Geo-Ethnoarchaeology in Action

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Abstract

For over half of a century, ethnoarchaeology has served as an important analytical tool in the development of archaeological theory and the interpretation of human culture. In recent years, with the growth of geoarchaeology as a subdiscipline of archaeological research, scholars have begun to examine contemporary and recent contexts by applying analytical methods from the field of geosciences (e.g., soil micromorphology, mineralogical, elemental, phytolith and isotope analysis) in order to better understand site formation processes and depositional and post-depositional processes. First, this paper explores, as contributions to archaeological sciences, the concept of ethnoarchaeology in general and the emergence of geo-ethnoarchaeology in particular. Second, through examination and synthesis of several key case studies, this paper emphasizes the usefulness of a broad range of laboratory-based analytical methods in linking the archaeological record and human activity. Third, this paper brings together data from recent geo-ethnoarchaeological studies conducted in Africa, South and Central America, Europe and South and West Asia that analyze floor deposits, hearths, degradation of mud houses, use of space, use of plants, animal husbandry and cooking installations. A wealth of information is assembled here to form a reference framework crucial to any study of archaeological materials and sites and for the interpretation of archaeological site formation.

1. Introduction

Ethnoarchaeology has been a well-established subdiscipline within archaeological research for over half a century. The ethnographic component, and especially the availability of direct information regarding human activity in relation to formation of archaeological materials and sites, plays a significant role in forming frameworks of interpretation of archaeological materials and sites (see David and Kramer, 2001, for detailed account on ethnoarchaeology). Geo-ethnoarchaeology is a research strategy applying geological principles and methods in an ethnoarchaeological context in order to link human activities (i.e., within sites and human interaction with the environment) and the formation of archaeological sites and landscapes. The main goal of geo-ethnoarchaeology is to facilitate interpretation of archaeological materials and contexts from a geosciences perspective.

1.1. The Emergence of Geo-Ethnoarchaeology

Although few studies could be considered geo-ethnoarchaeological prior to the 1990s (e.g., Gifford, 1978; Gifford and Behrensmeyer, 1977; McIntosh, 1974), it was during the last decade of the 20th century that geo-ethnoarchaeology became a popular research strategy. This research strategy emerged when several geoarchaeologists sampled sediments from living communities in order to obtain new data that might allow better association of the archaeological record beyond the visible range with past human activity and site formation processes (e.g., Brochier et al., 1992; Goldberg and Whitbread, 1993; Middleton and Price, 1996). In fact, the living context did allow geoarchaeologists to better understand the microscopic materials and chemical residue deposition patterns observed in archaeological sites. Geoarchaeologists were able to observe the complete sequence of events - from human activity to post-depositional processes - that eventually formed the archaeological record and associated specific activities or contexts with microscopic and chemical signatures.

A few pioneering geoarchaeological studies used ethnoarchaeological contexts and methods, and in doing so, they helped to establish geo-ethnoarchaeology as a widely used research strategy. One of the first geoarchaeologists to conduct a detailed study in an ethnoarchaeological context was Jacques Brochier (Brochier et al., 1992). Following his observation of microscopic fibroradial calcitic crystals associated with archaeological dung (Brochier, 1983), he studied with others several cave sites and open-air sites in Sicily that were used for sheep and goat herding. Their study was the first to establish a framework and guidelines for the identification of animal enclosures in archaeology (Brochier et al., 1992). Following this important study, many others embraced a geo-ethnoarchaeological approach to better understand archaeological dung remains (e.g., Elliott et al., 2015; Goren, 1999; Gur-Arieh et al., 2013; Lancelotti and Madella, 2012; Milek, 2012; Portillo et al., 2014; Shahack-Gross et al., 2003, 2008; Shahack-Gross and Finkelstein, 2008; Tsartsidou et al., 2008).

Another example of a pioneering geo-ethnoarchaeological study was performed by Paul Goldberg and Ian Whitbread (1993). They studied earth floor deposits of a living Bedouin tent through a micromorphological analysis of thin sections. They showed the association of specific micromorphological patterns and the presence of various materials within different activity areas (e.g., tent interior and exterior, dung heaps, hearth and refuse areas). In addition, they were able to both evaluate the turbation of the deposits due to post-depositional processes and estimate the ability to identify such patterns and materials in the archaeological record (Goldberg and Whitbread, 1993). Their work formed a methodological framework, later adopted by many others, that called for applying a micromorphological analysis of floor deposits in ethnoarchaeological contexts in order to better understand archaeological floor deposits and site formation processes (e.g., Boivin, 2000; Friesem et al., 2011, 2014a, 2014b; Goodman-Elgar, 2008; Milek, 2012; Shahack-Gross et al., 2003).

William Middleton and Douglas Price (1996) sampled floor deposits from a living house in Mexico. These samples were later analyzed for their elemental composition. Working in an ethnoarchaeological context, their results served as key reference data for associating specific activity areas with chemical signatures. Their work was widely used in later archaeological studies (e.g., Homsey and Capo, 2006; Huston and Terry, 2006; Milek and Roberts, 2013; Parnell et al., 2002; Sarris et al. 2004; Wells, 2004, to mention but a few). The study by Middleton and Price (1996) also inspired others to study living communities in order to evaluate the chemical residues left by human activities and to form a reference dataset of chemical signatures of human activity (e.g., Fernández et al., 2002; Knudson et al., 2004; Knudson and Frink, 2010; Lancelotti and Madella, 2012; Rondelli et al., 2014; Terry et al., 2004).

Although those few studies were influential and significant in laying the methodological foundations of geo-ethnoarchaeology, the wide spread of such an approach can be attributed to the beginning of the 21st century, which saw a major increase in geo-ethnoarchaeological publications. In her doctoral research, Nicole Boivin (2001) used soil micromorphology to study rituals in rural India that resulted in layered patterns of wall plaster. She associated the symbolic aspects of such rituals with the formation of microscopic deposition patterns, as observed by micromorphological analysis, and compared the patterns to similar patterns observed in the Neolithic site of Çatalhöyük (Boivin, 2000). In that aspect, Boivin succeeded in bridging the more 'common' ethnoarchaeology - which focused on symbolic and cultural meanings of material deposition - and micromorphology, which focused on analysis of microscopic deposition patterns. Two years later, Ruth Shahack-Gross published her own work, conducted as part of her doctoral study, in which she studied the formation of enclosure floors for herbivores (Shahack-Gross et al., 2003, 2004). To do so, she sampled sediments from recently abandoned animal enclosures of the Maasai of Kenya. By sampling recently abandoned sites, she could, on one hand, obtain detailed information by interviewing people who personally used the enclosures (e.g., animal type, duration of use, type of use and time of abandonment) and, on the other hand, simulate a near-archaeological setting in sites that were abandoned for more than twenty years since these sites usually had organic material already degraded. In her work, Shahack-Gross combined several methods of analysis to develop guidelines for the identification of animal enclosures in the archaeological context (Shahack-Gross et al., 2003, 2004, 2008). The work of Shahack-Gross and colleagues emphasized the importance and usefulness of using the ethnoarchaeological context to study recently abandoned sites - as opposed to sampling only living contexts - in order to form a near-archaeological setting to better simulate archaeological site formation processes. This approach was later followed in many other geo-ethnoarchaeological studies (e.g., Friesem et al., 2011, 2014a, 2014b; Goodman-Elgar, 2008; Koulidou, 1998; Mallol et al., 2007; Milek, 2012; Tsartsidou et al., 2008; Wilson et al., 2005, 2006, 2008).

2. Theoretical and Methodological Framework

2.1. Ethnoarchaeology

Ethnoarchaeology can be defined as a study embodying a range of approaches to understand the relationship of material culture to culture as a whole, both in the living context and as it enters the archaeological record. The aim of ethnoarchaeology is to exploit such understandings in order to inform archaeological concepts and to improve interpretation (David and Kramer, 2001).

Archaeological research uses various analytical methods to understand the nature of physical remains found in archaeological contexts. In many cases their formation, function and meaning are not known or obvious. In order to enable an interpretation and reconstruction of past human culture, behavior and environment, the archaeological research includes the following stages (Figure 1a): (1) Findings of archaeological physical remains; (2) Scientific analyses such as description and classification of the finds (e.g., typology and seriation), the use of external sources (e.g., texts, art and environmental data), laboratory-based analyses of the materials (e.g., composition, shape, formation and alteration processes, dating, biological data, etc.), experimental tests, application of theoretical models (e.g., economic, ecological and social models) and in some cases the use of what is considered by archaeologists to be reasonable logic; (3) Interpretation and explanation of the function of finds, human behavior at the site and reconstruction of the ancient environment. Overall, archaeology begins at archaeological sites with archaeological finds and moves toward understanding and interpreting human activity and culture. Ethnoarchaeological research does the exact opposite (Figure 1b). In ethnoarchaeology, researchers study living contexts where human activity and culture can be directly observed. Then, by applying similar analytical methods as in archaeology, the researcher is able to understand the nature of archaeological finds and their formation. In that sense, ethnoarchaeology is part of the archaeological scientific analysis aiming to enable better understanding and interpretation of the archaeological record by examining the ties between human activity and culture and archaeological physical finds.

