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The Santorini eruption. An archaeological investigation of its distal impacts on Minoan Crete

Jan Driessen

Université Catholique de Louvain, Belgium

1. Introduction

Our times are times of crisis. Some would claim that an interest in crisis and a rise in disaster studies started with the 9/11 WTC attack in 2001, the first in a long series of exceptional disasters that struck the world, including the Boxing Day South-East Asia tsunami in 2004, Hurricane Katrina in 2005, the Haiti earthquake in 2010, the Japan earthquake and tsunami in 2011, and the Arab Spring, starting in 2010, all killing many thousands of people each and leaving millions homeless. This actuality is, without doubt, why there is an increased interest in ancient crises and the way societies in the past coped with unforeseen events that dramatically impacted on their lives. The high number of publications and projects concentrating on crisis and collapse can of course partly be explained by the desire of archaeologists and historians to show the societal relevance of their fields by arguing that their findings may provide solutions for the future and, of course, the desire to obtain funding. Likewise, present-day interest in global warming and climate change has triggered a proliferation of books and articles on human ecodynamics — the relationship between climate, environment, and culture (Sandweiss and Kelley, 2012). In fact, the present attention to disasters somehow echoes the late 1980s boost in publications related to collapse and crises (Whittow, 1980; Tainter, 1988; Yoffee and Cowgill, 1988, see now also Cunningham and Driessen, 2017), underlining the popularity of these topics amongst archaeologists and ancient historians. That they are set to stay on the agenda is further underlined by a recent paper in *American Antiquity* in which crisis and collapse were ranked fifth in a poll asking a large sample of scholars what the most important topics for exploration would be in the next decade (Kintigh et al., 2014). Its continuing popularity as a field of research is amply illustrated by simply typing crisis and collapse into the ScienceDirect search function, an act that yields 867 hits from the beginning to 2001 and 18,668 since 2001. The main question, as Mary Van Buren (2001) put it, is how to incorporate natural disasters into archaeological thinking about social change and the present paper allows me to revisit our own work (Driessen and Macdonald, 1997; 2000) on the archaeologically traceable impact of the mid-2nd millennium BCE Santorini eruption.

2. The Santorini eruption

Despite continuing interest in the topic - at least two theses (available online) have been defended on the general aspects of the eruption (Sewell, 2011; Dunn, 2002; cf. also Meller et al., 2013) – the 2nd millennium BCE Santorini eruption and its potential effects on Minoan civilisation continue to divide scientists, especially the questions surrounding its absolute date, the precise sequence of volcanic events, the size of the eruption, and its impact on the ecosystem of the Ancient Mediterranean (e.g. Sigurdsson et al., 1990; Tsonis et al., 2010; Marriner and Morhange, 2013; Cadoux et al., 2015). All these different questions deserve further attention. Therefore, this paper will focus exclusively on those archaeological data that may help us appreciate the distal role the eruption played in the dominant society of the time, the Minoans.

In the *Troubled Island*, a monograph published in 1997, it was claimed that a series of changes in the Aegean, in particular in Cretan or Minoan Bronze Age society, were triggered by the L(ate) M(inoan) IA Santorini eruption (Driessen and Macdonald, 1997). Eventually, we argued, these changes would have caused the breakdown of the Minoan system over the course of a few generations, during L(ate) M(inoan) IB or the 15th c. BCE. The eruption, we further hypothesized, would have initially caused major problems in food production and distribution, undermining the central authority located at Knossos and leading to a process of decentralisation. This fragmentation would then have led incrementally to internal conflict, reflected by the wave of fire destructions that can be observed in many LM IB settlements. The situation normalised again when a new Knossian regime, partly composed of Mainlanders, restored order. The heyday of Minoan civilisation, however, was over. Although some scholars (Warren, 2001; Soles, 2009) have raised objections to the entire hypothesis, and others (Christakis, 1999; 2014; Platon, 2011) have criticised certain details or interpretations – sometimes with justification, as will be shown – our argument has in general been positively received (e.g. Rehak and Younger, 1998; Dunn, 2002, 281; Girella, 2013; Gorogianni, 2013). What we did not claim, however, was a direct causal link between the

E-mail address: jan.driessen@uclouvain.be.

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LM IA eruption and the LM IB destructions. In fact, traces of a declining state of society have now been recognised long before the eruption (Macdonald and Knappett, 2013). The general consensus nowadays is that 'Knossos' (whatever this may stand for) was overwhelmingly present throughout large parts of the island in M(iddle) M(inoan) III and LM IA, profoundly influencing local practices, and potentially sitting at the top of a state-like structure (Bevan, 2010). At the same time, the impact of earthquakes, which plagued the island especially during this period, has become better understood (Jusseret and Sintubin, 2017). Some combination of seismic activity, diminishing returns and geographical compartimentalisation, and/or an increasingly inefficient ruling apparatus that was growing more abstract and remote, may therefore have simply accelerated the process of disintegration of a pre-eruption Neopalatial Cretan system that seems to have been relatively fragile.

In view of the general theme of this issue, the present paper concentrates on the effects of the eruption that are archaeologically identifiable in the material record on the island of Crete during and following the eruption. I also give some attention to the identification of the agent or agents responsible for the subsequent LM IB destructions since these too have been given plenty of attention in recent studies (e.g. Brogan and Hallager, 2011; Puglisi, 2013). It needs to be stressed, however, that, despite the many destructions and abandonments documented, Minoan culture survived. This allows us to explore the society's reaction to natural and man-made catastrophes and to study its resilience in the form of mechanisms of adaptation, recovery and alternative pathways.

