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

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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 19th 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).**

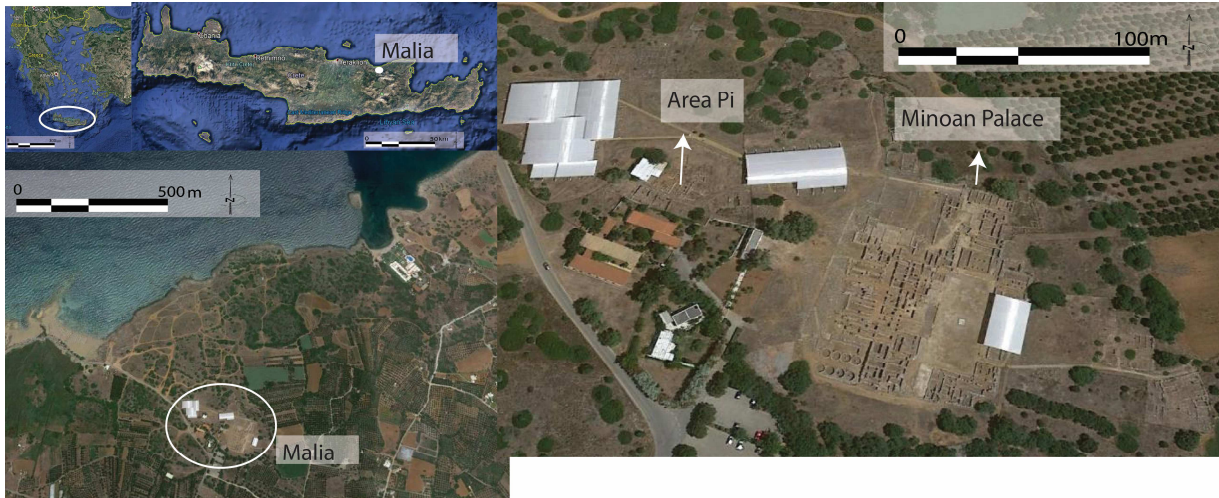
62 Different constructions were discovered in Area Pi and initially interpreted according to
63 plan and assemblages of artifacts and ecofacts. Primary deposits are not numerous, because of a
64 (perhaps gradual) abandonment of the Area during Late Minoan IA (LM IA) period. The
65 micromorphological 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).

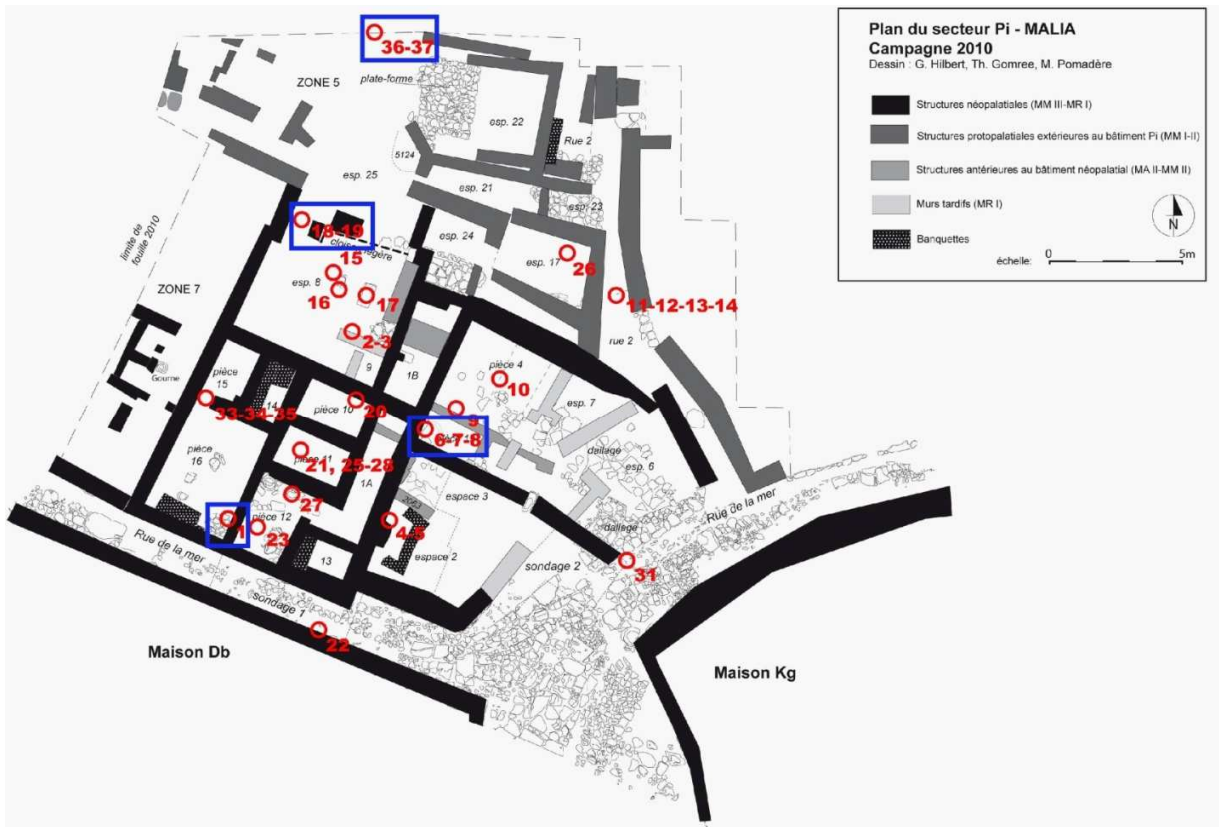
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87 Figure 1: The location of Malia in Crete and the Area Pi within the site (©Google Earth).

