Analysis of Site Formation Processes at the Fa'arah II Middle Paleolithic Site in Israel: A Multidisciplinary Proposal

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Inguruwattage Kishan Chaleendra Amarasinghe
Matricola 1903104

Relatore Prof. Laura Medeghini (Sapienza University of Rome)
Correlatore Prof. Nicola Schiavon (University of Evora - Portugal)

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ABSTRACT

Fa’arah II is a Middle Paleolithic open-air archaeological site in the western Negev Desert in Israel, which has been dated to 47-48 Ka. The site is characterized by several lithic and faunal remains accompanied by evidence of anthropogenic fire. The site has been scientifically dated with OSL and Radiocarbon dating but the length of human occupation is still debatable.

The thesis aims to propose a project to investigate the nature of fire episodes and determine the length of occupation at the Fa’arah II site by analyzing sediment samples from its occupation levels. The ultimate goal of the project will be to determine the nature of the human occupation the Fa’arah II site and if it represents single or multiple periods of occupation.

For this purpose, micromorphology, mineralogical analysis, and geochemistry have been proposed as methods to analyze the sediment samples. The proposal includes a detailed work plan with timing, indication of facilities, and cost estimates to complete the project within nine months. The work plan separates tasks related to the project and allocates time for each task.

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1. INTRODUCTION

Prehistoric habitation sites represent specific loci in a landscape where hunter-gatherer occupation occurred. The archaeological record at a habitation site may reflect human occupation over a short duration or a prolonged period, and may contain signatures related to a range of activities of those who frequent the place (Binford, 1980; Henry, 2012). Occupation surfaces are a result of complex syn-depositional and post-depositional processes that alter or create artefact patterns, and modify, destroy, or add new materials to archaeological deposits (Schiffer, 1983; Stein, 2001a). Archaeological strata subsume natural sedimentation episodes that occur simultaneously alongside cultural processes, and their post-depositional transformations. The study of these formation processes is one of the key themes in geoarchaeology (French, 2003). A comprehensive investigation of depositional sequences is imperative to distinguish between patterns in the archaeological record that reflect original cultural behavior and patterns that were created by later natural and cultural processes. Closely related to site formation studies is the identification of activity areas, which allows reconstruction of the spatial organization at the site (Pfalzner, 2015). Therefore, the study of formation processes and activity areas is central to the ultimate purpose of making in-depth explanations and interpretations regarding sociocultural behavior at a hunter-gatherer habitation site.

The present study proposes to employ a micromorphological and soil chemical approach in assessing site formation processes and activity areas at the Middle Paleolithic open-air site of Far’ah II in the western Negev in Israel. It is interpreted as a small encampment of a group of hunter-gatherers of less than ten individuals, who occupied this site for a very brief time of approximately a few weeks. Different loci of activities where combustion and flint knapping took place were identified by the archaeologists (Gilead & Grigson, 1984). The stratigraphy of this site has been described based solely on the comparison of physical features of sediments, color and texture with the taphonomy of artefacts, whereas the spatial patterning of lithic artefacts and faunal remains, and a description of sediment color lack. An adequate knowledge regarding depositional episodes and post-depositional disturbances in the archaeological record would be important to infer activity areas within the occupational space (Gilead & Grigson, 1984).

1.1. RESEARCH OBJECTIVES

The objective of this thesis is to propose a detailed project with the following aims: (1) to determine cultural and natural depositional events and their transformations in order to construct a precise stratigraphical sequence of the site, and (2) to reconstruct the spatial organization within the site by identifying functions of different areas.

1.2. SIGNIFICANCE OF THE RESEARCH

The significance of the project is fourfold. Firstly, it will enhance knowledge about the depositional history at Far’ah II, which would be fundamental in constructing a solid chronocultural framework for the site. The stratigraphy of the site would be redefined incorporating the short-term depositional episodes. Second, it will contribute to the understanding about the cultural behavior and subsistence strategies of hunter-gatherers who occupied the site. Adding to this, it will elucidate the micro-environmental setting in which human activities took place, which is useful to recognize localized variables in human-environment interaction. Finally, this thesis will provide guidelines useful to analyze the Fa’arah II formation that will be followed by other case studies related to the Late Middle Paleolithic in the Negev desert and in a regional scale, to the Levant.

1.3. THESIS STRUCTURE

This thesis comprises of six chapters. Chapter II provides a description of the context of research including the environmental setting and archaeological context of the western Negev. Chapter III includes a summary of previous research regarding theories of site formation, and archaeological and geoarchaeological studies in around the study area. Chapter IV explains the methodological framework including the sampling procedure and the laboratory techniques.

2. THEORETICAL BACKGROUND

The present project pertains to a Paleolithic open-air site in a semi-arid environment, which is interpreted as a short-term occupation site (Gilead & Grigson, 1984; Goder-Goldberger et al., 2020). Open-air sites are usually considered as temporary hunting camps that were used for activities related to acquisition of prey. Faunal remains associated with these sites indicate that although large mammals were hunted, foragers opted to abandon certain anatomic parts and transport body parts with the highest utility back to habitation sites. This pattern of selective exploitation points to the function of open-air sites as localities where initial processing of prey was carried out (Hovers, 2017). Artefact assemblages from open-air sites typically contain a high frequency of ready-made tools and partly-curated items, which denotes that foragers intended to minimize the time duration spent for preparing tools during the hunt and at the butchering site (Hovers, 2017; Rendu et al., 2011). In terms of site organization, open-air sites feature distinct characteristics. The absence of specific areas for knapping activities and middens that were used for the discard of faunal remains is a marked difference from cave sites where the occupation space had usually been segmented for different activities (Henry, 2012; Meignen, 2006). Evidence for the burial of the dead is rare at open-air sites. In contrast, the majority of cave sites have yielded buried human remains (Gopher & Barkai, 2017; Hovers et al., 2017; Meignen et al., 2017; Ronen, 2017; Vandermeersch & Bar-Yosef, 2017). This apparent dichotomy has led to considerations about cave sites and open-air sites as representations of different land use strategies (Hovers & Belfer-Cohen, 2013; Wallace & Shea, 2006).

Unlike cave sites, which consist of a microenvironment delineated by cave boundaries, open-air sites are situated in an unrestricted landscape. The lack of physical constraints resulted in the less probability of repeated use of a location by hominins even if they returned to the same area (Hovers, 2017). Shallow stratigraphic sequences that are a common feature of open-air sites is a consequence of this ephemeral nature of occupation. Furthermore, the unrestrained physical setting yielded these sites susceptible to effects of environmental dynamics of the wider landscape. Formation processes at open-air sites range from geochemical alterations to alluvial, colluvial and aeolian processes that affect archaeological deposits (Friesem et al., 2014; Hovers et al., 2014). As such, an accurate interpretation of deposits and the archaeological record of open-air sites rests on elucidating natural and human-induced processes that shaped the sedimentary sequence.

The theoretical premise of the present study is behavioral archaeology. Having originated from the New Archaeology paradigm of the 1960s, behavioral archaeology aimed to investigate interactions between humans and material culture in order to explain cultural variability in the archaeological record. Michael Schiffer is credited as the pioneer of this theoretical shift (Trigger, 2009). The new archaeology movement advocated studying culture as a dynamic process changing over time in order to explain variability in cultural behavior. Establishing correlations between human behavior and material culture was proposed as the means of determining regularities in human behavior to achieve the goal of reconstructing cultural systems and explaining cultural change (Trigger, 2009). Behavioral archaeologists proposed constructing empirical laws or law-like generalizations between human behavior and material culture, which was to be followed by explaining behavioral variability based on empirical laws (Schiffer & Walker, 2014). Human activities involve various combinations of interactions between people, artefacts, and externs (environmental phenomena such as water, rocks, minerals, and plants, etc.). Materials that constitute the archaeological record cease functioning in their behavioral system (systemic context) and enter the archaeological context, where they interact only with externs. Through this interaction, externs also become artefacts (Schiffer, 1972; Schiffer & Walker, 2014). The most significant theoretical consideration in behavioral archaeology concerns site formation processes. The archaeological record is not a static entity that represents cultural behavior in the systemic context. Artefactual material and places of human activity experience cultural and natural transformations which may alter artefacts and their depositional environments (Schiffer, 1983).

2.1. SITE FORMATION PROCESSES

Archaeological record is not a static entity that furnishes information of a behavioral system. Materials that constitute the archaeological record have ceased functioning in their behavioral system (systemic context) and entered the archaeological context, where they become artefacts (Schiffer, 1972). Processes that are responsible for the formation of the archaeological record are threefold. The initial formation deposits involve cultural behavior that produce, use, and discard objects (primary deposition). Activities contemporary to the formation may alter the original behavioral signatures or may produce their own imprints by adding or removing material to the record. Interference by archaeologists will further obscure associations and matrices of objects (Stein, 2001a).

