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What's wrong?

Hard science and humanities – tackling the question of the absolute chronology of the Santorini eruption

Věra Klontza-Jaklová

FILOZOFICKÁ FAKULTA
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PREFACE

The absolute chronology of the Late Bronze Age volcanic eruption in Santorini and its effects across the wider region has been a focus of my research since I studied archaeology at Charles University in Prague (Klontza-Jaklova 2008; 2012a; 2014). This topic, the problem of placing the event within the absolute chronology, is one of the most frequently discussed and studied topics of Aegean prehistory, especially since the mid 1970's, when the first radiocarbon dates from the region were published and the difference between those dates and archaeological/historical dates appeared. The debate is invariably lively and creative, sometimes even passionate. One particularly dramatic phase ended at the turn of the millennium when two monographs were published (Manning 1999; Friedrich 2000). In the subsequent few years several conferences dealt with the problems of assigning an absolute date to the Santorini eruption and absolute chronology in general (Cornell University 2006, Copenhagen 2007, Halle 2011[1]) and, circa ten years later, both above mentioned authors reviewed and re-edited their monographs (Friedrich 2009; Manning 2014). The very intensity of the debate provided adequate reason to place it (or the most significant representations of each opinion) on the pages of Antiquity (2014: 88/339). (More on the history of research can be found in chapter 1.3). Albeit the bibliography of this volume is bulky (about a fifth of the text), and my own, admittedly heuristic, approach has been continuous and meticulous for years, it has proved impractical to collect all the publications related to the topic or even to establish with any degree of accuracy how many exist. Thus, for the purpose of this publication, I have, of necessity, created just a choice of illustrative books and articles.

What, you may ask, can I add to the work of so many esteemed scholars? What is the aim of this monograph? Obviously, it is yet another review of the opinions; one in which I do not even try to compare the results of each method or approach. I try instead to compare the methodologies and approaches, their limits and uncertainties and I examine mainly those scientific methods which seem to make sense for use in archaeology. I use the critical methodology of 'hard' science for 'autocriticism' of the humanities, since I am primarily trained in the humanities. I am an archaeologist and, although I collaborate intensively with physicists, I don't feel competent to criticize their methods. I aim simply to underline the points where they may not be accurate or can introduce errors. I am, however, rigorous in criticizing archaeological results. I agree with David Warburton: *"…it is not chronological debate but methodological debate. (…) There is a fundamental problem and it must be admitted that that problem is fundamentally archaeological."* (2009, 295)

The problem of absolute chronology is not just a physical problem. Apart from the absolute and relative physical values (in Newtonian and quantum mechanics), time possesses a philosophical meaning which can vary in different periods, regions and societies, including our own. (Klontza-Jaklova 2011). Problems with chronology cannot be solved by physical science alone. It is also a part of human history and is one of the dimensions wherein human lives are realized. We need solutions to answer the historical questions we ask but we need to test our methods, their validity and accuracy.

One could argue that the problem of 120 years offset between the possible dating scales is not significant for the Late Bronze Age or that we should resign ourselves to this problem because, at present, it looks as though we are not in a position to find convincing arguments or reach consensus. However, I cannot agree with such opinions. Archaeology, as a part of the humanities, tries to explain the interactions between people, societies and their environments, the evolution and changes in their ways of thinking and understanding of the world around them, or us. We even try to define the regularities of human actions and interactions throughout time across the Earth. In this understanding of and approach to archaeology the time frame is crucial, even, or indeed especially, in the Late Bronze Age, when a large part of the Mediterranean was organized in states with characteristics similar to those of our, modern states (Klontza-Jaklová 2013). The correct absolute date of the Santorini Bronze Age eruption is essential for synchronization not only of Mediterranean and Near Eastern chronologies but also of pan-European chronologies because the northern European regions, although lacking written records, were nonetheless part of the 'global' trade network and one large cultural *koiné* (Kristiansen and Larsson 2005; Bouzek 2013).

I would like it to be noted that, while a multidisciplinary and transdisciplinary approach is obviously needed, co-operation and communication between humanities and hard sciences is still problematic, difficult and accompanied by a lot of misunderstandings. We often fail to trust each other, primarily because we don't understand the approaches, limits and methodologies of the other discipline. The "Santorini problem" is one of the fields where communication between humanities and natural sciences is intensive.

So, this volume's target is to evaluate the methodology of the humanities, in particular of contemporary archaeology, and attempt to offer some new methods and approaches in order to evaluate the 'weight' of each piece of possible archaeological evidence.

The problems I am going to present are very complex. It was extremely difficult for me to understand all the details and it took me a long time to become familiar with the large bibliography and various scientific methods. During the process I have changed my mind many times. However, this book is far from representing the end of my involvement with the topic; the "investigation" into the actual date of the oft-mentioned eruption continues apace and I fully intend to be a part of it.

