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## The contribution of soil micromorphology in understanding the use of space in Area Pi at Malia (Crete)

Pantelitsa Mylona, Maia Pomadère

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

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

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

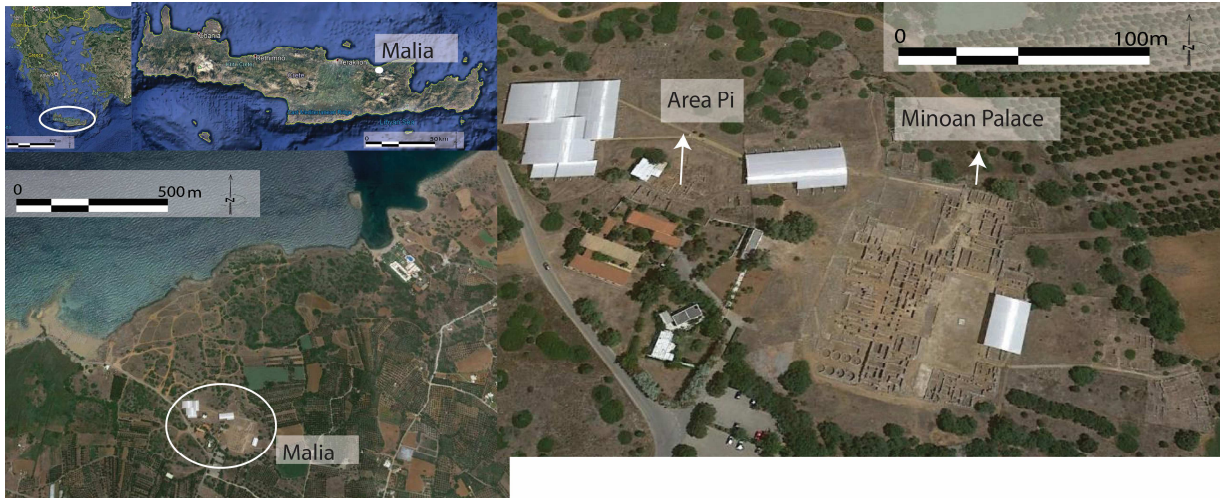
62 Different constructions were discovered in Area Pi and initially interpreted according to  
63 plan and assemblages of artifacts and ecofacts. Primary deposits are not numerous, because of a  
64 (perhaps gradual) abandonment of the Area during Late Minoan IA (LM IA) period. The  
65 micromorphological study was undertaken in order to provide a more thorough sight of activities  
66 and of the spatial organization in the Area Pi. Earthen floors, abundantly used in the Area Pi, can  
67 record traces of human or animal activities. The nature of earthen floors allows the application of  
68 geoarchaeological approach using soil micromorphology, in order to question archaeological  
69 interpretations on the use of space and on spatial distribution of activities. The micromorphological  
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  
80 from 2005-2014 (under the aegis of the French School at Athens) revealed a complex of rooms,  
81 mainly interpreted as domestic areas and some open spaces (fig.2) (Pomadère, 2009; 2011;  
82 Gomrée *et al.*, 2012; Alberti *et al.*, 2019). The occupation of the Area spans across protopalatial  
83 and neopalatial periods, however, building Pi is mainly dated to the Middle Minoan III (MM III)  
84 and Late Minoan IA (LM IA) period (ca. 1700-1450 BC) (Manning, 2014; Gomrée *et al.*, 2012).