These cultural transformations (C-transformations) are coupled with effects of natural processes (N-transformations) once an object is deposited in a context. At the site-level, archaeological sediments are affected by a wide range of natural processes; mixing of soil and sediments (pedoturbation), faunal activity such as those of rodents and burrowing animals (faunalturbation), plant roots that move aside sediments and organic deposits formed by decaying plant material (floralturbation), disturbance caused by freeze-thaw action (cryoturbation), mixing of sediments due to downslope movement caused by gravity (graviturbation), swelling and shrinking of clay deposits resulting in cracks that cause movements of larger particles and the introduction of materials into those cracks (argilliturbation), and disturbances to soil fabric caused by soil gas and wind (aeroturbation) (Schiffer, 1987). Natural phenomena at the regional level, such as aeolian, fluvial, and alluvial processes exert a profound impact on site formation processes. Blowing wind may erode away micro-scale archaeological material or may deposit dust that would conceal archaeological layers, while watercourses transport sediment material downstream and deposit them over wide surfaces in valley areas. It might also result in erosion of archaeological sediments, thus removing significant features of the archaeological record. In addition, material that are eroded downhill due to gravity or water action may form layers of colluvium over cultural deposits (Schiffer, 1987).

Natural phenomena that occur simultaneously with or subsequent to cultural deposition modify, destroy, or add new materials to the sedimentary sequence of a site. The depositional sequence of an archaeological site, therefore, is a product of human action and non-human agents followed by their post-depositional transformations (Courty, 2001). Open-air sites are particularly susceptible to a range of natural mechanisms due to their physical setting in the open landscape. Thus, examining lithostratigraphy of deposits is essential to identify sedimentation episodes and thereby to separate behavioral information from natural processes at such sites.

One of the objectives of the present study is to investigate the nature of human occupation at the site of Fa'arah II. This involves the timespan of occupation and the activities carried out at the site. Theoretical and empirical concepts draw upon two major models of occupation deposits; living floor model and palimpsest model. 'Living floor' refers to a discrete occupational event represented by an undisturbed spatial organization of artefact, floral and faunal assemblages deposited in a relatively short duration of time, i.e.: a single episode of occupation. It is considered to be a result of fast burial with overlying sediments sealing off the undisturbed occupation surface underneath. It follows that living floors reflect past human behavior in their original condition (Dibble et al., 1997; Malinsky-Buller et al., 2011; Villa, 1982). In contrast, the term 'palimpsest' denotes a sequence of temporally variable depositional episodes caused by anthropogenic activity or non-human agents. Conceptually, palimpsests are categorized into five groups; 1) true palimpsests in which traces of earlier episodes are erased by the most recent deposition 2) cumulative palimpsests, which consist of multiple episodes of deposition that are reworked and mixed together without removing earlier traces 3) spatial palimpsests that result from different activities which were carried out in different locations, preserving original patterns over a wider area 4) temporal palimpsests that are characterized by deposits consisting of materials and objects from different time periods 5) palimpsests of meaning, which denote the series of meanings given to a particular object or an assemblage in different contexts of use and associations from the original moment of manufacture through use to the context of burial, and ultimately in museums and in the theoretical discourse (Bailey, 2007).

Malinsky-Buller et al. (2011) categorize palimpsests based on the sediment accumulation rate. According to this model, traces of occupation episodes that occur on a single horizon in quick succession are categorized as 'rapid-accumulation palimpsests'. Anthropogenic clusters that form such a palimpsest are not reworked or mixed; thus, can be observed as separate entities (Malinsky-Buller et al., 2011). The 'slow-accumulation palimpsest' consists of several superimposing 'living floors' that are exposed for an extended period due to slow rates of natural deposition. As a result, anthropogenic sediments mix gradually with preceding cultural deposits as well as geological and biological material. This process enables mixing of mechanically damaged artefacts with more pristine materials (Malinsky-Buller et al., 2011). The two models mentioned above provide a point of departure to ascertain the nature of site use at Fa'arah II based on spatio-temporal aspects, and accumulations and post-depositional transformations of deposits.

3. ARCHAEOLOGICAL BACKGROUND

3.1. PREHISTORY OF THE LEVANT

Archaeological evidence points to continuous human presence in the Levant from the middle Pleistocene up to the late Holocene (Bar-yosef & Belfer-cohen, 2015; Bar-Yosef & Belmaker, 2010; A. N. Goring-morris & Belfer-cohen, 2011). The coastal plain of the Levant that narrows from the south to the north, bordered by the central mountain ranges that extend parallel to the shoreline, provided a corridor for hominid groups that left Africa and moved into Eurasia since the lower Paleolithic (Meignen, 2006). The resource rich zones of the Levant attracted some of these hunter-gatherers (Bar-Yosef & Belmaker, 2010).

Chronology of the Levantine prehistory is based on correlating the lithic techno-typological scheme with three scientific dating systems; Radiocarbon (C14) dating, electron spin resonance (ESR) dating, and optically stimulated luminiscence (OSL) dating (Goder-Goldberger et al., 2020; Shea, 2003). The Middle Paleolithic (MP) is divided into sub-periods: early Middle Paleolithic (250-128 ka), mid Middle Paleolithic (128-71 ka), late Middle Paleolithic (71-47 ka). These subdivisions are based on the variations in lithic assemblages and they are also roughly contemporaneous with major climatic events in the Levant (Meignen, 2006; Shea, 2003).

3.1.1. Upper Paleolithic period

The onset of the Upper Paleolithic period (47-20 ka) was marked by an increased variability in lithic traditions. Two main lithic industries appear in the Upper Paleolithic record; chamfered blades and flakes and Emireh points. During the Upper Paleolithic, the Ahmarian industry was widespread in the Negev and Sinai contemporaneously to a variety of flake industries (Bar-yosef & Belfer-cohen, 2015; A. N. Goring-morris & Belfer-cohen, 2018). The Ahmarian tradition is often associated with skeletal remains of Anatomically Modern Humans (AMH), which points to the presence of modern humans, whose dispersal from Africa to Eurasia corresponded with the Middle to Upper Paleolithic transition in the Levant (Mellars, 2006). The arrival of modern humans is considered to have changed the demography in the Levant, which was previously dominated by Neanderthals (Bar-Yosef & Belfer-Cohen, 2010; Kadowaki S., 2013; Shea, 2003). Open-air sites in the western Negev indicate ephemeral occupations during this period (Figure 1). The site of Nahal Nizzana XIII contained a limited scatter of Amharian blades, while assemblages consisting of flake products were documented at several other sites such as Ramat Matred, Har Lavan, Shunera XV, Har Horesha I, Arqov/Avdat, and Ein Aqev/Boker C (Bar-yosef & Belfer-cohen, 2015; Davidzon & Goring-morris, 2003; N. Goring-morris & Belfer-Cohen, 1986). Considering the raw material sources in the vicinities of many Upper Paleolithic occupation sites, the observed variability in lithic assemblages is viewed as a result of different cultural concepts rather than of environmental influence (Bar-yosef & Belfer-cohen, 2015).

3.1.2. Epipaleolithic period

During the Last Glacial Maximum, the steppe and semi-arid zone, which consisted of Negev and Sinai, were abandoned and people moved into areas with seasonal springs and water resources where seasonally migratory species were abundant. It was only after the climatic amelioration in the Middle Epipaleolithic that these areas experienced a demographic expansion as indicated by the variety of lithic industries from the Middle-Epipaleolithic (Goring-morris & Belfer-cohen, 2011). Throughout the rest of the Epipaleolithic, the Negev was inhabited by mobile hunter-gatherer groups whose subsistence must have depended largely on hunting large ungulates such as gazelle and ibex that inhabited the region (Bar-yosef & Belfer-cohen, 2015).

3.1.3. Pre-pottery Neolithic A

The end of the Epipaleolithic and the beginning of the Pre-Pottery Neolithic A period (~9,750–8,500 cal. BCE) in the Negev was marked by an increasingly warm spell. Despite these conditions, Early Natufian communities frequented the lowland areas of the Negev as small groups of mobile hunter-gatherers during the transitional period between the Epipaleolithic and the Pre-Pottery Neolithic A period (Goring-morris, 1987). Late Natufian communities in the Negev inhabited settlements of varying size. Settlements such as Rosh-Horesha Salufim, which represent large, central sites where a range of activities were performed, were located in the intermediate and highland areas. In contrast, sites in the lowland areas resemble hunting camps, which were located alongside the dunes and major drainage areas (Goring-morris, 1987; Goring-Morris, 1997). Evidence related to plant processing, such as mortars, and stone tools associated with hunting have been encountered at both types of sites. While sites in the lowland areas are considered temporary camps intended for resource exploitation, aggregation sites in the highlands resemble base camps (Barzilai et al., 2015; Goring-morris, 1987; Goring-Morris, 1997).

