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1	The contribution of soil micromorphology in understanding the use of space in Area Pi at				
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12	Abstract				
13	Geoarchaeology uses sediments to define the relation between human, soil and environment by				
14	approaching, among other questions, the use of space in different earthen structures. During the				
15	excavation of Area Pi in Malia, Crete, different questions were raised concerning the use and				
16	function of the space in and around the Neopalatial building (ca. 1700-1450 BC).				
17	Geoarchaeological study, using soil micromorphology, was applied in three rooms (Rooms 19, 25				
18	and 16) dated from Middle Minoan II to Late Minoan IA period in order to understand more				
19	thoroughly the activities of the Minoan inhabitants. The study allowed a correlation of				
20	archaeological and micromorphological data, to challenge hypotheses and propose interpretations				
21	on the use of space and spatial organization of occupation. The study revealed successive				
22	frequently used plaster floors in Room 19, exterior but roof protected space for the Space 25 and				
23	for Room 16 the study proposed the presence of a hole in the roof relating to a movable hearth.				
24					

Keywords: soil micromorphology, Crete, Minoan period, Malia, use of space 26

Introduction 27

25

The study of archaeological sediments in micro-scale can reveal activities and human 28 behaviors that sometimes, are not evident through a "classical" archaeological approach. 29 Geoarchaeology, using soil micromorphology, studies sediments in micro-scale in order to provide 30 information on earthen construction techniques, the site formation processes and the use of space. 31

The term "Geoarchaeology" was first proposed by Butzer (1982) in his book Archaeology 32 as Human Ecology, where he introduced Man as a geomorphic factor, equivalent to the natural 33 ones. In this book he describes, in a theoretical way, the site formation processes. These processes 34 have been the subject of several studies since the 1980s (i.e. Courty et al., 1989; Gebhardt, 1990; 35 Wattez, 1992; Gé et al., 1993; Wattez and Courty, 1996; Cammas, 1994; 1999; Matthews, 2001; 36 Karkanas, 2001; 2006; Wattez, 2009; Shillito et al., 2011; Onfray, 2017; Kulick, 2019). The 37 classification of geoarchaeology either as a discipline or as an interdisciplinary approach is still an 38 ongoing debate (Davidson and Shackley, 1976; Rapp and Gifford, 1982; Fouache, 2010). 39

Sediments are considered as cultural artifacts that record human and natural processes 40 41 (Schiffer, 1983). Geoarchaeology applied within a site aims to shed light on questions related to construction techniques of earthen structures like floors and wall, provide information on the use 42 43 and function of a space (activity surfaces) and define the post-depositional processes that could 44 affect earthen structures. In order to do that, geoarchaeology uses different methods. One of the most important is soil micromorphology and the study of thin sections applied in different 45 archaeological and geographical contexts in order to characterize the *chaîne opératoire* of earthen 46 construction techniques, from the collection of raw material to the setup technique (Cammas, 1994; 47 48 Cammas, 2003; Cammas and Wattez, 2009; Wattez, 2009; Onfray, 2017), the site formation 49 processes in both open-air site or caves (Matthews, 2001; Karkanas, 2001, 2006; Karkanas et al., 2007; Karkanas and Stratouli, 2008; Karkanas and Efstratiou, 2009; Shillito and Matthews, 2013; 50 Karkanas and Van de Moortel, 2014; Shahack- Gross et al., 2014) but also define post-depositional 51 processes that affect earthen material (Friesem et al., 2014). 52

The archaeological site of Malia comprises one of the oldest Minoan palaces, surrounded 53 by the Bronze Age town which has been partially excavated for a century (Poursat, 2010). The 54 excavations were mostly carried out during the 19th century without involving neither geo- nor 55 bioarchaeological methods. The archaeological project on Area Pi, one of the urban districts of 56 Malia (conventionally named after the letters of Greek alphabet), is the first project that includes 57 58 intra-site geoarchaeological approach using soil micromorphology, a method infrequently used on Cretan sites. Excavations of the Area Pi sought to explore a building of the Neopalatial period 59 (Middle Minoan III-Late Minoan I, ca. 1700-1450 BC), a period which still remains obscure at 60 Malia (Manning, 2014; Gomrée et al., 2012). 61

Different constructions were discovered in Area Pi and initially interpreted according to 62 plan and assemblages of artifacts and ecofacts. Primary deposits are not numerous, because of a 63 (perhaps gradual) abandonment of the Area during Late Minoan IA (LM IA) period. The 64 micromorphological study was undertaken in order to provide a more thorough sight of activities 65 and of the spatial organization in the Area Pi. Earthen floors, abundantly used in the Area Pi, can 66 record traces of human or animal activities. The nature of earthen floors allows the application of 67 geoarchaeological approach using soil micromorphology, in order to question archaeological 68 interpretations on the use of space and on spatial distribution of activities. The micromorphological 69 70 analysis defines, through different indicators, the use of space in an earthen structure, provides 71 information on different activities that occurred in the space and proposes interpretations 72 concerning its function (Gé et al., 1993; Nicosia and Stoops, 2017). The study of samples, in 73 micro-scale, from different rooms in Area Pi contributes to better define the organization and the 74 density of activities and the use of space.

75

76 The Area Pi at Malia

77 The site of Malia is located on the northern coast of Crete in a context of terra rossa and 78 calcareous formation, next to a swamp (fig.1) (Lespez et al., 2003). The Area Pi, where this study 79 is concentrated, is located at the north-west of the Minoan palace. Archaeological excavations from 2005-2014 (under the aegis of the French School at Athens) revealed a complex of rooms, 80 mainly interpreted as domestic areas and some open spaces (fig.2) (Pomadère, 2009; 2011; 81 Gomrée et al., 2012; Alberti et al., 2019). The occupation of the Area spans across protopalatial 82 and neopalatial periods, however, building Pi is mainly dated to the Middle Minoan III (MM III) 83 84 and Late Minoan IA (LM IA) period (ca. 1700-1450 BC) (Manning, 2014; Gomrée et al., 2012).