2.2. Geoarchaeology

Geoarchaeology has been an established subdiscipline of archaeological research and an integral part of archaeological sciences for the past half century. The common definition of geoarchaeology is the study, through application of geological principles and methods, of soils, sediments, landforms and stratigraphy in order to investigate archaeological sites and to answer archaeological questions regarding human activity in the past (French, 2003; Renfrew, 1976). Others may emphasize the use of analytical techniques from the field of earth sciences in order to form an integrated model of a geo-environmental system through the use of empirical data obtained from the archaeological record and external sources (Butzer, 1982). Goldberg and

Macphail (2006) subsume the geoarchaeological approach to the study of site formation processes (Figure 2).

The usefulness of an ethnoarchaeological context for geoarchaeologists studying archaeological site formation processes is twofold: (1) to learn how human activity affects the formation of archaeological materials and their deposition patterns, which can be efficiently obtained by observing and interviewing informants as they use or have used the studied materials and/or contexts; (2) for studying the natural and/or environmental factors that affect the deposition patterns and also the post-depositional processes that might preserve, alter or degrade materials. By studying recently abandoned sites, geoarchaeologists can still obtain detailed information regarding human activity. This can be done either by interviewing elders who recall the activity and history of the site, or by reviewing historical documents with detailed direct information regarding the human activity and history of the site. The recently abandoned context produces a near-archaeological setting where researchers can begin to follow the post-depositional and post-abandonment processes occurring at the site and evaluate the influence of the processes on the archaeological record.

The geo-ethnoarchaeological approach emphasizes the importance of fieldwork that allows gathering of information regarding the human activity at and history of the studied site. Gathering this type of information is key to understanding both the natural and anthropogenic site formation processes from a material perspective in general and in particular for materials beyond the visible range. In alignment with the aim of archaeology to reveal the unknown, in geo-ethnoarchaeology known materials and contexts are studied in order to improve our understanding of the archaeological unknown. This approach goes beyond the mere study of deposition patterns since the living context and the information gathered from the people enable better consideration of the human agency affecting the formation of the archaeological record. The living context is used as a context where both anthropogenic and natural factors can be studied from an archaeological perspective. The advantage of geo-ethnoarchaeology lies in its ability to follow the entire sequence of site formation processes from human production, utilization and abandonment of materials until post-depositional processes that preserve or alter the archaeological record at a macroscopic as well at a microscopic scale. Overall, geo-ethnoarchaeology aims to establish a scientific framework on which to base the interpretation of archaeological materials, sites, landscapes and human behavior.

3. Case Studies and Archaeological Implications

Over the years, geo-ethnoarchaeological studies have researched many different materials, activities and processes. To do so, researchers have used various analytical methods and instruments. Geo-ethnoarchaeology as a research strategy, rather than a subdiscipline, forms part of many different geoarchaeological studies. A geo-ethnoarchaeological approach is applied to studying elements of landscape, archaeological materials and processes. In addition, a broad range of analytical methods are being used by geo-ethnoarchaeologists, from field observations to laboratory-based analyses, studying the entire range of archaeological materials, from macroscopic to chemical materials. Basically, the geo-ethnoarchaeological approach aims to study the interaction between human activity and the formation of archaeological materials and sites.

Below, I review some of the key studies that had significant implications for the archaeological research. It is not within the scope of this paper to review the entire collection of studies using a geo-ethnoarchaeological approach, nor to present all the analytical methods used by those studies. The collection of studies presented below was chosen to emphasize the usefulness of such an approach and supply important guidelines for the identification of archaeological materials and processes resulting from geo-ethnoarchaeological studies.

Archaeological sites varied significantly throughout time and place and as a result, geo-ethnoarchaeological studies focused on a wide range of contexts. Due to the limited scope of this paper, I concentrate on domestic contexts, mostly within farming communities with mud architecture. By doing so, I hope to supply a representative example for the overall usefulness of this approach. First, I dwell on the study of mud structures' degradation processes as an example for studying site formation processes by applying field-observations and macroscopic, microscopic and chemical analysis. Then, I move to focus on a specific feature within such a context that bears significant importance to archaeologists – earth floors – and how one can link invisible materials with human activity. First, I describe studies which examined the microscopic characteristics of floors and activity areas. Later, I move to describe studies which investigated the chemical characteristics of floors that resulted from human activity. The fourth and fifth sections present two different materials which attracted a lot of attention among geoarchaeologists. The first is the study of animal dung which to a large extent was developed and introduced to geoarchaeology through the study of ethnoarchaeological contexts. The study of animal dung presents a good example of the contribution of geo-ethnoarchaeology to the study of archaeological materials and the usefulness of applying a broad range of analytical methods. The last section focuses on combustion features. Here I emphasize how geo-ethnoarchaeological investigation can provide crucial insights when interpreting the archaeological record. This case study presents the potential in geo-ethnoarchaeology for developing new analytical methods.

3.1. Degradation of mud structures

Mud architecture forms one of the common domestic contexts studied by archaeologists. Yet, in many cases the archaeological context does not present intact mud structures. As opposed to stone construction, mud is less durable and therefore easily degrades with time. This poses a serious problem to archaeologists since by the time they unearth the site, most of the structure cannot be traced and, in many cases, only some poor remains of the house foundations are visible to excavators. Geoarchaeologists, studying earth-based materials, are interested in understanding the process of mud structure degradation and the archaeological site formation processes that result from mud structure weathering. Since archaeological contexts exhibit the degradation process at its end, some geoarchaeologists have turned to ethnoarchaeological contexts, where semi-degraded mud structures at various stages of decay can be studied and the complete sequence of degradation can be followed. The main objective of geo-ethnoarchaeological studies of mud structure degradation is twofold: (1) to understand how the degradation and devolution of mud houses after their abandonment affect preservation of the archaeological record, and (2) to supply guidelines for the identification of archaeological materials (i.e., mostly sediments) resulting from this process.

Roderick McIntosh (1974) conducted one of the first ethnoarchaeological studies using a geoarchaeological approach in Ghana in the 1970s. He studied the decay of mud walls and made an important field observation when he found that water, which moved up the walls, contained salts that undercut the lower parts of the walls. In addition, McIntosh (1974) found that the accumulation and formation of mounds was directly associated with the decay of the mud walls. Agorsah (1985) also observed the role of water as the main agent of degradation of mud walls while studying mud structures in a different area in Ghana. He also described and emphasized the importance of mud wall maintenance. Using particle size analysis, Sophia Koulidou (1998) conducted a geoarchaeological study of mud brick degradation in a recently abandoned structure in Greece. Within the structure, she observed the formation of a U-shaped mound with finer particles in the center of the room, and larger amounts of sediments accumulating near the walls, which formed a talus. Although those studies presented important observations, they did not supply information regarding the effect of degradation processes on preservation of the archaeological record, nor did those studies supply guidelines for archaeologists to identify degradation processes in archaeological sites.

In Bolivia, Melissa Goodman-Elgar (2008) conducted a detailed micromorphological study of mud dwellings in various stages of decay, coupled with ethnographic information, regarding the use and activity that took place in each structure and the time of abandonment. She observed that degradation was enhanced following roof collapse and that rising dampness caused lower parts of the walls to suffer from severe decay. Most importantly, Goodman-Elgar (2008) related the accumulation of organic matter from collapsed roofs to soil faunal populations, which are attracted by the organic matter and in turn, through bioturbation, contribute significantly to site destruction. As a result, unless exposed to heat, identifying degraded mud brick material (also termed adobe melt in the New World) became almost impossible. And though there was some indication of hearths and pyrogenic activity in the form of charcoal and ash, the remains of animal dung confounded identification even further, as the dung could not be conclusively identified as fuel or droppings from animals that had used the house as a shelter post-abandonment (Goodman-Elgar, 2008).

Following Goodman-Elgar's work, Friesem et al. (2011, 2014a, 2014b) conducted a study of mud brick degradation processes in recently abandoned structures in two locations within the Eastern Mediterranean: arid southern Israel and temperate northern Greece (Figure 3). By using ethnographic information regarding each house studied, it was possible to compare the houses that were abandoned and left to gradual decay, houses later used as animal shelters and houses abandoned following a sudden destruction event, such as conflagration. The ethnoarchaeological context allowed Friesem et al. (2011, 2014a) to follow mud bricks in different stages of weathering, including preserved intact bricks, bricks showing features of initial degradation, and sediments infilling the decayed structure that resulted from complete degradation of the mud walls. Applying mineralogical and elemental analysis (using Fourier-

Transform Infrared Spectroscopy and X-ray Fluorescence, respectively) on sediments from the decayed house and the surrounding environments, they could identify degraded mud brick sediments within the various sediments infilling the decayed houses (Friesem et al. 2011). Applying micromorphological analysis helped to reveal the mechanism behind the degradation process of mud bricks in the different environments and their implications for site formation processes (Friesem et al. 2011; 2014a; 2014b). They showed how in arid environments, the accumulation of wind-blown sediment played a major role in the degradation of bricks, while in temperate environments bricks degraded much more rapidly due to higher amounts of precipitation. In both cases, mud wall degradation formed a talus from both sides of the weathered wall. As suggested by Friesem et al. (2011, 2014b), this talus formation promoted better preservation of activity remains near the walls, as the remains became buried under the rapidly accumulating degraded mud brick sediments. Conversely, remains deposited in the center of the room were less preserved. This study supplied guidelines for the identification of archaeological infill sediment as degraded mud brick material later used in archaeological sites (e.g., Regev et al. 2015).