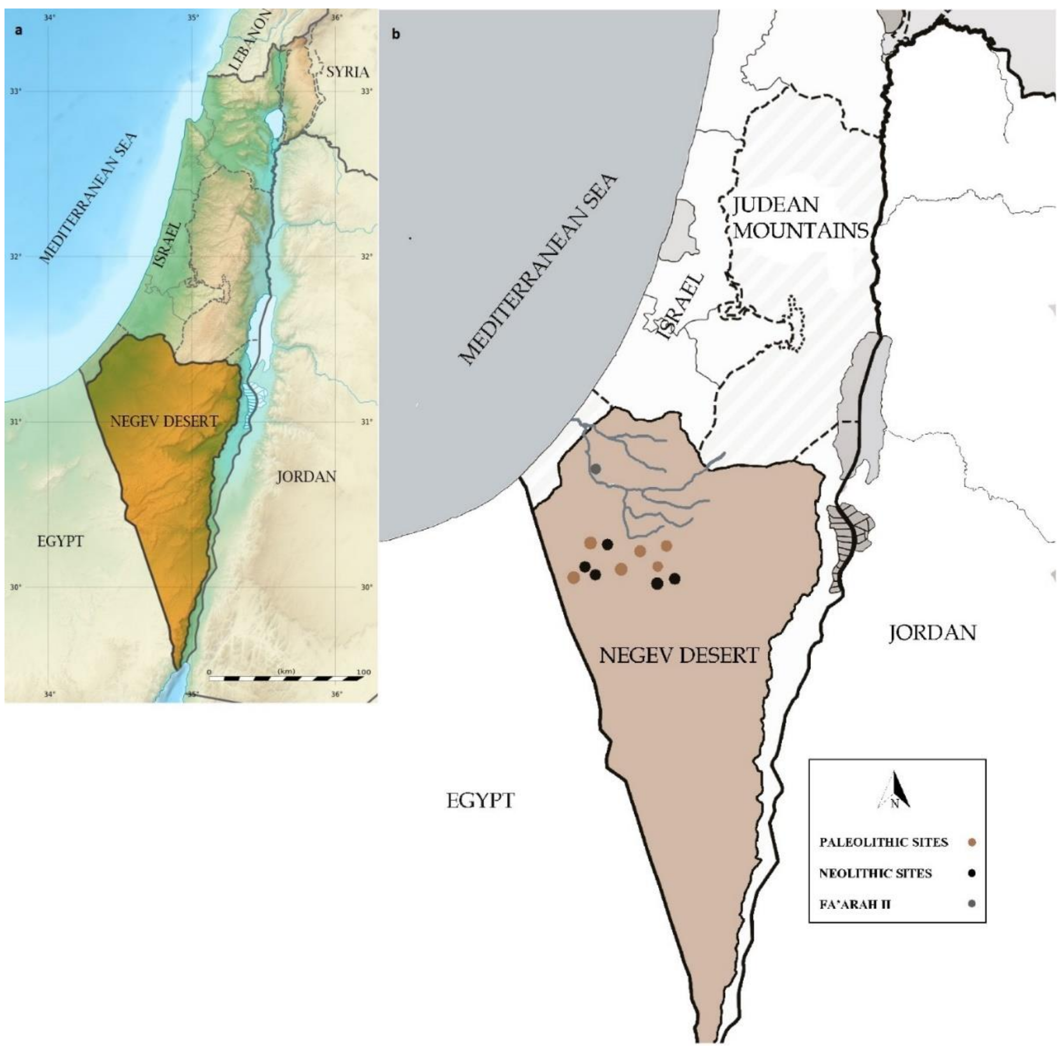

Fig. 1. (a) The extent of the Negev Desert (b) Locations of major Paleolithic and Neolithic sites within the Negev Desert

3.1.4. Pre-pottery Neolithic B

The Pre-Pottery Neolithic B period (~8,500-7000 BCE) coincided with the Early Holocene Climatic Optimum which caused a warm and wet climate in the Levant (Asouti et al., 2015; Goring-morris & Belfer-cohen, 2011). During the Middle- Pre-Pottery Neolithic B, the steppe semi-arid regions in the southern Levant experienced a transition towards a woodland steppe environment with moister/cooler localities that enabled forager communities to repopulate the region (Asouti et al., 2015). Cultural repertoire of late Pre-Pottery Neolithic B communities in the western Negev featured the Tuwailan industry that developed towards the end of this period. Large cortical knives typical of the Tuwailan were first identified at Tel Tuwail in the Nahal Besor valley, while sites of Hamifgash III and V, and Har Qeren XIV also yielded Tuwailan products (Goring-morris & Belfer-Cohen, 2014; Goring-morris & Sharon, 2014) (Figure 1). The economy of PPNB communities consisted of cereal cultivation as well as hunting (Goring-morris, 1987).

3.1.5. Pottery Neolithic

The forager lifestyle in the Negev continued until the population density declined in the mid-6 millennium BC. The sites of Hamifgash III and V in the western Negev that fall within this period yield evidence for the processing of goat meat, while axes and projectile points at Qadesh Barnea 3 indicate foraging activities. These collective evidences demonstrate a shift towards pastoral nomadism among communities in the southern Levantine desert areas from the mid- to late 6 millennium BC (Goring-Morris, 1993). Notably, archaeobotanical evidence suggest an expansion of the woodland landscape in the late Pre-Pottery Neolithic B, which is considered to have been partly influenced by herding activities (Asouti et al., 2015).

Towards the end of the 5 mil. BC, the Qatifian culture that was named after its type site Qatif, emerged in the coastal areas of Palestine and in the western Negev. Radiocarbon dates place this cultural entity at 5200-4800 cal. BC (Gilead, 2007). The hallmark of this culture was straw-tempered ware which could be viewed as an earliest type of pottery in the Negev region. The relatively high frequency of sickle blades and remains of domesticated species; sheep, cattle, goat, and pig from Qatifian contexts suggest that their economy was based on harvesting cereals and animal husbandry (Gilead, 2007).

A characteristic feature prevalent throughout the prehistory of Negev was the impact of climatic and environmental conditions over cultural behavior. Settlement patterns and subsistence practices of human communities in the region demonstrate cultural adaptations to the changes in the physical environment.

3.2. FA'ARAH II SITE

The site of Fa'arah II is located on the banks of Wadi Besor in the north-western Negev in Israel (Figure 2). Wadi Besor, which originates in the hilly area of Sde Boqer in the Negev Highlands, flows 80 kilometers across the western Negev into the Mediterranean Sea. It is the largest amongst the drainage systems in Israel that flow westwards (Alexandrov et al., 2008). Wadi Besor connects with two main tributaries along its way to the Mediterranean Sea; Nahal Be'er Sheva and Nahal Gerar (Greenbaum & Zilberman, 2017; Tsoar et al., 1993). It carries a mean annual discharge of 13.7 10^0 m^2. Currently, the stream and its tributaries are ephemeral. The Besor stream is part of the Besor Basin which drains an area of 3420km^2. This drainage basin extends across the western Negev, parts of the Negev Highlands and Judean Hills (Greenbaum & Zilberman, 2017). It is considered a physiographic region in the Negev (Singer, 2007). Soil cover of the basin mainly comprises of loess. From the western part of the basin, Haluza-Agur dune field that is part of the Sinai-Negev sand dunes, spreads towards the Besor stream (Tsoar et al., 2008).

3.2.1. Geology and geomorphology

Fa'arah II is situated on the Quaternary loess deposits that characterize the western Negev. The loess deposits are incised by numerous gullies that create a topography with low, rounded hillocks and vertical gully banks in the shape of micro-canyons (Singer, 2007).

Loess is defined as a terrestrial, calcareous or non-calcareous sediment of aeolian origin that is dominated by silt-sized particles (Muhs & Bettis, 2003). It is spread over an area of 5500 km^2 in the Negev. The loess stratigraphy is variable depending on geomorphology. Primary wind-deposited loess sequences that occur on hilltops and plateaus generally consist of basal clay loam to silty clay loam loess overlain by silty loam loess. The basal loess is associated with well-developed calcic soils whereas the calcic soils associated with the overlying loess are less-developed. The thickness of primary loess deposits varies from a few centimeters up to 5 m (Crouvi et al., 2017). Fluvial systems in the Besor Basin are dominated by reworked loess. The secondary fluvial loess appears as layered loess or alternating layers of gravel with loess, and form sequences of up to 15 m of thickness. Another secondary loess formation of colluvial or fluvial origin occurs as alternating gravel layers and gravel mixed with loess and buried soils. These reworked loess deposits filled pre-existing fluvial systems and valleys (Avni et al., 2006; Crouvi et al., 2017; Greenbaum & Zilberman, 2017).