87 Figure 1: The location of Malia in Crete and the Area Pi within the site (©Google Earth).



Figure 2: Plan of Area Pi showing the different excavated spaces. Red numbers and circles
correspond to micromorphological samples and those in blue rectangle are used for the present
study (Pomadère, 2009). Sample 1 comes from Room 16, samples 6, 7 and 8 are from Room 19,

- samples 18 and 19 come from the southern part of Space 25 (in transition from Space 8 to 25) and
 sample 36 comes from the northern part of Space 25.
- 95

96 Materials and Methods

In order to characterize the use of space, we applied intra-site geoarchaeological approach 97 which uses soil micromorphology as the main tool (Courty et al., 1989; Cammas and Wattez, 98 99 2009). Samples were collected from floors of different rooms of Area Pi based on the questions 100 raised during the excavations (fig. 2). Unfortunately, the person who was in charge for geoarchaeological study and sampling during the excavation (2008-2014), is not any more a 101 102 member of the team and no document of sampling protocol or of samples' exact position is available. We only have data on the layers that have been sampled and the room they belong. 103 Samples of undisturbed blocks were consolidated at the soil laboratory of the department of 104 «Dynamique des Milieux et Organisation Spatiale» at Agroparistech in Paris and studied under a 105 polarized microscope according to guidelines of Bullock et al. (1985) and Stoops (2003, 2010). 106 107 The present study is based on samples from Room 19 dated to Middle Minoan III period and Room 16 of the Late Minoan IA. Space 25 was used from Middle Minoan II to Late Minoan IA. 108

- The functional approach applied at Malia defined different indicators that can be used for
 identifying the nature and the use of space (Gé *et al.*, 1993; Wattez and Courty, 1996; Stordreur
 and Wattez, 1998; Wattez *et al.*, 1998; Wattez, 2009). Four indicators have been defined:
- The inclusions of animal and plant origin (charcoals, bones, excrements, burnt bones
 and aggregates). These indicators are related to different activities that can occur in a room such
 as the presence of hearth or the preparation and consumption of food;
- 115 2. The microstructure of trampling effect. Microstructure of earthen material interacts116 differently in trampling pressure in wet or dry environmental conditions;
- 3. Pedo-features of hydric conditions in the floor. Pedo-features of superficial runoff or the
 presence of coatings related to the water circulation in the soil can be considered as indicators of
 hydric conditions.
- 4. Biological activity. Activity of soil fauna and flora can be developed simultaneously tothe occupation or after the abandon. Biological activity developed in the sub-surface is considered

122 as contemporaneous to the occupation. Sometimes, horizontal channels and chambers of worm 123 activity are deformed under trampling pressure. Post-depositional biological activity of soil fauna 124 and flora destroys sediment organization in more than one micro-layer and it is characterized by 125 thick and long channels or chambers. Interconnected chambers and vughs related to root activity 126 are also identified in the samples, where, in some cases, residues of plant/roots tissues have been 127 observed.

A combination of those indicators allowed the creation of 4 micro-facies based on the nature of activities in a space and the degree of frequency. Micro-facies are summarized in table 1 and they can shed light on the nature and the use of space in Area Pi. The interpretations proposed are based on proportional comparison between the Spaces/Rooms under study.

132

Micro-facies	Micro-residues of plant and animal origin	Microstructure of trampling effect	Pedo-features of hydric conditions in the floor	Biological activity
Frequent and clean interior surfaces	+	++	-	-
Irregularly frequent used and non-clean interior surfaces	++	+	++	++
Frequent used and maintained semi open-air surfaces	++	++/ +++	++	++
Irregularly frequent used and non-maintained semi open-air surfaces	+	++	++	+++

Table 1: Micro-facies of activity surfaces identified in Malia and they correspond to the use (frequently or irregularly used) and the maintenance (maintained/clear or not maintained) of surfaces and their position (interior or semi open-air surfaces). Indicators and their frequency (+++ high presence, - low presence) are defined after a correlation of data collected from the samples under study. This table of frequency concerns only Room 16, 19 and Space 25.

138 **Results**

139 Room 19- Middle Minoan IIIA

Room 19 is a small space situated in the middle of the building. Entire vases, in a primary destruction deposit, including a pithos, have been found in the room, but no floor could be clearly attributed to Middle Minoan IIIA (MM IIIA) period. Activities of MM IIIA period seems to take place on the remains of the MM II floor. Fragments of plaster floors found in the Room may belong to this previous occupation (MM II) period or to fallen plaster from the wall (Pomadère, 2009).

145 The lower part of the stratigraphy (SU5055 and SU5052) contains coarse elements mixed with human debris such as ceramic, ashes and bones (tab. 2) (fig.3A). This layer can be interpreted 146 as a leveling floor followed by the setup of thinner and finer successive surfaces. Successive 147 plastered surfaces are quite common in Malia and related to a regular maintenance of the space 148 (Shaw, 2009). Both leveling floor and occupation surfaces are mainly made of red non-birefringent 149 striated clayey sediments. The surfaces (SU5043) are made of white carbonated silty sand 150 sediments, interpreted as a plaster, that were colored by red wash on the top (fig.3B). The red paint 151 wash (*badigeon* in French) was made of red clayey sediments mixed with large quantities of water. 152 153 The horizontal distribution of clays shows that wash was applied by spreading it on the surface (Wattez 2009; Karkanas, 2019). The successive surfaces are thin (around 5 mm of thickness) with 154 fine horizontal cracks that create a prismatic microstructure as a result of trampling activity (Gé et 155 al 1993; Rentzel et al., 2017; Karkanas 2019) (fig. 3C). Biological activity and micro-residues of 156 157 human activity are very few on each surface (tab. 2).