Geo-ethnoarchaeological evidence has proven that mud structure degradation is the most significant factor in the formation of archaeological mounds; the majority of infill sediments in archaeological sites of former mud houses are composed of degraded construction materials. Goodman-Elgar (2008) and Friesem et al. (2011, 2014a) supplied invaluable information regarding the archaeological site formation processes resulting from degradation of mud structures and were among the first to supply indicators for the identification of degraded mud construction materials. In addition, those studies showed how the time of roof collapse, abandonment type, secondary use and environmental setting influence the preservation of activity remains deposited on floors (Friesem et al., 2011, 2014a, 2014b; Goodman-Elgar, 2008).

3.2. Floor deposits and Activity Areas

Floors always have been of special interest to archaeologists. It is on the floor that evidence of human activity is deposited, and hopefully, left for archaeologists to reveal, study and reconstruct the human behavior at the site. Yet, in many archaeological sites, the evidence is often scarce or patchy. The biggest challenge archaeologists face is to distinguish between evidence of absence (i.e., people did not act in a certain way, which left no traces whatsoever) and absence of evidence (i.e., activity remains were deposited on the floor but post-deposition processes erased any traces). The most efficient way to investigate such challenges is by observing the depositional patterns and post-depositional processes that occurred on various activity remains deposited on floors. In addition, not all human activities result in the production of residues that can make their way into floor deposits. In order to understand the relations between certain human behaviors and the formation of archaeological deposits, several geoarchaeologists have turned to ethnoarchaeological contexts where they could follow the complete sequence of deposition and post-deposition processes. The ethnoarchaeological context allows documenting a wide range of human behavior (e.g., primary activity, maintenance practices, abandonment patterns, etc.), sampling and identifying the resultant deposits on floors and finally evaluating and understanding various post-depositional processes which alter and form the archaeological record of occupation surfaces.

Various studies, applying different methodologies, investigated the formation of archaeological floors and supplied guidelines for their identification (Table 1). In addition to geoarchaeological studies that examined preserved archaeological floors or experimental earth floors (e.g., Courty et al., 1994; Gé et al., 1993; Karkanas and Efstratiou, 2009; Macphail et al., 2004; Matthews et al., 1997; Rentzel and Narten, 2000), a few studied floors in an ethnoarchaeological context. Paul Goldberg and Ian Whitbread (1993) sampled a Bedouin tent floor and its surrounding activity surface. In this ethnographic context they were able to obtain information regarding various activity areas and associate them with the microscopic remains they observed in their floor samples. They observed a general difference between areas with intense human activity (i.e., hearth and dung heap) as opposed to limited ‘cultural affect’ (i.e., sleeping areas, general activity areas and the kitchen) in which the former consisted increased amounts of vegetal matter, ash and charcoal, while the latter were more compact, with smaller pore sizes and less turbation. They traced depositional pattern differences between the dung heap and other contexts. They also observed the post-depositional process of bioturbation, which resulted in pronounced aggregation of sediments, especially in the hearth and dung heap, where larger amounts of organic matter were initially deposited. Considering the fact that Goldberg and Whitbread (1993) pioneered the application of soil micromorphology in an ethnoarchaeological context, they managed very well to demonstrate the usefulness of soil micromorphological analysis to reconstruct depositional and post-depositional processes.

In a recently abandoned farmhouse in Iceland, Karen Milek (2012) applied the same technique in her detailed study on floor formation and floor deposits. By interviewing local people and observing their activities, she associated different practices related to floor preparation and maintenance with samples she collected from various abandoned floors. Her observations supplied important implications for archaeologists studying floor deposits. Milek (2012) showed how floor deposits, studied post-abandonment, are mainly driven from maintenance practices (e.g., sweeping, shoveling, repairing of roof, ash deposition, etc.) known to remove or alter any trace of other daily or economic activities that at one point took place on the floors. Only a few activities associated with large amounts of organic materials, such as animal stabling and the storage of organic matter (i.e., fuel), have the potential to produce a genuine diagnostic residue when deposited directly on the floor surface. She concluded that although certain kinds of activities might also leave diagnostic residues, archaeologists cannot take for granted that the spatial distributions of artifacts, organic residues, ashes, charred remains, or their associated elements are a direct result of the use of a particular space. Forbes and Milek (2014) examined in the same context the role of insects in bioturbation of floor deposits and assessed the association between insect type and function of rooms. Overall, they found it very difficult to identify room function based on entomological signatures alone.

Studying floor deposits in an ethnoarchaeological context, Friesem et al. (2014b) noted that the layer we initially identified as floor, which included activity remains, actually contained roof remains as well. The identification of the millimeters thick floor-roof complex, containing the activity floor surface, the activity remains and the collapsed roof remains, bears significant implications for archaeologists as it questions whether the analysis of so-called ‘floor deposits’ in archaeological sites reflect activity remains, roof remains or a mixture of both. Different layers within the floor-roof complex were identified thanks to detailed ethnographic information on the type of plants used as construction materials for the roof and the type of plants used as fodder and stored in rooms. Using a geo-ethnoarchaeological approach, the formation of a floor-roof complex could have been conceptualized, to be later applied in the challenging archaeological record (Regev et al. 2015).

Similar to Goldberg and Whitbread (1993) and Milek (2012), Friesem et al. (2014b), observed much better preservation of diagnostic activity residues associated with rich organic matter. In addition, houses in which the roof collapsed rapidly after abandonment or due to conflagration events caused the fast burial of residues deposited on the floor surface and thus enabled better preservation. Cases of planned abandonment, gradual house decay, initial maintenance practices, secondary use, post-depositional processes and exposure to the elements left very scarce evidence of activity remains which were once deposited upon and within the floors.

Using a different analytical method, Georgia Tsartsidou and colleagues studied phytolith assemblages (i.e., a silicate mineral formed in plants that reflects the plant's cell shape) in an agro-pastoral village in northern Greece. With the help of informants and observations, Tsartsidou et al. (2008) obtained high-resolution information regarding the use of plants and activities in each location sampled. They developed a new method of quantifying the differences in the phytolith assemblages when compared to regional control samples (i.e., areas with no human activity in the same geographical area). Using the Phytolith Difference Index (PDI), Tsartsidou et al. (2008) identified different uses of space in the village. Regional samples were similar to those of construction materials and living areas that were repetitively swept. Storage areas showed diagnostic evidence of cereal storage, while areas of stabling and feeding domesticated animals differed significantly from the former. Hearths and areas with dispersed ashes also were identified according to their low amount of indicative phytolith. Overall, they could differentiate between storage and living areas and between areas associated with animal stabling and feeding and areas of cereal processing and storage. The PDI method could have been developed only by the use of the ethnographic information in direct association with microscopic analysis. Once it was developed, Tsartsidou et al. (2009) used this method and the data obtained from the geo-ethnoarchaeological context to study the phytolith assemblages in the Neolithic site of Makri, at the same region as their aforementioned geo-ethnoarchaeological study. They showed that both agricultural and pastoral activities, involving mainly wheat and barley cultivation and use as animal fodder, were conducted in the site during the Neolithic period (Tsartsidou et al., 2009).

3.3. Chemical signatures of human activity

A common method used by archaeologists to detect diagnostic residues of human activity is the analysis of elements and phosphate concentrations found in floor sediments in archaeological sites (Goldberg and Macphail, 2006; Wilson et al., 2009). Geo-ethnoarchaeological studies took advantage of ethnographic information in order to associate specific activities with the resulting elemental signatures in floor deposits (Table 2). One of the pioneering studies of chemical signatures related to human activity was conducted by William Middleton and Douglas Price (1996). In their study, they first analyzed the elemental composition of floor sediments from a living house in Mexico. They used their results from the geo-ethnoarchaeological context as reference data for interpreting activities that took place in a nearby archaeological site and another archaeological site in Canada. The ethnoarchaeological part of their research was crucial in order to associate specific chemical signatures with corresponding activities or settings. Middleton and Price (1996) were able to identify two major chemical signatures at the living house that were also present in the archaeological contexts (Table 2). The first was a chemical signature associated with food processing and burning, mostly due to the presence of wood ash. Although waste areas were not sampled, they suggested that these would also exhibit similar chemical signatures. A distinctive chemical signature was associated with covered, enclosed spaces formed by people's cleaning practices, which remove ash and organic matter from the house floor.

Studying activity areas by chemical analysis in the Q’eqchi’ Maya village of Las Pozas, Guatemala, Fabián Fernández and colleagues (Fernández et al., 2002) sampled two living houses and one abandoned house. Their results exhibited a different chemical signature, aiding them in differentiating cooking/food processing areas from other areas associated with eating/food consumption (Table 2). Garden areas showed the deposition of organic and modern metal materials. Refuse disposal areas were also rich in chemical contents, as well as in disposal of modern metal materials. The pathway and patio areas showed lower concentrations of elements that were present in higher levels in other areas, probably due to maintenance activities such as sweeping (Fernández et al., 2002). While mentioning the usefulness of phosphate concentrations and pH levels to identify areas associated with food processing and consumption, Fernández et al. (2002) pointed out that in tropical environments, concentrations of K, Mg and trace elements may be quickly leached from the soils, as exhibited from their analysis of the old house they sampled. Since the rates of accumulation and depletion of specific elements vary according to soil properties and climates, Fernández et al. (2002) emphasized the importance of considering and calibrating chemical signatures of floors according to the environment.