The two modes of loess in the Negev originate from different sources. The fine silt and clays (<20 µm) that originated in the sand dunes of have been transported by cyclonic winds from sand dunes in northern Sinai, the Nile delta shelf, and from the Sahara, while the fine sand and coarse silt component (36–65 µm) is considered to have originated from the proximal sand dunes in Sinai and the Negev. Silt fraction that was originally absent in the sand was generated by abrasion of sand-sized grains. These coarse silt deposits were overlain by continuous sand incursions (Crouvi et al., 2017).

Lithostratigraphy of the lower Besor Basin is characterized by loess overlaying a conglomerate unit. This 10-17 m thick loess unit comprises of two different units (Sneh, 1983, as cited in, Goder-Goldberger et al., 2020). Fa'arah II site is located within the lower fluvial deposit

(Goder-Goldberger et al., 2020). The deposit is 6-12 m thick and consists of five different lithofacies with lithofacies 2 being the most abundant in the study area. Horizontally stratified siltstones and thin-layered, ripple cross-laminated, very fine, sandstones constitute this lithofacies. High-intensity flows are indicated by small scale truncations that form cut and fill features. Sneh (1983) suggests that these features point to a flood plain that was occasionally flooded and was devoid of any deeply incised streams (Sneh, 1983, as cited in, Goder-Goldberger et al., 2020). The structureless upper loess unit is considered to be of fluvial and/or aeolian origin (Sneh, 1983, as cited in, Goder-Goldberger et al., 2020).

Optically Stimulated Luminescence (OSL) ages have indicated that loess accretion in the Negev has occurred over a long period from the late Middle Pleistocene up to the Terminal Pleistocene. Primary aeolian loess has accumulated in variable rates from ~180 to ~10 ka (Crouvi et al., 2009). Secondary fluvial-reworked loess sediments were deposited during the last glacial period in three stages. The main interval of accretion occurred during 71– 22 ka. Subsequently, coarse gravel accumulated from 22 - 10 ka. This phase was followed by the deposition of another short interval of loess deposition during the terminal Pleistocene (13 - 10 ka). The period of secondary fluvial loess deposition roughly coincides with the marine oxygen isotope stages (MIS) 2–4; 70–10 ka (Crouvi et al., 2017).

3.2.2. Hydrology

The Besor stream causes an average two to three major flood events per year although it is an ephemeral stream (Kahana et al., 2002). Loess deposition profoundly impacted the hydrology of the Besor basin. The westward flawing streams transported and deposited fluvial-aeolian loess sediments along floodplains (Greenbaum & Zilberman, 2017). The reworked loess has increased the soil cover compared to the bedrock of the area. The high infiltration capacity of loess limits the frequency and magnitude of runoff. This affects the water concentration and leads to the creation of saline soils that are inhospitable for vegetation (Yair, 1987a, 1987b).

3.2.3. Climate

The climate of the north-western Negev is dictated by its narrow geography parallel to the Mediterranean Sea. A steep rainfall gradient of 300-100 mm yr^{-1} is experienced from north to south (Enzel et al., 2008). This rainfall pattern has been maintained during most of the late Pleistocene. East Mediterranean (EM) cyclones known as the 'Cyprus Lows' are considered to be the cause for dust transportation to western Negev from northern Sinai. Mean annual precipitation decreases from 300 mm in the northern Negev to ~25 mm in southern Negev. This is largely influenced by an evaporation rate of >2000 mm yr-1 in this desert region (Saaroni, Halfon, Ziv, Alpert, & Kutiel, 2010).

Isotopic data and the pattern of formation of Negev loess are suggestive of similar rainfall patterns during the late Pleistocene. Loess deposits of western Negev have accreted as a result of sand deposition under wet conditions, which were originated from a source in the EM. $^{18}O_{cc}$ and ^{12}C of speleothems from the northern Negev also suggest rainfall originating from an EM marine source. The higher ^{12}C ratio points to a vegetation dominated by C3 and C4 plants that reflects a low rainfall pattern (Bar-Matthews et al., 2017; Enzel et al., 2008).

3.2.4. Vegetation

The landscape is characterized by the Irano-Turanian type vegetation, while Mediterranean and Saharo-Arabian species are also present. *Acacia raddiana* and semi-shrub plants are widespread in the region. Anabasis articulata, Hammada (syn. Haloxylon) salicornia, Zygophyllum dumosum, Retama raetam, and Lycium shawii are some common (Danin, 1983, as cited in, Goder-Goldberger et al., 2020).

3.2.5. Archaeological excavations

Within the semi-arid zone of the Western Negev, prehistoric sites were occupied by hunter-gatherer groups since the Middle Paleolithic (128-48/47 ka) (Davidzon & Goring-morris, 2003; Gilead & Grigson, 1984; N. Goring-morris & Belfer-Cohen, 1986). A survey conducted by Goder-Goldberger et al. (2019) documented several lithic clusters on either bank of the Nahal Bezor stream. The type site of the later MP in the western Negev is Far'ah II, which is located on the eastern bank of Nahal Besor (Fig. 1). ESR dates placed the site between 60-50 Ka, and these dates were pushed back to 48-49 Ka with OSL and Radiocarbon methods (Goder-Goldberger et al., 2020; Schwarcz & Rink, 2002). This date places the site on the verge of the Upper Paleolithic in Levant. Excavations at the site from 1976 to 1978 revealed two distinct living surfaces. The upper horizon consisted of two concentrations of lithics and faunal remains accompanied by a combustion structure. This was the first ever indication of a hearth at a MP open-air site in the Levant (Gilead & Grigson, 1984). The lithic assemblage comprised of a low amount of Levallois products, while the faunal assemblage was primarily comprised of large ungulate remains; wild ass (*Equus asinus africanus*), onager (*Equus hemionus*), hartebeest (*Alcelaphus buselaphus*) and aurochs and (Bos *primigenius*) (Gilead & Grigson, 1984). Information from Gilead and Grigson (1984) were further augmented by the excavations of Goder-Goldberger et al. (2019). The lithic assemblage they recovered consisted predominantly of flakes and blades, while Levallois flakes and cores were also included in the assemblage. Aurochs constituted the majority of faunal remains, which was followed by an unidentified equids (Equus sp.) species (Goder-Goldberger et al., 2020). Tamarix spp., which is a typical species in arid environments, was dominant in palynological samples in association with pollen of oaks (*Quercus* spp.), wild olive (*Olea europaea*), pine (*Pinus halepensis*) and carob (*Ceratonia siliqua*) species, which are typical of Mediterranean environments (Goder-Goldberger et al., 2020).

Overall, lithic assemblages recovered from 1976-1978 and 2017 excavations were broadly similar in technological characteristics and raw materials. The intensive use of cores and flakes and the artefact-core ratio indicate that flint knapping was a major activity at the site. It also suggests a rather expedient mode of raw material management. Food processing at the site that is indicated by processing damage on the bones, calcined and charred bones coupled with fragments of charcoal implying combustion activities, points to a temporary hunting camp at Far'ah II (Goder-Goldberger et al., 2020).

The use of cores and flakes is prominently exhibited also in the assemblage from Rosh Ein Mor. Located on the Divshon Plain in the Central Negev, Rosh Ein Mor is an open-air site situated close to Nahal Zin stream. The absence of Levallois and Laminar methods and the variability in core reduction techniques suggests that this site also falls within the later LP (Goder-Goldberger & Bar-Matthews, 2019). An earlier TL date also confirms the contemporaneity of Rosh Ein Mor with Fa'rah II (Rink et al., 2003). The nature of assemblages from both sites point to a highly mobile subsistence strategy.