Higher in the stratigraphy (see SU5024: filling of destruction deposit), some residual surface crusts in relation with heterogenic material and a high degree of biological activity confirm an abandonment level or a thick leveling deposit composed of fine material mixed with some pebbles in order to prepare the space for the next occupation dating from LM IA.

162 Discussion on the use of space in Room 19

163 The low quantity of micro-artifacts on surfaces suggests a clean space or activities with 164 low production of debris. Moreover, no traces of sweeping or scratching (such as sorted elements 165 or depression filled with heterogeneous material) have been observed in relation with surfaces (Miller *et al.*, 2010; Benerjea *et al.*, 2015). Evidence of sweeping activity might can be revealed
by the micromorphological study of more samples from different place or the corners of the room
where cleaning activity could not be regular, but at this stage of the research, no more samples are
available for comparison. The presence of plant mat, according to present evidence, is not proposed
because of the quasi-total absence of phytoliths from the samples (Wattez and Courty 1996;
Karkanas and Efstratiou 2009; Shillito *et al.* 2011).

172 The combination of a clean space containing high degree of trampling suggests a frequently used and well-maintained space which refers to the frequently used and clean interior surfaces 173 micro-facies. Based on available micromorphological evidence, it could be proposed that the space 174 was not used for activities that left traces (hearth, domestic activities). Micromorphological 175 176 interpretation corresponds well to the interpretation of archaeologist as a storage room, suggested by the presence of a pithos and of a dozen of other vases (one amphora, at least five jugs and 177 178 several cups). It is a small space (ca. 2x1m) where activities were limited, but where people would 179 have entered and walked around frequently (tab. 2).

180 The floor of the room 19 was made of sediments coming from geological settings in the vicinity of the site (terra rossa formation) (Lespez et al., 2003). Room 19 was plastered and painted 181 with red color, perhaps during MM II when this type of plaster is well attested at Malia (Dandrau, 182 1999; Schmid and Treuil, 2017). However, it seems that the plastered floor of Room 19 was 183 184 destroyed partially, probably before MM III. Plaster fragments, either from floor or from the wall, can be identified only by microscopic analysis but some larger ones were collected during 185 excavation. Micromorphological study in Area Pi showed the use of red striated clay of low 186 birefringence as a paint wash. According to previous analyses conducted at Malia, the red color 187 results from the use of ochre (Dandrau, 1999, 30-31; Schmid and Treuil, 2017, 142). In Middle 188 Minoan Koumasa and other sites such as Phaistos, Knossos, Ayia Triada and Kommos, the red 189 color also comes from the use of iron oxides (hematite or goethite) (Boness et al., 2017). 190



Figure 3: Scan of thin sections from Room 19. A: Coarse and heterogeneous elements partially accommodated that form the leveling floor (SU 5052 and SU 5055) on which surfaces are developed (PPL); B: Red colored wash applied on the top of plastered floor (SU 5043). The microstructure is massive. The matrix is impregnated of red oxides (PPL); C: Well-maintained surface made of white carbonated sediments interpreted as a plaster and covered by a red wash on the top. Fine cracks on the white part of the surface are created due to trampling pressure (SU 5043) (PPL).

199

200 Space 25- Middle Minoan II-LM IA

Continuing towards the north of Area Pi (fig. 2), Space 25 was interpreted, based on archaeological data, as an open-air space during the Neopalatial period (Pomadère, 2009, 2011) 203 that could have been used as a court, garden or sheepfold. The passage (entrance) separating Space 8 and 25 (fig. 2) presents a succession of micro-layers (fig. 4A and 4B). The floor (SU 5099) is 204 constructed and characterized by coalescent clumps limited by fine curve cracks and the 205 distribution of sand grains is homogeneous. Both of elements show mixed and blended material 206 before the setup phase (Cammas, 2003; Wattez, 2009). Fine horizontal cracks related to textural 207 and structural crusts and fine cracks around the aggregates are the result of trampling (Gé et al., 208 209 1993) (fig.5A). Some structural crusts point to a circulation surface and they are in relation with platy aggregates and to the horizontal distribution of inclusions such as sand grains (Rentzel et al., 210 211 2017) (fig. 5C). Some channels of worm activity, simultaneous to the occupation, appear deformed under the trampling pressure (fig.5D). Human micro-residues such as micro-charcoals (0-2%), 212 pottery sherds (2-5%), burnt aggregates (2-5%) and bones (0-2%) (tab. 2) of different sizes are 213 214 present on crusts and related to the trampled surfaces (fig.5E). The micromorphological analysis 215 does not reveal any excrement residues that could explain the use of space as a sheepfold 216 (Matthews et al., 1997; Shillito et al., 2011; Shahack-Gross, 2017). Furthermore, none of the indicators of an open-air space such as rain drop effect or runoff marks are observed (Onfray, 217 2017). However, we noticed the presence of oxidize pedo-features (2-5%) and fine dusty clay 218 219 coatings (2-5%, 50-100µm of thickness) in the voids, related to the leaching of fine sediments in 220 very humid conditions (fig.5B).

221 Higher in the stratigraphy (SU 5059), environmental conditions seem to be drier while 222 oxidize pedo-features (0-2%) and coatings are fewer (0-2%) and thinner than before $(10-30\mu m)$. Trampling is more expressed in dryer conditions creating more intense cracks and structural and 223 224 textural surface crusts are more common. Also, the porosity is open and the biological activity is 225 more intense than in lower micro-layers. The variation of thickness and the abundance of clay coatings in the voids of different micro-layers suggest seasonal variations during the occupation 226 227 of the Space 25 rather than post-depositional processes. Despite the seasonal environmental 228 variations, no changes in the frequency of the use of space have been observed.