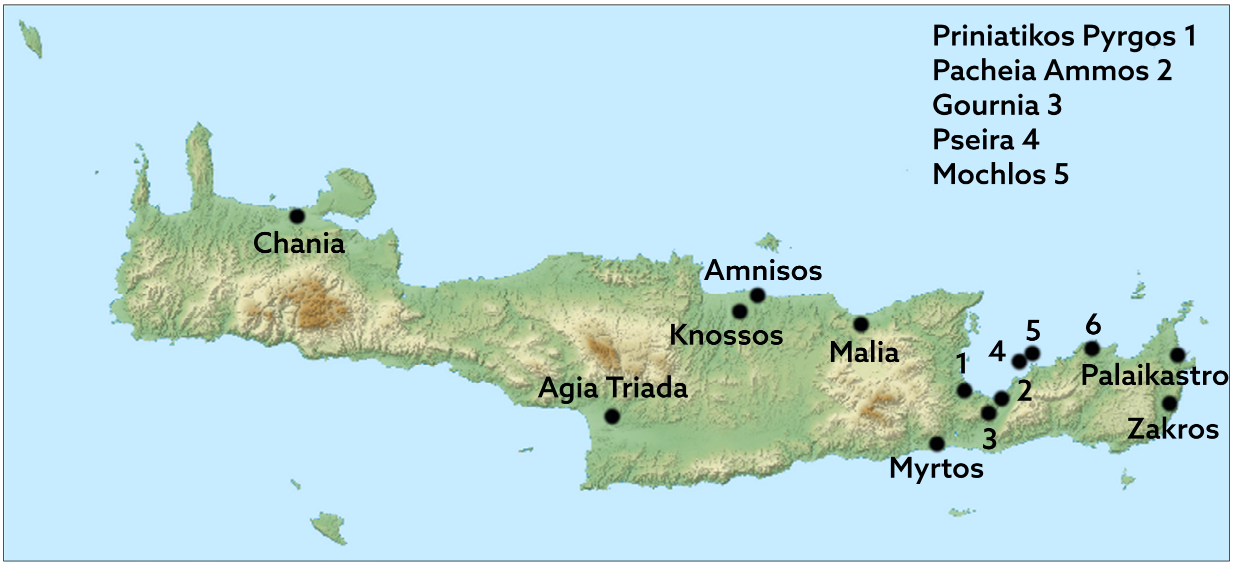
Acknowledgments

This volume would never have been concluded without help and support from a great many people. I am sorry that the order in which they are presented here does not necessarily reflect the extent of their help, which I greatly appreciate. I am also sorry that I have not been able to acknowledge by name all who have assisted me over the years. I am very grateful to Masaryk University for their brave decision to support the publication, to INSTAP for financial support for my research and to the INSTAP Study center for East Crete and the Institute for Classical Archaeology in Vienna for permission to use their libraries. I owe many thanks to Prof Phillip Betancourt, Prof Jan Bouzek, Dr Thomas Brogan, Dr Ricardo Fernandes, Mgr Manolis Klontzas, Prof Floyd McCoy, Dr Alexander J. MacGillivray, Prof Jennifer A. Moody, assoc. Prof Jana Mynářová, Prof Jeffrey Soles and many other colleagues and friends for their never ending patience in explaining to me the details of their research, for sharing their enthusiasm for the topic with me and constant support for my efforts to conclude this volume. I will never thank enough my friend and colleague Dr Sue Bridgford for her multiple edits of the manuscript and her patience with my English. I am also grateful to all of my students, on whom I first tested my arguments, for their comments, support and motivation. I especially want to thank to Michael Smíšek for the data he has collected and shared with me and Barbora Ruffini for her help with the editing of the manuscript.

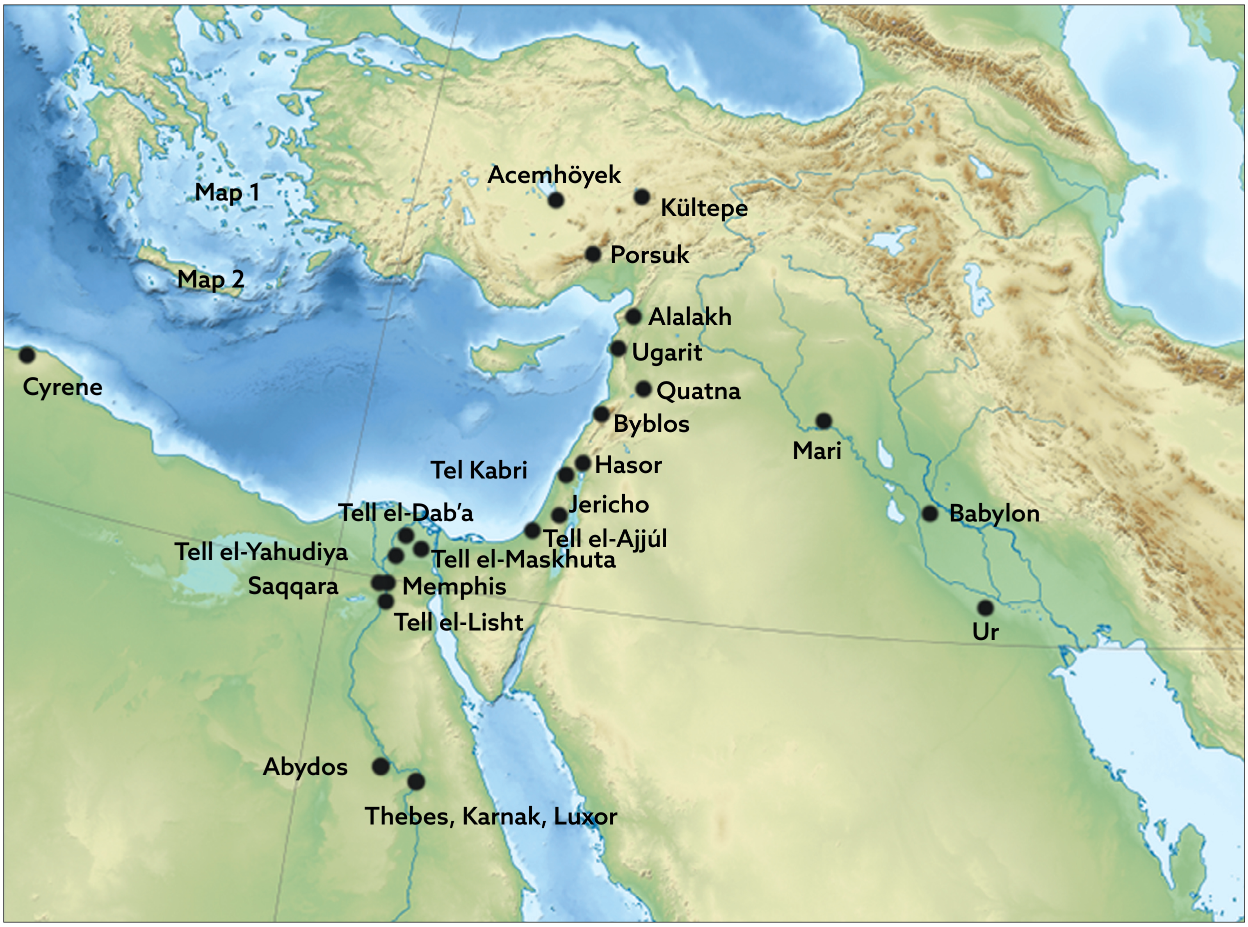
I have already mentioned the invaluable help of my husband Manolis Klontzas, but my son Odysseas deserves a special mention for the incredible patience with which he accompanied and assisted me on some of my surveys on Santorini and Crete.