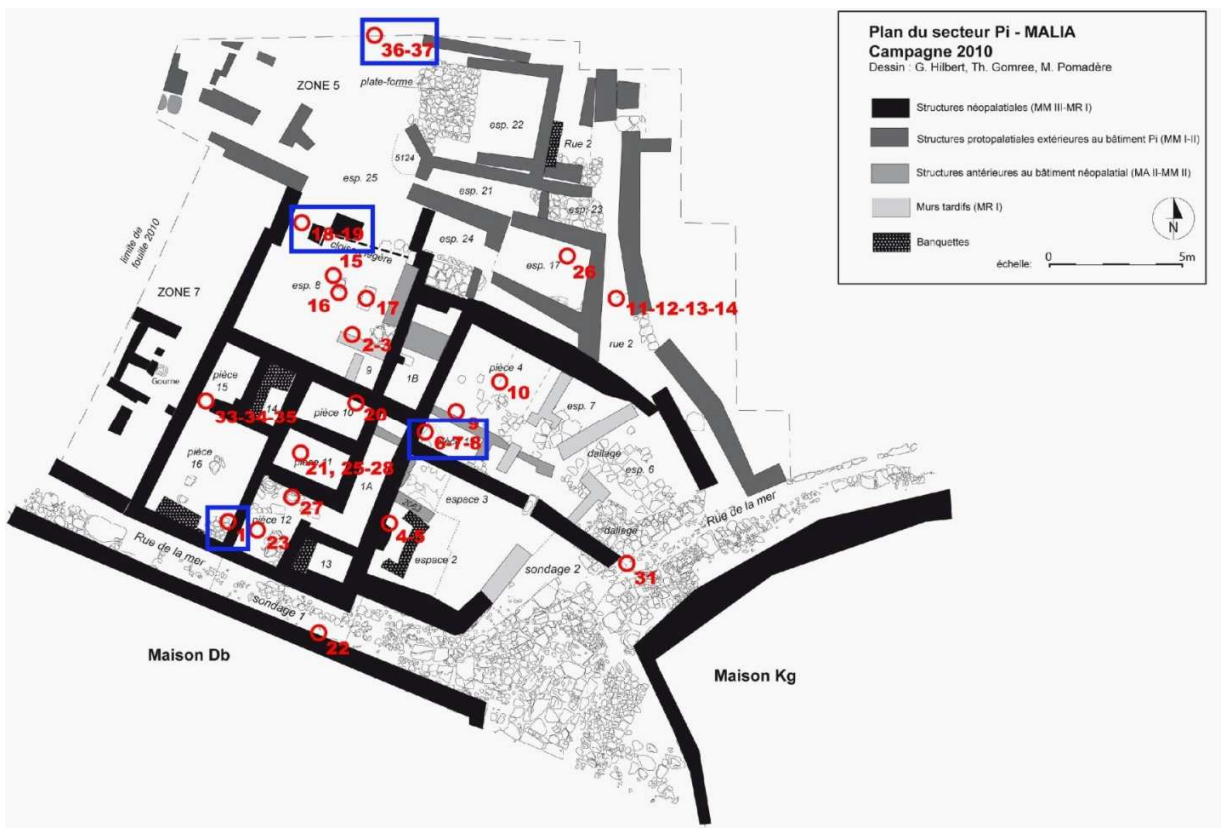
85



86

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

88



89

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

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

95

## 96 **Materials and Methods**

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

109 The functional approach applied at Malia defined different indicators that can be used for  
110 identifying the nature and the use of space (Gé *et al.*, 1993; Watez and Courty, 1996; Stordreur  
111 and Watez, 1998; Watez *et al.*, 1998; Watez, 2009). Four indicators have been defined:

112 1. The inclusions of animal and plant origin (charcoals, bones, excrements, burnt bones  
113 and aggregates). These indicators are related to different activities that can occur in a room such  
114 as the presence of hearth or the preparation and consumption of food;

115 2. The microstructure of trampling effect. Microstructure of earthen material interacts  
116 differently in trampling pressure in wet or dry environmental conditions;

117 3. Pedo-features of hydric conditions in the floor. Pedo-features of superficial runoff or the  
118 presence of coatings related to the water circulation in the soil can be considered as indicators of  
119 hydric conditions.

120 4. Biological activity. Activity of soil fauna and flora can be developed simultaneously to  
121 the 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.