In the northern part of Space 25 (sample 36) (fig. 2, 4C), the sample was retrieved more than 5m north of building Pi. This area offers evidence of building activity only from the protopalatial period while the neopalatial occupation is attested only by a layer of sherds (dump). The microstratigraphy was formed by the accumulation of trampled debris which created fine curve

cracks and some textural and structural surface crusts on aggregates (fig.5F). However, trampling 233 effects are less intense than in the southern part of the Space 25. Biological activity of worms and 234 root (Babel 1975) is stronger than in the southern part destroying the microstructure. Chambers 235 and channels of biological activity are deformed due to trampling pressure (fig.5G). However, 236 post-depositional biological activity of soil fauna and flora is quite strong: wide channels pass 237 through trampled surfaces. Dusty clay coatings are presented on this location as well. Vertical 238 changes on the thickness of coatings suggest seasonal environmental variations (fig.5H; tab. 2). 239 Micro-residues of human activities (charcoals 0-2%, burnt aggregates 0-2%, shell 0-2%, bones 0-240 2%) have been found in relation to the surfaces. 241

242 Discussion on the use of space in Space 25

243 Based on the micromorphological data, we were able to observe spatial variations within the occupation of Space 25 and to call into question the hypothesis of an entire open-air space. The 244 absence of excrements, runoff and rain-drop features goes against this interpretation. The presence 245 of biological activity of roots and worms (Babel, 1975; Kooistra and Pulleman, 2010) and dusty 246 clay coatings would more likely suggest a semi- sheltered space in the Southern area during the 247 248 Neopalatial phase (Pagliai and Stoops, 2010). More precisely, it could have been a space covered by perishable materials without walls. The southern part of Space 25 is characterized by frequent 249 used and maintained semi open-air surfaces, corresponding to the area of the entrance into the 250 251 house.

Concerning the northern part of Space 25, biological activity during the occupation of the 252 253 Area is stronger than in the southern part, showing a less maintained space. Strong postdepositional activity is also observed. The presence of slightly fewer micro-debris and the weaker 254 trampling activity could be connected to the larger distance to the core of activities. The northern 255 256 part of Space 25 corresponds to irregularly used and less maintained semi open-air surfaces micro-257 facies (tab. 1). Despite the absence of some micromorphological indicators (Vissac, 2005), the 258 hypothesis of a garden (Alberti *et al.*, 2019) should be investigated through other types of analyses 259 such as organic carbon, image analyses and particle size distribution.



Figure 4: Position of samples from Space 25 and scan of thin sections. A and B: samples No 18 (SU 5093) and 19 (SU 5099) respectively showing the microstratigraphy and the succession of surfaces related to surfaces crusts, horizontal distribution of sand grains and trampling cracks. Micro-debris such as charcoals and bones are related to these surfaces. Biological activity is expressed by chambers and channels; C: sample 36 from the northern part of Space 25. Biological activity is more developed than in the southern part and destroyed important part of the sample.



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Figure 5: A: trampling cracks around aggregates (SU 5099) (PPL); B: Dusty clay coatings in pores (arrows) (SU 5099) (PPL); C: surface crust with trampling cracks (PPL); D: Biological activity channel (in the middle of the photo) destroyed due to trampling (SU 5099) (PPL); E: human microresidues: bone (B) and micro-charcoals (arrows) (SU 5099) (PPL); F: surface crust and flatten aggregates containing sand grains (PPL); G: Chambers and channels of biological activity (C) (PPL); H: Thick dusty clay coatings in pore (arrows) (PPL).

275 Room 16- Late Minoan IA

Room 16 (4,25 x 3,10m) was identified as a space dedicated to various activities (food 276 preparation, cutting stone tools, weaving etc.) based on the presence of a grindstone, cooking jar 277 and various tools. They were concentrated on the south-west part of the Room whereas, a big part 278 of the room was found empty. There is not any evidence of destruction and it is assumed that Room 279 16 was abandoned and perhaps left open (Pomadère, 2009). The sample comes from a place next 280 to a small triangular stone pavement at the south-east corner. Several rooms of the Area Pi include 281 282 a similar pavement in a corner, which suggests that they were devoted to specific needs. In one case, a tripod cooking pot was standing on the pavement, and in another one, a thick layer of ashes 283 284 covered the floor abutting to the pavement. These elements point to the use of fire in relation with these pavements. The few fine cracks and the surface crust identified in the sample show a space 285 irregularly used (SU 4091) (fig.6A). In some cases, channels and chambers of biological activity 286 287 (mainly of roots and worms) are destroyed under the trampling pressure, although, the presence of trampling simultaneously with biological activity points to a poorly kept floor. In other words, 288 despite the fact that the floor was used, it was neither regularly used nor well maintained. Burnt 289 micro-residues such as charcoals (2-5%) and burnt aggregates (2-5%) (tab. 2) have been identified 290 291 in thin sections and could be related to a hearth. The presence of dusty clay coatings shows that 292 sediments underwent changes with regards to the humidity. This observation corresponds with the existence of a poorly protected space from the weather conditions (fig. 6B) (Onfray, 2017). 293

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- 295

Discussion on the use of space in Room 16

Comparing archaeological data (especially the presence of a cooking jar in the room) and 296 297 micromorphological observations, we assume that the pavement supported a movable hearth which could indicate the presence of a hole on the roof in order to evacuate the smoke. This 298 299 chimney allowed humidity variations due to seasonal meteorological changes (humid weather, 300 rain) to be recorded on the floor next to the hearth. At this stage of the research, clayey coatings are not considered as taphonomy effect due to the reason that their thickness varies from one micro-301 302 layer to the other but also, they are not observed in all collected samples from the Area Pi. The 303 presence of humidity in the floor favors biological activity during the occupation, which also can 304 affect the good preservation of the floor. Post-depositional biological activity is not as strong as it is in other rooms despite that the room was abandoned (Kooistra and Pulleman, 2010). It should 305

306 be noted that manganese nodules and oxide features are presented in the sample (Lindbo et al., 307 2010). However, their abundance varies in micro-layers from 0-2% to 2-5%, where their high presence is related with thick clayey coatings. According to different micromorphological 308 309 indicators and observations, such as biological activity synchronous to the occupation and irregular trampling activity, the place around the pavement seems to be irregularly frequent used and less 310 maintained (tab. 1) than the rest of the room (cf. Onfray and Wattez, 2013; Mylona, 2018). The 311 position of the sample in a corner, next to the pavement and the wall can explain the infrequent 312 use of this location. 313



314

Figure 6: Scan of thin section showing the micro-layers that present characteristic of a surface (SU

4091). Rectangular show the position of photomicrographs. Photomicrographs of the sample from
Room 16. A: fine cracks related to trampling pressure (PPL); B: Fine dusty clay coating in pores
(arrows) (PPL).