I would like to dedicate this book to my father – a physicist – who supported and observed the process of this book's birth with immense interest and exceptional love; he was always happy to help and discuss. Unfortunately, he passed away before the manuscript was finished.

Map 1 / Map of the Aegean showing major sites mentioned in the text. (Illustration by author)

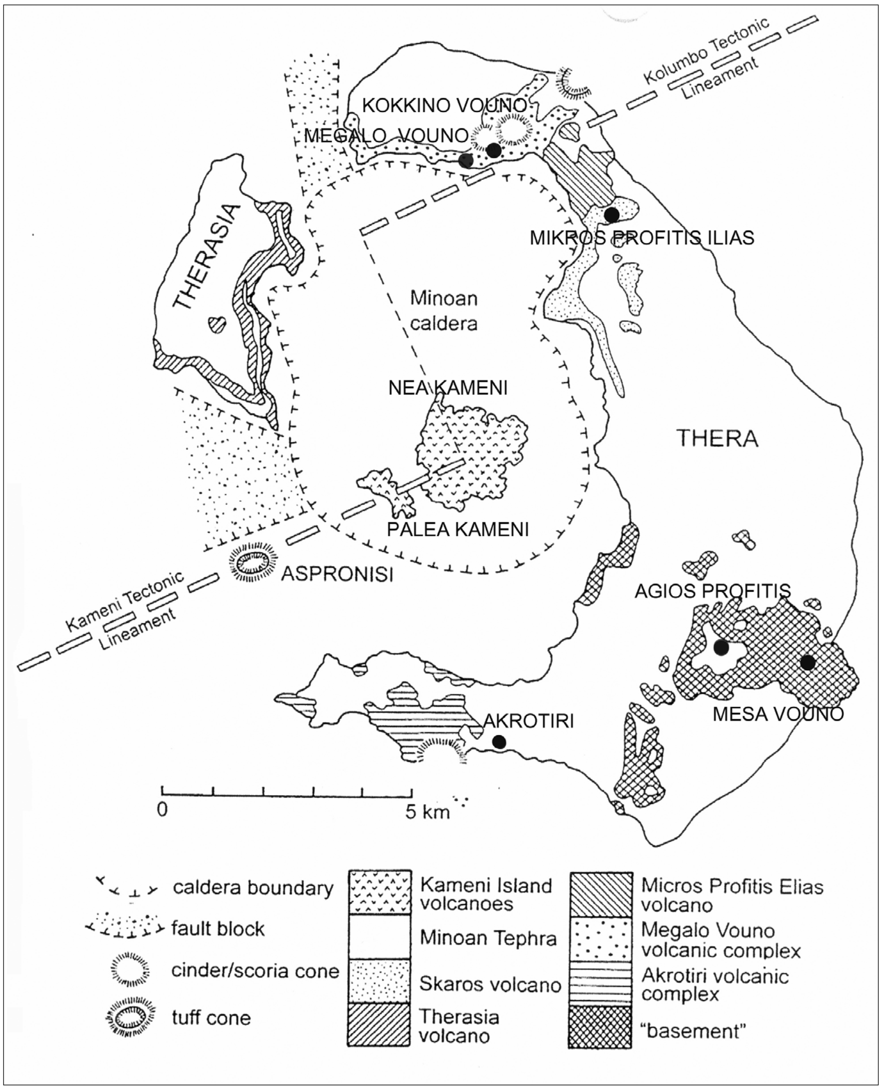


Map 2 / Map of Crete showing major sites mentioned in the text. (Illustration by author)



Map 3
Map of the Near East and Egypt showing major sites mentioned in the text. (Illustration by author)

Map 4
Map of Cyprus showing major sites mentioned in the text. (Illustration by author)



Map 5
Map of contemporary Santorini (Thera) island system. (Illustration modified by author, from McCoy 2017)

Chronoogy HIGH	LOW	CRETE	GREECE	EGYPT	CYPRUS	Near East	Europe Reinecke	Europe Conventional
	1800	MM IB	MH II		MC II	MB I	BA3	EBA
		MM II				MB I - II	BB1	MBA
	1700	MM III	MH III	SIP	MC III	MB II		
1700	1600	LM IA	LH I		LC IA	MB III	BB2 (BC1)	
1600	1500	LM IB	LH IIA			LB I		
				DYN XVIII	LC IB			
1500	1400	LM II	LH IIB				BC (BC2)	
		LM IIIA1	LH IIIA		LC II A	LB II		
		LM IIIA2	LH IIIB		B		BD	LBA
	1300	LM IIIB	LH IIIC					

Table 1
Simplified chronological overview.

1. INTRODUCTION

1.1 The Santorini archipelago

1.1.1 Geographic and geological overview

The group of islands and islets around Santorini (Fig. 1), circa 120km North of Heraklion, belongs to the Cyclades and comprises a main island and four adjacent smaller uninhabited islets, together with three further islets of volcanic origin, which lie southwest of and at some distance from the main group. The largest main island, also called the ring island, has an area of 76.2km^2. The main island and some of the islets once connected to it were formed on a base of sedimentary limestone (also containing metamorphed limestone, such as phylite, and volcanic rocks) and were created circa 120k years ago, when the sediments were deformed and lifted up by the Alpine orogeny. (McBirney 2009, 68; McCoy 2017). Today the main body of the island consists of volcanic materials which were piled high by numerous eruptions. Circa 12 Plinian eruptions, during the last 120k years, have been recognized within the volcanic strata (McCoy 2009, 76, Fig. 3).