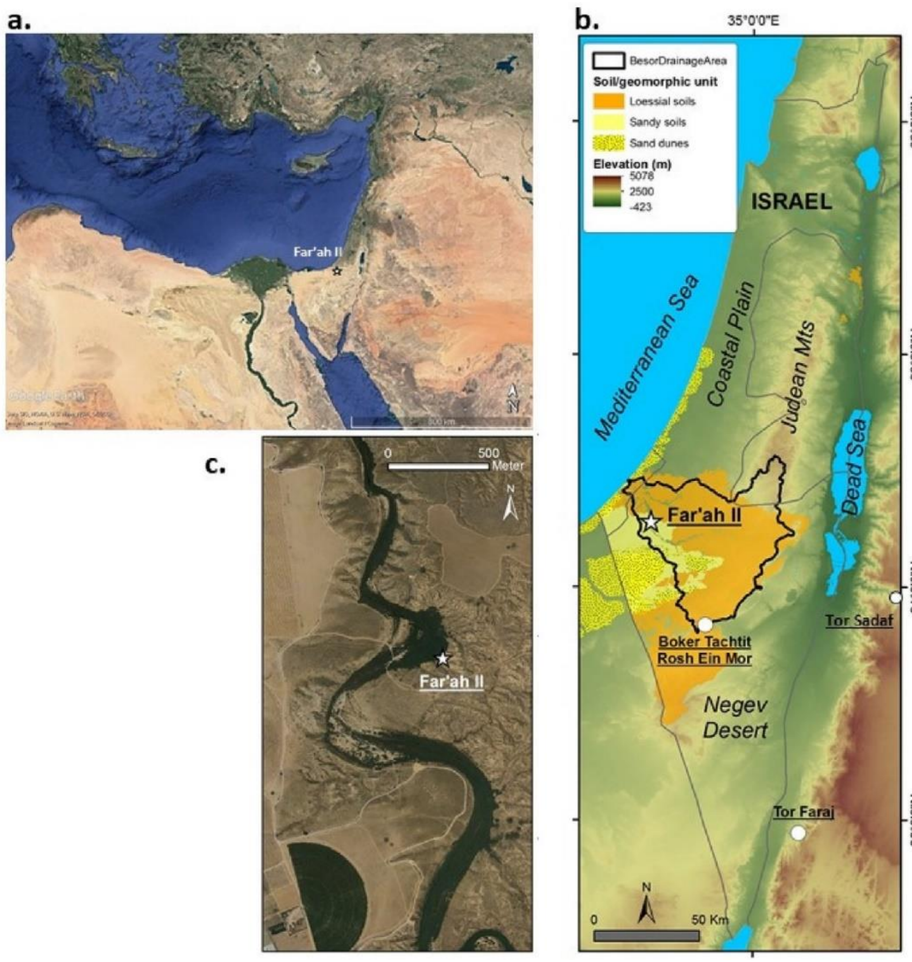

Fig. 2. (a) Location map of the study site in a regional context (b) Digital elevation model of Israel and surroundings, showing the location of Far'ah II within the Negev desert and the Besor basin (black line) (c) An aerial photo showing the location of Far'ah II along the eastern bank of Wadi Besor (after Goder-Goldenberger et al., 2020).

4. PREVIOUS RESEARCH

Formation processes at open-air sites are susceptible to cultural and natural processes and their post-depositional transformations in varying degrees. This chapter intends to discuss the existing research related to the two major themes of this thesis; site formation processes and activity area analysis. It will focus on studies conducted at open-air sites in the Negev and will also draw examples from research conducted at sites located elsewhere in the Levant region, i.e., open-air sites and cave sites. Previous research on anthropogenic fires and combustion features were specifically focused since they constitute a major theme in site formation studies. Due to their prominent use in site formation analysis, studies that utilized micromorphology and geochemical methods will also be discussed in this chapter. In addition, studies conducted at some archaeological sites that are located outside the Levant were also taken into account. An analysis of this research will enable comparison of methods and results from studies in similar environments.

Traditionally, soils and sediments at archaeological sites were analyzed with methods such as grain-size analysis, soil pH measurement, and carbonate and organic matter analysis. However, the limitation in those methods was that they were unable to detect textural and chemical variations within micro-level sediments (Goldberg, 1979, 1992). The pioneer of soil micromorphology was Austrian scientist W.L. Kubiëna who initiated this discipline in the 1930s (Kubiëna, as cited in Stoops & Nicosia, 2017). He further developed the scope of study by introducing quantification of components and features within soils (Kubiëna, as cited in Stoops & Nicosia, 2017). Micromorphology was first utilized in archaeology by Cornwall (1958) who described sampling methods and the potential for this study within the field of archaeology. Concurrently, Dalrymple (1958) studied sediments and soil fabric of paleosoils from three Pleistocene sites in England to distinguish anthropogenic sediments and naturally-deposited sediments. Information from this study were used to infer environmental and climatic conditions (Dalrymple, 1958). Systematic use of micromorphology in archaeology was initiated in Israel in the 1970s by Paul Goldberg. His pioneering studies involved the application of micromorphology, bulk chemistry, and granulometry on sediments from cave and open-air sites located in Sinai, Negev, and Judean deserts (Goldberg, 1976, 1979, 1981; Jelinek, Farrand, Haas, Horowitz, & Goldberg, 1973). An important observation was that phosphate minerals that were present within sediments in the Tabun Cave were partly derived from bone dissolution (Goldberg, 1976; Jelinek et al., 1973). Results from cave and open-air sites were based to infer the nature of environment and climate during the Pleistocene and the Holocene periods. Referring to the loess deposits that overlay the gravel layer at several loci, Goldberg (1981) suggested that the climate in the desert regions of Sinai, Judea, and Negev alternated between wet and dry conditions from the late Middle Pleistocene to the Late Pleistocene. Formation processes of cave deposits were the primary area of research during the 1980s and the 1990s. Studies at Amud, Hayonim, and Kebara cave sites indicated that stratigraphy of these sites had been altered due to bioturbation and that bat guano would have resulted in phosphate mineral content in sediments (Goldberg & Bar-Yosef, 1998). During the 1990s, the focus shifted towards obtaining a greater knowledge about diagenetic processes that influence the preservation of the archaeological record. A number of studies examined different materials within archaeological deposits in order to assess diagenetic pathways and factors that influence their preservation (Berna et al. 2004; Karkanas et al. 2000; Schiegl et al. 1996; Shahack-Gross et al. 2004; Stiner et al., 2001; Weiner et al. 1993). Due to the renewed interest on open-air sites, several investigations were conducted at previously discovered and newly discovered open-air sites during the first two decades of the 2000s (Stahlschmidt et al., 2018; Tsatskin & Zaidner, 2014).

A review of previous research displays that site formation processes have not been studied at open-air sites in the western Negev. However, there have been few attempts to explore formation processes and organization of occupation surfaces at open-air sites in the northern Negev. Generally, these studies have applied a combination of techniques to ascertain the origins of deposits.

Mallol et al. (2011) investigated the depositional history and post-depositional processes at the Lower Paleolithic site of Bizat Ruhama in the northern Negev. Well-preserved faunal remains and lithic artefacts at this site had indicated rapid burial. Mallol et al. (2011) suggested the presence of low-energy depositional episodes based on microscopic observations grain size of finer-grained deposits and bedding layers in microstructures. Fine-grained sediments had increased impermeability of sediments resulting in the formation of ponds with low water levels. Furthermore, less-abraded bones and lithic objects were suggestive of their primary deposition or a short distance transport by fluvial action. However, reddened substrate of human occupation pointed to iron-manganese segregation that is caused by percolating water in wet season and dehydration during dry season. Based on this information, Mallol et al. (2011) concluded that anthropogenic activity had taken place on an aeolian deposit, which was subsequently enclosed by sediments in a low-energy depositional environment. Human occupation had taken place in a semi-arid landscape that was seasonally inundated, resulting in low-level water bodies (Mallol et al., 2011). This study is relevant to the present study since Fa'arah II is also located in a landscape affected by fluvial processes.

Friesem et al. (2014), and Tsatskin and Zaidner (2014) investigated the formation processes at Nesher Ramla, a Middle Paleolithic site situated on a karst depression in the western Judean foothills, further to the north. The former study examined the lower depositional units (III-VI), while the latter was focused on the uppermost units (I-II) of the depositional sequence (Friesem et al., 2014; Tsatskin & Zaidner, 2014). Friesem et al. (2014) identified an *in-situ* hearth with microscopic observation of ash pseudomorphs, charcoal, and burnt bone. According to data obtained by Fourier transform infrared spectroscopy (FTIR), calcined bones in the deposit had undergone temperatures higher than 550°C. Moreover, an unstratified midden composed of burnt bone fragments, ash pseudomorphs, and microcharcoal indicated that the hearth floor had been reworked. This study was the first instance where the sequence of fire in a hearth, reworking of ash by raking out, and the secondary deposition was identified (Friesem et al., 2014). It demonstrates that micromorphology and FTIR can be used as complementary techniques to investigate hearths and combustion structures.

In contrast to the lower sequence, evidence related to burning events was absent in the upper sequence of Nesher Ramla. Tsatskin and Zaidner (2014) employed micromorphology and magnetic susceptibility to examine the depositional sequence. The thin sections did not contain residues indicative of fire, while magnetic susceptibility provided no evidence of pyrogenic enhancement. Based on the data, it was concluded that no combustion activities have taken place during the period from ~90ka to ~70ka (Tsatskin & Zaidner, 2014). However, a weakness in this study was the limited number of techniques it utilized. Especially considering the calcareous nature of the substrate, FTIR analysis would have been useful to recognize any heat-induced alteration on sediments, which would enable identifying evidence of burning (Mentzer, 2014).