Following the study of soil chemical signatures in ethnoarchaeological and archaeological sites in Guatemala (Fernández et al., 2002; Parnell et al., 2002), Richard Terry and colleagues (Terry et al., 2004) applied a similar methodology in a recently abandoned guardhouse. Subsequently, they compared their results with samples they collected from the adjacent Mayan archaeological site dating to the 9th century A.D. (Table 2). Terry et al. (2004) identified disposal areas (i.e., in the form of middens) and areas of food processing, which were located adjacent to the house's exterior. The presence of high levels of heavy metals in the guards' structures were associated with filing machetes and disposing of flashlight batteries. In contrast, high concentrations of these elements in the archaeological contexts were associated with the use of mineral pigments and craft activities. Their research showed that the activities of the ancient Mayan inhabitants left chemical imprints, providing clues to revealing past practices and space use, which are difficult to judge from the artifact record alone (Terry et al., 2004).

Kelly Knudson and Lisa Frink and others investigated the chemical signature in soils from ethnoarchaeological contexts of arctic seasonal fish camps in the Yukon–Kuskokwim Delta in western Alaska (Knudson et al., 2004) and later on Nelson Island (Knudson and Frink, 2010) in western Alaska as well. Their studies presented a chemical signature produced by fish processing activities (Table 2). By studying several camps with different durations of occupation, they showed that length of occupation is associated with the strength of anthropogenic soil signatures (Knudson et al., 2004). In addition, they were able to distinguish between fish processing areas and offsite areas, probably as a result of marine products incorporated into the soils near fish processing areas (Knudson and Frink, 2010).

Rondelli et al. (2014) conducted a geo-ethnoarchaeological study in a domestic unit of rural India. They collected sediment samples from the earth floors of a living house and its exterior veranda, and they observed and recorded different activities that took place in each space and could associate each with a chemical signature and test various statistical models and their implications on the association of chemical signatures with human activity. Rondelli et al. (2014) showed how different areas such as sleeping, storage and food processing areas (i.e., preparation of food, cooking and eating) inside the house and the exterior veranda, where a hearth was used for cooking as well, had produced a chemical signature (Table 2). Yet, applying statistical models, they concluded that identification of single events is archaeologically rarely possible, but repetition of the same activity in a specific area can create spatial variability (concentrations or tendencies) of a residue.

Clare Wilson, Donald Davidson and Malcolm Cresser performed a series of studies (Wilson et al., 2005, 2006, 2008) in which they sampled soils from abandoned historic farms across the UK. They applied a geo-ethnoarchaeological approach at those sites, since direct information regarding the location and type of human activities in each farm was available to them. In addition, because they were abandoned for 60-100 years, these contexts provided significant information regarding the post-depositional processes affecting chemical concentrations in floors. They tested the relationships between element concentrations and known functional areas (Wilson et al., 2005, 2006, 2008) and assessed the variability between the different sites they sampled and the post-depositional processes affecting the chemical signatures in soils (Wilson et al., 2008, 2009). When compared to off-site soil overall, their results (Table 2) clearly exhibited chemical traces in direct association with areas with intensive human activity, such as hearths, houses and byres (Wilson et al., 2005, 2006, 2008). While Ti, Ni and Fe concentrations were found to be influenced by site, Ca, Zn and P were less influenced by site and more associated with specific functional areas (Wilson et al., 2008). An important contribution of their work is their study of the post-depositional effects on the enrichment of these elements as anthropogenic markers (Table 2). They emphasized how, even though sites were located in similar geological settings with similar human activity, each site produced its own unique elemental composition (Wilson et al., 2008, 2009). They reported that a pattern of distinct elemental fingerprints will be damaged due to mixing of materials with the local soil (Wilson et al., 2008). In addition, post-abandonment anthropogenic activities, such as secondary use or cleaning, significantly affected concentrations of elements used as anthropogenic markers (Wilson et al., 2009). Wilson et al. (2009) suggested the use of a model based on a range of studied geo-ethnoarchaeological sites of the same geological environment over the application of general models or one-to-one comparative models. Nevertheless, geo-ethnoarchaeological studies are the main source of reliable comparative data for associating human activity with chemical signatures found in archaeological sites.

3.4. Animal dung

Animal dung, and in particular herbivorous livestock dung, is valuable archaeological material, as it embeds information regarding animal husbandry, agro-pastoralism and pastoralism, domestication and use of animals, exploitation of the environment, reconstruction of the paleoenvironment, domestic use of fuel, activity areas, site structure and finally archaeological site formation processes (for detailed review on archaeological dung, see Shahack-Gross, 2011). Geoarchaeologists adopting a geo-ethnoarchaeological approach have made significant contributions to the study of human activity associated with human husbandry and the use of animal dung. By bringing together the results of several geo-ethnoarchaeological studies, a comprehensive model for identification of archaeological dung was produced (Figure 4). In addition, a localized approach points out the usefulness of combining ethnoarchaeological methods when studying archaeological sites in specific environments.

One of the first geo-ethnoarchaeological studies was conducted by Jacques Brochier and colleagues (Brochier et al., 1992). They studied contemporary sheepherding caves and open-air sites in Sicily in order to provide diagnostic nonfaunal criteria for the identification of herding activities in prehistoric sites. This study was initiated following a previous study, also by Brochier (Brochier, 1983), in which he associated the presence of microscopic calcitic fibroradial crystals - termed 'dung spherulites' - with archaeological deposits of herbivore dung. In their geo-ethnoarchaeological study, Brochier et al. (1992) used sites known for sheepherding activity to establish a methodological framework for the identification of archaeological dung and herding activities. They found several durable mineral residues that served as indicators of dung deposited in animal enclosures. Studying caves and rock shelters used for sheep and goat herding, they mentioned the presence of spherulites, phytoliths, layers of burnt dung and rock polish produced by animal fleece and hooves on cave walls and stone blocks. In some cases, they used architectural features such as stone walls enclosing stock pens as complementary evidence of animal pens or enclosures. According to their study, spherulites also can be found in open-air sites but tend to preserve better under a roof or following fast burial. They observed in a few cave sites that gypsum resulted from the former presence of vegetal matter. In addition, they suggested that a distinction between goat and sheep enclosures can be made based on the former exhibiting the presence of spherulites, low or total absence of phytoliths and rock polish in difficult-to-reach areas (Brochier et al., 1992).

Following Brochier et al. (1992), Yuval Goren (1999) sampled several caves and open-air dung deposits of contemporary wild animals in Israel. Goren's (1999) study sampled sediments and dung deposits from cave sites and open-air sites in nature reserves at which specific wild animals are known to be present. Spherulites were found in non-domesticated animals: pigeon, ibex, gazelle and a few in rat dung. Other samples from hyrax and fruit bat did not contain spherulites. Goren (1999) noted that dung spherulites should not be used solely as indicators of the presence of domesticated animals in archaeological sites, as some wild animal dung also contained spherulites.

Shahack-Gross et al. (2003, 2004, 2008) conducted one of the most profound geo-ethnoarchaeological studies in general and regarding archaeological dung and livestock enclosures in particular. Aiming to identify and define durable indicators of livestock enclosures, they gathered ethnographic information based on interviews with local Maasai informants and sampled sediments in and around currently occupied and recently abandoned livestock enclosures. They sampled both enclosures associated with cattle and enclosures used for caprine, ranging in ages between one and forty years post-abandonment coupled with regional samples as controls (i.e., sediments that lack anthropogenic remains and therefore serve as a background representing the natural environmental setting prior to human activity). As mentioned by the geo-ethnoarchaeological work of Goren (1999) regarding dung spherulites, Shahack-Gross et al. (2003) determined that using one analytical technique, or the presence of one microscopic material associated with dung, alone is not sufficient to definitively identify an enclosure and hence pastoralist occupation. Shahack-Gross et al. (2003, 2008) showed how a combination of micromorphological features, mineral distributions and phytolith concentrations together can identify livestock enclosures in open-air sites. They describe the indicators of animal enclosures as: (1) unique microlaminated wavy structures observed in soil micromorphological analysis, in some cases in addition to presence of dung spherulites, phytoliths and degraded organic matter; (2) relatively high concentrations of minerals derived from livestock dung, such as monohydrocalcite (i.e., the mineral which dung spherulites are composed of). In sites of poor preservation, Mg-rich calcite and/or phosphatic minerals would appear as indication for degraded dung material; (3) high concentrations of phytoliths (>2million phytoliths per 1gr sed), though analyzing the phytolith morphologies could not differentiate for them cattle from caprine enclosures; and (4) enrichment of heavy nitrogen isotopes in enclosure sediments as compared to regional soils. Studying the carbon isotopic compositions was found useful for differentiating cattle from caprine enclosures due to their dietary preferences (i.e., grazers versus browsers). Finally, they used their geo-ethnoarchaelogical data for regional archaeological comparison in which they reconstructed human activity and use of space among Neolithic pastoral sites in Kenya (Shahack-Gross et al., 2004). This localized approach, combining an initial ethnoarchaeological study followed by comparative study in nearby archaeological sites, became common methodology in geo-ethnoarchaeology (e.g., Elliott et al., 2015; Middleton and Price, 1996; Milek, 2006; Milek and Roberts, 2013; Portillo et al., 2014; Shahack-Gross and Finkelstein, 2008; Terry et al., 2004; Tsartsidou et al., 2009).

