241.29	17690.19	3326.03	60	16573.2	148.5	677.71	50	36.66	409.16
WF940 811	707273.13	4957.86	157152.16	9628.08	84151.88	1133.75	12327.05	2196.24	60	16747.69	117.1	2177.89	1516.23	8	323.03
WF940 813	699160.94	4823.26	171116.38	10613.44	80906.57	1497.4	10105.82	2145.96	60	14569.71	115.02	2772.93	1666.89	21.73	207.43

Sample	Bal	Mg	Si	K	Ca	P	Fe	Ti	Mn	Al	Sr	S	Cl	Zn	Zr
WF940 814	717483.38	3498.74	183074.09	7968.92	59120.06	646.53	9799.45	1527.94	60	15667.45	87.41	633.67	167.27	8	150.67
WF940 815	705243.38	5588.92	158568.27	11565.46	81292.69	659.23	11621.58	2940.89	60	17419.67	106.18	2317.56	2149.87	8	193.44
WF940 816	707866.19	3856.39	150191.33	10276.1	92845.94	269.18	12924.52	3340	60	16624.98	120.36	893.33	426.7	24.55	223.13
WF940 818	699398.88	4906.73	158262.64	10473.5	87101.76	506.81	12665.06	3002.14	60	18952.46	117.56	2321.49	1458.39	8	332.76
WF940 821	733673.88	3633.46	145936.36	7476.33	78480.11	2394.48	9314.28	2099.25	60	10695.79	122.99	4724.65	1133.07	23.88	107.68
WF940 823	705141.5	5544.99	164170.86	8345.21	84766.26	1790.95	10131.71	2198.78	60	15610.86	147.44	1385.69	280.87	8	215.83
WF940 825	679366.38	6027.84	180526.64	10666.72	84824.52	519.31	12335.98	2563.22	60	21240.25	128.71	1020.08	211.25	8	318.71
WF940 827	693679.81	4961.19	165426.13	8758.25	89803.79	624.06	13048.63	2774.02	60	19263.33	125.4	794.54	57.1	8	395.88
WF982 873	610901.06	17055.19	35390.28	5025.54	309591.19	3595.8	6614.72	1014.23	1213.84	5614.6	1269.53	1608.98	451.77	77.6	97.28
WF982 875	605233.63	16319	58464.49	10999.03	278472.31	4229.1	9297.49	1498.4	1156.15	8439.77	997.95	2870	1041.73	87.28	135.02
WF982 876	655627.31	6184.31	221775.09	8957.15	69129.51	1853.05	10148.84	2518.74	327.32	21354.4	87.17	1068.8	95.82	21.74	330.63
WF982 900	695738.69	6374.31	103832.37	9215.59	148860.91	4883.82	11390.74	3451.36	362.37	10953.94	262.93	3691.63	260.91	48.62	332.41
WF982 901	655062.19	7236.2	166841.48	13749.36	111421.17	1682.96	16052.12	2907.91	509.25	19953.84	155.29	3218.62	379.63	40.88	206.62
WF982 902	650329.88	6324.58	229594.78	9595.89	68873.38	1312.49	9946.91	2448.32	266.85	19702.22	91.93	773.02	50	18.8	295.68
WF982 912	670923.19	4739.48	153968.23	9520.3	121513.48	5171.79	12261.72	2557.85	407.68	14989.63	191.05	2873.14	48.5	46.92	292.02
WF982 971	649826.44	6051.23	184249.55	8850.29	111268.28	200	13734.79	3290.04	397.61	19055.28	103.74	1217	41.23	26.18	548.31
WF982 903	647956.63	5982.39	237305.88	8717.44	68080.84	1134.59	7407.46	2319.58	156.95	19233.51	69.43	907.8	84.93	10.48	193.51
WD1	588209.44	15327.5	33817.69	54414.66	243643.25	4363.87	8316.02	1079.86	305.52	5463.81	1089.06	37813.06	5424.59	82.96	128.02
WD2	576557.06	17107.74	46806.15	35453.56	260068.11	13870	10042.62	1477.52	468.69	7336.84	680.09	18344.61	10986.77	157.49	117.49
WD3	763037.56	4681.18	67826.22	16992.67	106097.11	3999.12	10776.2	1859.69	181.12	7944.83	224.85	5661.46	10201.7	56.83	131.25
WD4	778950.13	2374.11	55836.89	19345.19	107171.55	2312.49	12592.87	2128.14	191.91	5818.64	215.38	4790.52	7861.37	57.58	149.32
WD5	830210.88	500	28966.24	16330.47	102206.9	1017.5	8907.1	2038.09	60	1676.45	177.38	3024.91	4786.84	49.33	91.31
WD6	826566	2400.49	33536.98	23320.94	83361.44	5552.67	5955.78	692.9	60	2945.61	186.33	8478.38	6803.65	69.96	35.04
WD7	809078.38	3117.84	43548.94	20905.31	90931.05	4059.3	8815.85	1282	60	4805.87	190.4	4952.72	8048.77	47.75	58.75
WD8	741864.63	4411.95	77378.78	24275.34	112729.41	2620.49	14625.46	2237.49	183.13	9617.39	203.9	3765.22	5477.52	92.91	189.78
WD9	577179.81	19136.32	34644.65	24602.05	307078.13	4574.92	9566.67	1272.88	382.71	6169.77	1066.53	8779.99	4655.55	100.41	119.25
WD10	720432.13	6632.55	85807.38	21911.28	117139.05	3210.06	13695.58	2233.09	291.15	11604.71	256.42	5152.32	11052.26	61.41	131.08