Formation processes at the site of Ein Qashish were investigated in two studies by Hovers et al. (2014) and Stahlschmidt et al. (2018). It is the only open-air site of the Middle Paleolithic where human remains were encountered (Ekshtain et al., 2019). The study by Stahlschmidt et al. (2018) aimed to explore depositional processes, preservation status of bones, and evidence related to combustion. They combined microscopic examination of sediments with FTIR, x-ray diffraction (XRD), and inductively coupled plasma mass spectrometry (ICP-MS) analyses to define the mineralogical and chemical composition. Soil pH and organic carbon content were measured, while scanning electron microscopy with energy dispersive spectroscopy (SEM-EDS), x-ray fluorescence (XRF), and ICP-MS were applied to determine the elemental composition of bones, while the collagen crystallinity of bone minerals was analyzed with infrared splitting factor in order to evaluate their state of preservation. Adding to these, stable carbon and oxygen isotopes analyses were conducted on white nodules present in the sediments. The site comprised of a uniform composition of clay with silt-to-fine sand quartz sediments, which indicated their origins from a single fluvial source. Stahlschmidt et al. (2018) argued that iron-manganese (Fe-Mn) oxide staining of sediments had resulted from alternating phases of flooding and evaporation. Fe-Mn signature on fossil bones was also suggestive of a standing water body. Signs of bone diagenesis in moving water were present; lack of phosphate minerals due to dissolution; presence of rare earth elements in bones. These lines of evidence suggested that Neanderthal hominins inhabited an alluvial plain consisting of vegetation cover and seasonal water bodies that were created by nearby streams. Evidence of anthropogenic fire could not be identified since ash and charcoal were absent (Stahlschmidt et al., 2018). This study exemplifies the complexity of natural and anthropogenic processes that would be represented in a depositional sequence and demonstrates the necessity of a combination of techniques to explore site formation processes.

The scheme that was employed by Hovers et al. (2014) focused only on evidence of physical alterations caused by fluvial processes on sediments and assemblages. They explored artefact movement and secondary deposition through fabric and stratigraphic analyses and the examination of artefact and bone taphonomy. The artefacts displayed a vertical distribution and a similar pattern of breakage across depositional context, which suggested that artefact fragmentation was a result of fluvial processes rather than of tool production. Fabric analysis was indicative of flood water with a low flow velocity. These data implied that humans had occupied a location close to the Qishon stream. Low-to-moderate velocity flooding had transported and redeposited artefacts and bones over an area closer to the occupation site, which were later displaced by various post-depositional processes (Hovers et al., 2014). However, this study highlights that the success of both fabric analysis and stratigraphic analysis depends on larger-sized objects (Brantingham et al., 2007; Lenoble & Bertran, 2004). Therefore, their utility is minimal in a setting with micro-scale artefactual material or where they are completely absent.

Karkanas et al. (2007) and Shahack-Gross et al (2014) employed complementary methods including micromorphology, FTIR, and stable isotope analysis to identify formation processes and to determine the nature of combustion activities at Qesem Cave in northern Israel. The recurrence of calcined bones as microstructures and isotopic evidence of well-preserved wood ash that was indicative of fires at high temperatures demonstrated that inhabitants of Qesem cave had repeatedly used fire from 400 to 200ka (Karkanas et al., 2007). Shahack-Gross et al (2014) specifically focused on combustion features at Qesem cave. Their combined methodology involving micromorphology, and bulk sediment and micro-FTIR analyses suggested that superimposed layers of bone fragments associated with ash laminations had been calcined at temperatures greater than 500°C (Shahack-Gross et al., 2014). Both these studies manifest the importance of combining micromorphology with other complementary techniques especially in the study of combustion features.

The abovementioned approach is discussed in detail by Goldberg et al. (2017). Combustion features usually consist of deposits that result from various anthropogenic behavior and natural processes including hearth construction, maintenance (raking-out), maddening, dissolution of bones, and secondary precipitation of carbonates and phosphates (Goldberg et al., 2017; Mentzer, 2014). Micromorphology is the primary method that is employed to examine these alterations in the microscopic level. The authors propose integrating micromorphology with results from other techniques such as FTIR, SEM, isotope analyses, XRD, and chromatography. A combination of methods to assess heated material (FTIR analysis), lithified organic remains (organic petrology), and scanning electron microscope (SEM) along with micromorphology would remove the necessity of other methods. The micro-contextual approach involves the application of all analytical methods directly on materials visible on the thin section or the sediment block (Goldberg et al., 2017). All the physical and chemical characters of deposits in a combustion feature may be elucidated with this method.

The study by Homsey and Capo (2006) involved the application of micromorphology to analyze archaeologically-determined anthropogenic and geogenic features, and inductively-coupled plasma-atomic emission spectroscopy (ICP-AES) to characterize the chemical composition of microstratigraphic units. The authors correlated high ratios of K and P with pit hearths, while Sr and Ca ratios were considered to be indicating nut processing and fish consumption (Homsey & Capo, 2006). This study demonstrates how micromorphological data can improve geochemical information to delineate activity areas at a prehistoric site.

A salient feature in cave sites is the ash deriving from hearth features that has to be examined separately. Schiegel et al. (1996) identified that wood ash was originally biogenic calcium oxalate that was converted into calcite crystals. With the application of FTIR along with micromorphology, Schiegel et al. (1996) and Weiner et al. (2002) were able to determine a variety of phosphate minerals that derived from the dissolution of wood ash. Their hypothesis was that the sequence of chemical transformations of wood ash resulted in mineral phases with different degrees of stability; calcite ($CaCO_3$), dahllite ($Ca_5(PO_4)_3(OH)$), montgomeryte ($Ca_4MgAl_4(PO_4)_6(OH)_4 \cdot 12H_2O$), leucophosphite ($KFe^{3+}_2(PO_4)_2(OH) \cdot 2H2O$), and silicious aggregates. The presence of these minerals in turn suggested the state of preservation of hearths from the well-preserved ones to the poorly-preserved ones (Weiner et al., 2002). Weiner et al. (1993) examined bone concentrations within sediments in different areas inside the Kebara Cave in order to distinguish between primary burial and differential dissolution of bones. The presence of bones within sediments containing primary wood ash indicated their original deposition, while the absence of bones in certain areas was attributed to original non-deposition or post-burial dissolution. The basis for this conclusion was the relative stability of dahllite compared to calcite

(Weiner et al., 1993). These studies are of great importance for the study of activity areas and site organization as they enable identifying altered materials based on their modern analogs.

A major characteristic of the open-air sites discussed here is the narrowly constrained vertical distribution of anthropogenic deposits. The majority of sites consisted of anthropogenic deposits that were confined to a single or an extremely limited number of strata, which suggests a short duration of human occupation at these localities (Mallol et al., 2011; Stahlschmidt et al., 2018). These anthropogenic deposits at open-air sites are almost entirely composed of lithic artefacts and faunal remains. An exception is Nesher Ramla, where at least five stratigraphical units indicate human habitation (Friesem et al., 2014; Tsatskin & Zaidner, 2014). The results prove that open-air sites represent temporary hunting camps (Rendu et al., 2011), whereas the site of Nesher Ramla represents a particular instance where the depositional sequence points to multiple discrete occupations (Bailey, 2007).

Open-air sites are a result of the dynamic interplay between natural processes and anthropogenic activity. The complexity in depositional environments emanating from these processes warrant the use of different methods to identify their material analogs. Geoarchaeological research on site formation processes underlines the utility of micromorphology in elucidating various depositional mechanisms. The particular strength of micromorphology lies in its ability to examine the composition, structure, and fabric of microstratigraphic features, thus enabling the identification of various mechanisms that contributed to the formation of depositional environments (Mallol et al., 2011; Stahlschmidt et al., 2018; Stein, 2001b). It is an effective method even when artefactual materials are absent in a deposit. Mineralogical analysis provides a complementary method to Micromorphology, by identifying mineral phases that indicate processes such as combustion and oxide staining by applying FTIR and XRD analyses on burnt sediments, charcoal, and bones (Berna et al., 2004; Karkanas et al., 2000, 2007; Tsatskin & Zaidner, 2014; Weiner et al., 1993). Apart from micromorphology and mineralogical analysis, geochemical methods also provide a window to the site formation processes by aiding in the identification of activity areas based on chemical signatures.

With this background, the most appropriate methodology would be to employ micromorphology, mineralogical analysis, and geochemistry as complementary methods, which would provide a thorough insight into the nature of the deposits.

