Times of historical developments and environmental changes in the Minoan town of Malia, Crete: an intra and off-site geoarcheological approach

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Abstract

The site of Malia, on the northwest coast of Crete is stimulating for geoarchaeological research. A Minoan palatial town developed during the Middle and Late Bronze Ages in an area that was occupied for a long time, and has been the subject of archaeological excavations for a century. A small wetland located near the sea and close to the archaeological site offers rich natural archives and new record. The latter can now be combined with archaeological data and allow to address some important questions on the history of the whole area. New excavations have improved our knowledge of the relative chronology at the site, but the duration of these successive phases, the causes and rates of change observed are difficult to precise and call for a dialogue with specialists of natural sciences. Can we link the major shifts identified in the material culture and history of the site with broader environmental changes, sudden or durable? This paper addresses the methodological problems for time reading and exemplify them by focusing on two important time lapses, the first occupation of the area (Neolithic and Early Bronze Age) on the first hand, and the Neopalatial phase on a second hand. For each example, we discuss the complexity to establish relationships between the off-site and intra-site events and shifts. We highlight, nevertheless, the growing evidence for an impact of the Santorini eruption on the landscape as well as on the Minoan town of Malia. The preliminary results show that the implementation of multidisciplinary researches and the combination of scales of study is productive to build new or more precise narratives for the history of a site.

Key words: Crete, Archaeology, Protohistory, Chronology, Geoarchaeology

Résumé

Le site de Malia, sur la côte nord-est de la Crète, constitue un terrain d'étude stimulant pour la géoarchéologie. L'agglomération et le palais de l'âge du Bronze sont explorés par les archéologues depuis un siècle, et sont bordés par un petit marais littoral qui offre de riches archives sédimentaires, récemment investiguées. La combinaison des données archéologiques et environnementales permet ainsi de reprendre les questions majeures de la chronologie et des causes de changements marquant l'histoire du site. Si de nouvelles fouilles sur le site ont permis de préciser la chronologie relative, la durée des phases, les causes et rythmes des changements sont plus difficiles à définir et impliquent une réflexion commune avec les spécialistes des sciences naturelles. Quels liens peut-on établir entre les mutations observées par l'archéologie et les évolutions ou ruptures enregistrées dans l'environnement ? Comment articuler les échelles chronologiques obtenues intra et hors-site ? Après un rappel des problèmes méthodologiques liés aux datations archéologiques, deux cas d'étude différents sont analysés : d'une part la première phase d'occupation de Malia, au Néolithique et Bronze ancien, d'autre part la période Néopalatiale. Pour chaque exemple, nous montrons la complexité d'une définition de relations claires entre les événements naturels et les changements matériels observés. Les témoignages d'un impact direct de l'éruption du volcan de Santorin sur l'environnement et la ville minoenne de Malia sont cependant de plus en plus probants. Les résultats, bien qu'encore provisoires,

montrent combien la recherche pluridisciplinaire, menée à différentes échelles (chronologiques et spatiales) peut être fructueuse pour bâtir ou préciser des scénarios historiques plus solides.

Mots clés : Crète, Archéologie, Protohistoire, Chronologie, Géoarchéologie

The Minoan palatial town of Malia, excavated since the beginning of the 20th century (see history of research in Poursat 2010a), is located on the north-eastern coast of Crete, in an area that has been densely occupied for a long time (Figure 1). The area was first settled during the Final Neolithic and a palatial town flourished during the Middle and, to a lesser extent, the Late Bronze Ages, before its abandonment in Late Minoan IIIB in the 13th century BC. Close to the archaeological site, a small marsh located near the sea offers rich sedimentary archives (Figure 2). After a first program of investigations on the paleoenvironment, which remained unfinished (Dalongeville 2001; Lespez *et al.* 2003), new research was undertaken in the marsh in 2015. The new paleoenvironmental data can now be combined with archaeological data from recent excavations conducted at Malia in the area Pi (Gomrée *et al.* 2012; Pomadère 2011; Pomadère *et al.* 2015-2016) and allow addressing some important questions on the history of the site. The question of chronology is at the core of this research.

The Minoan chronological framework has been established long ago by Arthur Evans, after the stratigraphy and typology of the pottery from the palace of Knossos (Evans 1921). His tripartite chronological frame (Early/Middle/Late Minoan), considerably refined since, is still in use for the pottery sequence, but the absolute chronology is fluctuating and under debate, especially for the Late Bronze Age (Wiener 2003; Warburton 2009; Manning 2014) (Table 1). The new excavations in the area Pi of Malia have improved our knowledge about relative chronology at the site (Knappett *et al.* 2018). Nevertheless, the duration of specific events and phenomena, their causes and rates of change are difficult to define and call therefore for a dialogue with specialists of natural sciences in order to explore diverse explanatory frameworks.

The main aim of this paper is to consider the correlation of the different temporal frames yielded by intra and off-site data, in order to get a better understanding of specific events or disruptions but also of the more durable interactions between men and environment. Can we link the major shifts identified in the material culture and history of the site with broader environmental changes, either sudden or progressive? Could we get a more precise idea about the tempo of these processes, and not only about the dates of the events?

In order to answer to these questions, a real interdisciplinary work needs to be undertaken, which is not such an easy task: as specialists of different disciplines, we have different goals, rooted in

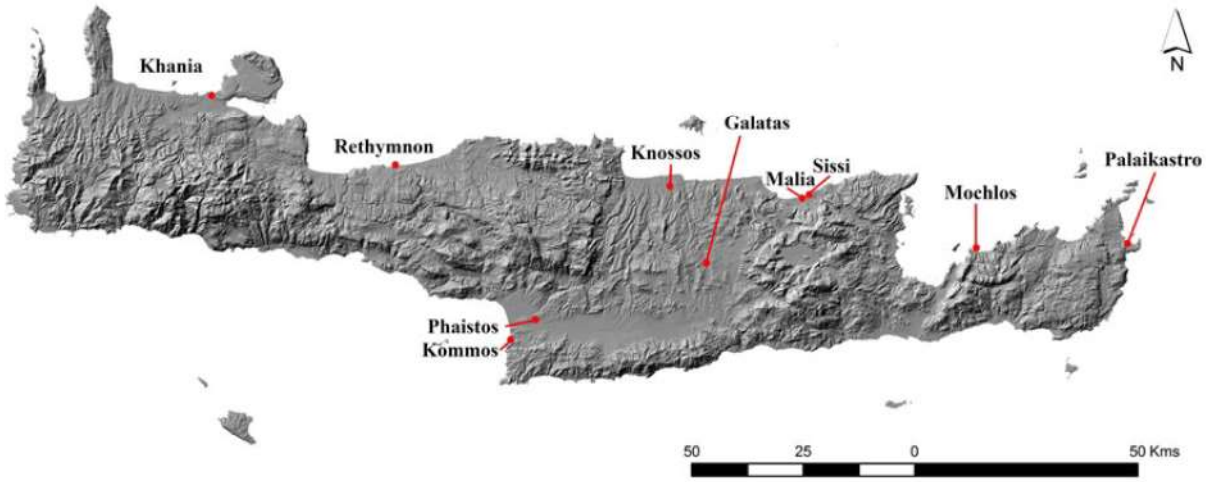

Figure 1. Map of Crete with the sites mentioned in the paper (© IMS-FORTH/Q. Letesson).