Perhaps some facts first. Firstly, there can be little doubt that the eruption happened during the ceramic phase we call Late Minoan IA and, on present evidence, rather late during this phase. We know this because one of the ceramic type fossils of Late Minoan IB, the ogival cup, does not occur in pre-Santorini tephra layers on Crete nor on Rhodes, while it does immediately afterwards. Thus far, there is no good evidence for a LM IA sub-phase after the eruption. On the other hand, considerable progress has been made in distinguishing several moments of destruction within the Late Minoan IB phase on Crete. Some sites seem to have been destroyed earlier in the period others suffering only much later, while still others were struck by several destructions within this phase (Brogan and Hallager, 2011). The high number of similarities between decorative styles found at Akrotiri on Thera and Gournia and Zakros on Crete can then perhaps be explained by the fact that these sites were destroyed at a moment close in time (Platon, 2011). There is, however, still no agreement on the *absolute date* of the eruption. Quite a few earth scientists take the late 17th c. BCE date (between 1630 and 1600 BCE) for granted, whereas many archaeologists stick to the traditional late 16th c. BCE date, roughly around 1530-1520 BCE. Both camps have a series of convincing arguments but if the earlier date were to prove correct, it would have a butterfly effect and require a considerable readjustment of traditional Egyptian chronology on which, through a series of synchronisms, Aegean chronology is constructed. Friedrich and colleagues (2006; 2014) discovered an olive-tree branch buried alive in the tephra on Santorini and dated this with 95% confidence in the range 1627–1600 BCE (Heinemeier and Friedrich, 2009) but this too has recently been criticised (Cherubini et al., 2013; 2014). Moreover, Manning and Kromer (2012), although defending a high date, admit "*the possibility of a mid-16th century BCE date (within ~1593–1530 cal BCE)*". Both Felix Höflmayer (2012) and Malcolm Wiener (2015) have presented sound analyses of the chronological evidence. They conclude that it remains safer to accept that the eruption took place *after the start* of the Egyptian New Kingdom, i.e. after 1540 BCE, or if the new C14 dates are correct, in between 1566 and 1552 BCE (68.2% probability) or in between 1570 and 1544 BCE (95.4% probability), but certainly not in the 17th c. BCE. Following Wiener (2009) and Warren (2009; 2010), a 1525 BCE date thus remains most plausible. Still, this discussion will continue as long as no robust local series of stratigraphically fine-tuned C14 dates are obtained from Cretan sites.

Secondly, there is little doubt that the eruption was preceded and probably even triggered by one or more earthquakes calculated to have been around 7 on the Richter scale, since it caused stone staircases to fracture and walls to tumble (Vougioukalakis, 2006). This earthquake struck at least several months before the eruption, but opinions as to how many differ since no erosion of the seismic debris took place. But at Akrotiri, there is good archaeological evidence that a rescue and demolition operation had started after this earthquake: beds had been taken outside, unsafe walls were being torn down with wrecking-ball type hammers, recyclable stones had been selected, etc. All these works were interrupted by the eruption (Doumas, 1983, 134–135; Palyvou, 2005; Vougioukalakis, 2006). During the eruption, too, earth tremors must have taken place (Saltogianni et al., 2014 - tremors could also have been caused by volcanic 'bombs' [Doumas, 1983, 134–135]). A similar sequence of events has been reconstructed at certain sites on Rhodes, Kos and Crete, where earthquake damage is closely associated with ash fall (Marketou, 2010a; 2010b; Molloy et al., 2014; Soles et al., 2017) but thus far we have been unable to distinguish between earthquakes that *preceded* the eruption by a few months from those that *accompanied* it.

Thirdly, there can be no doubt that, during the eruption, large amounts of ash and pumice were emitted. How much exactly is a matter of controversy (Johnston et al., 2014) but many Cretan sites have yielded deposits of tephra, discussed below, and these are, for the moment, our paramount evidence for the distal impact of the eruption. The great unknown remains the size of the eruption (M6?, M7?) and the total volume of dense-rock ejecta, a question on which volcanologists still do not agree (Johnston et al., 2014). This figure has been lowered by some, such as Pyle (1997) but increased by others (such as Tsonis et al., 2010); some believe there was no or little global impact, others a great deal (Riley, 2004).

Fourthly, it may be assumed that this eruption (and/or the associated earthquakes) was accompanied by one or more tsunamis. This was already convincingly shown through a study of seabed anomalies by Kastens and Cita (1981) and recently confirmed by the discovery of a sedimentary deposit on the continental shelf off Caesarea Maritima, Israel, dated and attributed to tsunami waves produced during the Late Bronze Age eruption of Santorini (Goodman-Tchernov et al., 2009; 2011). Work by Sakellariou et al. (2012) around Santorini itself leaves no doubt about the reality of tsunami generation and simulations by Novikova et al. (2011) suggest that the north coast of Crete was struck by highly variable wave amplitudes, ranging from negligible to 28 m. These, however, presuppose caldera collapse, and since this can no longer be claimed, tsunamis can only have been caused by pyroclastic flows, with the implication that their magnitude should be downsized (already Pareschi et al., 2006). Estimates of a maximum height up to 10–12 m (Nomikou et al., 2016) are more reasonable. Unfortunately, certain Atlantis-like catastrophe scenarios (e.g. Perianez and Abril, 2014, cf. Marriner and Morhange, 2013) incorporating monster waves seem more influenced by the 2004 Boxing Day and 2011 Japan disasters than based on actual archaeological evidence. Since the presence of pumice in the 13th c. BCE ruins of Gouves cited by Minoura et al. (2000) should be entirely dismissed as tsunami-related (cf. Gaignerot-Driessen and Driessen, 2012, for the presence of pumice in contemporary layers at Sissi and Malia), the evidence for tsunamis on Crete remains extremely meagre. Only the shore deposit at Palaikastro on the east coast of the island (Bruins et al., 2008; 2009) which comprises a mixture of LM IA sherds, architectural debris, Theran ash and other commingled material, including maritime foraminifera and marine molluscs, may effectively represent the remains of tsunami action (e.g. Goodman-Tchernov et al., 2009; Höflmayer, 2012; Bruins, this volume). However, this suggestion may need independent confirmation as well as a much more robust representation of the geoarchaeological