The highest point of the island is Agios Profitis[2], which is 565 m above sea level (Fig. 2). Other peaks include Megalo Vouno[3] (330 m asl), Mesa Vouno (369 m asl, Fig. 3), Mikros Profitis Elias[4] (314 m asl) and Kokkino Vouno[5] (283 m asl). These (except Agios Proftis and Megalo Vouno) are volcanic cones and were created by deposits of lava and ash.

Based on the latest census in 2011 the island had 15,550 inhabitants.

The islet of Therasia, which, until the Bronze Age eruption, might be connected with the main island, was abandoned after the eruption and earthquake of 1956.

The small islet of Aspronisi[6] was formed from the white pumice of the Bronze Age eruption and its highest point is 60 m above sea level. (Fig. 1, 4, 5).

These three islets lie around a central basin, known as the caldera, which is up to 400 m deep and 84km^2 in area. The caldera is shaped by four depressions.

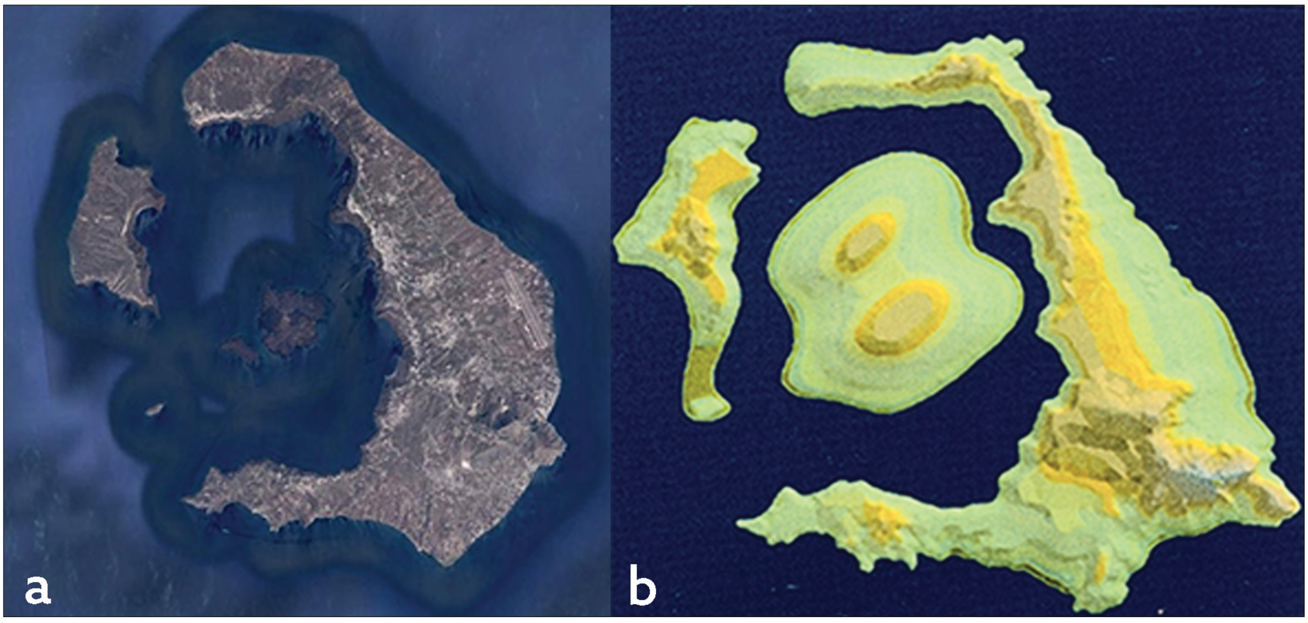


Fig. 1 / Santorini: a) contemporary shape of the island, b) reconstructed island's shape before the Minoan eruption. (Illustration by author after McCoy 2009; 2017.)

Fig. 2 / Agios Profitis. (Photo by author)

Fig. 3 / Mesa Vouno. (Photo by author)

Fig. 4 / Aspronisi. (Photo by author)

Fig. 5 / View from Nea Kameni to Palea Kameni and Aspronisi. (Photo by author)

Fig. 6 / Cliff of Palea Kameni. (Photo by author)

In the centre of the caldera is Palea Kameni[7] (Fig. 5, 6), an active volcano, which arose after the Bronze Age eruption. Part of this islet sank in the late Middle Ages. The Church of Saint Nicolas (Fig. 7) was built there, atop layers of lava flows, the latest volcanic layer of the region.