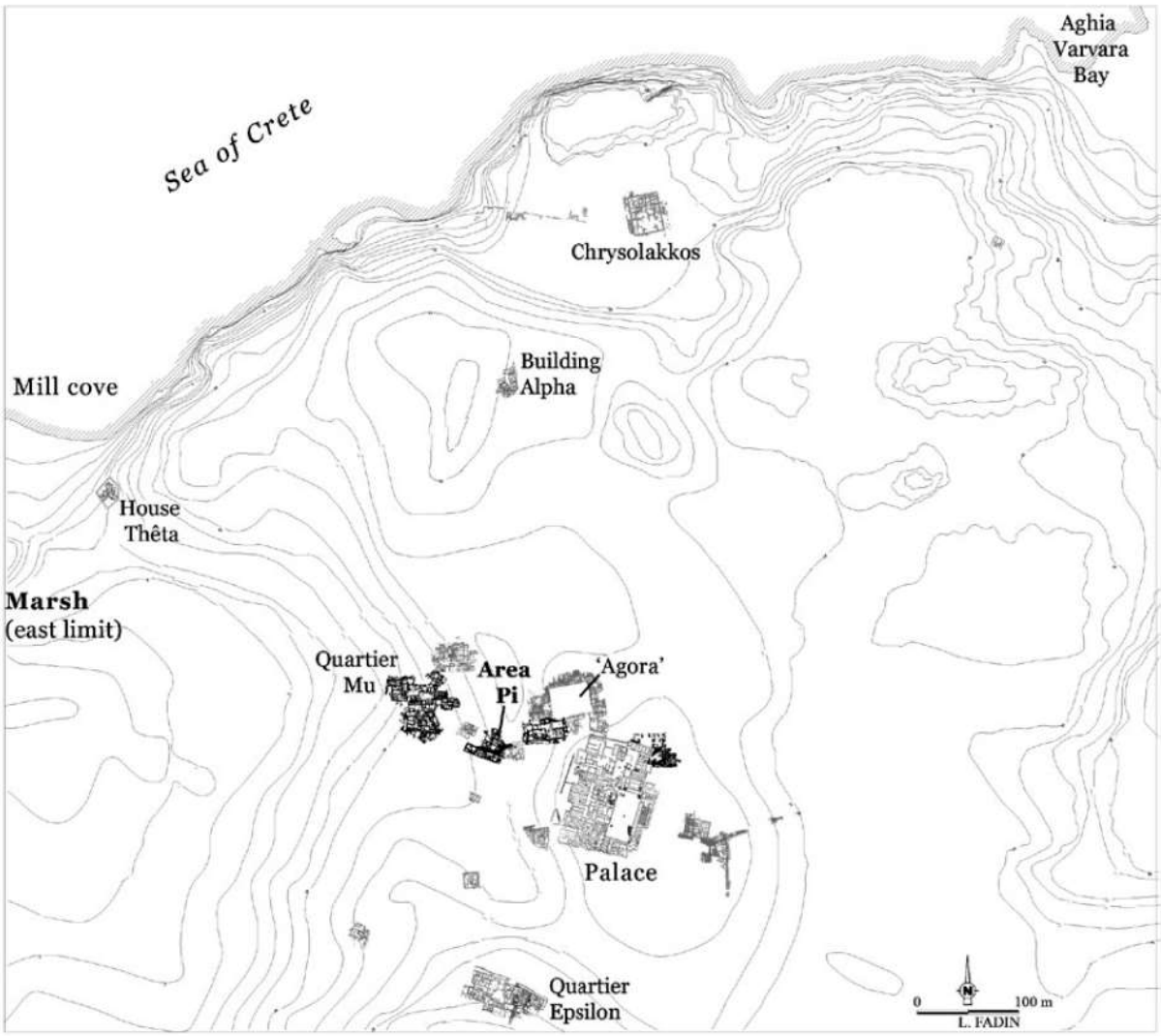

Figure 2. Map of the archaeological site of Malia (© EFA/L. Fadin).

different timescales. Archaeologists are concerned with material and cultural changes at the human scale (short to mid-term), including episodes of building or destruction on a site, and the investigation of their causes. Geomorphologists are interested in broader evolutions within a deeper scale of time, the so-called 'longue durée' (Braudel 1958).

1. Study Area and dating methods

1.1. Environmental and archaeological contexts

The Bronze Age town of Malia was established at the foot of the Selena Mountain (1600 m), on a low plateau (15-20 m above sea level) closing the eastern part of a small plain and overlooking a small coastal marsh (Lespez *et al.* 2003). During the Middle Minoan period, the town extended as far as the east border of the marsh and the coastline to the north, covering ca. 50ha, while the palace was built at 1300 m from the sea (Figure 2) (Müller 1991; Müller Celka 2007; Lespez *et al.* 2016: 248). The marsh is separated from the sea by a low, rocky coast composed of Pleistocene calcarenites, partly covered by a sandy beach ('Mill Cove'). Today, there is no perennial stream to supply the marsh, but thanks to aquifers hosted in the Cretaceous and Neogene limestones, it is never completely dry.