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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.

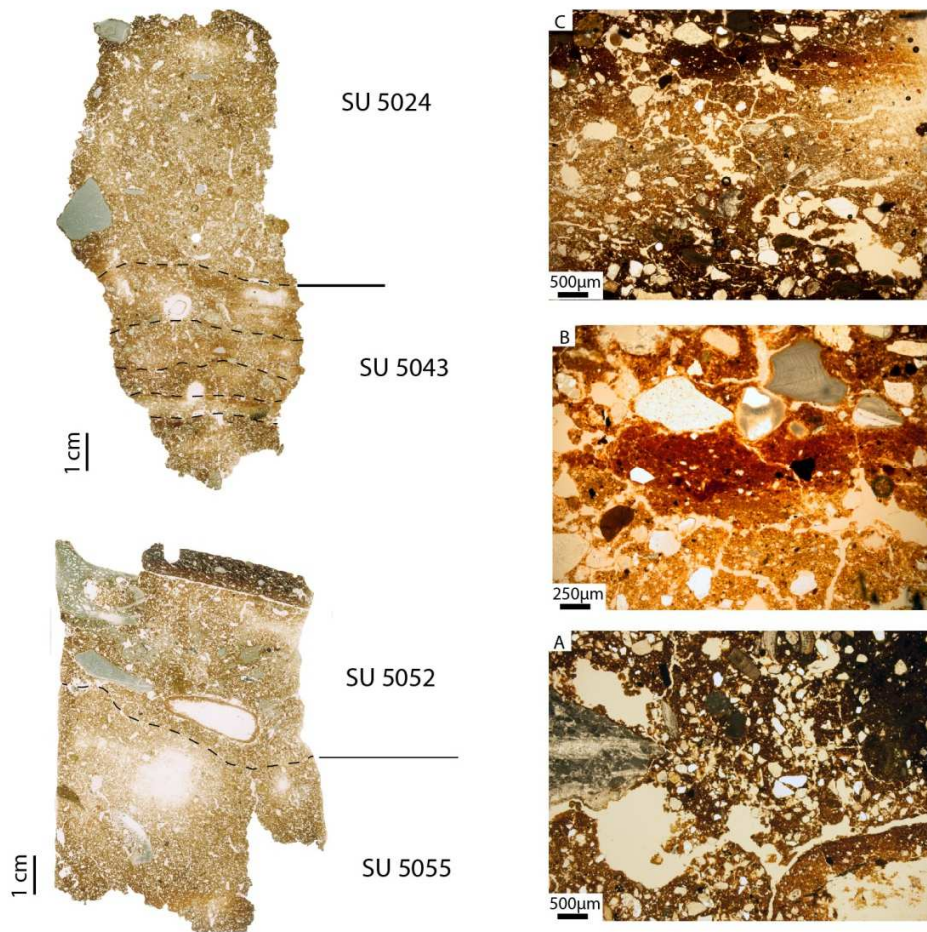
162 *Discussion on the use of space in Room 19*

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).



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200 Space 25- Middle Minoan II-LM IA

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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).

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
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; Wattez, 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.