While working in living villages in rural north India, Carla Lancelotti and Marco Madella (2012) sampled numerous dung cakes while documenting their production and use. Their study involved chemical analysis and studying the distributions of both phytolith and spherulite concentrations. The ethnographic observations and information they gathered aided them in characterizing phytolith assemblages according to stages of crop processing, their products and their by-products. Lancelotti and Madella (2012) showed that phytolith assemblages composed mainly of leaves and stems were associated with animal fodder as by-products of the early stages of crop processing (i.e., the fodder was used for feeding domesticated animals and therefore phytolith assemblages composed of leaves and stems would be expected in domesticated animal dung remains). On the other hand, assemblages associated with inflorescence phytoliths were associated with storage and advanced stages of crop processing (i.e., as those are the plant parts that are commonly used for human consumption, such as the case of cereals). In addition, the ethnographic context supplied them information regarding the process of producing and using dung cakes as fuel. Their analyses showed that the phytolith content of dung cakes is mostly associated with grass leaf/stem phytoliths (ca. 95%) and very few inflorescence and woody phytoliths. They found very few spherulites in their dung cake samples. Based on this important observation, they stated that the lack of spherulites could not be taken as absence of dung input. Studying the elemental composition of each dung cake sampled, they aimed to verify if indicative elements are affected by factors such as location of site, type of fodder, type of animal and if fresh or burnt. By performing a statistical analysis, they showed that the only significant factor was whether the dung was fresh or ashed. Overall, Lancelotti and Madella (2012) presented how the combination of phytolith and chemical analysis could be a reliable proxy for the inference of dung presence in archaeological contexts (Figure 4).

In addition to the above studies, which aimed to produce general guidelines for the identification of archaeological dung remains, a more localized approach has emerged (see also Shahack-Gross et al., 2004). Ruth Shahack-Gross and Israel Finkelstein (2008) studied early Iron Age settlements in arid southern Israel. In order to understand the archaeological deposits, they incorporated in their study a geo-ethnoarchaeological approach in which they sampled reference materials collected from recently abandoned Bedouin camps in the same region (i.e., two sites were sampled: one abandoned for only few weeks, and the other for more than twenty years). Their ethnographic study supplied them information about animal types, their diet, location of enclosures, duration and season of use and time since abandonment. Using this geo-ethnoarchaeological data, they reported similarities between the phytolith assemblages in their archaeological samples and the ethnoarchaeological dung samples associated with winter free-grazing desert livestock and lichen-grazing black dwarf goats. In addition, the presence of spherulites and wood ash suggested the use of wood and dung as fuel materials. Based on ethnographic and archaeological parallels and on the absence of phytoliths associated with crop processing, they suggested that the early Iron Age site was most probably used by pastoralists who subsisted on livestock herding (Shahack-Gross and Finkelstein, 2008).

In northeastern Syria, Marta Portillo and colleagues (Portillo et al., 2014) adopted a geo-ethnoarchaeological approach to study phytolith and dung spherulite content and their spatial distribution in domestic contemporary structures. Their overall aim was to improve the interpretation of household activity during the Neolithic period in the nearby site of Tell Seker al-Aheimar. Using information regarding the phytolith assemblages and spherulite content associated with each activity area, Portillo et al. (2014) were able to use their results as a reference framework to better understand early farming communities in this region. The relation between phytoliths and spherulite content, as inferred from ethnoarchaeological data, allowed them to identify in the archaeological site that vegetal matter was deposited in domestic structures due to use of animal dung and agricultural products and by-products, such as crop storage, fodder, building materials, animal dung and fuel material. Household debris included construction materials, crop processing remains and fuel residues, and that fuel was obtained from a mixture of dung and plants (Portillo et al., 2014).

In the lower Zagros Mountains of Iraqi Kurdistan, Sarah Elliott and colleagues (Elliott et al., 2015) explored how living families used and managed their livestock within the local landscape. Elliott et al. (2015) also explored how to identify traces of such activity. Conducting detailed ethnographic fieldwork, they gathered information on the behavior of several households in the area (in some cases over a time span of 70 years) and noted shifts in practices and uses of the local landscape over time. Comparing dung remains of different species, they found variation in spherulite production, phytolith concentration and phosphorus values across samples originating from different animal species. They concluded that the above materials could not be used for archaeological interpretation of animal dung to species. Yet, they mentioned that their results exhibited some degree of difference in phytolith morphologies between sheep/goats and cows. This was due to the diet preferences of the animals. Sheep/goats produced more spherulites than cows. The result of their analysis of strontium isotopes helped them see variation in the physical environment, which differentiated between the alluvial floodplain and the lower foothills. This localized approach involving geo-ethnoarchaeological methods was initiated by Elliott et al. (2015) to be used as reference material for comparative purposes for their future research on the archaeological evidence in the area.

3.5. Hearths and Cooking Installations

Combustion features are of interest to archaeologists. Inorganic materials exposed to high temperatures tend to preserve better in the archaeological record and, as a result, provide significant information regarding human pyrogenic activity (Weiner, 2010). As mentioned above, some geo-ethnoarchaeological studies included examinations of hearths and kitchen floors, yet two studies focused specifically on the archaeological formation processes related to hearths and cooking installations (Gur Arieh et al., 2013; Mallol et al., 2007). They were able to supply important observations and guidelines for identifying human activity associated with pyrotechnology and the taphonomic processes combustion features undergo.

Carolina Mallol and colleagues (Mallol et al., 2007) sampled five different types of hearths used by the Hadza, a hunting and gathering group in eastern Africa (Table 3). Mallol et al. (2007) analyzed blocks collected from each hearth using soil micromorphology analysis. Together with detailed ethnographic data regarding the Hadza's use of fire, they were able to relate each of their samples to the different use of each hearth and its location, duration of use and time since abandonment. While they observed that even a short duration of use (15-20 minutes) left indicative features, similar hearths after a year from their time of abandonment showed poor preservation of these indicative residues, mainly due to wind and rain erosion and invasion of roots. By comparing the post-depositional processes occurring in various hearths, Mallol et al. (2007), concluded that, when hearths were located inside huts or other shelters, they were protected from wind and rain and therefore had increased chances of better preserving indicative burnt features in comparison to open-air hearths. In cases where organic matter was also preserved, they were able to determine the function of the hearth.

In rural Uzbekistan, Shira Gur-Arieh and others (Gur-Arieh et al., 2013) studied earth-based installations, cooking practices and the use of wood and dung as fuel. The ethnoarchaeological context enabled them to conduct experiments in a context more similar to archaeological sites than if the context were reconstructed in laboratory conditions. They measured the temperatures within the cooking installations over time and sampled their walls, the raw earthy materials they were built from and the different fuel materials used. They showed that there was no significant difference in temperature pattern over time across various cooking installations and different fuel types. Although the installations reached temperatures as high as 800˚C, after ca. 20 minutes, temperatures usually dropped rapidly, as the actual cooking temperatures leveled out around 350-250˚C. Yet, when measuring the walls of clay-based installation using Fourier-Transform Infrared (FTIR) spectroscopy, the interior part of the installation showed signs of clay mineral alteration associated with the maximal temperature that the walls were exposed to (>800°C), much higher than the actual cooking/baking temperature. The exterior walls, on the other hand, showed no signs of clay mineral alteration due to burning, suggesting the use of fire and burning of fuel just at the installation interior. In an attempt to investigate the fuel type used in cooking installations, Gur-Arieh et al. (2013) showed that phytolith analysis was not sufficient, as both dung and ash samples used as fuel exhibited similar phytolith assemblages, probably due to some degree of mixing. To overcome this problem, they sampled each fuel material separately before inserting it into the installations and then after it was used for cooking/baking (e.g., in its ashed form). Later, they compared their initially separated samples with gradually mixed samples. This allowed them to develop a new method to better differentiate between two calcitic microscopic remains, each indicative for a different type of fuel (i.e., calcitic wood ash pseudomorphs for wood fuel and calcitic dung spherulites for dung cake fuel) (Figure 5). This method significantly improved the ability of geoarchaeologists to identify the type of fuel used in archaeological combustion features. This method could have been developed only within the experimental near-archaeological conditions that the ethnoarchaeological context supplied. Their result was later used in order to interpret Iron Age cooking installations and the taphonomic processes of those installations (Gur-Arieh et al., 2014).

4. Conclusions

The emergence of the geo-ethnoarchaeological approach is a continuation and reflection of the direct relation between ethnography and archaeological research between archaeology and geosciences. In past few decades, the establishment of geoarchaeology as a subdiscipline of archaeology has called for the development of more methodological frameworks and comparative reference data sets. Geo-ethnoarchaeology should be perceived as part of a geoarchaeological research in which researchers work among living communities and recently abandoned sites where direct information can be gathered in order to facilitate the association of human behavior and the formation of the archaeological record. The growing number of studies incorporating a geo-ethnoarchaeological component in their studies have proven the approach's usefulness for building interpretative frameworks of reference to understand deposition and post-deposition processes and the formation of archaeological materials and sites. The strength of the geo-ethnoarchaeological approach lies in its ability to bridge the archaeological material record with human agency, human behavior and the dynamic of a culture as a whole. Geoarchaeologists should make use of ethnographic data and the application of a broad range of analytical methods to better understand the archaeological record.

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Table 1

Table 1: Key features for identification of archaeological floors according to geo-ethnoarchaeological studies.