5. METHODOLOGY

5.1. SAMPLE COLLECTION

Sampling will be performed in relation to the aims of the project; identifying the length of occupation, and types and spatial configuration of activities at the site. Sections of the pits will be observed and described in detail before the collection of samples. Micromorphological samples will be acquired from the archaeological layer in square L2, the upper level of the archaeological layer and layers above it in the square L3, and the layer below the archaeological layer that is visible in squares F5 and F6 (Goder-Goldberger et al., 2020) (Figure 2). Three samples each will be obtained from L2 and L3 squares, while two samples each will be taken from F5 and F6 squares. Additionally, one sample each will be obtained from the strata that correspond to the archaeological layer in H2, H3, and H5 pits. Sampling will be specifically focused on charcoal-rich sediments in squares L2, L3, and H2 as they were used for radiocarbon dating of the site (Goder-Goldberger et al., 2020). Sediment blocks will be collected with Kubiena tins (8×7 cm metal boxes) (Goldberg & Macphail 2003). Two monolith sediment samples each will be collected from squares L2 and L3, and one sample each from squares H2, F5, and F6 using PVC downpipes (30 cm) (Goldberg & Macphail, 2003). Control samples for chemical analysis will be obtained from an adjacent vertical gully bank. The number of samples may be increased based on the opinions by archaeologists.

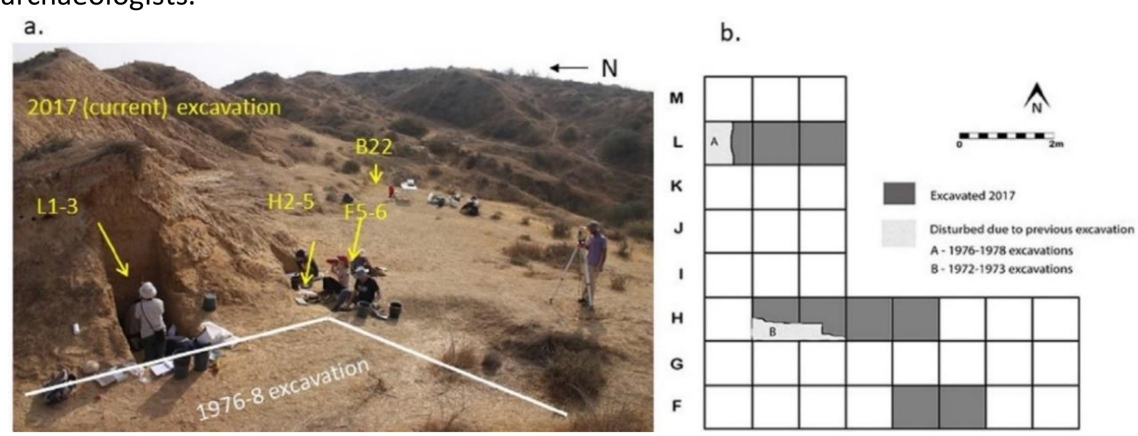

Fig. 3. Previous and current (2017) excavations at Far'ah II. (a) Photo of the study area looking West, (b) Plan of the current excavation area (after Goder-Goldenberger et al., 2020).

5.2. LABORATORY METHODS

Sediment samples will be analyzed with Optical Microscopy (OM), X-Ray Diffraction (XRD), Fourier-Transform Infrared Spectroscopy (FTIR), and Inductively-Coupled Plasma-Atomic Emission Spectroscopy (ICP-AES).

5.2.1. Micromorphology

Micromorphology is the study of undisturbed samples of soil or sediment thin sections using microscopic techniques. It is the most prominent method employed to examine the composition, structure, and fabric (geometric relationships) of sediments (Goldberg et al., 2017; Karkanas & Goldberg, 2008). An optical microscope with a resolution of up to 0.5 μm and magnifications up to × 2000 is employed to obtain information such as the grain size, shape and distribution, nature and distribution of inclusions, the relationships between different components, and the fabric and the structure of grains (Artioli, 2010; Courty, 2001). These data enable assessing the depositional context and the mode and rapidity of deposition. Also, by examining the crystal phases present in a sample, micromorphology can identify the mineralogical composition of sediments, which provides information related to combustion episodes (Courty, 2001; Goldberg et al., 2017).

The method usually employed to produce samples for thin section analysis involves the drying of sediment blocks at 60°C for several days before impregnating them with epoxy or polyester resin under a vacuum. The hardened block is sliced with a geological cutter, and the slices are glued to a glass. The slices are then smoothed to 20-30 μm with the aid of silicon carbide powder mixed with water (Goldberg, 1992).

Thin section samples are observed with different sources of light of a petrographic microscope. Three main sources of light are used; plain polarized light (PPL), cross polarized light (XPL), oblique incident light (OIL) (Goldberg & Macphail, 2006). Each of these sources aid in identifying certain types of mineral. Organic rich areas in the sample are visible in PPL, while the

XPL assists in identifying calcium carbonate rich areas such as secondary carbonate and ash. Iron or manganese-stained areas can be identified in OIL. Adding to this, blue light (BL) allows observation of calcium phosphate-rich materials (Goldberg & Macphail, 2006).

- Sample preparation

Sample preparation process follows Mallol et al. (2013) and MacLeod (2008). The oriented blocks are oven-dried 60 °C before being impregnated with a mix of polyester resin, styrene and the catalyzer methyl ethyl ketone peroxide (MEKP) in the ratio 7:3:0.1. The hardened blocks will be cut into 1 cm-thick slices using a Buehler Petrocut abrasive cutter after being cured for two weeks. The slices are lapped on a lapping plate (LP40/50) using 15 µm silicon carbide powder in water. Then the sample slices are bound to glass slides with etched surfaces with 301 epoxy resin, and the excess material is removed with the abrasive cutter. The targeted thickness of 30 µm for each slide is obtained by lapping on the LP40/50 lapping plate. Afterwards, the slides are polished with a CL-40 polishing machine with 3 µm diamond in oil suspension, and any residual oil is removed with a non-solvent cleaner. Finally, a coverslip is bonded to the slide with Epotek 301 epoxy resin and placed in the bonding jig overnight in order to protect the sample surfaces from damage (MacLeod, 2008; Mallol et al., 2013).

- Experimental conditions

Thin section samples will be examined with Olympus BH-2 petrographic microscope in plane-polarized (PPL) and cross-polarized (XPL) light at ×40, ×100, and ×400 magnifications (Mallol et al., 2011; Tsatskin & Zaidner, 2014).

5.2.2. X-Ray Diffraction

X-ray diffraction is an analytical method that is used to determine the crystalline compounds and identify and quantify crystalline phases in polycrystalline materials (Artioli, 2010; Malainey, 2011). It allows identifying primary and secondary minerals that are constituents of sediments, based on their atomic arrangement in crystal lattice (Goldberg et al., 2017).

There are three methods of XRD analysis; single crystal diffraction, powder diffraction, and oriented specimens (fibres, thin films, and polished surfaces). Powder method is more suitable for soils due to their physical state. The particles are randomly oriented when the sample is ground and their lattice planes are suitably aligned to produce diffraction peaks (Bish, 2015).

The semi-quantitative results obtained by XRD reveal information about the exposure of material to heat. Peak patterns characteristic of certain crystalline phases enable identifying molecular changes that occur in certain materials such as bones (Goldberg et al., 2017). Crystallinity of inorganic materials increase parallel to increasing temperature. Hydroxyapatite crystals in bones begin to reshape and turn into calcium oxide (CaO) when exposed to temperatures above 600 °C, and decarbonation takes place between 800 and 900 °C. Changes at these high temperatures occur as a result of the factors such as increased ordering of the crystal structure, increased crystal size and/or decreased strain (Pijoan et al., 2007; Reidsma et al., 2016).

- Sample preparation

The samples grinded with an agate mortar to a fine powder (<10 µm). Then, around 1-2 g of each sample is mounted on a glass slide (Bish, 2015).

- Experimental conditions

Samples will be analyzed using a Bruker D8 focus diffractometer with Cu Kα radiation, operating at 40 kV and 30 mA at the Department of Earth Sciences of Sapienza University of Rome. Spectra are collected from 3° to 60° 2θ, with a scan step of 0.02° 2θ and 2s per step as counting time. Data processing, including semi-quantitative analysis based on the "Reference Intensity Ration Method", are performed using XPowderX© software.

5.2.3. Fourier-Transform Infrared Spectroscopy

Fourier- transform infrared (FTIR) spectroscopy is the most common analytical tool used to identify the molecular structure of a material (Malainey, 2011).

FTIR analysis may be conducted in two modes; transmittance spectroscopy or reflectance spectroscopy. Transmittance spectroscopy is a quantitative technique used for solid, liquid, and gas samples. Solid samples are analyzed in three methods; a disk made of the compound diluted in potassium bromide (KBr) or sodium chloride (NaCl) powder, a smooth paste (mull) obtained by grounding the sample and dispersing it in Nujol or paraffin, and a film produced by either solvent casting or melt casting. Liquid samples include sealed cell and liquid film that has the sample placed in between two infrared plates (Stuart, 2007).

On the contrary, Reflectance spectroscopy is a non-destructive qualitative analytical method and Attenuated Total Reflectance (ATR) is the principle technique used (Stuart, 2007). Transmittance spectroscopy will be used for the present study as it aims to quantify the mineral components in soil samples.