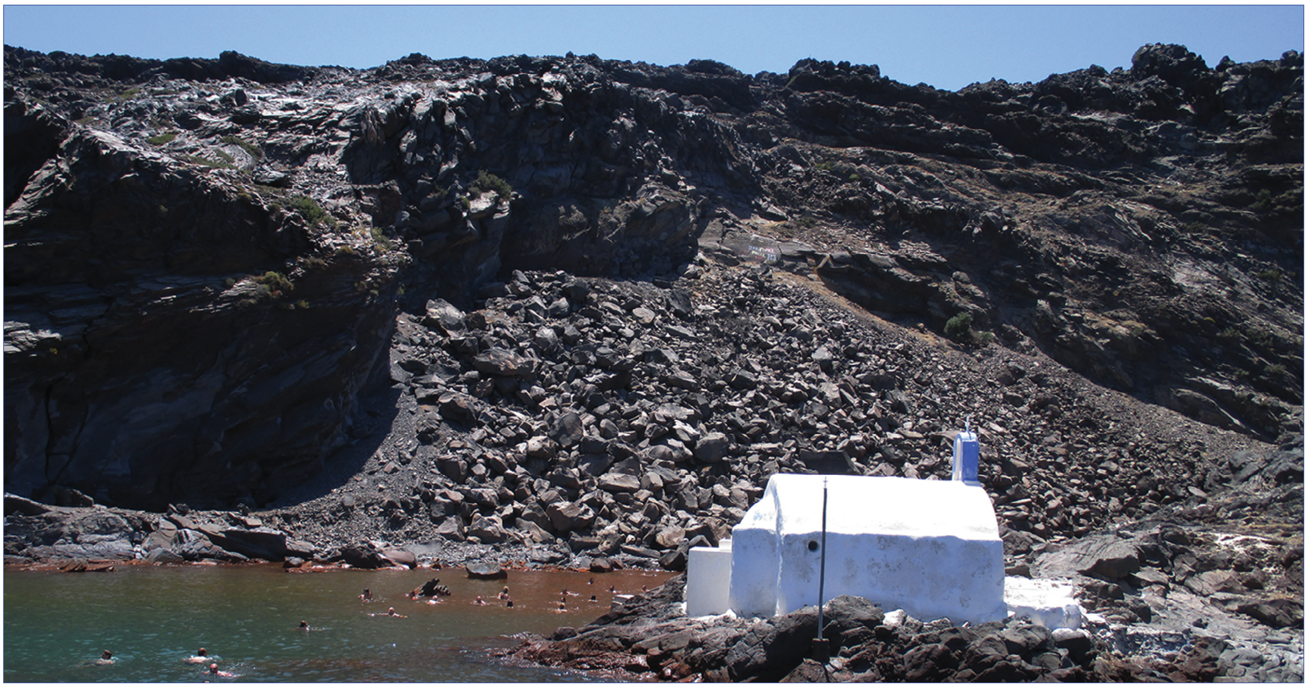


Fig. 7 / Church of St. Nicolas on Palea Kameni. (Photo by author)

Fig. 8 / Nea Kameni. (Photo by author)

The latest formation, adjacent to Palea Kameni and also volcanically active, was created in its contemporary shape by the eruption in 1707 and is called Nea Kameni[8] (Fig. 8). At the summit (124 m above sea level) is the Georgios crater (Fig. 9).

There is an underwater volcano, called Colombo, situated approximately 7–8 km North-East of the main island. Its highest point is 18 m below sea level and it was last active 1649–1650.

Three other islands of volcanic origin, Christiani, Askania and Eschati, are included in the Santorini

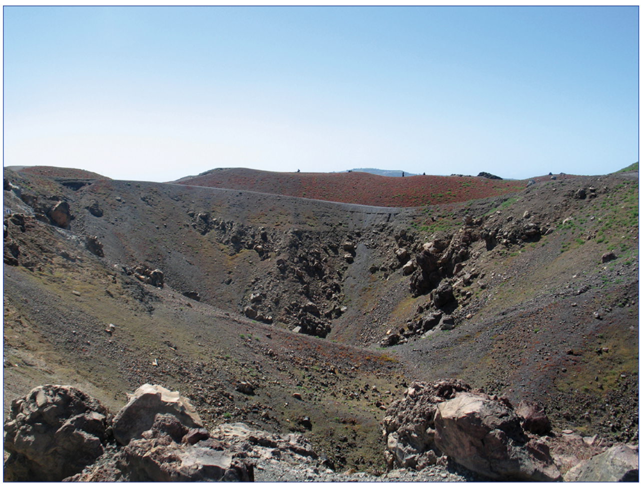


Fig. 9 / Georgios Crater on Nea Kameni. (Photo by author)

group and lie some dozens of kilometers southwest of Palea Kameni.

The entire Santorini archipelago is situated within the Aegean volcanic arc. (Friedrich 2000, 8–29, 2009, 34–49). Santorini itself is a volcano whose volcanism is set in a complex tectonic regime resulting from the collision of two major tectonic plates. As Africa moves northward it converges on the Eurasian continent and plunges at a rate of 5 to 6 cm per year beneath its southern margin. (McBirney 2009, 67) Interaction of three tectonic plates makes Santorini one of the most seismically active zones on Earth. (McCoy 2009, 76; Fig. 10)

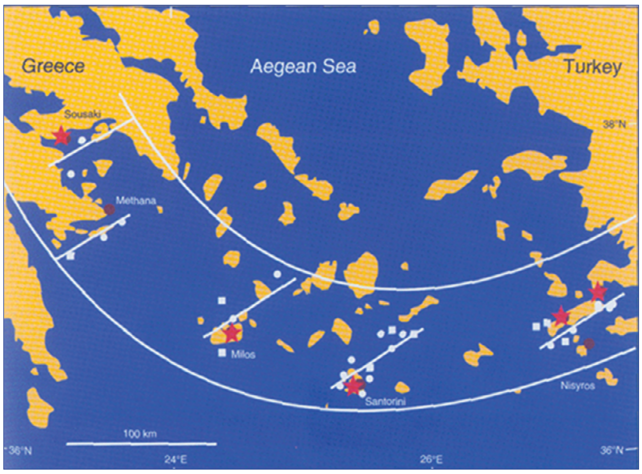


Fig. 10 / Aegean volcanic bow. (After Friedrich 2000, fig. 2.5)