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

132

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

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

138 **Results**

139 Room 19- Middle Minoan IIIA

140 Room 19 is a small space situated in the middle of the building. Entire vases, in a primary  
141 destruction deposit, including a pithos, have been found in the room, but no floor could be clearly  
142 attributed to Middle Minoan IIIA (MM IIIA) period. Activities of MM IIIA period seems to take  
143 place on the remains of the MM II floor. Fragments of plaster floors found in the Room may belong  
144 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  
146 with human debris such as ceramic, ashes and bones (tab. 2) (fig.3A). This layer can be interpreted  
147 as a leveling floor followed by the setup of thinner and finer successive surfaces. Successive  
148 plastered surfaces are quite common in Malia and related to a regular maintenance of the space  
149 (Shaw, 2009). Both leveling floor and occupation surfaces are mainly made of red non-birefringent  
150 striated clayey sediments. The surfaces (SU5043) are made of white carbonated silty sand  
151 sediments, interpreted as a plaster, that were colored by red wash on the top (fig.3B). The red paint  
152 wash (*badigeon* in French) was made of red clayey sediments mixed with large quantities of water.  
153 The horizontal distribution of clays shows that wash was applied by spreading it on the surface  
154 (Wattez 2009; Karkanas, 2019). The successive surfaces are thin (around 5 mm of thickness) with  
155 fine horizontal cracks that create a prismatic microstructure as a result of trampling activity (Gé et  
156 al 1993; Rentzel *et al.*, 2017; Karkanas 2019) (fig. 3C). Biological activity and micro-residues of  
157 human activity are very few on each surface (tab. 2).

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

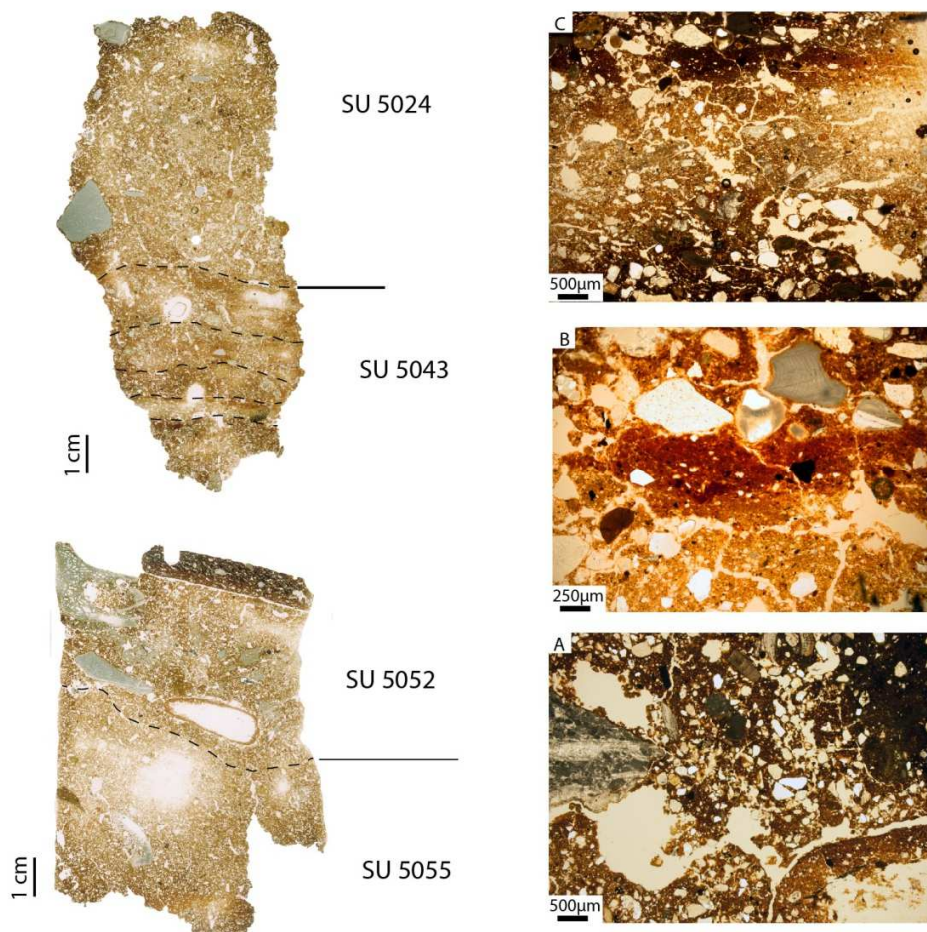
162 *Discussion on the use of space in Room 19*