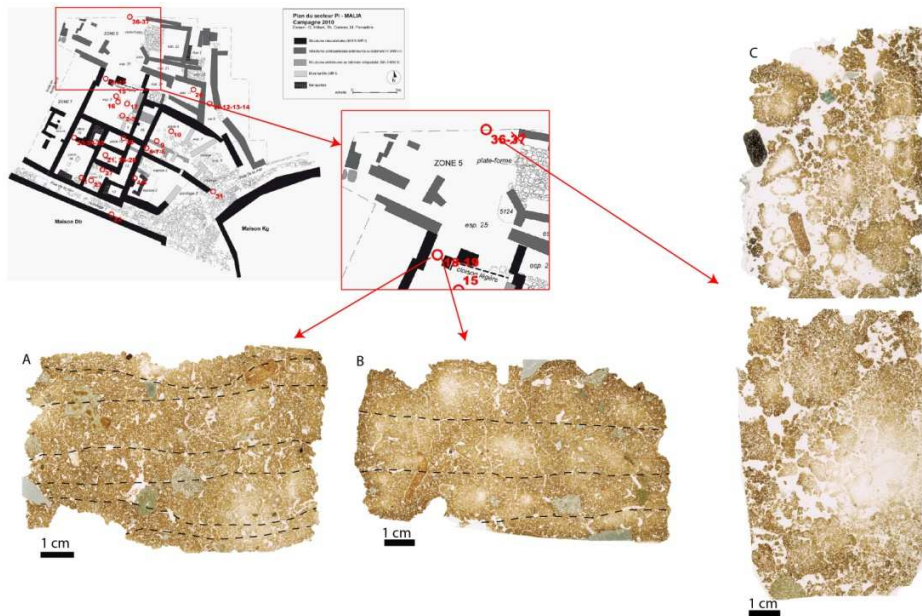
229 In the northern part of Space 25 (sample 36) (fig. 2, 4C), the sample was retrieved more
230 than 5m north of building Pi. This area offers evidence of building activity only from the proto-
231 palatial period while the neopalatial occupation is attested only by a layer of sherds (dump). The
232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

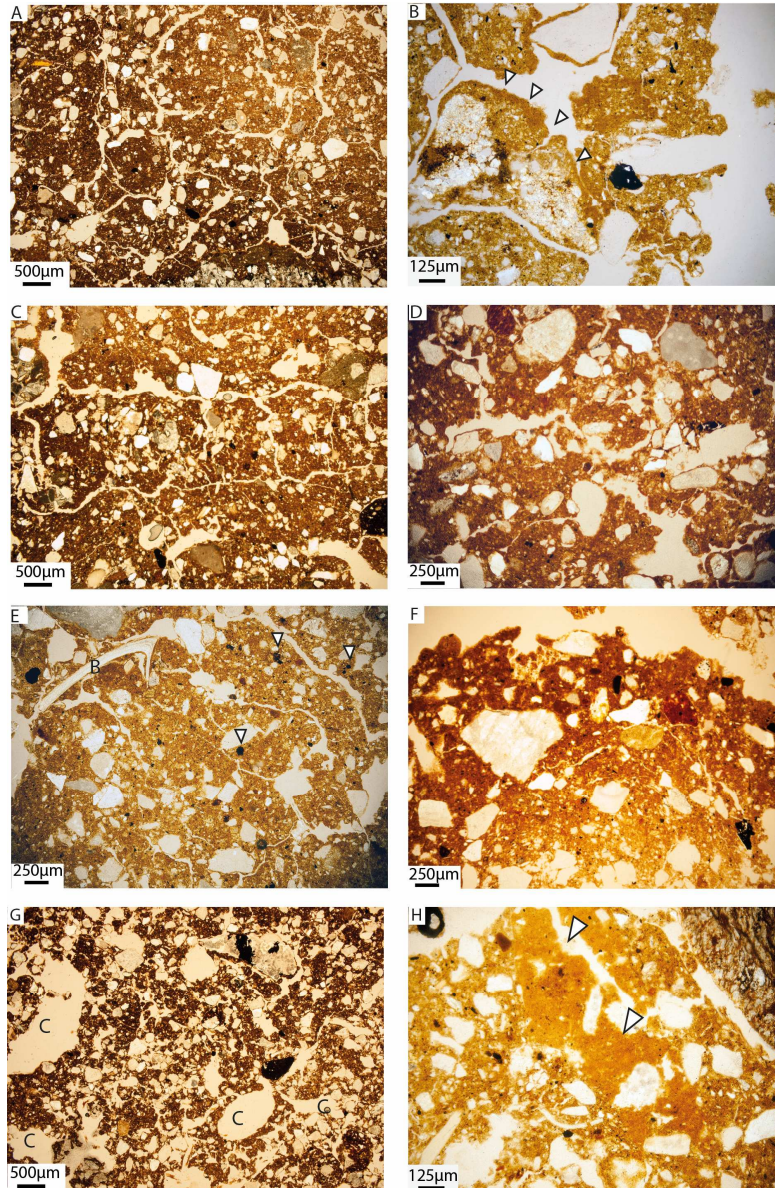
243 Based on the micromorphological data, we were able to observe spatial variations within
244 the occupation of Space 25 and to call into question the hypothesis of an entire open-air space. The
245 absence of excrements, runoff and rain-drop features goes against this interpretation. The presence
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).