evidence, including section drawings, a proper framing within a local and regional contextual and geomorphological study, and a complete seashore reconstruction. It cannot be excluded that part of this deposit – which extends over ca. 100m along the shore – includes the debris of a flash flood that was caused by extreme weather conditions accompanying the eruption. At nearby Choiromandres, flash floods seem to have affected the dams (Vokotopoulos et al., 2014, and see below), and, during their reconstruction, a foundation deposit with specially collected Theran tephra was installed, which seems to imply that the damage happened at the time of the Santorini eruption. Flash floods are not uncommon in this part of the island and can cause considerable damage: in 1901, for example, a storm carried more than 4,000 trees to the sea (Hogarth, 1901: 123). More such cases are known from the historical records of the island (Rackham and Moody, 1997). The dearth of geoarchaeological evidence for tsunamis is matched by the general absence of archaeological signs for such an event even if we cannot exclude the possibility that tsunami action was in fact responsible for the poor conservation of LM IA levels in North Cretan coastal settlements. If so, we may have underestimated the capacity of humans to recover and to clean up effectively after disasters, be they earthquakes or tsunamis (Driessen and MacGillivray, 2011).

Fifth and last, there can be no doubt that a wave of fire destructions affected Cretan settlements during and at the end of the ceramic phase we call Late Minoan IB. These destructions have variously been attributed by archaeologists to internal revolt, Knossian expansion, Mycenaean invasion, or to a major natural disaster involving earthquakes. Hypotheses such as that advanced by Gorokhovich (2005) and Gorokhovich and Ullmann (2010), that earthquake damage to aquifers and changes in groundwater supplies formed a potential reason for the collapse or that it was caused by climate change (Tsonis et al., 2010), may be attractive to the general public but are still far from being archaeologically confirmed. Climate change or environmental deterioration remain avenues for earth scientists to explore in detail. The archaeological evidence, however, favours humans as being responsible for at least some of the destructions, for the following reasons (Fig. 1):

1. *The selectivity of the fire destructions.* In some Minoan settlements (e.g. Petras, Myrtos-Pyrgos), only the central buildings burnt down, with the surrounding houses escaping destruction, while in others (e.g. Knossos), only the houses were destroyed, with the central buildings themselves remaining untouched.
2. *Much destruction involved burning.* In LM IB, fire is the *only* destruction agent that can be identified with absolute certainty. Although earthquakes may also occasionally cause fires to break out, seismic destructions can only be rarely be identified for this period (for Mochlos, see Soles et al., 2017, also Macdonald, 2017 on Archanes).
3. *Fires seem to have been prepared.* Considerable evidence exists for the presence of brush wood and other flammable materials being brought into the buildings that subsequently burned down (Cunningham, 2007).
4. *The absence of later reconstruction and reoccupation.* In earlier periods of Minoan history, earthquake destructions were always followed by reconstruction and reoccupation. This does not happen after the LM IB destructions.
5. *Plunder and malicious destruction.* Certain LM IB destruction deposits do not contain any valuables or metals while others illustrate the smashing and the intentional breaking of prestigious artwork, as is best illustrated by the chryselephantine Palaikastro Kouros (Driessen and Macdonald, 1997; Macdonald, 2017).
6. *Emergency measures.* Many sites witness remarkable pre-destruction activities, such as the protection of access, water supplies and livestock, and the hiding/hoarding of valuables, which all seem to reflect emergency procedures as reactions to imminent danger (Driessen, 1995, 1997).
7. *A succession of destructions.* At certain sites, several phases of destructive events can be recognised during LM IB. This suggests that the troubles were more of a prolonged duration than a short-term event. This too suggest human intervention (Rethemiotakis and Christakis, 2011, 227).