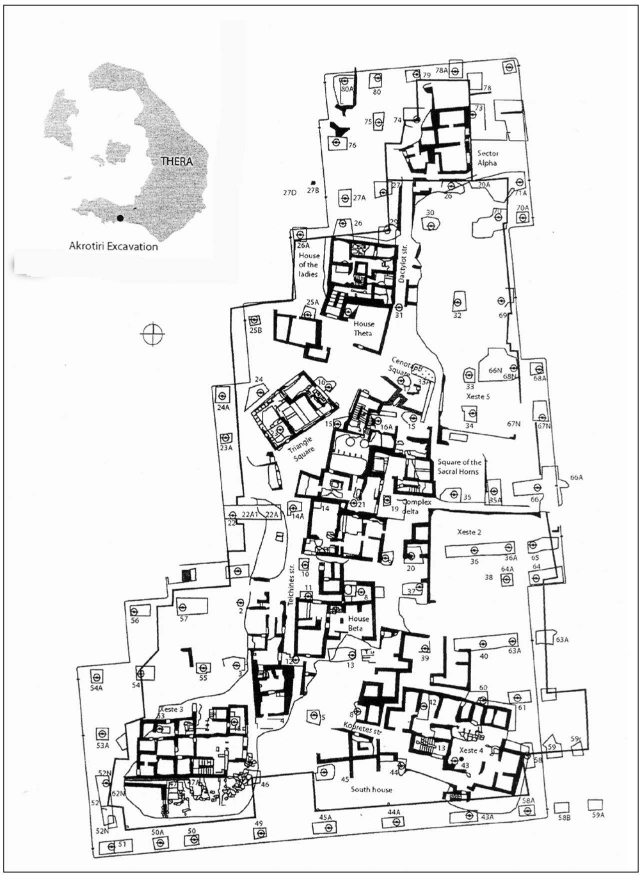


Fig. 11 / Plan of the excavated part of Akrotiri. (After Friedrich and Sigalas 2009, Fig. 9)

1.1.2 Brief history

The archaeology of Santorini has not been widely explored, due to the massive tephra layer sealing the pre-Late Bronze Age habitation, and even today there are not many known and excavated archaeological sites. The island has been inhabited at least since the Early Cycladic period (Friedrich 2009, 173). At the end of Cycladic period it became part of the Minoan cultural sphere and it has been generally accepted that the site of Akrotiri (Fig. 11; 12) was one of the main emporia of the Minoans. After the total catastrophe in LM IA/B the island seems to have been without permanent habitation until the Geometric period. A few Knossian Linear B texts dated to LM IIIA refer to the Qa-ra-si-ja people, who are hypothetically connected with the inhabitants of Thera.

Herodotus mentioned (Hist. IV, 147) that the Phoenicians founded a site on the island but there is no archaeological evidence for it, as far as I know. The first post-eruption inhabitants built their graves during the 9th century BC on the south slopes of Mesa Vouno. They didn't favour the coast and their main settlement was established on the spectacular mountain top of Mesa Vouno (Fig. 13). It is a marble block on the south coast of the main island, 369 m high, close to the highest island's point of Profitis Ellias. Mesa Vouno offers a perfect view covering all the south and east coast of the ring island. The establishment of this city is traditionally connected with the Dorians but probably should be related to the period of intensive connections between the so-called Orient and the Aegean islands, and later the Greek mainland. Geometric pottery of the 9th century BC (Fig. 14) was found mainly in cemeteries around the city. So called public enclosures, connected with the formation of a ruling class and dated to the 7th century B.C., were documented on the slope of Mount Profitis Elias. (Wallace 2010, 301). According to Herodotus (Hist. IV, 149–156), after a drought lasting for seven years, the city of Thera sent out colonists who founded a number of cities in northern Africa, including Cyrene, with Cretans and Rhodians. (Boardman 1990, p. 153–9)

The earliest surviving architecture of the city was dated to the 6th century BC. In that period Thera shows use of Doric dialect and the island claimed the status of a Spartan colony. In the 5th century BC, Spartan political features also appeared in Thera and can be understood as a result of a political alliance of Sparta with the South-West. During the Peloponnesian wars Thera was Sparta's ally against Athens. (Wallace 2010, 373) During the Hellenistic period, the island was a major naval

Fig. 12 / The site of Akrotiri today. (Photo by author)

Fig. 13 / Ancient Thera. (Photo by author)

base of Ptolemaic Egypt. The majority of architectural remains of ancient Thera originate in this period.

Later on, Thera was ruled by Romans and Byzantines. Thera is particularly mentioned in 727, during the reign of Leon III (the Isaurian) when its volcano was active again.

During the Crusades, Thera was captured by Franks[9], renamed Santorini, after Saint Irene, who is reputed to be buried on Therasia, and became part of the Duchy of Naxos.

Santorini was conquered by the Turks in 1579, became independent of Ottoman rule in 1821 during the Greek War of Independence and was later, in 1830, united with Greece, under the terms of the Treaty of London. (Doumas 1996, 67–84; Friedrich 2000, 13–17; Fig. 15)

1.2 Reconstruction of the Santorini Bronze Age eruption

The Bronze Age eruption of the Santorini volcano was probably the strongest volcanic eruption in the last 10,000 years. It impacted not only the geology and geography of the region but the climate of the entire northern hemisphere in both the short and long term. Effectively it changed the course of human history and did so well beyond its immediate neighbourhood. Reconstruction of this event is extremely difficult. Not only was it not reliably described by any ancient sources but eruptions of similar intensity are extremely rare and each eruption is unique. The reconstruction of the main phases, described below, was modelled to accord with the visible stratigraphy of the eruption products and the sequences exhibited by analogous eruptions documented and described in historical periods.

Fig. 14 / Funeral amphorae from the Iron Age cemetery on Mesa Vounos slopes. (Archaeological museum at Fira, photo by author)

The eruptions of Tambora (1815) and Krakatoa (1883) represent the main parallels and reference for the Santorini Bronze Age eruption (Friedrich 2000, 67–68; McCoy 2009, 87–88).

0. – warning phase (the precursor eruption)[10]

Initially quakes of low intensity, and possibly steam rising from the volcano, probably warned the inhabitants of the island that the situation was not normal. Floyd McCoy assumes that the island's *"residents did not know they lived on a volcano, much less one with an extraordinary geologic history of mega-eruptions, because there had been no active volcanism in the southern Aegean region (except for small phreatic eruptions on Nisyros) for hundreds, perhaps thousands, of years before the Bronze Age. Travellers to the west would have been familiar with erupting volcanos in Sicily and mainland Italy but application of that observation to the Aegean as a contemporary hazard rather than as a subject for mythology remains questionable"* (McCoy 2009, 78–79).