Rooms	Inclusions		Microstructure	Pedofeatures	
Room 19	Preparation floor Bones 0-2% Micro-charcoals 2-5% Ceramics 5-10% Ashes 2-5%	Constructed floor Bones 0-2% Micro- charcoals 0-2% Ceramics 0-2% Shells 0-2%	Massive to sub- angular. Micro- layers with spongy microstructure	Oxidize pedo-feature 2-5% Clayey coatings: very few (0-2%) max thickness: 10-20µm Red impregnation of the groundmass Biological activity very few (0- 2%)	
Space 25 south part	Bones 0-2% Micro-charcoals 0-2% Ceramics 2-5% Burnt elements 2-5%		Spongy to crumb microstructure	Oxidize pedo-feature 0-2% with concentrations of 2-5% Red impregnation of the groundmass Clayey coatings: 2-5% 100- 150µm where they are thick and 20-40µm where they are thin Biological activity 2-5%	
Space 25 north part	Bones 0-2% Micro-charcoals 0-2% Burnt elements 0-2% Shells 0-2% Ceramics 0-2%		Spongy to granular microstructure	Oxidize pedo-feature 0-2% to 2- 5% in some layers Red impregnation of the groundmass Clayey coatings 0-2%, <30-50µm of thickness in the lower part and 100-150µm in the upper part Biological activity 10-20%	
Room 16	Micro-charco concentratio Shell (Burnt aggreg Bones flak	als (0-2%- in ons (2-5%) 0-2%) (ates (2-5%) es (0-2%)	Spongy microstructure to sub-angular blocky, accommodated	Oxidize pedo-feature 0-2% to 2- 5% Clayey coatings (2-5%) changes on their thickness (100-150µm) to 10-20µm where they are thin Chambers and channels of biological activity 0-2% to 2-5%	

320 Table 2: the table summarizes micromorphological indicators (inclusions, microstructure, pedo-

321 features), according to their frequency, used for the interpretation of Rooms in Area Pi.

322

323 Conclusions

The functional analysis in Area Pi at Malia revealed frequently used spaces that are 324 characterized by laminar microstructures and trampling cracks. Micro-residues are generally 325 poorly represented, a fact that shows maintained spaces and activity of low production of debris. 326 327 The presence or absence of biological activity contemporaneous to the occupation constitutes an indicator on the degree of use and maintenance of spaces. For instance, in Space 25, where a 328 sample comes from a marginal place, biological activity occurs simultaneously with evidence of 329 occupation but surfaces are also affected by post-depositional biological activity. The presence of 330 organic material related to human debris as well as soil humid conditions could favor soil fauna to 331 332 develop under the surface. This could perhaps point to the existence of a garden. This interpretation, however, necessitates further investigation through different and more thorough 333 analyses in order to be confirmed. 334

335 Moreover, the use of earthen material could serve as an evidence for environmental conditions. Earthen materials are able to record activity in their microstructure or in form of 336 specific pedo-features, different changes in humidity levels and water. A correlation of pedo-337 features between micro-layers of the same sample can point to high or low moisture on the floor 338 and thus it is considered as an environmental indicator of seasonal changes during the occupation 339 340 instead of a post-depositional effect which is expected to affect micro-layers as a whole. Also, 341 biological activity could be an indicator for exterior or interior spaces, although it is usually stronger in open areas. In the case of Malia, the indicators used for studying the environmental 342 conditions such as porosity, biological activity, oxide features, dusty clay coatings as well as the 343 344 absence of runoff and rain-drop features, show that some rooms did not have walls but were more likely covered by a light roof. Therefore, micromorphology constitutes a valuable approach, in 345 346 combination with more traditional methods, to refine the interpretation of spaces, especially when the archaeological evidence is not straightforward. 347

The earthen material used in construction comes from the vicinity of the site, like most of architectural material of the site (Schmid and Treuil, 2017;129). The red color clayey sediments observed in Area Pi were collected from terra rossa formation. Moreover, they used high amount of sediments already on the site. For example, for the construction of the leveling floor in Room 19, sediments are, on the one hand, backfills containing older archaeological levels and debris of human activity (pottery sherds, charcoals, bones, ashes) and, on the other hand, the well- prepared surfaces are made of red clayey sediments of terra rossa formation.

Further micromorphological analyses in other Spaces and Rooms of the Area Pi would shed 355 light on the use of space in different rooms and allow better defining micro-facies regarding the 356 nature of activities and the density of the use of space. Micromorphology can also contribute to 357 the characterization of the chaîne opératoire of earth building materials both of mudbricks and 358 earthen floors from the same Area, as a *continuum* to the study conducted by Marta Lorenzon 359 (Devolder and Lorenzon, 2019). Finally, it is desirable to compare our results with 360 micromorphological data from other Minoan sites, like the neighboring site of Sissi (currently 361 under study), for a more thorough understanding of the behavior of communities in Bronze Age 362 363 Crete.