Only one of the six cores drilled in 1993 in the marsh has undergone laboratory analyses and provided radiocarbon dates. The results showed that this was a freshwater marshy area during most of the Holocene and highlighted some sedimentary events, but they lacked chronological precision

Periods in Crete	*Sub-phases in Crete*	Warren and Hankey 1989: 169 (EM-MM III); Warren 2006 (LM I-III) *Low Chronology*	Manning 1995: 217 *High Chronology*	*Main phases and pharaons in Egypt*
Prepalatial period	Early Minoan I	3650/3500-3000/2900	3100/3000-2700/2650	Old Kingdom (Dynasty 3 to 6)
	Early Minoan IIA	2900-2300/2150	2650-2450/2350	
	Early Minoan IIB		2450/2350-2200/2150	
	Early Minoan III	2300/2150-2160/2025	2200/2150-2050/2000	
	Middle Minoan IA	2160/2025-1900	2050/2000-1925/1900	
Protopalatial period	Middle Minoan IB	1900-1800	1925/1900-1900/1875	
	Middle Minoan II	1800-1700/1650	1900/1875-1750/1720	
Neopalatial period	Middle Minoan IIIA	1700/1650-1640	1750/1720-1700/1680	Middle Kingdom Dynasty 11 and 12
	Middle Minoan IIIB	1640-1580		
	Middle Minoan IIIB/ Late Minoan IA		1700/1680-1675/1650	
	Late Minoan IA	1580-1480	1675/1650-1600/1550	Second Intermediate Period (Dynasty 13 to 15: Hyksos)
	Eruption of Santorini volcano	*1550-1530*	*1628; 1613±13 (Heinemeier et al. 2009)*	
	Late Minoan IB	1480-1425	1600/1550-1490/1470	
Final Palatial period	Late Minoan II	1425-1390	1490/1470-1435/1405	
	Late Minoan IIIA1	1390-1370	1435/1405-1390/1370	
	Late Minoan IIIA2	1370-1330	1390/1370-1360/1325	New Kingdom Dynasty 18
Post-palatial period	Late Minoan IIIB	1330-1200	1360/1325-1200/1190	Thutmosis III Amenhotep IV/ Akhenaton Dynasty 19

Table 1. Chronological table and concordances with Egyptian chronology.

(Dalongeville 2001; Lespez *et al.* 2002; Lespez *et al.* 2003). This is why new core drillings were made in 2015 (Figure 3): 11 cores, which have produced 45 radiocarbon dates, are currently under study (Lespez and Pomadère 2015-2016; Lespez *et al.* 2016). Current analyses include sedimentology, magnetic susceptibility, geochemistry (XRF); palynology, NPPs and Fire signature; foraminfers and ostracods.

On the archaeological site itself, excavations in the Area Pi, one of the town blocks situated 150 m west of the Minoan Palace of Malia, were conducted through five campaigns between 2005 to 2014. The main goal of this research programme was to better define the nature of the various activities held in the town of Malia and the material culture, with special emphasis on local developments throughout the different phases of the Neopalatial period. It also encompassed the question of the interactions between the population and its environment. Unfortunately, the alkaline nature of the sediment leads to poor conservation of seeds and phytoliths and limits the potential results on this issue.

If the two projects, on- and off-site, were independent at their beginnings, it soon appeared that crossing the questions and results would enrich our understanding of the local human and environmental dynamics.

1.2. Time reading on and off-site: problems of methods

Archaeologists are, most of the time, unable to distinguish very short terms events (i.e. daily or even seasonal) in the archaeological records (Foxhall 2000; Gilchrist 2000: 325). We can mostly

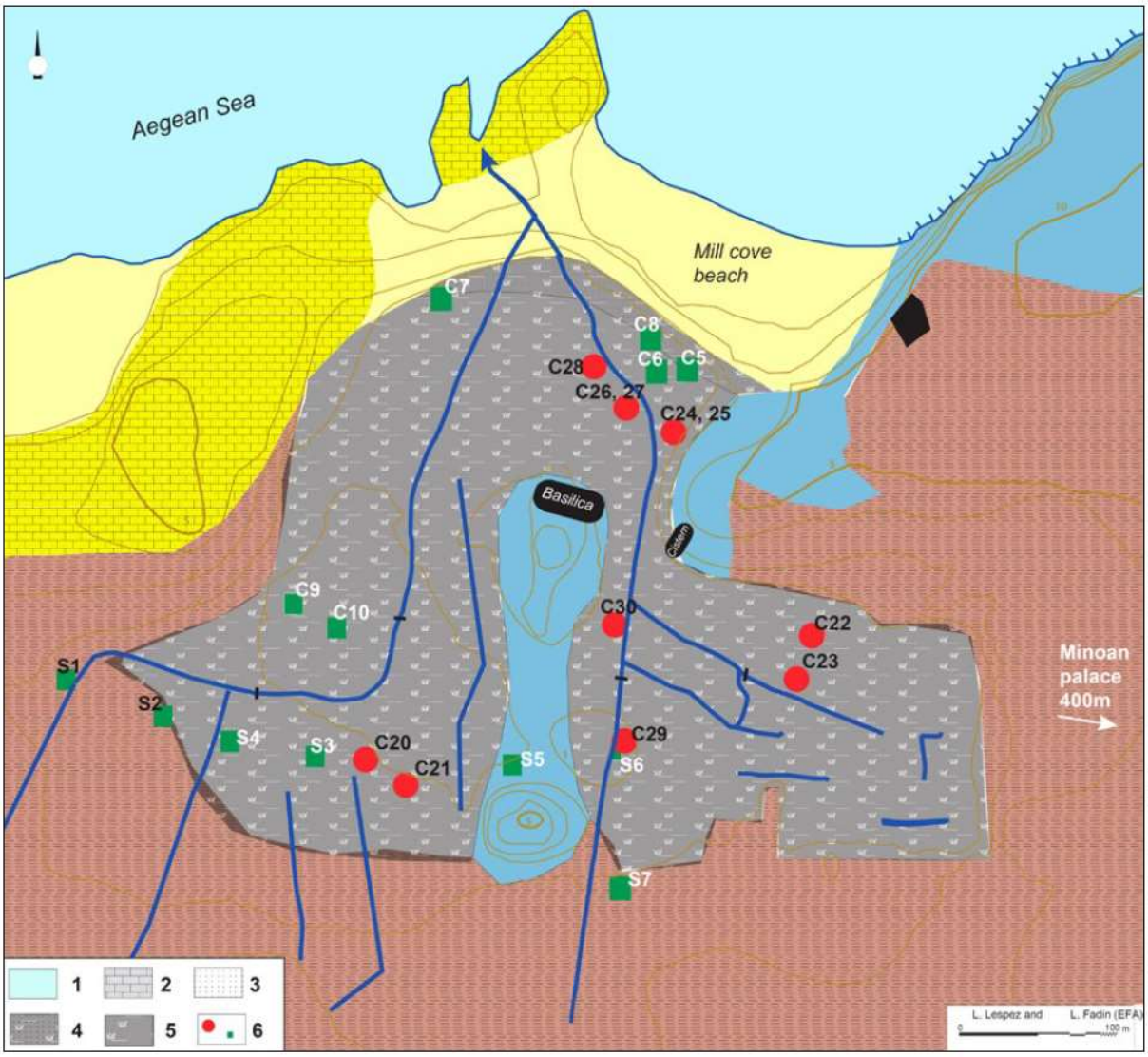

Figure 3. Geomorphological map of the Malia marsh and investigations conducted before 2003 (Lespez *et al.* 2003) and in 2015 (© L. Fadin/L. Lespez). 1. Cretaceous limestone (*sideropetra*); 2. Tyrrhenian calcarenite (*ammouda*); 3. sandy beach; 4. sandy barrier beach covered with reeds; 5. Holocene marsh deposits mainly covered by a reed bed and its belt of hygrophyl plants (rushes, etc.); 6. Ante 2015 surveys and cores (green square) and 2015 campaign cores (red circle).