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

166 (Miller *et al.*, 2010; Benerjea *et al.*, 2015). Evidence of sweeping activity might can be revealed  
167 by the micromorphological study of more samples from different place or the corners of the room  
168 where cleaning activity could not be regular, but at this stage of the research, no more samples are  
169 available for comparison. The presence of plant mat, according to present evidence, is not proposed  
170 because of the quasi-total absence of phytoliths from the samples (Wattez and Courty 1996;  
171 Karkanas and Efstratiou 2009; Shillito *et al.* 2011).

172         The combination of a clean space containing high degree of trampling suggests a frequently  
173 used and well-maintained space which refers to the frequently used and clean interior surfaces  
174 micro-facies. Based on available micromorphological evidence, it could be proposed that the space  
175 was not used for activities that left traces (hearth, domestic activities). Micromorphological  
176 interpretation corresponds well to the interpretation of archaeologist as a storage room, suggested  
177 by the presence of a pithos and of a dozen of other vases (one amphora, at least five jugs and  
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  
181 vicinity of the site (terra rossa formation) (Lespez *et al.*, 2003). Room 19 was plastered and painted  
182 with red color, perhaps during MM II when this type of plaster is well attested at Malia (Dandrau,  
183 1999; Schmid and Treuil, 2017). However, it seems that the plastered floor of Room 19 was  
184 destroyed partially, probably before MM III. Plaster fragments, either from floor or from the wall,  
185 can be identified only by microscopic analysis but some larger ones were collected during  
186 excavation. Micromorphological study in Area Pi showed the use of red striated clay of low  
187 birefringence as a paint wash. According to previous analyses conducted at Malia, the red color  
188 results from the use of ochre (Dandrau, 1999, 30-31; Schmid and Treuil, 2017, 142). In Middle  
189 Minoan Koumasa and other sites such as Phaistos, Knossos, Ayia Triada and Kommos, the red  
190 color also comes from the use of iron oxides (hematite or goethite) (Boness *et al.*, 2017).



191

192 Figure 3: Scan of thin sections from Room 19. A: Coarse and heterogeneous elements  
 193 partially accommodated that form the leveling floor (SU 5052 and SU 5055) on which surfaces  
 194 are developed (PPL); B: Red colored wash applied on the top of plastered floor (SU 5043). The  
 195 microstructure is massive. The matrix is impregnated of red oxides (PPL); C: Well-maintained  
 196 surface made of white carbonated sediments interpreted as a plaster and covered by a red wash on  
 197 the top. Fine cracks on the white part of the surface are created due to trampling pressure (SU  
 198 5043) (PPL).

199

200 Space 25- Middle Minoan II-LM IA

201 Continuing towards the north of Area Pi (fig. 2), Space 25 was interpreted, based on  
 202 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  
204 8 and 25 (fig. 2) presents a succession of micro-layers (fig. 4A and 4B). The floor (SU 5099) is  
205 constructed and characterized by coalescent clumps limited by fine curve cracks and the  
206 distribution of sand grains is homogeneous. Both of elements show mixed and blended material  
207 before the setup phase (Cammass, 2003; Watez, 2009). Fine horizontal cracks related to textural  
208 and structural crusts and fine cracks around the aggregates are the result of trampling (Gé *et al.*,  
209 1993) (fig.5A). Some structural crusts point to a circulation surface and they are in relation with  
210 platy aggregates and to the horizontal distribution of inclusions such as sand grains (Rentzel *et al.*,  
211 2017) (fig. 5C). Some channels of worm activity, simultaneous to the occupation, appear deformed  
212 under the trampling pressure (fig.5D). Human micro-residues such as micro-charcoals (0-2%),  
213 pottery sherds (2-5%), burnt aggregates (2-5%) and bones (0-2%) (tab. 2) of different sizes are  
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  
217 indicators of an open-air space such as rain drop effect or runoff marks are observed (Onfray,  
218 2017). However, we noticed the presence of oxidize pedo-features (2-5%) and fine dusty clay  
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 (10-30µm).  
223 Trampling is more expressed in dryer conditions creating more intense cracks and structural and  
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  
226 coatings in the voids of different micro-layers suggest seasonal variations during the occupation  
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.