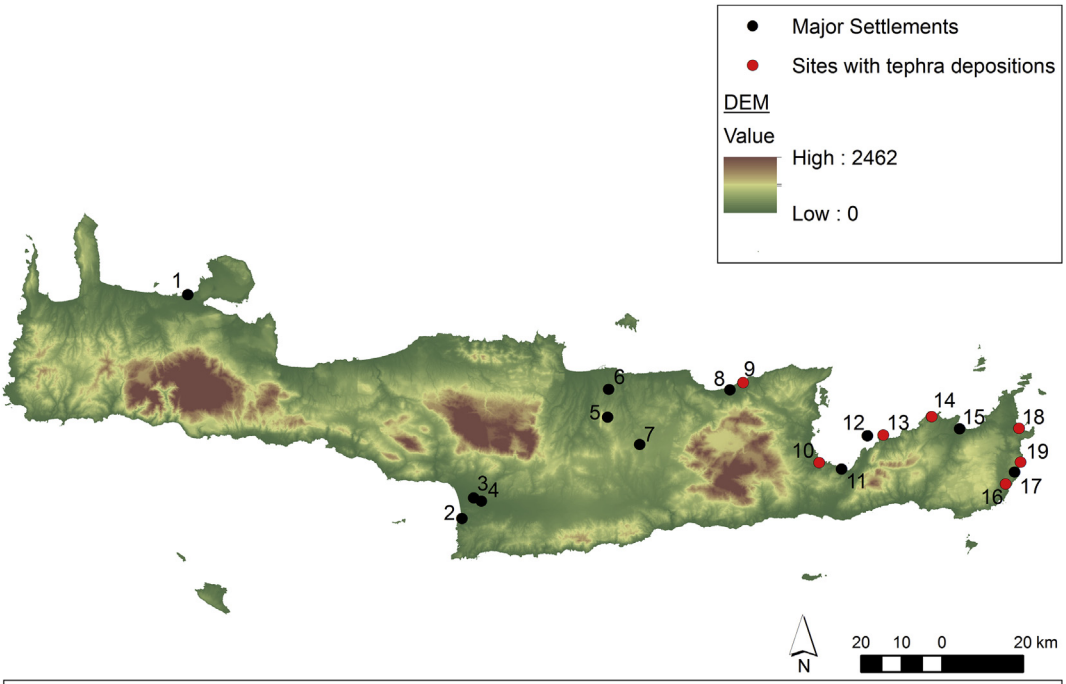

Fig. 1. Island of Crete: Main sites and sites in which archaeological contexts with Santorini tephra have been identified. Map by Sylviane Déderix.

If more evidence for selective destruction and the smashing of prestigious items can be found during future excavations, the case for human aggression would become stronger. Moreover, it would imply that the aggression was directed primarily at symbols of authority. This then would in turn allow looking for a social explanation for the demise of Minoan palace culture in LM IB (Driessen and Macdonald, 1997; 2000).

The main question is of course whether the process that led to the breakdown of Minoan society in LM IB or approximately 1450 BCE was set in motion by the effects of Santorini eruption two or three generations earlier. Was the eruption a catalyst (through the damage caused by earthquake, ash-fall, tsunami, anomalous weather, etc.) which triggered a disintegration process? Our thesis in the *Troubled Island* was that these effects indeed caused severe economic dislocation, which forced local centres to adapt and to assume greater independence from the regional authorities, represented by the palatial centres. This decentralisation, we argued, led to political fragmentation and internal conflict with increasing competition, largely related to the acquisition of resources, between the haves and have-nots, the elites (some newly constituted) and non-elites. We saw something like a state of anarchy at the end of the LM IB period that eventually paved the way for a Mycenaean intervention and Crete's gradual absorption into the Mycenaean, and hence Greek, world.

3. Transformation studies

When writing the book in 1997, disasters as transformative events had not yet received much attention. This has changed, no doubt partly influenced by some popular books (Diamond, 2005 - but see McAnany and Yoffee, 2010 and Cunningham and Driessen, 2017, for approaches that defend historical particularism and multiple strands of explanation rather than generalization). A disaster is an event that involves a "*combination of a potentially destructive agent(s) from the natural and/or technological environment and a population in a socially and technologically produced condition of environmental vulnerability*" (Oliver-Smith, 1996, 305; cf. Rodriguez et al., 2007). The impact of disasters on human societies depends on the magnitude, duration and frequency of the phenomenon, on its impact on natural resources, on the pre-existing adaptive strategies of the affected human population and on the event's size and distribution. Moreover, it very much depends on the human populations' resilience, their ability to anticipate, contend with, and recover from a disaster, or their vulnerability, the degree to which they experience harm (Turner et al., 2003; Riede, 2015). Furedi (2007) has argued that community response to a disaster episode is far more likely to be defined by its vulnerability than its resilience and that vulnerability is a cultural construct, a state of mind, rather than a state of being that emerges in response to a disaster, i.e. it is something that precedes, not follows, disaster (also Cardona, 2003). The impact of a disaster, then, is strongly governed by both the nature of the hazard and the characteristics of the population at risk (Blaikie et al., 1994). When disasters damage the major socioeconomic organizational elements and physical facilities of a community to such a degree that the essential functions of that society are interrupted or destroyed, individual and group stress combined with social disorganization is the result. Disasters, therefore, tend to affect most aspects of community life (Alexander, 1997).

With this in mind, we can look at the archaeological record of Late Minoan I Crete and distinguish between three moments of importance: before (MM III-LM IA), during (LM IA end) and after (LM IB) the eruption. It is only through such a finer chronological distinction that we can try to identify whether the effects of the eruption left any trace on Minoan culture.