approach short to mid-term changes (estimated to more or less one generation, i.e. 20 to 25 years). These changes are however embedded in conventional stages, those relative phases delineated by the analysis of sites' stratigraphy and ceramic developments (ex. in the case of Minoan Crete, Middle Minoan IIB). Although crucial for our diachronic understanding of a site's history, these conventional subdivisions are not without raising some questions and methodological problems: they seem indeed to 'freeze' some portions of time in a rigid framework, assuming a high cultural coherence and underestimating the dynamism and evolutions *within* each phase (Adams 2007: 391). Moreover, pottery decoration and morphology ('style') have long been the main criteria for dating, regardless of technical traditions and techno-stylistic trends, which can also offer a solid base for establishing chronology (Roux 2010; for studies in this perspective in Crete, Van de Moortel 2006; Caloi 2011).

The definition of the relative chronological sequence of the Minoan occupation at Malia only became a major concern from the 1960's onwards (Pelon 1970, 1983). French archaeologists that worked previously on the site had a limited interest in stratigraphy. At the scale of the island, the synchronism between the ceramic sequences as defined in the different sites and regions still

constitutes a major challenge within Minoan archaeology and research (e.g. Brogan and Hallager 2011; Macdonald and Knappett 2013; Langohr 2017). Moving to absolute chronology, archaeologists of Aegean prehistory mainly rely on a chronological system based on synchronisms between Aegean/Cretan and Egyptian/Near Eastern contexts within which Cretan imports (mainly pottery) have been found, and vice-versa in the Aegean. The method is far from perfect: we are aware that sherds only give a *terminus post quem* to a material assemblage, and that the latter possibly reflects the aggregation of successive activities, and not necessarily a well-defined event or specific action. Therefore, it is certainly more accurate to recognize that archaeologists define intervals of time, rather than precise events (Boissinot 2015: 137). Regarding laboratory methods, radiocarbon dating is the main method used to date archaeological deposits, but its use has been sporadic until now at Malia as at Cretan sites in general. Most available radiocarbon dates from archaeological levels are indeed imprecise and cover such a broad chronological range that they are of little use (Poursat 2010b: 62; Darcque 2014: 165). We will show later that the same remarks apply to radiocarbon dates from off-site contexts.

2. Case studies

In order to pinpoint the kinds of 'time reading' problems frequently encountered in the case of Minoan Crete, we present here two specific time lapses in the occupation of Malia and attempt to compare the results of our intra- and extra-site research works.

2.1. The Neolithic and Early Bronze Age: from the first settlers to the first village

The Neolithic is the longest as well as the less well known phase of the early history of Malia. The new cores show that the coastal wetlands especially developed from the 5th millennium onwards, during the Late Neolithic. The increase of freshwater resources, although generally considered to be favorable for human settlement, was apparently not paralleled by any installation in the plain, near the marsh. A unique Final Neolithic site (i.e. 4th millennium BC, more likely FN IV according to the material) has been identified by the regional survey on the slopes of a hill overlooking the plain of the later town, the Arkovouno (Müller 1998: 549). Nevertheless, the study of cereal pollens from a core made in the marsh in 1993 suggested anthropisation of the environment already during the 6th millennium, i.e. in the Middle Neolithic (Dalongeville 2001). This result needs to be further assessed by the current palynological analyses. In fact, we ignore everything about the location, extension and nature of the settlement(s) of the local communities in the area of Malia before the 4th millennium. This is a major discrepancy between archaeological and environmental data. It echoes the widespread archaeological invisibility of Neolithic sites in the entire Crete until the last stage of Final Neolithic, at least partly due to taphonomic and research biases (Tomkins 2008: 36-41; 2014: 353). The situation at Malia also reminds the complexity of the relations between human and environmental dynamics during this period, recently enhanced on a broader scale for the Greek mainland (Weiberg *et al.* 2019).

The first consistent occupation of the site of Malia, below the subsequent town and palace, is dated to Early Minoan II period (ca. 2900-2300 BC). Two key features are worth mentioning as regards the evolution of the wetland. Although the wetland continued to extend during the period of the Early Bronze Age, some rapid events have destabilized the marsh environment. On the seashore, marine sand input into the marsh has been observed, testified by the sedimentological analyses and the presence of some specific microfossils (Lespez *et al.* 2003), whereas into the marsh, a deposit suggests a high energy event of continental origin (flood). The latter event is more difficult to interpret and needs further examination. These deposits, at the seashore and at the back of the marsh, are not yet well dated, neither is it clear if they are coeval, but they fall within a time interval between 3300 and 2000 BC. This/these probable short-term event(s) did not alter the marshy environment, while its/their impact(s) on human settlement, not well known for this period, is unclear. A second feature is a concentration of charcoals recorded in the cores and dated at ca. 2600 BC. It points to

large fires, which could correspond to the first important exploitation of the marsh and the plain in relation with various human activities (agriculture, building, etc.).

The Malia Palace was erected during the Middle Minoan I phase (later abbreviated MM I, ca. 2000 BC) and a town flourished until MM IIB, during two to three centuries (Poursat 2010a, 2010b; Devolder 2016), following a process that appears quite continuous. In the same period the marsh continued to extend in surface. This period was also marked by a multiplication of rural sites in the plain and the surroundings mountains (Müller Celka 2007). The likely intensification of agriculture around the town of Malia probably left some traces in the pollen records. The palace and town were destroyed by fire at the end of MM IIB. This violent destruction marks the end of the first palace and a main rupture in the history of the town, although it was followed by the rebuilding of parts of the settlement and of a new palace. This next stage is usually labeled the 'Neopalatial' period.

2.2. The Neopalatial phase (MM III – LM IA) and the question of the Santorini eruption effects

The recent excavations in the area Pi at Malia focused on the first part of the Neopalatial era, i.e. the MM III-LM IA phases, which was considered until recently as a blurry period in the settlement's history, although it included, precisely, the rebuilding of the palace, probably in two stages (Poursat 2010a). The MM III phase is not properly distinguished in the stratigraphy and ceramic sequence of all parts of the site. For instance, in the area to the north-east of the palace, the main change within the Neopalatial period is associated with the LM IA phase but the latter forms one and a same chronological period *with* the MM III phase (Darcque 2014: 180-181). At the scale of the island, the confusing label of 'transitional phase' for the MM III period reflects above all a lack of knowledge, since the MM III phase had spanned around one and a half century (MacGillivray 2013; for a thorough presentation of the MM III period and remaining issues, see Macdonald and Knappett 2013).