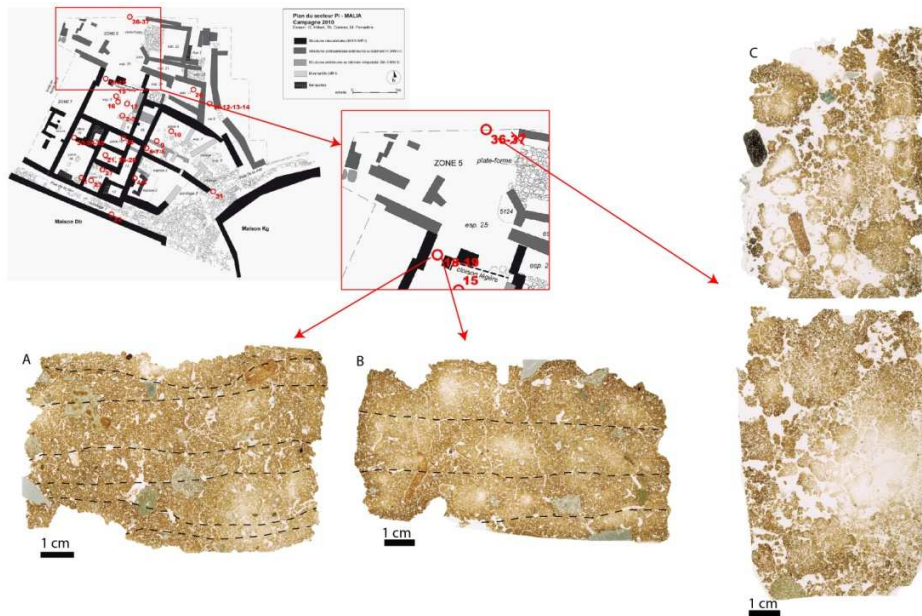
229 In the northern part of Space 25 (sample 36) (fig. 2, 4C), the sample was retrieved more  
230 than 5m north of building Pi. This area offers evidence of building activity only from the proto-  
231 palatial period while the neopalatial occupation is attested only by a layer of sherds (dump). The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