On the other hand the mythological memory can keep quite accurate information about such events, even for thousands of years (Barber and Barber 2004, 1–15) and, albeit the habitants didn't have any direct experience, they could still have known what a volcanic eruption is.

Physical indicators of impending eruptions are well known today and they are used for predicting eruptions. Although the inhabitants of the island didn't know what these phenomena preceded, the moment arrived when they evidently ceased to await events passively and realized that evacuation was essential. This means that this phase may have lasted days, weeks, or even a month[11] and could have represented the consequences of active magma intrusion within the volcanic edifice; tremors[12] of high intensity, causing some damage, and clouds of ash and steam ascending from the volcano (McCoy 2009, 78–79). Their increasing intensity convinced them that evacuation would be necessary. There was still time to organize the evacuation, clear evidence for which was found at Akrotiri, the only site so far subjected to extensive excavation. Smaller mobile items, which would normally be found in situ within a destruction layer, had been largely removed from this settlement, where only a few examples remained. Piled up furniture, and larger and heavy vessels (sometimes still containing raw materials) were found placed along the walls and between doors jambs under the lintel. This disposition suggests that the inhabitants had some experience with earthquakes. The people had abandoned the place, for another, as yet unknown, destination.

Stronger earthquakes must have followed and caused damage to buildings. Probably there were waves of tremors but these were clearly separated by quiet periods, when groups of people returned, started to remove rubble and collapsed debris and began making repairs, for which evidence has also been unearthed at Akrotiri. This indicates that the inhabitants, at least those of Akrotiri, had not, at this stage, abandoned the island but had sheltered somewhere nearby, making the return for repair work possible. These efforts to restore the settlement were not completed since the eruption continued with greatly increased intensity. This may well have happened almost without warning, when the volcano appeared to be calming down, judging by the incomplete repairs and hastily discarded tools found within Akrotiri. Despite the obvious rapidity of their final departure, the people themselves managed to abandon the city and no bodies have been found. (Doumas 1990, 48–50; McCoy 2009, 80; Friedrich and Sigalas 2009, 92)

I. and II. – phreatic and phreatomagmatic explosion
The eruption started with a huge, high volcanic plume and it is impossible to tell precisely how long this phase lasted; months, weeks or minutes. At first the column of material rose from the crater to great heights but the pressure of concentrated magma rising through the volcanic vent was so high that the walls of the vent disintegrated. The caldera was so enlarged that it completely changed the mode of the eruption. (Friedrich and Sigalas 2009, 97) The tephra started to flow under high pressure into the sea. This reaction was extremely rapid and its speed and intensity were supported by the very high temperatures of the tephra. Melted materials and large boulders freed from the broken vent and caldera slopes were catapulted in to the air. Some of them fell like bombs onto the settlement at Akrotiri along with the first layer of tephra. Pumice later sealed not only this settlement but a large part of the island as well. (Friedrich 2000, 71)

Simultaneously, fragments of volcanic ejecta 'peppered' the island; in Akrotiri some frescoes (e.g. the Fisherman in room 5 of the West House) look as though they have been hit by hundreds of bullets, mainly in their upper parts (Friedrich and Sigalas 2009, 92, Fig. 8).

However, this must have happened quite soon after the first major tremors because there are no sediments between the last traces of human activity and the layers created during this phase. It can be inferred that the boulders (and with them the first dose of tephra) fell onto houses which had been cleared out, ready for repair. We should assume days, no more (Doumas 1990, 48–50).

III. – so called Plinian phase
The tephra of this phase is easily recognizable: it contains dark fragments (Fig. 16; Friedrich and Sigalas 2009, 99). Layers of this phase's pumice are, on some parts of the island, as much as 11m high. In this phase, which represents the most intense of the eruption, at least 1.4 km^3 of melted material was catapulted into the atmosphere. The column of ash was up to 38 km high and even the stratosphere was impacted (more in chapter 2.1.2). The amount of material calculated to have been produced by the volcano is a broad

Fig. 15 / Carl Rottmann: Santorini in 1845. (After Rott et al. 2007) approximation, based on the mass of tephra sediments. (Friedrich 2000, 71–73; Friedrich and Sigalas 2009, 92) The eruption spread a huge fan of tephra (pumice and ash) over the eastern part of Mediterranean (from Santorini to the Black Sea, Near East, Egypt and South Aegean). The experience of similar eruptions in historical periods indicates that this phase could have lasted for a few hours. (Friedrich 2000, 71–73; Friedrich and Heinemeier 2009, 57) Many of the Akrotiri houses, or at least their ruins, were found still standing, solely because the rooms were completely filled by the pumice from this phase (Doumas 1990; 48–50, McCoy 2009, 81). In this phase the tephra and pumice covered the tree(s) whose branches were found in 2003 and 2007 and used for radiocarbon dating and dendrochronology. (Friedrich and Sigalas 2009, 97). The processes and reactions described above were continuing and repeating. Remnants of the volcanic chimney fell in pieces and magma again mixed with sea water and re-initiated a phreatomagmatic reaction. Pressures within the magmatic chamber and vent must still have been very high because the volcanic vent's fragments were launched in all directions with speeds of around 200 km per hour. This process was accompanied by clouds of ash, dust and smoke. This time the amount of pumice is calculated as 2 km^3. Part of the material fell back into caldera and the crater walls were re-built. A column of material, forced out from its narrow neck, once more touched the stratosphere, 38 km from the Earth's surface. This new chimney then, in turn, collapsed and its fragments were thrown into the air for one last time. (Friedrich 2000, 73–74)