One of the main results of the excavations in the area Pi is the recognition of material evidence for an extended length as well as sequencing of the MM III phase, broadly bearing out the subdivisions previously outlined by O. Pelon (1970, 1983, 2005) at the site. This phase now appears as a pivotal point between the old and new palatial systems at Malia, in accordance with the results from other Cretan sites (especially Knossos, Galatas, Kommos) although the gradual processes and dynamics that led to the formation of a new political geography for Crete during the Neopalatial period still need to be clarified. Moreover, the stratigraphical, ceramic and architectural study of the building Pi (the Neopalatial building of Area Pi) allowed us to recognize four neopalatial sub-phases (Gomrée *et al.* 2012). We have distinguished secondary evidence for both MM IIIA and MM IIIB occupation horizons within the building: they are defined by large homogenous fills whose rapid deposition can be explained as the result of cleaning operations following a destructive event. Each of these two phases is also associated with significant changes in ceramic production. The building Pi underwent a major rebuilding after the MM IIIB destruction but a new, widespread destruction struck the town and the palace during the LM IA (Driessen and Macdonald 1997: 88-89; Pelon 2005; Poursat 2010a: 265; Devolder 2012-2013; a unique destruction is challenged in Darcque 2014: 180), as evidenced again in area Pi by massive fills spread in several rooms, resulting from the large-scale cleaning operations.

Among these LM IA fillings were several bones of fetus of caprine, which suggest a destruction during spring. It is worth mentioning this unusual seasonal detail, as this large destruction could be an effect of the Santorini eruption that occurred in mature LM IA, and likely during the spring (Johnston *et al.* 2012). It is assumed that the Santorini eruption left a layer of tephra over a large region in East Mediterranean and that it triggered a tsunami which could have devastated the north coast of Crete (Minoura *et al.* 2000; Bruins *et al.* 2009; Novikova *et al.* 2011; Athanassas *et*

al. 2018). Material traces of the eruption have been reported from several sites of Eastern Crete (Mochlos: Soles *et al.* 1995; a layer of tephra up to 20 cm at Palaikastro: Bruins *et al.* 2009), and could tentatively be extended to the region of Malia, as some Theran ash has recently been evidenced at the neighbouring site of Sissi, 4km east of Malia. Nevertheless, it is properly identified in a single part of the site for now (Jusseret 2018a: 237; Claeys 2018: 279), while no tephra has been noticed in the cores drilled in the Selinari lowlands surrounding the settlement of Sissi (Jusseret 2018b: 336).

The palaeoenvironmental research at the site of Malia should bring some new data on this point. Sedimentary analysis reveals some perturbations between the 18th and 15th c. BC. Near the seashore, a 20 cm thick sandy tsunamogenic deposit has been identified on the core drilling C6 (Lespez *et al.* 2003), while the recognition of layers deposited by the tsunami and/or of evidence for erosion of the Holocene sedimentation by the waves generated by the explosion of the Santorini volcano is one of the main aims of the last core drilling survey. The analyses are in progress but it is now clearly established that a tsunami destabilized the beach ridge and has affected the palaeogeography of the Malia marsh (Lespez *et al.* 2016).

No layer of Theran ash was recorded in the previous excavations at Malia (Darcque 2014: 170) and traces of a tsunami remain imperceptible in the archaeological record (a unique layer of pumice has been observed on the coast during the survey, Müller Celka 2000). However, a significant amount of pumice and layers of greenish ashes were found in the LM IA fills of building Pi (a heap of more than 800 pumice stones in the mature LM IA backfill of one room): they still wait geochemistry analysis which could determine an origin in the Santorini volcano. They could result though from various anthropogenic (ashes from domestic fires, pumices brought with other building material, such as sand from the beach) or environmental events (earlier eruptions), other than the big Santorini eruption. The hypothesis, also considering the possibility of a 'Minoan flood' cleaning the tephra at Malia (Athanassas *et al.* 2018), needs to be further explored.

The absolute chronology of the eruption is still debated and the results from Malia do not change this situation. In general, the uncertainty associated to the radiocarbon dating does not allow determining precisely the time of the event from off-site contexts. The sandy layer of the C6 core drilling from the Malia marsh is attributed to a period lasting from the middle of the second millennium BC to the beginning of the first Millennium AD (Lespez *et al.* 2003; Lespez *et al.* 2016). The probable tsunamogenic sand deposits have been described but unfortunately, in the absence of organic remains, they cannot be dated. Their examination shows an erosional contact with underlying marshy deposits but it is not possible to estimate the extent of erosion and truncation of the deposits underlying the sands. Furthermore, with a usual margin of error of two standard deviations, the deposit of the marshy layer located just below the sandy layer has been set up between 1744-1506 BC. This date, too imprecise, prevents us from assigning the erosion of this deposit to a precise time, and thus from shedding new light on the 'low' and the 'high' chronology still under debate for the eruption of the Santorini volcano and its consequences (see Table 1). Indeed, the scientific community is faced since a few decades now with a discrepancy between the traditional archaeological sequence ('low chronology', dating the eruption around 1530-1500 BC: Warren and Hankey 1989; Warren 2006) and the radiocarbon dates obtained on the volcano deposits and on the island of Santorini or on the ice core ('high chronology', often pointing to a date one hundred years earlier around 1628 BC: Heinemeier *et al.* 2009; Manning 1995, 2014). Although there is now an important bibliography admitting that radiocarbon heads towards a 'high' eruption date, it raises significant problems. On one hand, statistical interpretation of the radiocarbon results is subject to caution and critics (Fantuzzi and Antolini 2018). Archaeologists are not usually experienced for a critical analysis of radiocarbon dates, which can lead to overconfidence on the results (Hamilton, Haselgrove and Gosden 2015: 656). Moreover, some results on radiocarbon calibrations were not taken into account: revised calibrated ranges for the eruption of Thera indicate a date around the middle of the 16th century, compatible with traditional, archaeological dates of Egyptian chronology (Pearson *et al.* 2018).

On the other hand, the results pointing to the higher date are problematic for the Egyptian chronology and political history of East Mediterranean (Cherubini *et al.* 2014). It explains why most archaeologists are still in favor of the low, traditional date for the eruption, in the late 16th century BC. In the time being, the results obtained at Malia do not favor one or the other hypothesis.