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

#### 242 *Discussion on the use of space in Space 25*

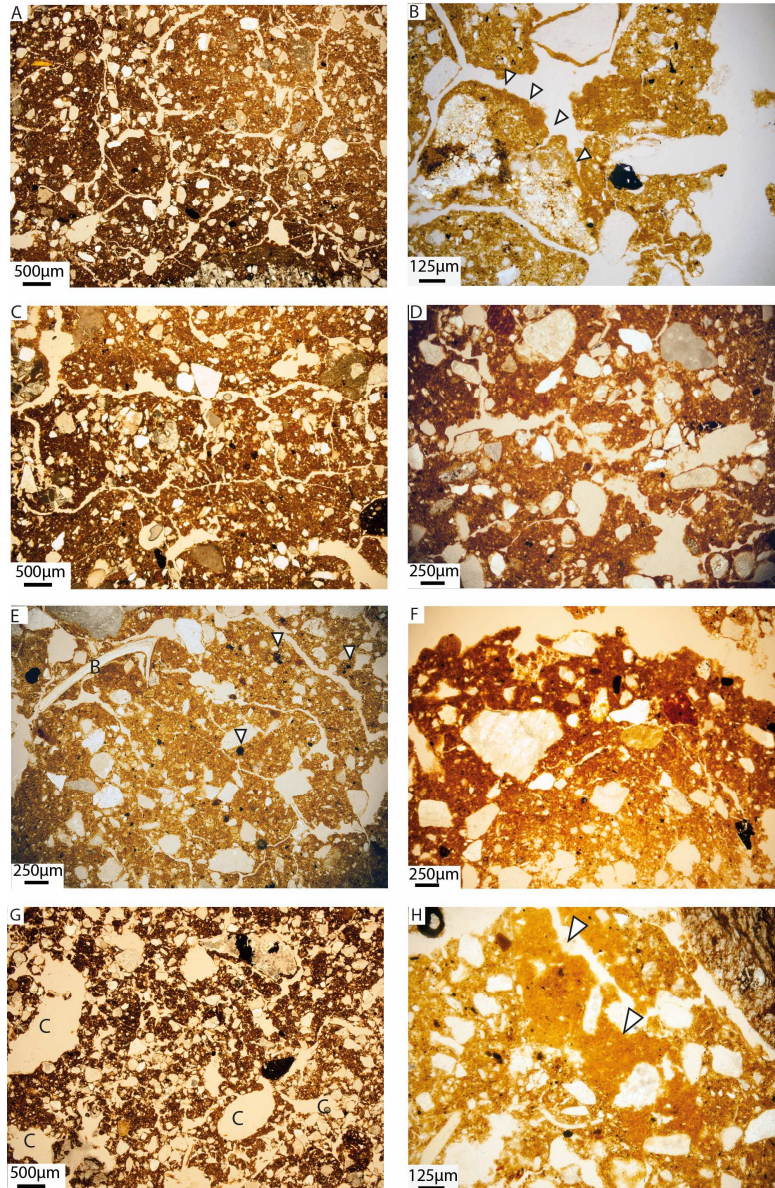
243 Based on the micromorphological data, we were able to observe spatial variations within  
244 the occupation of Space 25 and to call into question the hypothesis of an entire open-air space. The  
245 absence of excrements, runoff and rain-drop features goes against this interpretation. The presence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

252 Concerning the northern part of Space 25, biological activity during the occupation of the  
253 Area is stronger than in the southern part, showing a less maintained space. **Strong post-**  
254 **depositional activity is also observed. The presence of slightly fewer micro-debris and the weaker**  
255 **trampling activity could be connected to the larger distance to the core of activities. The northern**  
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.