4. Prior to the eruption

Recent research has revised the traditional, one-sided view of Neopalatial Minoan Cretan society as a golden age prior to the eruption (Macdonald and Knappett, 2013). There is more and more evidence, for example, that Middle Minoan IIIA was a moment of major change when quite some exceptional ashlar buildings were built, including those at Kommos, Galatas, Palaikastro (Block M), Sissi and Gournia. The palace at Knossos was also rebuilt and some authors claim that the Middle Minoan III period represented the real period of Knossian expansion whereas, by the mature LM IA phase, signs of trouble were already evident with some important settlements abandoned (details in Driessen et al., 2002). Sites that seem to have been either in ruin or in decline in the mature LM IA period comprise most of the Messara sites, including Phaistos, Hagia Triada and Kommos, but also Galatas and Sissi, perhaps Malia and most of the sites in the Mirabello Bay and East Crete. The palace of Knossos also has some considerable LM IA deposits, which is also suggestive of a major disturbance in this phase, but it lacks LM IB deposits which are, however, frequent outside the palace (Macdonald, 2017). The construction of the palace of Phaistos, and probably that of Zakros and the monumentalizations observed at Palaikastro and Mochlos, are, however, LM IB undertakings. Neither Phaistos nor Zakros may have had a palace in LM IA (La Rosa, 2002, 83; Platon, 2002), while occupation at Hagia Triada was sparse at the most and central building T at Kommos was already in ruins with a kiln built on top of its south stoa and grinding activities taking place within its north stoa (Shaw, 2002, 101). The same goes for the ceremonial buildings at Galatas, Kastelli Pediada and Sissi: the latest pottery on their floors is early LM IA (Rethemiotakis, 2002, 60, 65; Rethemiotakis and Christakis, 2011, 226; Driessen, 2018). All three complexes were built during Middle Minoan IIIA or B and are seen as Knossian-inspired constructs. The same is true for the central area of the settlement at Palaikastro: in Middle Minoan III, a Knossian-looking building with pier-and-door partition, columns, court and frescoes was constructed but it was already in ruins and scavenged before the eruption took place (Knappett and Cunningham, 2012). Several quarters of Gournia town were deserted during LM IB while the palace façade was patched up with recycled ashlar (J. McEnroe, pers. com.). This state of affairs is also reflected by survey data: only in the Knossos region is there a considerable increase in the number and density of occupation in LM IA, while elsewhere there is a decrease (Driessen, 2001a; Bevan, 2010). From MM IIIA into LM IA, Knossos most certainly had close contacts with Santorini, as is illustrated by the presence of Knossian sealings found at Akrotiri, some actually impressed by the same gold rings that left impressions in other Minoan sites (Goren and Panagiotopoulos, 2009). These facts, combined with other features (Wiener, 2016), may provide some support for the claim of a Knossian supremacy. Perhaps this means that, in MM IIIB and early LM IA, previously independent political units were incorporated into a Knossian state, in which earlier palatial centres were demoted to secondary centres while others were promoted from tertiary to secondary centres in an attempt to undermine local traditional power relations. This would evidently have been accompanied by an agricultural overspecialisation and an intensification in the complexity of hierarchical and administrative structure, rendering the system unstable and hence vulnerable (Hamilakis, 1996; Haggis, 2002).

5. During the eruption

The most convincing evidence for a direct impact of the various eruptive processes on the island of Crete is still very much represented by layers of volcanic Santorini ash in stratified archaeological contexts. One recent study on tephra deposition heavily relies on seabed cores, and argues that Crete would not have been affected much (Johnston et al., 2012), but this view needs to be adjusted by a more solid reappraisal of the data (Athanassas et al., 2017), which also takes account of the tephra found on Crete itself. Leaving aside non-Cretan sites, such as those on Rhodes, Kos and on the West coast of Asia Minor (Niemeier in Cunningham, 2011, 237), where ash fall was much more

considerable, the Cretan evidence may briefly be reiterated. Our westernmost (and most recent) certified case of tephra comes from the site of Sissi, 4 km east of the palatial centre at Malia, where a water-borne layer comprising Santorini tephra lapilli, confirmed through chemical and microscopic analyses by Christine Lane, mixed with LM IA pottery was redeposited on a ramp next to the abandoned remains of the ceremonial building (Driessen, 2018). About 40 km to the east, at Priniatikos Pyrgos in the Bay of Mirabello, a considerable layer of tephra, 10 cm thick, was discovered in a context with LM IA pottery immediately above a street surface. This tephra, too, was redeposited by water action. Here, as at Sissi, deposition coincides with the end of occupation in the immediate neighbourhood (Molloy et al., 2014). The next site, about 15 km further east, is Mochlos, where several instances of tephra deposition, 5–10 cm thick, were identified in clear stratigraphical contexts throughout the Neopalatial town (Soles, 2009). Some of this may actually represent the result of direct wind-blown action. The coastal site of Papadiokampos, 40 km east of Mochlos, has also yielded several tephra layers in clear stratigraphical contexts, some of considerable thickness (15 cm). Part of one layer may be wind-blown, but the remaining are water-borne (Brogan and Sofianou, 2009). The thickest deposit of tephra (ca. 15–20 cm) was found again 30 km east, in Block M at Palaikastro, where it may also have a combined wind-and water-borne origin. Other smaller deposits of tephra were found throughout and outside of the town (Driessen et al., 2006; Knappett and Cunningham, 2012). A 10–12 cm thick layer of tephra has also been reported from within the Pelekita cave near Zakros, ca. 18 km south of Palaikastro, but this has not yet been published. Finally, at Choiromandres, approximately 10 km south of Zakros, close to a Minoan country building with annexed agricultural terraces and a water collection system, a foundation deposit composed of a vase, containing pure tephra, probably intentionally collected, was placed beneath a dam during the early LM IB phase. Incidentally, the same archaeological team was able to show that considerable rainfall had intensified erosion, forcing the Minoans to modify field systems precisely at the time of the eruption (Chryssoulaki et al., 1990; Vokotopoulos et al., 2014, 257–258). The massive concentration of tephra in East Crete undoubtedly suggests that this part of the island was differently affected from the central and western regions and, even if most of these deposits were water-borne redepositions, they nevertheless suggest that the original tephra cover may have been considerable. In Central and West Crete, however, the tephra fall must have been much lighter, since it is only identified as particles (Siart et al., 2008; Siart and Eitel, 2013). In any case, volcanic ash remains our most tangible evidence for the Santorini eruption, but we have made little progress in identifying its short-and long-term consuequences. As for short-term effects, intensive rainfall may explain the cases of tephra redeposition. We can also assume that the hiding of the sun and moon with darkness had a profound psychological impact, causing panic, but again this is conjectural. There have also been claims that Santorini tephra contained a relatively high fluorine content, potentially poisonous and capable of polluting water supplies, killing animals and destroying crops, but thus far, no conclusive research has been carried out on this. Likewise, if the sulphuric acid aerosol was considerable, climatological anomalies and even a volcanic winter may have occurred, again with disastrous consequences for agriculture and society but, apart from dendrochronological anomalies and the water erosion events noted above, no study has picked up on this lead (Rampino et al., 1988). There are, therefore, still a number of questions to be addressed by earth scientists before a robust conclusion can be reached.