It is now fully accepted that the Santorini eruption did not mark the end of the second Minoan palaces, but it could have initiated a decline at Malia, and more broadly within the Minoan society, for different reasons (Driessen and Macdonald 1997). In spite of the severity of the destruction(s) that struck the site during the LM IA, the area Pi and some other buildings of the settlement of Malia were rapidly and at least partly reoccupied and rebuilt during a final stage of LM IA, before their final abandonment at the end of LM IA or during LM IB (Pelon 2005; Poursat 2010a; Darcque 2014: 181). The mid to long-term effects of the Santorini eruption and its impact on economy and society (crisis, decline, disintegration process, Driessen and Macdonald 1997; Driessen 2002, 2018) remain debated and must be considered at a regional scale, within the different parts of Crete.

Lastly, the perception of changes again differs when one considers different geographical scales of data. The destruction, or short-term events evidenced in the Neopalatial stratigraphy of the town of Malia through excavations are not corroborated by the data recovered from the survey undertaken within the surrounding territory, at the exception of the LM IA massive destruction. For instance, the MM III disruptions identified in the settlement are not visible, at the moment, in the rural sites identified by surface material. This lack of recognition can however be mainly due to the fact that MM III and LM IA pottery is not differentiated in survey material (Puglisi 2007). The chronological resolution of survey data, based on very fragmented and eroded ceramic material, therefore rather corresponds to the mid-term scale. In the specific case of the Malia survey, the resolution of the collected data confirms that the town and its territory reached their acme during the MM II, before a gradual decline in population density during the Neopalatial phase, but does not allow a finer restitution of the chain of events (Müller Celka 2007).

The influence of climate changes over the long-term, with dryer conditions during the LBA, remains to be evaluated for the region of Malia as well as for the whole Crete.

Conclusion

The need to better define the rates and factors of human and environmental change at Malia prompt us to organize an interdisciplinary research program combining intra-site archaeology and off-site geomorphology. Even if it is now the rule for archaeological projects to involve multidisciplinary teams, a real combination of approaches, implying discussions between distinct specialists on specific questions or working hypotheses beforehand, is neither frequent in Crete, nor easy (Livarda, Orengo and Veropolidou 2015; Weiberg *et al.* 2019). Building chronologies using intra-site time frames and chronological markers provided by the study of the surrounding environment remains a challenge, because it implies the critical use of several methods and the combination of both relative and absolute dating, as well as the consideration of different timescales. As John Bintliff underlined, the result would produce at best 'a mapping of interactions between temporal processes and societal and ecological structures, with discrete events and individual people, without predictable and a priori interrelations' (Bintliff 2006: 192). The present overview, in an attempt to define our main aims and methodological processes in the specific case of Malia, has hopefully shown that the combination of datasets from intra- and extra-site investigations may help to build new or more precise narratives for the history of a site. Forthcoming results will provide new input to this research programme and refine, modify or even refute some of the current hypotheses related to our diachronic understanding of main events or disruptions that had punctuated (and then, for us, structured) this long history.

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Bibliographie

Adams, E. 2007. Time and chance: unraveling temporality in North-central Neopalatial Crete. *American Journal of Archaeology,* 111: 391-421.

Athanassas, C.D., Modis, K., Alçiçek, M.C., Theodorakopoulou, K. 2018. Contouring the cataclysm: a geographical analysis of the effects of the Minoan eruption of the Santorini volcano. *Environmental Archaeology,* 23(2): 160-176. DOI: 10.1080/14614103.2017.1288885.

Bintliff, J. 2006. Time, structure, and agency: the annales, emergent complexity, and archaeology. In J. Bintliff (ed.), *A Companion to Archaeology*. Oxford: Blackwell Publishing: 174-194.

Boissinot, P. 2015. *Qu'est-ce qu'un fait archéologique ?* Paris: EHESS.

Braudel, F. 1958. Histoire et sciences sociales: La longue durée. *Annales. Économies, Sociétés, Civilisations*, 13: 725-753.

Brogan, T.M. and Hallager, E. (eds) 2011. *LM IB Pottery: Relative Chronology and Regional Differences. Acts of a workshop held at The Danish Institute at Athens in collaboration with the INSTAP Study Center for East Crete, 27-29 June 2007*. Athens: the Danish Institute at Athens; Århus: Aarhus University Press.

Bruins, H.J., Van der Plicht, J. and MacGillivray, J.A. 2009. The Minoan Santorini eruption and tsunami deposits in Palaikastro (Crete): dating by geology, archaeology, ^{14}C, and Egyptian chronology. *Radiocarbon,* 51(2): 397-411.

Caloi, I. 2011. Le innovazioni tecnologiche nella Messarà: dal wheel-fashioning al wheel-throwing. In F. Carinci, N. Cucuzza, P. Militello and O. Palio (eds), *Κρήτης Μινωίδος: Tradizione e identità minoica tra produzione artigianale, pratiche cerimoniali e memoria del passato. Studi offerti a Vincenzo La Rosa per il Suo 70° compleanno*. Padova: Erasmo (Studi di Archeologia Cretese 10): 87-102.

Cherubini, P., Humbel, T., Beeckman, H., Gärtner, H., Mannes, D., Pearson, C., Schoch, W., Tognetti, R. and Lev-Yadun, S. 2014. The olive-branch dating of the Santorini eruption. *Antiquity,* 88: 267-273.

Claeys, T. 2018. 5.5. Continuing excavation of the West Wing (Zone 10). In Driessen *et al.* 2018: 257-280.

Dalongeville, R. 2001. Malia : un marais parle. *Bulletin de Correspondance Hellénique,* 125(1): 67-88.

Darcque, P. (dir.) 2014. *Fouilles exécutées à Malia. Les abords nord-est du palais. I, Les recherches et l'histoire du secteur*. Athènes: École française d'Athènes (Études Crétoises, 35).

Devolder, M., 2012-2013. Le Quartier Nu (Malia, Crète). L'occupation néopalatiale. *Bulletin de Correspondance Hellénique,* 136-137(1): 1-82.

Devolder, M. 2016. The Protopalatial state of the Western Magazines of the Palace at Malia (Crete). *Oxford Journal of Archaeology,* 35: 141-159.

Driessen, J. and Macdonald, C.F. 1997. *The Troubled Island: Minoan Crete before and after the Santorini Eruption*. Liège: Université de Liège; University of Texas at Austin, Program in Aegean Scripts and Prehistory (Aegaeum, 17).