Scale	Proxy	Data	Remarks	Reference
Macroscopic	Architectural features	Lime plaster Mud plaster Stone pavement		Boivin 2000, 2001
	Activity remains	Plants remains Bones Artifacts (lithic, ceramic, metal, etc.) Charcoal Ash	The presence of macroscopic activity remains depends on the type of human activity (not all activities result in material deposition and maintenance practices can remove primary remains) and type of abandonment (i.e., planned abandonment, sudden destruction event, gradual abandonment, etc.) Activity remains can also be found in waste areas	Agorsah, 1985; Boivin 2000, 2001; Friesem et al. 2011, 2014b; Goldberg and Whitbread 1993; Mallol et al. 2007; Milek 2012; McIntosh 1974; Tsartsidou et al. 2008
Microscopic	Occupation deposits	Artifacts fragments Bones fragments Seeds Phytoliths (construction material, human use of plants or fuel)	See remark above regarding macroscopic activity remains Occupation deposits can also be found in waste areas (i.e., middens)	Friesem et al. 2011, 2014b; Goldberg and Whitbread 1993; Milek 2012; Tsartsidou et al. 2008
		Coprolites dung spherulites (in enclosures or used as fuel)	Can also be found in animal enclosure surface	Shahack-Gross et al. 2003, 2008
		Microcharocoals Wood ash pseudomorphs	Can also be found in combustion features	Gur-Arieh et al. 2013; Mallol et al. 2007;
	Micromorphology	Prismatic or a platy microstructure	Indication for trampling	Friesem et al. 2011, 2014b; Goldberg and Whitbread 1993; Goodman-Elgar 2008; Milek 2012; Shahack-
		Iron mobilization and reprecipitation	Possible indication for animal enclosure surface	

				Gross et al. 2003
		Upper reactive zone showing disaggregation with sub-horizontal cracks	Can also be caused due to bioturbation	
Chemical	Elements	High levels of P, K and Mg	Associated with deposition of organic matter often interpreted for areas of food processing and food consumption or middens	Fernández et al. 2002; Middleton and Price, 1996; Rondelli et al. 2014; Terry et al. 2004; Wilson et al. 2005, 2006, 2008
			With high levels of Ca, could indicate animal enclosure surface	Shahack-Gross et al. 2003; Wilson et al. 2008
		High levels of Ca, Sr and Na	Enclosed spaces (P is removed due to maintenance)	Middleton and Price, 1996; Rondelli et al. 2014

Table 2

Table 2: Highlights from geo-ethnoarchaeological studies of chemical signatures related to human activity.

Reference	Location of study	Ethnoarchaeological Context	Chemical Signature (elevated concentrations of elements)	Remarks
Middleton and Price 1996	Mexico	Food processing and burning	P, K, Mg	Dominated by wood ash presence
		Enclosed spaces	Ca, Sr, Na	P removed by maintenance and cleaning practices in the interior house spaces. Ca-Sr associated with the use of lime, dried maize and water.
Fernández et al. 2002	Guatemala	Food processing (cooking area)	P, K, Mg, high pH	Deposition of ash and maize soaking water
		Food consumption (eating area)	P, K, Mg, low pH	
		Gardens	P, Zn, low pH	Deposition of organic matter and modern metal waste
Terry et al. 2004	Guatemala	Food processing, consumption, and disposal	P	Deposition of organic matter in kitchens and middens
		Filing of machetes and disposal of batteries	Zn, Fe	Archaeologically associated with the use of mineral pigments and craft activities
Knudson et al. 2004	Alaska	Fish processing	Na, P, K, Mg	Length of occupation directly affected the strength of the anthropogenic chemical signature
Knudson and Frink 2010	Alaska	Fish processing camps	Low Ba/Sr, Ba/Ca, and Sr/Ca	Marine products incorporated into the camp's soil
		Off-site areas	High Ba/Sr, Ba/Ca, and Sr/Ca	

Rondelli et al. 2014	India	Food processing and food deposits	P, K, Mg, Ca, Sr and fatty acids	
		Burning areas	P, K	Distinction between type of fuel deposited near/within the hearths done according to: Dung: Al, Ba, Ca, Co, Cr, Fe, Mn, Mo, Ni, Pb, P (see Lancellotti and Madella 2012) Wood Ash: Ca, K, Mg, Al, P (see Milek and Roberts 2013)
		Sleeping and storage areas	Ca, Sr and protein	
Wilson et al. 2005, 2006, 2008	UK	Intensive anthropogenic activity (in decreasing concentrations order): hearths, houses, byres, middens, gardens and arable fields.	Ba, Ca, Zn, Cu, Sr, Pb P (highest in byre)	An obscure pattern of distinct element fingerprints can be caused due to mixing of materials with the local soil
		Post-depositional retention due to charcoals and bones presence	Ca, Sr, P, Zn, Cu	

Table 3

Table 3 – Summery of key field and micromorphological observations on hearths made by Mallol et al. (2007)

Hearth Function	Duration of burning	Sampling	macroscopic appearance	micromorphological observations
A fire near a kill site of an impala	about 20 min	10 days later	A 60cm in diameter and 8cm deep circular blackened area with thin grey ashes layer in its center	High concentrations of browned organic matter and charcoal fragments Ash present only as reworked bundles of calcitic crystals or partly calcified wood within the top centimeter
An open air cooking fire by a hut.	continuously for 4 months	1 year later	Few shades of grey were left on the crumbly surface with a homogenous appearance in the profile with abundant fresh roots	The only traces of fire left were reworked fragments of charcoal, scattered throughout the matrix, which showed a high birefringence in a speckled groundmass
A sleeping fire at the entrance of a hut	continuously for 4 months	1 year later	Homogeneous appearance with a very thin grey layer of ash at the top. The fire was covered by dry grass, belonging to the abandoned hut	The top contains abundant charred organic material that has masked the original birefringence of the groundmass Well preserved layer of ash with calcified and pseudocarbonized wood and isolated grains with oxidized clay coatings
A tuber roasting fire	about 15 min	1 day later	a circular shape of about 60 cm in diameter, composed of a thin	Crystals of calcitic ash mixed with fine organic particles found in the

			layer of light grey ash on the surface, followed by a thin (2 cm) black layer of burnt sediments directly on top of the natural soil	upper part grey part Loose, crumbly microstructure of the burnt substrate showing reddened sediments with charcoal fragments
An open air communal cooking fire	3 months	2 months later	A light grey ash lens underlain by a concave black layer grading downwards into brown and light brown	Calcitic wood cells and pseudocarbonized fragments, as well as burnt sediment rip-ups Reddened clays lacking charred organics at the top centimeter of the burnt substrate comprised. High concentration of organics at the burnt sediment

Figure Captions

Figure 1: (a) The archaeological research method. Note that ethnoarchaeology forms part of the scientific analysis stage in the archaeological research. (b) The archaeological and ethnoarchaeological research strategy.

Figure 2: Archaeological site formation processes. The formation processes can be divided into natural and cultural processes. They can be regarded as all the events that create the setting and materials that archaeologists encounter during their research.

Figure 3: Geo-ethnoarchaeological examples of site formation processes related to degradation of mud brick structures (based on Friesem et al. 2011, 2014a, 2014b). (a) Photograph of degraded mud brick structure in temperate environment (scale bar =20cm). A talus is formed on both sides of the wall (marked with red arrow) with massive infill sediment showing crude layering. Identification of this infill sediment as decayed mud brick material is based on micromorphological observations showing slope deposition with inclination away from the wall and (b) specific features such as grains covered by a thin layer of clay, indicating gravitational rolling; and (c) indications for low energy flows which wash away the fine fraction, leaving residual silt. (d) Photograph of degraded mud structure in arid environment (scale bar =20cm). Wall degradation forms a talus inclined from the wall toward the house center (marked with red arrow). Note the alternating layers showing yellow wind-blown sediment and inclined grey layers. Identification of the grey infill sediment as the product of mud brick degradation is based on micromorphological observations showing (e) mud slurry movement of fine fraction and coarse fraction in reverse bedding (the lower part contains small fraction overlain by coarse grains) forming thin layers (brown) within wind-blown material (grain supported matrix). Note how the layering is disrupted and mixed by bioturbation.

Figure 4: Proposed model for the identification of archaeological dung based on geo-ethnoarchaeological studies (i.e., Lancellotti and Madella, 2012; Shahack-Gross et al., 2003). Note that, in most cases, several lines of evidence are used in order to ascertain the identification of archaeological dung and its formation processes.

Figure 5: A plot of phytolith vs. wood ash pseudomorphs/dung spherulites ratio (PSR) concentrations for fuel identification based on Gur-Arieh et al. (2013, 2014). The plot includes ethnoarchaeological samples (Gur-Arieh et al. 2013) and archaeological samples (Gur-Arieh et al. 2014). The gray area indicates samples that can be interpreted either as mixtures of well-preserved dung with wood or partially dissolved dung-dominated ash. Samples with PSR values lower than 1 can safely be interpreted as dominated by dung ash and samples with PSR values higher than 5 can safely be interpreted as dominated by wood ash (the figure was modified based on a previous version courtesy of S. Gur-Arieh).