6. After the eruption

Disaster studies have shown how such events produce long-term effects that act as catalysts for political, economic, social and psychological actions (Gibbs, 2000; 2003; Leach, 1994; Dynes and Tierney, 1994). With these studies in mind, we may now evaluate what the combined outcome of a potentially vulnerable societal situation on the island of Crete was when it was faced with the effects of the eruption. It may be best to distinguish between an emergency phase, the period during which the immediate impact of the disaster was most strongly felt, and a rehabilitation phase, when attempts were made to bring the community back to its former level of existence. Crisis studies have shown that violence, antisocial behaviour and community conflicts are in fact rather rare in the emergency period, but frequent during the rehabilitation period because of the discriminatory nature of the recovery process, when underprivileged minority groups find it much more difficult to regain their former level of subsistence and unleash their grievances. Conflict then usually arises because of problems with the allocation of resources for rehabilitation and the assignment of blame (Brändström, 2016). Regarding the emergency phase, we can be brief: the number of settlements (or residences therein), of ritual sites and of funerary sites that were abandoned during Late Minoan IA is considerable (Driessen and Macdonald, 1997; details on new sites can be found in Driessen and Langohr, 2014; Macdonald, 2017) but apart from the above mentioned cases of Sissi and Priniatikos Pyrgos, where tephra actually seals the abandonment phase, we cannot yet distinguish archaeologically between a mature (i.e. prior the eruption) and final (i.e. contemporary to the eruption) LM IA abandonment. Serious LM IA destructive events have been confirmed at Chania, Zominthos, Knossos, Poros, Galatas, Zakros, Petras, Mochlos, Symi, Papadiokampos, and Vai, which sometimes, correctly or not, have been explicitly connected to the Santorini eruption. The wholesale or partial reconstruction of some settlements early in LM IB, discussed below, may also be a sign that the LM IA damage caused during the eruption was considerable. Again, however, this is conjectural. Whether specific archaeological features, such as the abandonment of older wells and the digging of new ones, were caused by tephra-pollution needs further investigation, but the Choiromandres evidence mentioned above could point in this direction. Moreover, if a sudden increase in the mortality rate occurred because of the impact of the eruption's distal effects (cf. Blaikie et al., 1994; McCaughey et al., 1994; Doocy et al., 2013), alternative methods of body disposal may have been necessary to control the spread of disease and/or maintain certain social or religious standards. And although this could partly explain the absence of burials during LM IB, it does not do so for the earlier periods (Devolder, 2010). Our main challenge remains finding sufficient funerary data, and thus osteological evidence, for the period in question that would allow us to assess the impact of the eruption and subsequent events on men, women and children.

As far as the rehabilitation period and the post-eruption period are concerned, it has become clear that LM IB was a (much?) longer phase than the single generation once assumed by Mervyn Popham (1967). A recently published volume on LM IB pottery (Brogan and Hallager, 2011) presents a wealth of new data and is especially relevant for the recognition of LM IB sub-phases at various sites such as Kommos, Hagia Triada, Malia, Pseira, Chania and Gournia (Watrous et al., 2015; Gorogianni, 2013), in addition to the previously known cases of Mochlos and Palaikastro. And, although there is still much room for a refinement of internal LM IB stylistic phasing, partly by paying more attention to local developments and less to fragmentary elite wares, we are on much firmer ground when it comes to recognising a pattern of intermittent and non-contemporaneous destructions, reinforcing the impression of a longer period of crisis rather than a single event. In the Messara, for example, the Phaistos palace and the Hagia Triada *villa reale* were destroyed by fire in LM IB, but at both sites slightly later LM IB contexts also exist, namely the Chalara house at Phaistos and the *edificio ouest* at Hagia Triada (Cucuzza, 2011). Similar sequences have been observed at nearby Kommos. The LM IB destructions at Knossos are said to be contemporary with those at Tylissos and Nirou Chani but later than those in the Messara, while the LM IB destruction at Pseira happened earlier than those at Gournia and Mochlos. This underlines the necessity of presenting site-based relative chronologies: archaeological levels are caused by specific events. If nothing remarkable

happens, no deposition occurs (Driessen, 2013). This finer chronological resolution allows us to return to the discussion of how the allocation of resources for rehabilitation and the assignment of blame manifested themselves materially during the post-eruption period.