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371

372 Bibliography

- Alberti, M. E., Müller Celka, S., Pomadère, M. 2019. The Management of Agricultural Resources in the Minoan Town of Malia (Crete) from the Middle Bronze Age to the Early Late Bronze Age, in: Garcia, D., Orgeolet, R., Pomadère, M., Zurbach, J. (Eds.) Country in the City. Agricultural functions in protohistoric urban settlements (Aegean and Western Mediterranean). Archaeopress Archaeology, Oxford, pp.51-71.
- Babel, U., 1975. Micromorphology in soil organic matter, in: Gieseking, J., E. (Ed.), Soil
 Components, vol. 1, Organic components, New York, Springer Verlag, pp.369–473.
- 380 3. Banerjea, R., Y., Bell, M., Matthews, W., Brown, A., 2015. Applications of
 micromorphology to understanding activity areas and site formation processes in
 experimental hut floors. Archaeol Anthrop Sci. 7(1), 89-112.

- Boness, D., Panagiotopoulos, D., Goren, Y., 2017. Minoan plaster technology as evident
 from the 'precinct' structure at Koumasa, Crete: A microarchaeological study. J. Archaeol.
 Sci.: Rep. 14, 392-408. https://doi.org/10.1016/j.jasrep.2017.06.001.
- 386 5. Bullock, P., Fedoroff, N., Jongerius, A., Stoops, G., Tursina, T., Babel, U., 1985.
 387 Handbook for Soil Thin Section Description. WaineResearch.
- Butzer, K.W., 1982. Archaeology as Human Ecology: Method and Theory for a Contextual
 Approach. Cambridge University Press, Cambridge; New York.
- Cammas, C., 1994. Approche micromorphologique de la stratigraphie de Lattes, premiers
 résultats, in: Garcia, D. (Ed.), Exploitation de la ville portuaire de Lattes, Les ilôts 2, 4sud, 5, 7-est, 8, 9 et 16 du Quartier Saint-Sauveur. Édition de l'association pour la
 Recherche Archéologique en Languedoc- Oriental (Lattara, 7), Lattes, pp. 181-202.
- Cammas, C., 1999. Dynamique pedosedimentaire urbaine à Lattes, in: Py, M. (Ed.),
 Recherches sur le Quatrième Siècle avant notre ère à Lattes. Édition de l'association pour
 la Recherche Archéologique en Languedoc- Oriental (Lattara, 12), Lattes, pp. 211-227.
- Cammas, C., 2003. L'architecture en terre crue à l'âge du Fer et à l'époque romaine:
 apports de la discrimination micromorphologique des modes de mise en œuvre, in: de
 Chazelles, C.-A., Klein, A. (Eds.), Échanges Transdisciplinaires sur les constructions en
 terre crue, 1. Terre modelée, découpée ou coffrée. Matériaux et modes de mise en œuvre.
 actes de la table ronde (Montpellier, 2001). Editions de l'Espérou, Montpellier, pp. 38-53.
- 402 10. Cammas, C., Wattez, J., 2009. L'approche micromorphologique : méthode et application
 403 aux stratigraphies archéologiques, in: Ferdières, A. (Ed.), La géologie: les sciences de la
 404 Terre appliquées à l'archéologie. Errance (Archéologiques), Paris, pp. 181-216.
- 405 11. Cammas, C.,1994.Approche micromorphologique de la stratigraphie de Lattes, premiers
 406 résultats, in: Garcia, D. (Ed.), Exploitation de la ville portuaire de Lattes, Les ilôts 2, 4407 sud, 5, 7-est, 8, 9 et 16 du quartier Saint-Sauveur. Édition de l'association pour la
 408 Recherche Archéologique en Languedoc- Oriental (Lattara, 7), Lattes, pp. 181-202.
- 409 12. Courty, M.-A., Goldberg, P., Macphail, R., 1989. Soils and Micromorphology in
 410 Archaeology. Cambridge University Press (Cambridge manuals in archaeology),
 411 Cambridge. New York.

- 412 13. Dandrau, A., 1999. La peinture murale minoenne, I. La palette du peintre égéen et égyptien
 à l'âge du Bronze. Nouvelles données analytiques. B. Corresp. Hellenique. 123.1, 1-41.
- 414 14. Davidson, D., Shackley, M., 1976. Geoarchaeology: Earth Science and the Past. Westview
 415 Press.
- 416 15. Devolder, M., Lorenzon, M., 2019. Minoan Master Builders? A Diachronic Study of
 417 Mudbrick Architecture in the Bronze Age Palace at Malia (Crete). B. Corresp. Hellénique.
 418 143.1, 63-124. http://hdl.handle.net/2078.1/221602.
- 419 16. Fouache, É., 2010. L'approche géoarchéologique, in: Alarashi, H., Chambrade, M.-L.,
 420 Gondet, S., Jouvenel, A., Sauvage, C., Tronchère, H. (Eds.), Regards croisés sur l'étude
 421 archéologique des paysages anciens : Nouvelles recherches dans le bassin méditerranéen,
 422 en Asie Centrale et au Proche et au Moyen-Orient (Travaux de la Maison de l'Orient et de
 423 la Méditerranée, 56). Maison de l'Orient et de la Méditerranée, Lyon, pp. 17–30.
- 424 17. Friesem, D., Karkanas, P., Tsartsidou, G., Shahack-Gross, R., 2014. Sedimentary processes
 425 involved in mud brick degradation in temperate environments: a micromorphological
 426 approach in an ethnoarchaeological context in northern Greece. J. Archaeol. Sci., 41, 556427 567. http://doi.org/10.1016/j.jas.2013.09.017.
- 428 18. Gé, T., Courty, M.-A., Matthews, W., Wattez, J., 1993. Sedimentary formation processes
 429 of occupation surfaces, in: Goldberg, P., Nash, D. T., Pétraglia, M. D. (Eds.), Formation
 430 processes in archaeological context. Prehistory press (Monographs in world archaeology,
 431 17), Madison, pp. 149-163.
- 432 19. Gebhardt, A., 1991. Evolution du Paléopaysage dans le Nord-Ouest de la France : Apport
 433 de la Micromorphologie. PhD thesis, Université de Rennes 1, Rennes.
- 434 20. Gomrée, T., Langohr, C., Pomadère, M., 2012. Excavations in the Pi Area at Malia (2005435 2010), in: Andrianakis, M., Varthalitou, P., Tzachili, I. (Eds.), Αρχαιολογικό Έργο Κρήτης
 436 2. Πρακτικά της 2ης Συνάντησης, Ρέθυμνο, 26-28 Νοεμβρίου 2010 / Archaeological Work
 437 in Crete 2. Proceedings of the 2nd Meeting, Rethymnon, 26-28 November 2010.
 438 Rethymno, pp. 89-97.