Figure 1

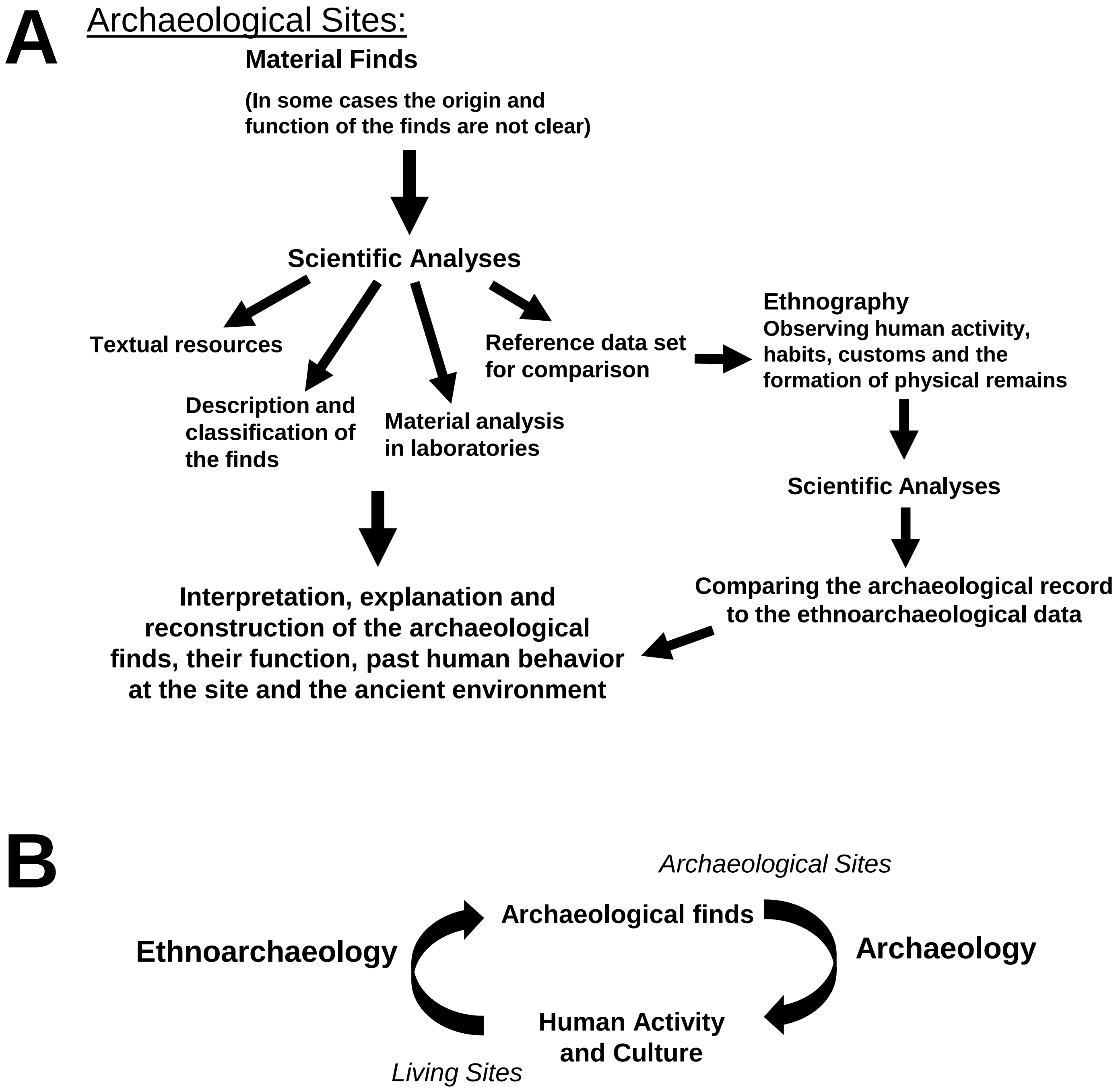
A
Archaeological Sites:
Material Finds
(In some cases the origin and
function of the finds are not clear)
Scientific Analyses
Textual resources
Description and
classification of
the finds
Material analysis
in laboratories
Reference data set
for comparison
Ethnography
Observing human activity,
habits, customs and the
formation of physical remains
Scientific Analyses
Comparing the archaeological record
to the ethnoarchaeological data
Interpretation, explanation and
reconstruction of the archaeological
finds, their function, past human behavior
at the site and the ancient environment
B
Archaeological Sites
Archaeological finds
Ethnoarchaeology
Archaeology
Human Activity
and Culture
Living Sites

Figure 2

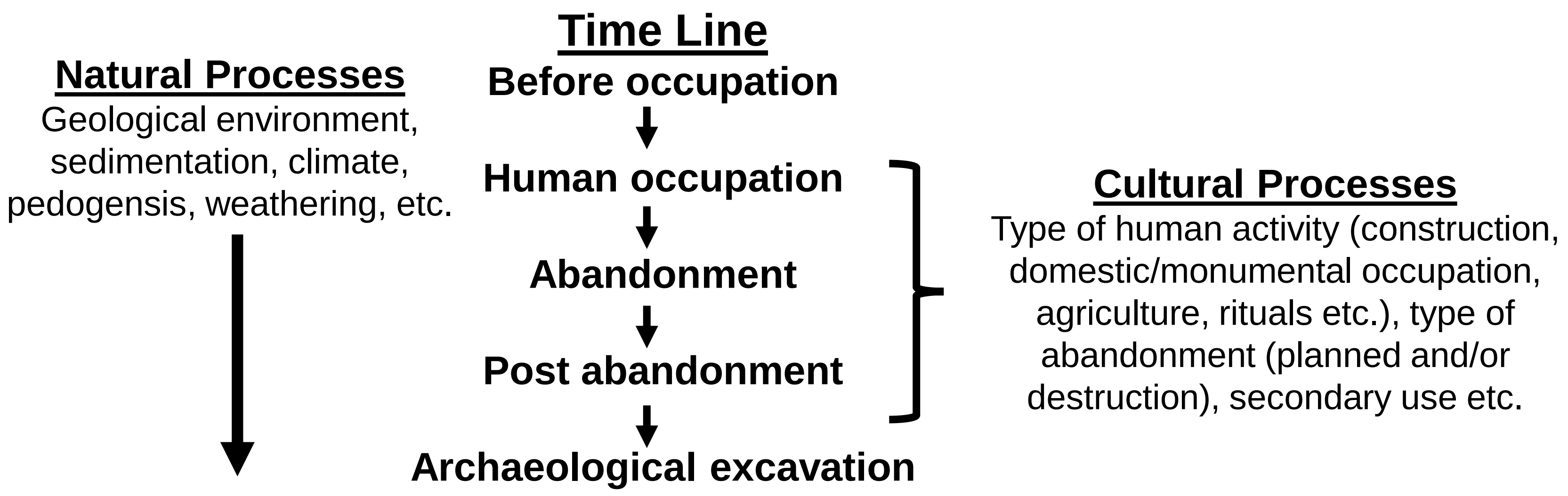
Time Line
Natural Processes
Geological environment, sedimentation, climate, pedogensis, weathering, etc.
Before occupation
Human occupation
Abandonment
Post abandonment
Archaeological excavation
Cultural Processes
Type of human activity (construction, domestic/monumental occupation, agriculture, rituals etc.), type of abandonment (planned and/or destruction), secondary use etc.