Where the *allocation of resources* is concerned, many authors have underlined the role of famine as an accelerator of historical change, with effects on demography, economy, politics, society and culture (Vanhaute, 2015). Frequent cultural responses to reduced harvest yields include a reduction in population size, a change in the distribution of human groups (including their mobility patterns), a diversification of production and the conversion of food into direct and indirect storage, all features evidenced during LM IB (Driessen and Macdonald, 1997). The best evidence for increased food production comes perhaps from the previously mentioned central building at Galatas where a very large number of ground stone implements (519 of which 429 were quern stones) as well as ovens were found (Rethemiotakis, 2002). These suggest industrialised production rather than a normal subsistence pattern, with the collection, transformation and perhaps distribution of cereals organized on a massive scale. Often, however, it is not the lack of resources but rather their distribution that is problematic, since disasters often disrupt the infrastructure. This is how I read the paper by Knappett et al. (2011): using computational network analysis, they suggest that the Minoan collapse at the end of LM IB was one result of an incremental increase in exchange costs required to maintain commercial ties following the disappearance of Santorini as a key node in the network, with the remaining sites concentrating their exchange/trade efforts into a smaller number of stronger links at the expense of weaker ones. Likewise, a tendency for hoarding, which is very evident in LM IB, may also be considered as disruptive to the exchange system. That resources were especially under threat during LM IB is underlined by what I have dubbed crisis archaeology (Driessen, 1995), the archaeological correlates of what may be called post-and pre-traumatic stress syndromes (cf. Zuckerman, 2007; Driessen, 2013). Our original argument for a prolonged period of crisis relied heavily on an evaluation of material culture as an indicator of ancient emergencies (Driessen and Macdonald, 1997), which has since been confirmed by more recent archaeological finds. Architectural modifications especially reflect a tendency to render access to the interior of residences more difficult and secure – a kind of *warchitecture* (Herscher, 2008; Lahoud, 2010; Mateo, 2010). Thus, at Chania in West Crete, Maria Andreadaki-Vlazaki (2011, 73–74) notes extensive repairs and the presence of make-shift features in the architecture, which, she suggests, reflects a crisis situation in the last days of the LM IB settlement. The same has been noted for the palace at Zakros (Platon, 2011, 609) while both at Chania and elsewhere (as for example, at Papadiokampos, Kastelli Pediada, and perhaps Skinias, in addition to those already known), prestigious rooms such as the Minoan Halls went out of use before the final LM IB destruction. In other sites, like at Pseira, there was only a squatter occupation in the final LM IB phase (Betancourt, 2011). A feature which has also been emphasized during recent excavations is the increase in storage space in the mature LM IB phase. This is clear at Petras (Tsipopoulou and Alberti, 2011, 463) but has also been stressed for Skinias-Kolokithi (Mandalaki, 2011, 390), Palaikastro (Cunningham, 2011, 264), Sphendili (Christakis et al., 2015) and Archanes-Tourkogeitonia where a fine ashlar hall was used as a pithos storage room before the LM IB destruction (Macdonald, 2017). Storage also appears to have been essential in the central building at Damantri near Protoria in the Eastern Messara (cf. Driessen and Langohr, 2014). All these buildings burned down in LM IB. It is possible that this increase in storage should be read as an increase in conspicuous consumption by elites which, in turn, augmented the pressure on lower classes, further aggravated by environmental stress (Christakis, 1999; 2014, 253; Rethemiotakis and Christakis, 2011, 227). While the degraded nature of most settlements on Crete after the eruption has been noted, several witness more intense construction activity up to the eve of the LM IB destruction. In some cases, as at Gournia, this rebuilding, repair and construction may have been necessitated because of the damage caused by the earthquake and direct impact of the eruption, thus explaining the makeshift character of some of the structures. In other cases, however, this post-eruption phase is characterized by a major investment. At Phaistos and Zakros, monumental palatial structures were constructed, while at Mochlos, Hagia Triada and Palaikastro, existing structures were monumentalized, especially through the construction of invasive architectural features such as ashlar veneers. Nevertheless, the obvious signs for conspicuous consumption and energy investment – not only in architecture but also in luxury objects made of ivory, stone and metal – that can be shown to have taken place after the eruption and in the period before the final LM IB destruction, have usually been taken at face value, rather than as a blatant sign of a system breakdown. Indeed, symbolically charged production and consumption appear to have become incrementally centralised in LM IB, showing up in fewer elite contexts than in earlier periods. This may well suggest a greater inequality and, therefore, a source of discontent. Rather than a sign of affluence, these signs may hence be interpreted as attempts to hide a system breakdown, which was actually exacerbated by concurrent increased investment (cf. Bernard, 2012). The generally standardised, monotonous and lower quality of LM IB ceramic material, as seen at Chania, Palaikastro, Malia, Zakros and Mochlos (e.g. Barnard and Brogan, 2011), with special wares (such as Marine Style) forming only a tiny fraction of the assemblage, hints at a similar situation.