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275 Room 16- Late Minoan IA

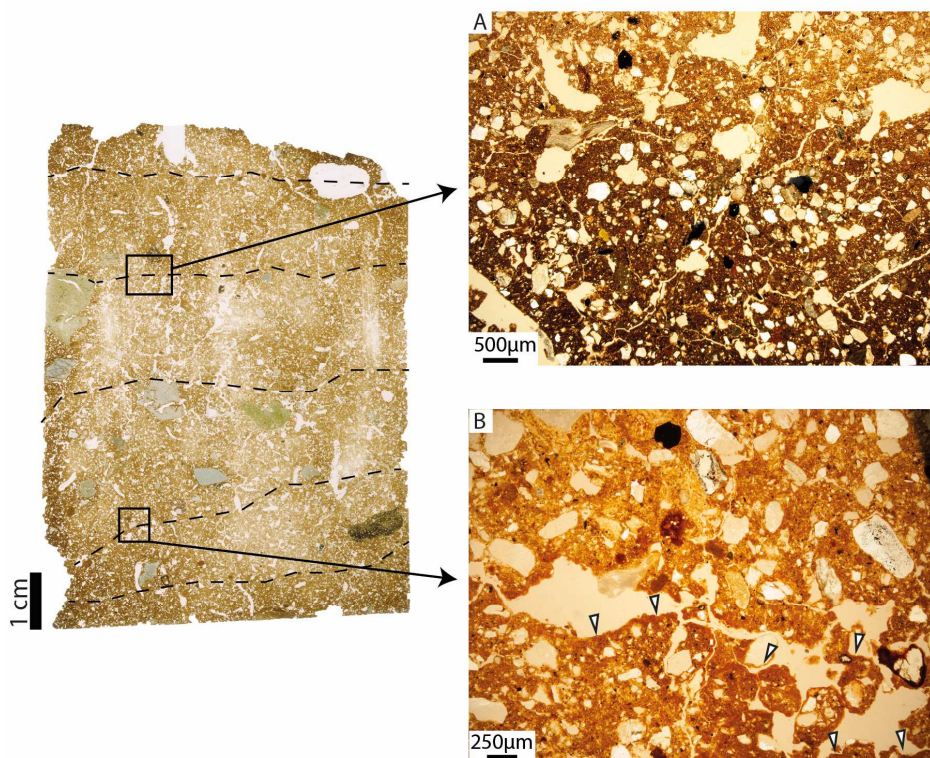
276 Room 16 (4,25 x 3,10m) was identified as a space dedicated to various activities (food
277 preparation, cutting stone tools, weaving etc.) based on the presence of a grindstone, cooking jar
278 and various tools. They were concentrated on the south-west part of the Room whereas, a big part
279 of 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 Watez, 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>
Room 19	<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%		
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-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

372 **Bibliography**

- 373 1. Alberti, M. E., Müller Celka, S., Pomadère, M. 2019. The Management of Agricultural
374 Resources in the Minoan Town of Malia (Crete) from the Middle Bronze Age to the Early
375 Late Bronze Age, in: Garcia, D., Orgeolet, R., Pomadère, M., Zurbach, J. (Eds.) Country
376 in the City. Agricultural functions in protohistoric urban settlements (Aegean and Western
377 Mediterranean). Archaeopress Archaeology, Oxford, pp.51-71.
- 378 2. Babel, U., 1975. Micromorphology in soil organic matter, in: Gieseking, J., E. (Ed.), Soil
379 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
381 micromorphology to understanding activity areas and site formation processes in
382 experimental hut floors. *Archaeol Anthropol Sci.* 7(1), 89-112.