Figure 3

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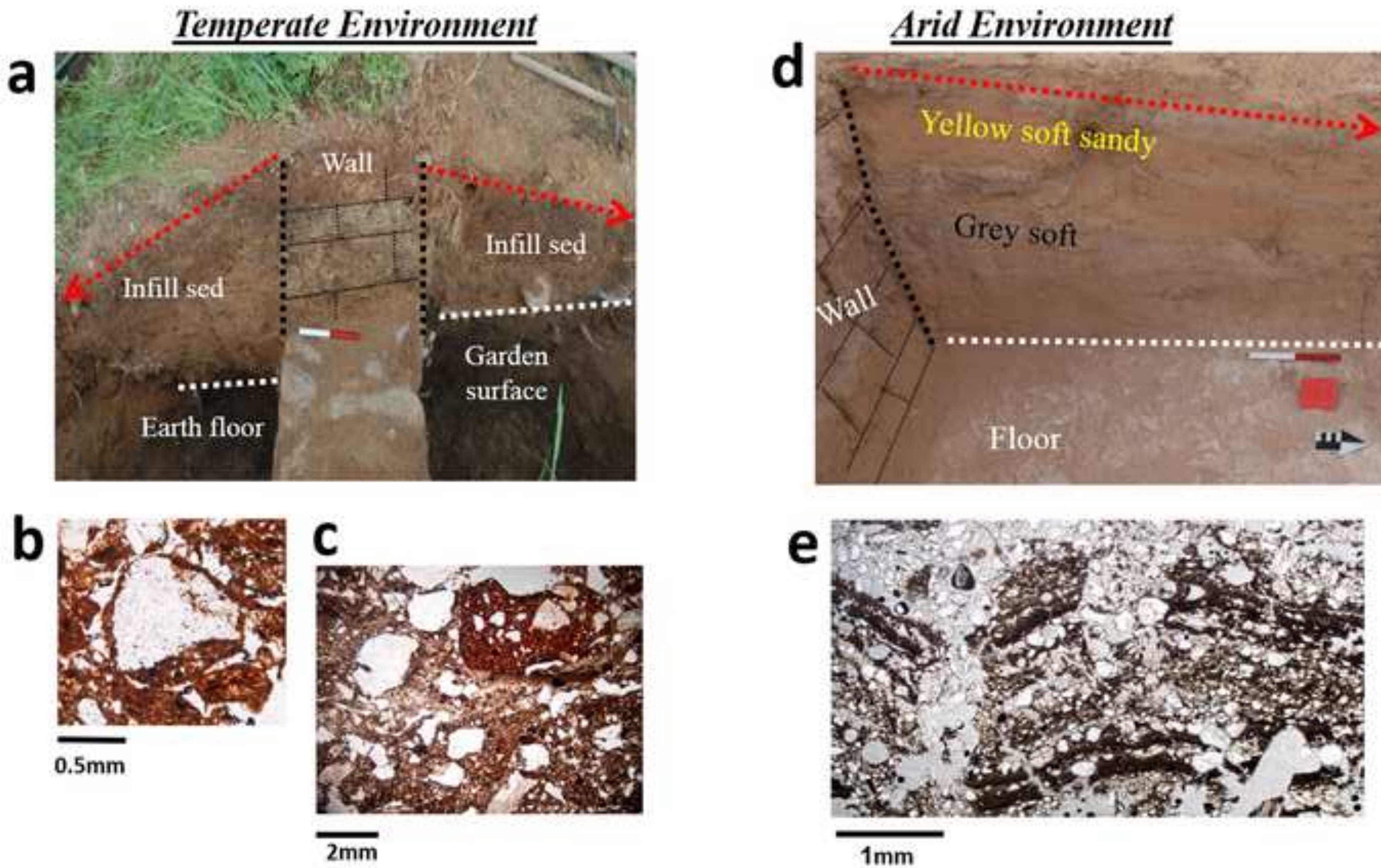
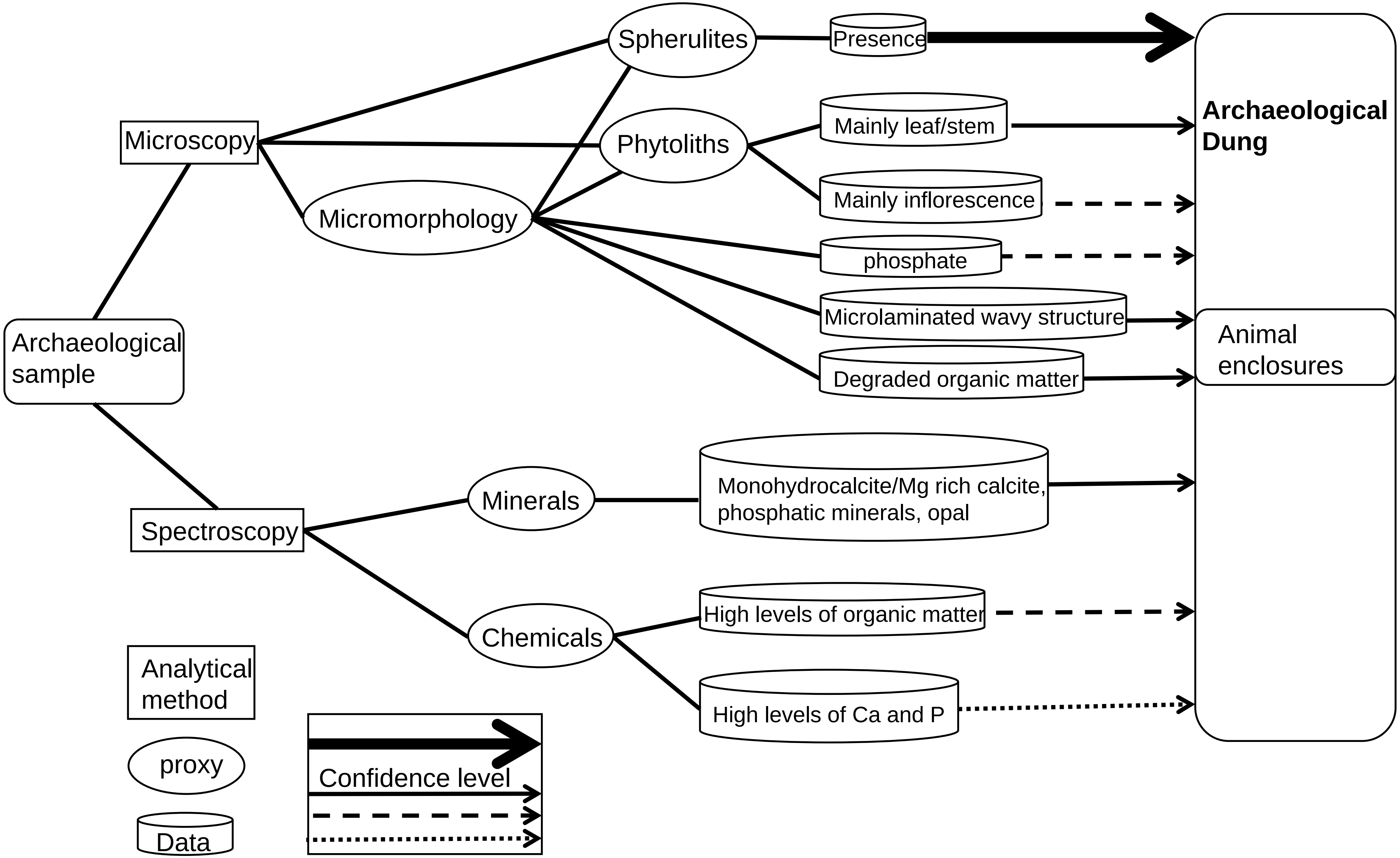
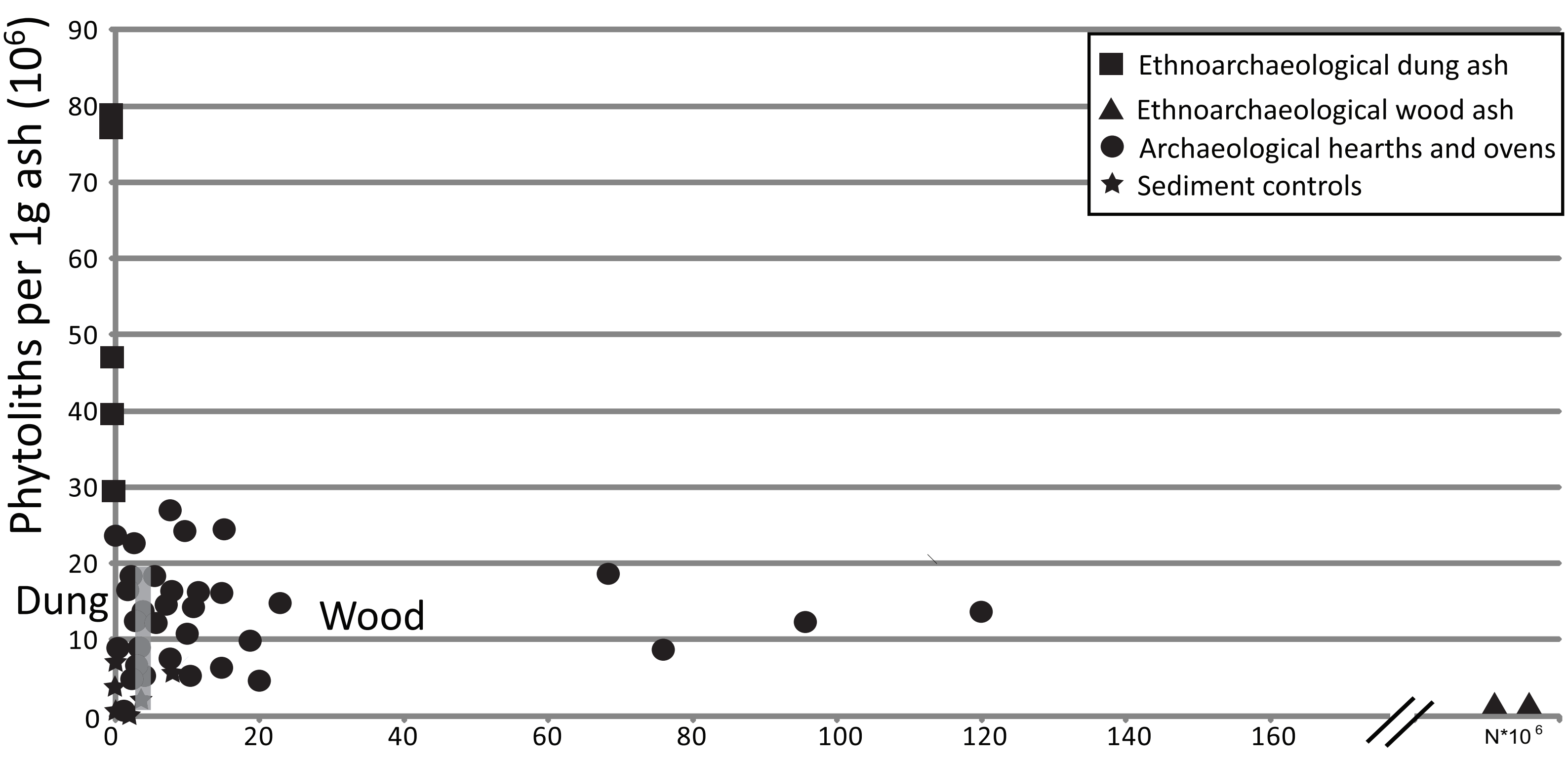


Figure 4



Spherulites
Presence
Microscopy
Phytoliths
Mainly leaf/stem
Archaeological Dung
Micromorphology
Mainly inflorescence
phosphate
Microlaminated wavy structure
Animal enclosures
Archaeological sample
Degraded organic matter
Minerals
Monohydrocalcite/Mg rich calcite, phosphatic minerals, opal
Spectroscopy
Chemicals
High levels of organic matter
Analytical method
High levels of Ca and P
proxy
Confidence level
Data

Figure 5



$$PSR = \frac{\text{Wood ash pseudomorphs per 1gr ash}}{\text{dung spherulites per 1gr ash}}$$