- 439 21. Karkanas, P., 2001. Site formation processes in Theopetra Cave: A record of climatic
 440 change during the Late Pleistocene and Early Holocene in Thessaly, Greece.
 441 Geoarchaeology.16/4, 373–399.
- 442 22. Karkanas, P., 2006. Late Neolithic household activities in marginal areas: the
 443 micromorphological evidence from the Kouveleiki caves, Peloponnese, Greece. J.
 444 Archaeol. Sci. 33, 1628–1641.<u>https://doi.org/10.1016/j.jas.2006.02.017</u>.
- 445 23. Karkanas, P., 2019. Microscopic deformation structures in archaeological
 446 contexts. Geoarchaeology. 34/1, 15-29.
- 447 24. Karkanas, P., Efstratiou, N., 2009. Floor sequences in Neolithic Makri, Greece:
 448 micromorphology reveals cycles of renovation. Antiquity. 83, 955-967.
- 449 25. Karkanas, P., Shahack-Gross, R., Ayalon, A., Bar-Matthews, M., Barkai, R., Frumkin, A.,
 450 Gopher, A., Stiner, M., 2007. Evidence for habitual use of fire at the end of the Lower
 451 Paleolithic: Site-formation processes at Qesem Cave, Israel. J. Hum. Evol. 53, 197–212.
- 452 26. Karkanas, P., Stratouli, G. 2008. Neolithic lime plastered floors in Drakaina cave,
 453 Kephalonia Island, Western Greece: evidence of the significance of the site. The Annual
 454 of the British School at Athens. 103, 27–41.
- 455 27. Karkanas, P., Van De Moortel, A., 2014. Micromorphological analysis of sediments at the
 456 Bronze Age site of Mitrou, central Greece: patterns of floor construction and maintenance.
 457 J. Archaeol. Sci., 43, 198-213. https://doi.org/10.1016/j.jas.2014.01.007.
- 458 28. Kooistra, M., J., Pulleman, M., M. 2010. Features Related to Faunal Activity. in: Stoops,
 459 G., Marcelino, V., Mees, F. (Eds), Interpretation of micromorphological features of soils
 460 and regoliths. Elsevier, Amsterdam, pp. 397–418.
- 461 29. Kulick, R., 2019. Urban micromorphology: A microecological narrative of a Neopalatial
 462 neighborhood at Bronze Age Palaikastro, Crete. Geoarchaeology. 34/4, 430-447.
 463 <u>https://doi.org/10.1002/gea.21725</u>.
- 464 30. Lespez, L., Dalongeville, R., Pastre, J.-F., Darmon, R., Poursoulis, G., 2003. Late-Middle465 Holocene palaeo-environmental evolution and coastline changes of Malia (Crete), in:
 466 Fouache, E. (Ed.), The Mediterranean World Environment and History. Elsevier, Paris, pp.
 467 439-452.

- 468 31. Lindbo, D., L., Stolt, M., H., Vepraskas, M., J., 2010. Redoximorphic Features. in: Stoops,
 469 G., Marcelino, V., Mees, F. (Eds), Interpretation of micromorphological features of soils
 470 and regoliths. Elsevier, Amsterdam, pp. 129-147.
- 471 32. Manning, S.W., 2014. A Test of Time and A Test of Time Revisited: The Volcano of Thera
 472 and the Chronology and History of the Aegean and East Mediterranean in the Mid-Second
 473 Millennium BC. Oxbow Books, Oxford and Philadelphia.
- 33. Matthews, W., 2001. Microstratigraphic sequences: Indications of uses and concepts of
 space, in: Matthews, R. (Ed.), Excavations at Tell Brak; Vol. 4, exploring an Upper
 Mesopotamian regional centre, 1994-1996. British School of archaeology in Iraq /
 McDonald Institute for archaeological research, London /Cambridge, pp. 377-388.
- 478 34. Matthews, W., French, C., A., I., Lawrence, T., Cutler D., F., Jones, M., K., 1997.
 479 Microstratigraphic traces of site formation processes and human activities. World
 480 Archaeol. 29/2, 281-308. http://dx.doi.org/10.1080/00438243.1997.9980378
- 481 35. Miller, C., E., Conard, N., J., Goldberg, P., Berna, F., 2010. Dumping, sweeping and
 482 trampling: experimental micromorphological analysis of anthropogenically modified
 483 combustion features. Palethnologie. 2, 25-37.
- 484 36. Mylona, P., 2018. L'approche géoarchéologique des systèmes d'occupation au PPNA à
 485 Chypre : le cas du site de Klimonas à Ayios Tychonas : Unpublished PhD thesis, Muséum
 486 National d'Histoire Naturelle.
- 487 37. Onfray, M., 2017. Du Sol à la Reconstitution de l'Espace Habité: Géoarchéologie des
 488 Modes d'Occupation de la Fin du Néolithique (3600-2255 av. n.-è.) dans le Sud-Ouest du
 489 Bassin Parisien. Unpublished PhD thesis, Université Paris 1 Panthéon-Sorbonne.
- 38. Onfray, M., Wattez, J., 2014. Les nappes de mobilier en Beauce : état de la question et
 apport de la géoarchéologie pour leur compréhension, in : Laurelut, C., Vanmoerkerke, J.
 (Eds.), Occupations et exploitations néolithiques. Et si l'on parlait des plateaux?, 31e
 colloque InterNéo : October 2013, Châlons-en-Champagne, France. pp.61-73.
- 494 39. Pagliai, M., Stoops, G., 2010. Physical and biological surface crusts. in: Stoops, G.,
 495 Marcelino, V., Mees, F. (Eds), Interpretation of micromorphological features of soils and
 496 regoliths. Elsevier, Amsterdam, pp. 419–440.