Driessen, J. 2002. Towards an archaeology of crisis: defining the long-term impact of the Bronze Age Santorini eruption. In R. Torrence and J. Grattan (eds), *Natural Disasters and Cultural Change*. London and New York: Routledge: 250-263.

Driessen, J. 2018. The Santorini eruption. An archaeological investigation of its distal impacts on Minoan Crete. *Quaternary International* (2018), https://doi.org/10.1016/j.quaint.2018.04.019.

Driessen, J., Anastasiadou, M., Caloi, I., Claeys, T., Dédérix, S., Devolder, M., Jusseret, S., Langohr, C., Letesson, Q., Mathioudaki, I., Mouthuy, O. and Schmitt, A. 2018. *Excavations at Sissi IV. Preliminary*

Report on the 2015-2016 Campaigns. Louvain-la-Neuve: Presses universitaires de Louvain (Aegis, 13).

Evans, A. 1921. *The Palace of Minos: A Comparative Account of the Successive Stages of the Early Cretan Civilization as Illlustrated by the Discoveries at Knossos, vol. 1*. London: Macmillan.

Fantuzzi, T. and Antolini, F. 2018. Drawing the line: Bayesian modelling and absolute chronology in the case-study of the Minoan eruption at Thera. In G. Baldacci and I. Caloi (eds), *Rhadamanthys. Studi di archaeologia minoica in onore di Filippo Carinci per il suo 70° compleanno*. Oxford: Archaeopress (BAR I.S. 2884): 247-254.

Foxhall, L. 2000. The running sands of time: archaeology and the short-term. *World Archaeology,* 31(3): 484-498.

Gilchrist, R. 2000. Archaeological biographies: realizing human lifecycles, -courses and -histories, *World Archaeology*, 31(3): 325-328.

Gomrée, T., Langohr, C. and Pomadère, M. 2012. Excavations in the Pi Area at Malia (2005-2010). In M. Andrianakis, P. Varthalitou and I. Tzachili (eds), *Αρχαιολογικό Έργο Κρήτης 2. Πρακτικά της 2ης Συνάντησης, Ρέθυμνο, 26-28 Νοεμβρίου 2010 / Archaeological Work in Crete 2. Proceedings of the 2nd Meeting, Rethymnon, 26-28 November 2010*. Rethymno: 89-97.

Hamilton, W.D., Haselgrove, C. and Gosden, C. 2015. The impact of Bayesian chronologies on the British Iron Age. *World Archaeology,* 47(4): 642-660.

Heinemeier, J., Friedrich, W.L., Kromer, B. and Bronk Ramsey, C. 2009. The Minoan eruption of Santorini radiocarbon dated. In Warburton 2009: 285-293.

Johnston, E.N., Phillips, J.C., Bonadonna, C. and Watson, I.M. 2012. Reconstructing the tephra dispersal pattern from the Bronze Age eruption of Santorini using an advection-diffusion model. *Bulletin of Volcanology,* 74: 1485-1507.

Jusseret, S. 2018a. 5.4. The excavation of the West Wing (Zone 10). In Driessen *et al.* 2018: 217-255.

Jusseret, S. 2018b. 8. Report on the geomorphological survey. In Driessen *et al.* 2018: 331-336.

Knappett, C., Pomadère, M., Gardeisen, A., Gomrée, T., Theodoropoulou, T. and Westlake, P. 2018. Deux dépôts MM IIA dans le secteur Pi de Malia. *Bulletin de Correspondance Hellénique,* 141(2): 485-552.

Langohr, C. (ed.) 2017. *How Long is a Century? Late Minoan IIIB Pottery: Relative Chronology and Regional Differences*. Louvain-la-Neuve: Presses universitaires de Louvain (Aegis, 12).

Lespez, L., Dalongeville, R., Pastre, J.-F. 2002. La cité minoenne de Malia et la mer. Etudes paléoenvireonnementales. Résultats préliminaires : analyses du sondage 6. In M.-F. Boussac (ed.), *Morphogenèse en Méditerranée orientale pendant les époques historiques. Topoi*. Lyon: Maison de l'Orient Méditerranéen: 17-34.

Lespez, L., Dalongeville, R., Pastre, J.-F., Darmon, F., Mathieu, R. and Poursoulis, G. 2003. Late-Middle-Holocene paleo-environmental evolution and coastline changes of Malia (Crete). In E. Fouache (ed.), *The Mediterranean World: Environment and History*. Paris : Elsevier: 439-452.

Lespez, L. et Pomadère, M. 2015-2016. Rapports sur les travaux de l'école française en 2014. Malia, rapport sur la campagne de carottages dans le marais. *Bulletin de Correspondance Hellénique*, 139-140(2): 937-939.

Lespez, L., Müller Celka, S. et Pomadère, M. 2016. Changements environnementaux et impact des sociétés humaines autour de la cité minoenne de Malia (Crète, Grèce): bilan des acquis et nouvelles recherches. In M. Ghilardi (ed.), *Géoarchéologie des îles méditerranéennes*. Paris : CNRS Éditions: 245-258.

Livarda, A., Orengo, H. and Veropoulidou, R. 2015. Palaikastro. Urban – landscape interactions in Minoan Crete. *Association for Environmental Archaeology Newsletter*, 127: 5-7.

Macdonald, C.F. and Knappett, C. (eds) 2013. *Intermezzo: Intermediacy and Regeneration in Middle Minoan III Palatial Crete*. London: British School at Athens.

MacGillivray, J.A. 2013. Absolute Middle Minoan III – the bigger picture: early Neopalatial Crete's relations with the ancient Orient in the mid-second millennium BC. In C.F. Macdonald and C. Knappett (eds), *Intermezzo: Intermediacy and Regeneration in Middle Minoan III Palatial Crete*. London: The British School at Athens (BSA Studies 21): 221-224.

Manning, S.W. 1995. *The Absolute Chronology of the Aegean Early Bronze Age*. Sheffield: Sheffield Academic Press (Monographs in Mediterranean Archaeology, 1).

Manning, S.W. 2014. *A Test of Time and A Test of Time Revisited: The Volcano of Thera and the chronology and history of the Aegean and east Mediterranean in the mid-second millennium BC.* Oxford and Philadelphia: Oxbow Books.

Minoura, K., Imamura, F., Kuran, U., Nakamura, T., Papadopoulos, G.A., Takahashi, T. and Yalciner, A.C. 2000. Discovery of Minoan tsunami deposits. *Geology*, 28(1): 59-52.

Müller, S. 1991. Travaux de l'École française d'Athènes en Grèce en 1990. Malia, prospection archéologique de la plaine. *Bulletin de Correspondance Hellénique,* 115(2): 741-749.