The general psychological consequences and the unusual behaviour provoked by the *allocation of blame* following disasters have been studied in detail (references in Black, 1981; Hansell et al., 2006; Johrendt, 2007; Doocy et al., 2013). As one example, we can cite the study by Adams and Adams (1984), who describe how, during the seven months following the Mt St Helens eruption, there was an 18.6% increase in mortality rate, a 21% increase in emergency room visits, a 198% increase in stress-related illnesses, a 235% increase in mental illnesses, a 25.5% increase in sick leave, a 45.5% increase in domestic violence, and a 37.5% increase in aggression in the area where the ash had fallen (cf. Shore et al., 1986). One consequence which has been noted in several case-studies is a greater cohesion amongst local groups, which, in political terms, sometimes translates into moves towards regionalism, decentralization and the formation of new groups (Kirschenbaum, 2003; Rodriguez et al., 2007; Stor et al., 2016). 'Acts of God' may represent an easy way out for modern-day insurance companies, but disasters in ancient societies were closely connected to religion and ritual (Douglas, 1995; Driessen, 2001b; 2015). We have already drawn attention to the many ritual and religious changes that can be observed immediately following the eruption. These include the potential tsunami-inspired origin of Marine Style decoration for exceptional symbolic ceramics, but also the change from a female to a male supreme divinity, the abandonment of natural sanctuaries, etc. (Driessen and Macdonald, 1997; Driessen, 2001b; 2015). Since there is a widespread tendency to explain disasters in terms of the sins of the people or its leaders, victimization and scapegoating are common human reactions in the aftermath of disasters. Such blame is often directed against specific, individual groups, especially during the recovery process. The biased nature of violent destruction contexts (e.g. restricted to the central building of a settlement) and the intentional destruction of status objects mentioned above clearly suggest that such victimization took place. Blame may have also played a role in the post-disaster phase when it comes to issues of authority and leadership, as new, strong figures or charismatic persons may have replaced earlier institutionalized and more collective or corporate lines of command (McCaughey et al., 1994; Rodriguez et al., 2007). Whatever the particulars, the potential for radical change resulting in uncommon authority structures and innovative social organization exists. The rather sudden attention to male figures – very often in isolated position – in Minoan iconography during the post-eruption period can then perhaps be interpreted as a change that suggests incipient kingship for which there is absolutely no prior evidence. The evidence for increased

martiality put forward by Molloy (2012), combined with the prolonged state of uncertainty as suggested by successive LM IB destruction levels, may indicate that, during the post-eruption phase, one-time ceremonial buildings lost their collective aspect and were usurped by a more individualistic, elite type of control, thus paving the way for the later Mycenaean *wanax* or king. It has also become more evident that, during the post-eruption LM IB phase, Mycenaean involvement manifests itself in a much more tangible way, not only in the Cyclades and on Kythera, but also in Asia Minor (Mountjoy, 2004; Mountjoy and Ponting, 2000). In terms of pure quantity - and the publication of Skinias and Makryghialos (in Brogan and Hallager, 2011) has added more examples -, the number of Mycenaean imports and imitations is much higher on LM IB Crete than during the more advanced Late Bronze Age (LM II-IIIA/B1). It is hence very likely that Mainlanders were involved in the post-eruption history of the island. They were certainly present at LM II Chania where the Argive connections of the warrior graves are clear (Andreadaki-Vlazaki, 2010). They may have taken advantage of the situation to replace the Minoans gradually, first on the islands and eventually at some places on Crete itself.

7. Conclusions

In this paper, I have argued that the basic hypothesis presented in 1997 - that of a gradual process of disintegration of Minoan society over the course of several generations triggered by the Santorini eruption rather than a single dramatic event that took place at the end of the period - still stands. Certain elements, such as the greater resolution of different phases in LM IB and the increased importance of MM IIIA-B for understanding the subsequent periods, have helped to provide greater historical precision. Moreover, new finds of tephra and sound archaeological contexts all reinforce the picture of a crisis on Crete well before its societal system finally broke down. What I hope I also have done is highlight what kind of evidence we still need to strengthen this hypothesis: well-dated archaeological sequences that span the entire period in question; sound human and faunal osteological data that may inform on potential effects of the eruption, and finally, an island-wide program of geomorphological coring that could provide us with a robust series of soil analyses that would not only detect the presence and importance of tephra in regional signatures, but would also assess its potential effects on land use and human activities. The results of these analyses could then also be used as proxies by climatologists to identify weather-induced erosion patterns during the period in question. We still do not know whether the people of Thera managed to escape from their disintegrating island since we lose track of them post-eruption. Whether refugees succeeded in reaching friendly shores seems altogether unlikely, despite the presence of some isolated Cycladic features at LM IB Myrtos-Pyrgos, on the southern island of Gavdos and, further away, at Morphou Bay on Cyprus (Catling, 1980; Cadogan, 1984; Kopaka, 2015). It is more likely that they perished en route.

Whether the picture I have drawn here comes close to Tainter (1988)'s law of diminishing returns awaits to be seen. Was the Minoan system bound for collapse from the outset? Were elites not willing to adapt, instead remaining too focused on feeding on a 'weakened population' with the eruption simply accelerating the situation? With the law of diminishing returns, one would assume that the collapse was something of a sensible economic decision, decreasing political complexity, breaking down the social landscape into more simple units and eliminating the cost of the managerial organization (cf. Rethemiotakis and Christakis, 2011). The subsequent Mycenaean-inspired period, LM II-IIIA/B, seems, however, to suggest that the opposite was the case, with an even more complex administrative organization based on the introduction of a new language using Linear B script (Driessen and Langohr, 2007). Future research should focus on clarifying the socio-political situation during the LM I period and establishing whether the system was indeed unstable, requiring only the eruption and its accompanying effects to push the system to, and beyond, its inherent limits.

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