- 497 40. Pomadere, M., 2009. Malia, Secteur Pi. B. Corresp. Hellenique. 133.2, 633-644.
 498 https://doi.org/10.3406/bch.2009.7594.
- 499 41. Pomadere, M., 2011. Malia. B. Corresp. Hellenique. 135.2, 601-624.
 500 <u>https://doi.org/10.3406/bch.2011.7906.</u>
- 42. Poursat, J.-C. 2010. Malia: palace, state, city. in: Krzyszkowska, O. (ed.), Cretan
 Offerings. Studies in Honour of Peter Warren. London, The British School at Athens
 (BSA Studies, 18), pp. 259–267
- 43. Rapp, G.R., Gifford, J.A., 1982. Archaeological geology. Am. Sci. 70 (1), 45-53.
- 44. Rentzel, P., Nicosia, C., Gebhardt, A., Brönnimann, D., Pümpin, C., Ismail-Meyer, K.,
 2017. Trampling, poaching and the effect of traffic, in: Nicosia, C., Stoops, G., (Eds),
 Archaeological Soil and Sediment Micromorphology, Wiley, pp. 281-298.
- 508 45. Schiffer, M.B., 1983. Toward the Identification of Formation Processes. Am. Antiquity.
 509 48, 675-706.
- 510 46. Schmid, M., Treuil, R., 2017. Fouilles Exécutées à Malia : le Quartier Mu. VI, Architecture
 511 Minoenne à Malia : les Bâtiments Principaux du Quartier Mu (A, B, D, E) (Minoen Moyen
 512 II) (Etudes crétoises, 36). De Boccard Édition, Athens, Paris.
- 47. Shahack- Gross, R., 2017. Animal Gathering Enclosures, in: Nicosia, C., Stoops, G., (Eds),
 Archaeological Soil and Sediment Micromorphology, Wiley, pp. 265-280.
- 515 48. Shahack-Gross, R., Berna, F., Karkanas, P., Lemorini, C., Gopher, A., Barkai, R., 2014.
 516 Evidence for the repeated use of a central hearth at Middle Pleistocene (300 ky ago) Qesem
 517 Cave, Israel. J. Archaeol. Sci. 44, 12-21.
- 518 49. Shaw, J.W., 2009. Minoan Architecture: Materials and Techniques. Studi di Archeologia
 519 Cretese 7. Padova: Bottega d'Erasmo.
- 50. Shillito, L.-M., Matthews, W., 2013. Geoarchaeological Investigations of MiddenFormation Processes in the Early to Late Ceramic Neolithic Levels at Çatalhöyük, Turkey
- 522 ca. 8550-8370 cal. B.P. Geoarchaeology. 28, 25–49. <u>https://doi.org/10.1002/gea.21427.</u>

- 51. Shillito, L.-M., Matthews, W., Almond, M.J., Bull, I.D. 2011. The microstratigraphy of
 middens: capturing daily routine in rubbish at Neolithic Çatalhöyük, Turkey. Antiquity.
 85, 1024–1038.
- 526 52. Stoops, G., 2003. Guidelines for Analysis and Description of Soil and Regolith Thin
 527 Sections. Soil Science Society of America, Madison.
- 528 53. Stoops, G., Marcelino, V., Mees, F., 2010 (Eds.), Interpretation of Micromorphological
 529 Features of Soils and Regoliths. Elsevier, Amsterdam; Oxford.
- 530 54. Stordeur, D., Wattez, J., 1998. À la recherche de nouvelles clés. Étude géoarchéologique
 531 à Qdeir 1, PPNB final, désert syrien, Cah de l'Euphrate. 8, 115-138.
- 532 55. Vissac, C., 2005. Study of a historical garden soil at the Grand-Pressigny site (Indre-et533 Loire, France): evidence of landscape management. J. Cult. Herit. 6, 61–67. <u>http://</u>
 534 <u>doi:10.1016/j.culher.2004.07.002.</u>
- 535 56. Wattez, J., 1992. Dynamique de Formation des Structures de Combustion de la Fin du
 536 Paléolithique au Néolithique Moyen : Approche Méthodologique et Implications
 537 Culturelles. Unpublished PhD thesis, Université Paris 1 Panthéon-Sorbonne, Paris.
- 57. Wattez, J., 2009. Enregistrement sédimentaire de l'usage de la terre crue dans les
 établissements néolithiques du sud de la France : le cas des sites du Néolithique Final de
 La Capoulière 2 et du Mas de Vignoles IV, in: Beeching, A., Sénépart, I. (Eds.), De la
 maison au village. L'habitat néolithique dans le Sud de la France et du Nord-Ouest
 méditerranéen. Actes de la table ronde des 23 et 24 mai 2003, Société Préhistorique
 Française (Mémoire, 48), Marseille/Musée d'Histoire de la Ville de Marseille, Paris, pp.
 199–218.

545 58. Wattez, J., Cammas, C., Courty, M., A., 1998. Marqueurs spatio-temporels des ambiances
546 pédo-climatiques dans les sols archéologiques. Actes du Congrès mondial de Science du
547 Sol, Montpellier, France, août 1998.

548 59. Wattez, J., Courty, M,-A., 1996. Modes et rythmes d'occupation à Tell Halula. Approche
549 géoarchéologique (premiers résultats), in: Molist Montana, M. (Ed.), Tell Halula (Siria):
550 un yacimiento neolitico del valle medio del Euphrates Campanas de 1991-1992. Ministerio
551 de Educacion y Cultura, Madrid, pp. 53–67.