Müller, S. 1998. Travaux de l'École française en Grèce en 1997. Malia, prospection archéologique de la plaine. *Bulletin de Correspondance Hellénique*, 122(2): 548-552.

Müller Celka, S. 2000. Travaux de l'École française en Grèce en 1999. Malia, prospection de la plaine. *Bulletin de Correspondance Hellénique*, 124(2): 501-505.

Müller Celka, S. 2007. Terroir et territoire à Malia à l'époque protopalatiale. *Bulletin de Correspondance Hellénique,* 131.2, 855-860.

Novikova, T., Papadopoulos, G.A. and McCoy, F.W. 2011. Modelling of tsunami generated by the giant late Bronze Age eruption of Thera, South Aegean Sea, Greece. *Geophysical Journal International*, 186(2): 665-680.

Pearson C.L., Brewer P.W., Brown D., Heaton T.J., Hodgins G.W.L, Jull A.J.T., Lange T., Salzer M.W. 2018. Annual radiocarbon record indicates 16th century BCE date for the Thera eruption. *Science Advances* 4(8) eaar 8241.

Pelon, O. 1970. *Fouilles exécutées à Malia : exploration des maisons et quartiers d'habitation (1963-1966), Troisième fascicule*. Paris: Paul Geuthner (Études Crétoises, 16).

Pelon, O. 1983. L'épée à l'acrobate et la chronologie maliote. *Bulletin de Correspondance Hellénique,* 106(1): 165-190.

Pelon, O. 2005. Les deux destructions du palais de Malia. In I. Bradfer-Burdet, B. Detournay et R. Laffineur (éds), *Κρης Τεχνίτης. L'artisan crétois. Recueil d'articles en l'honneur de Jean-Claude Poursat, publié à l'occasion des 40 ans de la découverte du Quartier Mu*. Liège: Université de Liège, Histoire de l'art et archéologie de la Grèce antique and University of Texas at Austin, Program in Aegean Scripts and Prehistory (Aegaeum, 26): 185-196.

Pomadère, M. 2011. Rapports sur les travaux de l'École française en 2010. Malia, secteur Pi. *Bulletin de Correspondance Hellénique,* 135(2): 601-624.

Pomadère, M., Alberti, M.E., Avramut, A.M., Devogelaere, J., Gilon, A., Gomrée, T., Langohr, C., Leclercq, C., Lorenzon, M., Montagné, M.-P., Ntinou, M., Papayiannis, K., Rivière, K. et Westlake, P. 2015-2016. Rapports sur les travaux de l'École française en 2014. Malia, secteur Pi. *Bulletin de Correspondance Hellénique*, 139-140(2): 917-937.

Poursat, J.-C. 2010a. Malia: palace, state, city. In O. Krzyszkowska (ed.), *Cretan Offerings. Studies in Honour of Peter Warren.* London: The British School at Athens (BSA Studies, 18): 259-267.

Poursat, J.-C. 2010b. Avant Akrotiri: la chronologie égéenne pour l'époque des premiers palais crétois. In L. Godart, M. Negri and A. Sacconi (eds), *Atti del colloquio internazionale 'Riflessioni sulla cronologia egea alla luce delle recenti scoperte di Santorini', Milano, 27-28 aprile 2009, Pasiphaé* 4: 61-66.

Puglisi, D. 2007. Le territoire de Malia à l'époque néopalatiale. Premières données de la prospection. *Bulletin de Correspondance Hellénique,* 131(2): 865-869.

Roux, V. 2010. Lecture anthropologique des assemblages céramiques. Fondement et mise en œuvre de l'analyse technologique. *Les nouvelles de l'archéologie*, 119: 4-9.

Soles, J.S., Taylor, S.R. and Vitaliano, C.J. 1995. Tephra samples from Mochlos and their chronological implications for Neopalatial Crete. *Archaeometry,* 37: 385-393.

Tomkins, P.D. 2008. Time, space and the reinvention of the Cretan Neolithic. In V. Isaakidou and P.D. Tomkins (eds), *Escaping the Labyrinth: The Cretan Neolithic in Context*. Oxford: Oxbow Books (Sheffield Studies in Aegean Archaeology 8): 21-48.

Tomkins, P.D. 2014. Tracing complexity in 'the missing Millennium': an overview of recent research into the Final Neolithic period on Crete. In B. Horejs and M. Mehofer (eds), *Western Anatolia before Troy: Proto-Urbanisation in the 4th Millennium BC? Proceedings of the International Symposium held at the Kunsthistorisches Museum Wien, Vienna, Austria, 21-24 November, 2012*. Vienna: Austrian Academy of Sciences (Oriental and European Archaeology 1): 345-364.

Van de Moortel, A. 2006. Chap. 3. Minoan Pottery from the Southern Area, 2. Middle Minoan IA and Protopalatial pottery. In J.W. and M.C. Shaw (eds), *Kommos V. The Civic Center*. Princeton: Princeton University Press: 264-377.

Warburton, D.A. (ed.) 2009. *Time's Up: Dating the Minoan Eruption of Santorini. Acts of the Minoan Eruption Chronology Workshop initiated by Jan Heinemeier and Walter L. Friedrich, Sndjberg November 2007*. Athens: The Danish Institute at Athens (Monographs of the Danish Institute at Athens, 10).

Warren, P. and Hankey, V. 1989. *Aegean Bronze Age Chronology*. Bristol: Bristol Classical Press.

Warren, P. 2006. The date of the Thera eruption in relation to Aegean-Egyptian interconnections and the Egyptian historical chronology. In E. Czerny, I. Hein, H. Hunger, D. Melman and A. Schwab, (eds), *Timelines: Studies in Honour of Manfred Bietak*. Leuven: Uitgeverij Peeters en Departement Oosterse Studies (Orientalia Lovaniensia Analecta 149, Volume 2): 305-321.

Weiberg, E., Bevan, A., Kouli, K., Katsianis, M., Woodbridge, J., Bonnier, A., Engel, M., Finné, M., Fyfe, R., Maniatis, Y., Palmisano, A., Panajiotidis, S., Roberts, N. and Shennan, S. 2019. Long-term trends of land use and demography in Greece: a comparative study. *The Holocene* https://doi.org/10.1177/0959683619826641.

Wiener, M.H. 2003. Time out: the current impasse in Bronze Age archaeological dating. In K.P. Foster and R. Laffineur (eds), *Metron: Measuring the Aegean Bronze Age. Proceedings of the 9th International Aegean Conference, New Haven, Yale University, 18-21 April 2002*. Liège: Université de Liège, Histoire de l'art et archéologie de la Grèce antique and University of Texas at Austin, Program in Aegean Scripts and Prehistory (Aegaeum, 24): 363-399.