260

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



267

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

274

275 Room 16- Late Minoan IA

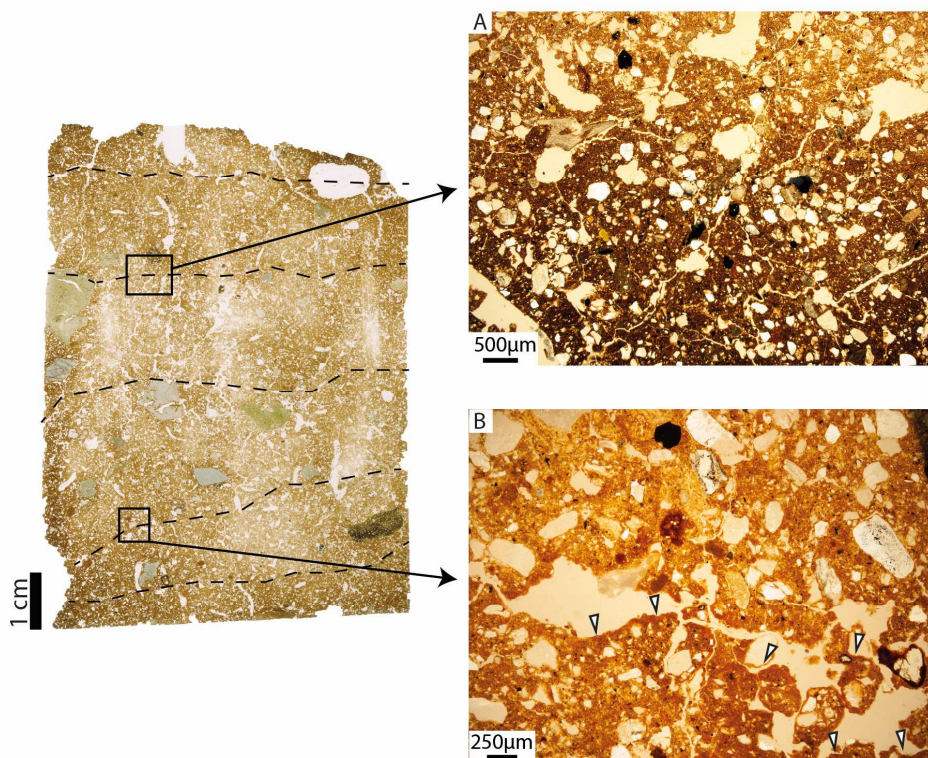
276 Room 16 (4,25 x 3,10m) was identified as a space dedicated to various activities (food  
277 preparation, cutting stone tools, weaving etc.) based on the presence of a grindstone, cooking jar  
278 and various tools. They were concentrated on the south-west part of the Room whereas, a big part  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

294

295 *Discussion on the use of space in Room 16*

296 Comparing archaeological data (especially the presence of a cooking jar in the room) and  
297 micromorphological observations, we assume that the pavement supported a movable hearth  
298 which could indicate the presence of a hole on the roof in order to evacuate the smoke. This  
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  
301 are not considered as taphonomy effect due to the reason that their thickness varies from one micro-  
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  
305 is in other rooms despite that the room was abandoned (Kooistra and Pulleman, 2010). It should

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  
308 presence is related with thick clayey coatings. According to different micromorphological  
309 indicators and observations, such as biological activity synchronous to the occupation and irregular  
310 trampling activity, the place around the pavement seems to be irregularly frequent used and less  
311 maintained (tab. 1) than the rest of the room (cf. Onfray and Wattez, 2013; Mylona, 2018). The  
312 position of the sample in a corner, next to the pavement and the wall can explain the infrequent  
313 use of this location.



314  
315 Figure 6: Scan of thin section showing the micro-layers that present characteristic of a surface (SU  
316 4091). Rectangular show the position of photomicrographs. Photomicrographs of the sample from  
317 Room 16. A: fine cracks related to trampling pressure (PPL); B: Fine dusty clay coating in pores  
318 (arrows) (PPL).

319

<i>Rooms</i>	<i>Inclusions</i>		<i>Microstructure</i>	<i>Pedofeatures</i>
<b>Room 19</b>	<i>Preparation floor</i>	<i>Constructed floor</i>	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%)
	Bones 0-2% Micro-charcoals 2-5% Ceramics 5-10% Ashes 2-5%	Bones 0-2% Micro-charcoals 0-2% Ceramics 0-2% Shells 0-2%		
<b>Space 25 south part</b>	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%
<b>Space 25 north part</b>	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%
<b>Room 16</b>	Micro-charcoals (0-2%- in concentrations (2-5%)) Shell (0-2%) Burnt aggregates (2-5%) Bones flakes (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**

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

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

348 The earthen material used in construction comes from the vicinity of the site, like most of  
349 architectural material of the site (Schmid and Treuil, 2017;129). The red color clayey sediments  
350 observed in Area Pi were collected from terra rossa formation. Moreover, they used high amount  
351 of sediments already on the site. For example, for the construction of the leveling floor in Room  
352 19, sediments are, on the one hand, backfills containing older archaeological levels and debris of  
353 human activity (pottery sherds, charcoals, bones, ashes) and, on the other hand, the well- prepared  
354 surfaces are made of red clayey sediments of terra rossa formation.

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

364

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371

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