- 383 4. Boness, D., Panagiotopoulos, D., Goren, Y., 2017. Minoan plaster technology as evident
384 from the 'precinct' structure at Koumasa, Crete: A microarchaeological study. *J. Archaeol.*
385 *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.
- 388 6. Butzer, K.W., 1982. *Archaeology as Human Ecology: Method and Theory for a Contextual*
389 *Approach*. Cambridge University Press, Cambridge; New York.
- 390 7. Cammas, C., 1994. Approche micromorphologique de la stratigraphie de Lattes, premiers
391 résultats, in: Garcia, D. (Ed.), *Exploitation de la ville portuaire de Lattes, Les îlots 2, 4-*
392 *sud, 5, 7-est, 8, 9 et 16 du Quartier Saint-Sauveur*. Édition de l'association pour la
393 *Recherche Archéologique en Languedoc- Oriental (Lattara, 7)*, Lattes, pp. 181-202.
- 394 8. Cammas, C., 1999. Dynamique pedosedimentaire urbaine à Lattes, in: Py, M. (Ed.),
395 *Recherches sur le Quatrième Siècle avant notre ère à Lattes*. Édition de l'association pour
396 *la Recherche Archéologique en Languedoc- Oriental (Lattara, 12)*, Lattes, pp. 211-227.
- 397 9. Cammas, C., 2003. L'architecture en terre crue à l'âge du Fer et à l'époque romaine:
398 apports de la discrimination micromorphologique des modes de mise en œuvre, in: de
399 Chazelles, C.-A., Klein, A. (Eds.), *Échanges Transdisciplinaires sur les constructions en*
400 *terre crue, 1. Terre modelée, découpée ou coffrée. Matériaux et modes de mise en œuvre.*
401 *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 îlots 2, 4-*
407 *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
413 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, 556-
427 567. <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 (2005-
435 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. <https://doi.org/10.1016/j.jas.2006.02.017>.
- 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 Kephallonia 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 <https://doi.org/10.1002/gea.21725>.
- 464 30. Lespez, L., Dalongeville, R., Pastre, J.-F., Darmon, R., Poursoulis, G., 2003. Late-Middle-
465 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.
- 474 33. Matthews, W., 2001. Microstratigraphic sequences: Indications of uses and concepts of
475 space, in: Matthews, R. (Ed.), Excavations at Tell Brak; Vol. 4, exploring an Upper
476 Mesopotamian regional centre, 1994-1996. British School of archaeology in Iraq /
477 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.
- 490 38. Onfray, M., Wattez, J., 2014. Les nappes de mobilier en Beauce : état de la question et
491 apport de la géoarchéologie pour leur compréhension, in : Laurelut, C., Vanmoerkerke, J.
492 (Eds.), Occupations et exploitations néolithiques. Et si l'on parlait des plateaux?, 31e
493 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 <https://doi.org/10.3406/bch.2011.7906>.
- 501 42. Poursat, J.-C. 2010. Malia: palace, state, city. in: Krzyszkowska, O. (ed.), Cretan
502 Offerings. Studies in Honour of Peter Warren. London, The British School at Athens
503 (BSA Studies, 18), pp. 259–267
- 504 43. Rapp, G.R., Gifford, J.A., 1982. Archaeological geology. *Am. Sci.* 70 (1), 45-53.
- 505 44. Rentzel, P., Nicosia, C., Gebhardt, A., Brönnimann, D., Pümpin, C., Ismail-Meyer, K.,
506 2017. Trampling, poaching and the effect of traffic, in: Nicosia, C., Stoops, G., (Eds),
507 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.
- 513 47. Shahack- Gross, R., 2017. Animal Gathering Enclosures, in: Nicosia, C., Stoops, G., (Eds),
514 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’Erasmus.
- 520 50. Shillito, L.-M., Matthews, W., 2013. Geoarchaeological Investigations of Midden-
521 Formation Processes in the Early to Late Ceramic Neolithic Levels at Çatalhöyük, Turkey
522 ca. 8550-8370 cal. B.P. *Geoarchaeology.* 28, 25–49. <https://doi.org/10.1002/geoa.21427>.

- 523 51. Shillito, L.-M., Matthews, W., Almond, M.J., Bull, I.D. 2011. The microstratigraphy of
524 middens: capturing daily routine in rubbish at Neolithic Çatalhöyük, Turkey. *Antiquity*.
525 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-et-
533 Loire, France): evidence of landscape management. *J. Cult. Herit.* 6, 61–67. [http://](http://doi:10.1016/j.culher.2004.07.002)
534 doi:10.1016/j.culher.2004.07.002.
- 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.
- 538 57. Wattez, J., 2009. Enregistrement sédimentaire de l'usage de la terre crue dans les
539 établissements néolithiques du sud de la France : le cas des sites du Néolithique Final de
540 La Capoulière 2 et du Mas de Vignoles IV, in: Beeching, A., Sénépart, I. (Eds.), *De la*
541 *maison au village. L'habitat néolithique dans le Sud de la France et du Nord-Ouest*
542 *méditerranéen*. Actes de la table ronde des 23 et 24 mai 2003, Société Préhistorique
543 Française (Mémoire, 48), Marseille/Musée d'Histoire de la Ville de Marseille, Paris, pp.
544 199–218.
- 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.