FTIR spectroscopy is of vital importance in sediment analysis because molecular vibration by radiation may indicate phase changes in mineral constituents of a sediment sample. It is particularly useful in identifying phase changes in wood ash that may also indicate temperature ranges of firing episodes. Also, FTIR spectroscopy assists in identifying primary and secondary minerals (Goldberg et al., 2017).

- Sample preparation

Sediments collected from L2, L3, and H2 pits will be subjected to FTIR analysis in particular to examine the mineralogy of charcoal-containing layers. Samples will be prepared following

Bertaux et al. (1998) and Haberhauer et al. (1998). Sediment samples are mechanically ground in an agate mill to acquire 2 µm particles. 1 mg of each milled soil sample are mixed with 100 mg of potassium bromide (KBr) in an agate mortar and the mixture will be pressed in a vacuum die to produce a pellet. The pellets are dried in an oven at 110°C before data acquisition (Bertaux et al., 1998; Haberhauer et al., 1998).

- Experimental conditions

Samples will be analyzed with the Perkin-Elmer 2000 Fourier transform IR spectrophotometer at the Sapienza University of Rome. Pellets are placed on the sample holder and the analysis is done at 21 ±1°C in the 5200-450 cm^{-1} energy range with a 2 cm^{-1} resolution. An Infrared Data Manager software will be used to process the data, and absorbance will be computed relative to a background of sample holder with a pure KBr pellet (Bertaux et al., 1998; Haberhauer et al., 1998).

5.2.4. Inductively Coupled Plasma-Atomic Emission Spectroscopy

Inductively coupled plasma-atomic emission spectroscopy (ICP-AES) is a widely used quantitative technique for elemental characterization and for trace element analysis (Malainey, 2011; Pollard et al., 2010). Extremely low detection levels (1–100 parts per billion) and the ability for simultaneous measurement of up to 20 elements in a single sample makes ICP-AES an ideal method to determine the chemical constituents of sediments (Pollard et al., 2010).

Samples are prepared by acid-digestion of the material, a process which may result in the loss of some volatile elements (Pollard et al., 2010).

- Sample preparation

The soil samples are dried in an air drying cabinet at 25°C for 3 days before being sieved through a 2-mm sieve. Then, the samples are grinded in an agate pot to a fine powder (< 170 µm) (Li et al., 1995).

- Experimental conditions

A Varian Vista MXP Rad ICP-AES at the Department of Earth Sciences of the Sapienza University of Rome will be employed with an inductively-coupled argon plasma excitation source. Liquid samples are introduced into the plasma with a coaxial pneumatic nebulizer and spray chamber assembly. The flow of argon into the nebulizer will be measured to the nearest 0.01 L/min by a calibrated mass flow gauge (McQuaker et al., 1979).

The equipment will be calibrated prior to the analysis with standard solutions prepared in 3.5% HC104. Room temperature will be maintained at 23.0 ± 0.5 °C to control the thermal effects in the spectrometer during calibration.

6. WORK PLAN

One objective of this project is to determine the length of human activities at Fa’arah II site and to ascertain if it represents a single episode of occupation or multiple episodes of occupation. For this purpose, micromorphological analysis coupled with FTIR and XRD analyses will be used to distinguish cultural and natural depositional events and to construct a precise stratigraphical sequence of the site.

The second objective of the proposed project is to reconstruct the spatial organization within the site by identifying functions of different areas. Since Fa’arah II is one of the few open-air sites that has revealed charcoal evidence for anthropogenic fire, chemical analyses of sediments will specifically seek evidence for combustion events in different parts of the excavation.

The following questions are posed in relation to these objectives;

- What was the length of occupation at Far’ah II site?
- Does the site represent a single episode of occupation or multiple episodes of occupation?
- What cultural and non-cultural processes contributed to the creation of the archaeological record at the site?
- What was the nature of the fireplace at the site?

Plan of work

Task 1 - Obtaining permissions

Timing: Month 1

Within the first month, I will obtain permissions from the Ministry of Finance of Israel under which the Israel Customs Administration functions to export sediment samples from Israel to Italy.

Task 2 - Sampling

Timing: Month 2

In order to collect samples, I will travel to Be'er Sheva in Israel where I will be based during fieldwork. A total of approximately 30 samples are planned to be obtained. Sampling will be performed based on the archaeological stratigraphy, the extension of archaeological remains, and types of sediments present. Samples will be brought to Rome and will be stored at the Department of Earth Sciences of the Sapienza University of Rome.

A total of €1135 is expected to cost for the sampling program. This amount includes the visa fee, air fare, and costs for travel and lodging, food, and local transportation. It is necessary to rent a vehicle to access the field site which lies in the Negev desert and away from Be'er Sheva. Cost for transporting equipment and personnel on a daily basis is €160. This price includes rental, maintenance and fuel costs.

Task3 - Mineralogical characterization (OM, XRD, and FTIR analyses)

Timing: Month 2 to month 6

At the Department of Earth Sciences, Sapienza University of Rome

Sediment samples will be analyzed first with the petrographic microscope to examine their grain size, shape and distribution, the fabric and the structure of grains, and the relationships between different components. Afterwards, XRD analysis will be performed on samples. OM provides information on the depositional context and the rate of deposition. Additionally, it assists in identifying evidence for fire based on crystal phases present in a sample. Small amounts of finely grounded material from each sample will be analyzed with XRD to identify and quantify crystalline phases, which would allow identifying primary and secondary minerals in sediments. In order to precisely determine the temperature ranges of firing episodes, mineral phase changes in charcoal will be assessed by analyzing previously ground sediment samples on FTIR. Furthermore, it will assist in verifying the data obtained by XRD on primary and secondary minerals.

The total cost for the analyses will be €1255. This includes €455 for thirteen thin-section samples, €600 for five XRD samples, and €200 for five FTIR samples.

Task 4 - Chemical characterization (ICP-AES analysis)

Timing: from month 3 to month 5

At the Department of Earth Sciences, Sapienza University of Rome

To identify and quantify the major, minor, and trace elements present in the sediments, small amounts of material from air-dried samples will be finely grinded and analyzed on ICP-MS.

The cost for analyzing seven ICP-AES samples will be €112.

Task 5 - Interpretation of results

Timing: from month 5 to month 9

The above plan of work might change due to circumstances that arise from the Coronavirus pandemic. Under current measures by the Israeli government, entry to Israel for foreign nationals is allowed only under exceptional reasons. All foreign nationals are required to spend a mandatory quarantine period. This situation would adversely affect the fieldwork related to the project. If such circumstances continue for a prolonged period, the possibility of importing samples from the site to the laboratory in Rome will be sought in order to perform the investigation.

Gantt chart

Activities	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Bibliographic study									
Obtaining permissions and visas									
Sampling									
OM, XRD, and FTIR									
ICP-AES									
Interpretation of data									

BUDGET				
Item			Amount	
			€	€
Travel	International travel	1 x round trip airfare Rome-Tel Aviv-Rome	350	
		Excess baggage	75	
	Local travel/transportation requirements	Train fare	40	
		Vehicle rental (4 days × c40/day) **	160	
	Sub total for travel			625
Living expenses (food and logding)	Lodging in Be’er Sheva (€20/day x 7 days)		140	
	Food (€40/day x 8 days)		320	
	Sub-total for Living Expenses			460
Other costs associated with research	Visa fees		50	
	Lab/Analytical costs	Thin section analysis - 13 samples (€35/sample)	455	
		XRD - 5 samples for 6 hours (€103.70/hour)	600	
		FTIR - 5 samples (€40/sample)	200	
		ICP-AES - 7 samples (€16/sample)	112	
	Sub-total for Other Costs			1367
Supplies and equipment	1 hammer		15	
	Field supplies - plastic bags, plaster		10	
	Sub-total for supplies and equipment			25
Total budget				2477

7. CONCLUSIONS

Fa’arah II represents one of the earliest open-air Paleolithic sites in the Negev, and it is one of the few open-air sites in the Levant where evidence for anthropogenic fire has been encountered. The results of the proposed project will assist in understanding the nature of these fire episodes.

Furthermore, investigation of sedimentary components and microstructures will reveal the length of human occupation at Fa’arah II site. Gilead and Grigson (1984) inferred that human occupation at Fa’arah II had taken place over few weeks. This project will determine the validity of this assumption and ascertain if the site represents a palimpsest of occupations or a single episode of occupation. It will contribute towards the discussion on Paleolithic resource exploitation strategies of the habitation sites and open-air sites.

In the regional scale, results of the project will provide a better understanding of the nature of human activity in the Besor basin. Goder-Goldberger et al. (2020) identified several lithic scatters along the banks of the Besor stream, which might include more open air sites. The sedimentary sequence at Fa’arah II may reveal information on the local paleoenvironment which may be used to understand the environmental context of the Paleolithic sites in the Besor basin.

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