IV. – concluding phase (debris and mud fows)

In this phase the volcano was still producing highly characteristic tephra: black shiny grains of pyroclastic material were spread within massive layers of darker coloured pumice. Although a column of smoke and ash was still ascending from the crater, it was slowing down and becoming lower and lower. The atmosphere around was full of dust and hot gases spreading not only from the crater but also from the waters of the caldera, which would have looked like a caldron full of boiling milk. A large area around the island was covered in pumice, which not only blanketed the island but also floated on the sea surface. This pumice was still very warm. There was darkness over a large region of Eastern Mediterranean. It was in this phase that the magma chamber (Fig. 17) was finally emptied. Although the body of the fallen material covering the island was huge, only a part of material concentrated in the magma chamber before the eruption was catapulted out and the majority wound up in the caldera. (Friedrich 2000, 74–77)

V. – secondary processes

All active reactions having concluded, large amounts of the dust and ash which had fallen on the body of the island shifted into the sea. This has been documented mainly in the south and south east of the island. (Doumas 1990, 48–50). It remains open to question whether the tsunami was born in this phase or, more probably, earlier, during the process which provoked the dilapidation of the caldera, or by entry of pyroclastic flows into the sea, as indicated by parallels from modern eruptions.

Fig. 16 / Tephra of the Plinian phase. (Photo by author)

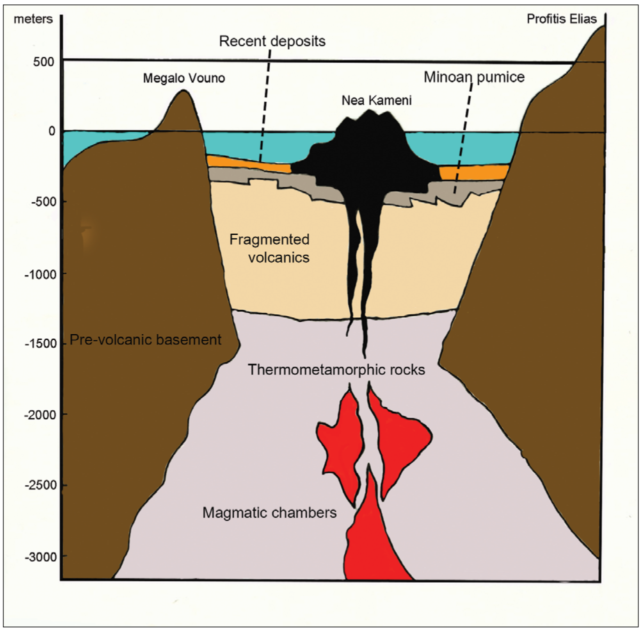


Fig. 17 / Section of Santorini volcano. (Illustration by author after Friedrich 2000)

(Pareschi et al. 2006; McCoy 2009, 82; Novikova 2011, 665). Sets of tsunami waves could have been produced as a result of any or all of these effects. (Pareschi et al. 2006; McCoy 2009, 86–87; Fig. 18), e. g. sea floor displacement caused the I. e. December 26 2004 Great Indian Ocean Tsunami (Yeh et al. 2005).

The Santorini tsunami clearly had huge energy, like the tsunami after the Krakatoa eruption, which ran twice around the Earth, and, when it crashed onto the Sumatran coast, killed about 36,000 inhabitants of the island, who were trying to reach higher land. That eruption was very loud and was audible on Madagascar, Sri Lanka, London and in Australia. The shockwave was even felt in Potsdam. The cloud of ash had a diameter of 30 miles and ash from this eruption was detected 3,300 miles away. The cloud of material in the atmosphere reduced sunlight so much that it induced ecological catastrophe over a broad region. (Fig. 19) The worldwide climate became colder during the years which followed and this was accompanied by extreme climatic phenomena. Yet the Krakatoa eruption was ten times smaller than Thera (Barber 1987, 221; Friedrich 2000, 69; Grove and Rackham 2003, 140, Table 8.1; McCoy 2009, 86–87, 89).

It can be concluded that very similar effects appeared during and after the Santorini eruption, which would not have produced one single tsunami but numerous sets (Pareschi et al. 2006).[13]

The Santorini tsunami, which most affected the south Aegean (Pareschi et al. 2006, Figure 2, 3), hit the north coast of Crete. Sediments composed of pumice (which not come with the tsunami but was washed in later – F. McCoy, *pers. comm.* unication), pebbles, shells and architectural fragments, have been identified in Amnissos (the port serving Knossos). When the major wave hits the coast it would have been from a few meters to 28m in height (Novikova et al. 2011, 665) and its speed could have reached the speed of sound. (McCoy and Heiken 2000, 59–64). It may have been as high as 50m near Thera (Pareschi et al. 2006). On Amnissos, Malia and Gournia there exists evidence, such as the removal of large blocks from their original positions, that these sites were hit by such a wave. (Driessen and MacDonald 1997, 89–90).

The Santorini volcano produced about 100 km^3 of magma[14] (Fischer 2009, 262). In the main phases magma was ejected from the vent into the atmosphere at a speed of about 3–10km per second (McCoy 2009, 82), the volume of ejecta was approximately 60 km^3 (Sigurdsson et al. 2006, 338) and the tephra accumulation rate is estimated to have been of the order of 3cm of material per per minute (McCoy 2009, 82). Phases 0, I. – IV. could have kept going for some hours or up to 4 days. The entire process (phases 0 – VI) lasted at most for a few months.

The main phases started in late spring/early summer according to the additional evidence from excavation in Akrotiri (McCoy and Heiken 2000, 48–49; MacGillivray 2009, 158–159).

In Crete the ash and tsunami deposits have been found on many sites and evidence for the post-eruption activities has also been documented. The worst of the tsunami damage was in central Crete and the Mirabello gulf: Waves in Mallia could have been circa 3m high but in Mochlos and Gournia they could easily have reached a height of 40 m. Tsunami were to blame for the dislocation of some ashlar blocks in the Villa of the Lillies at Amnissos (Marinatos 1939) and large pithoi were swept against walls at Zakros (Driessen and Macdonald 1997, 89–90). In the Dodecanese and

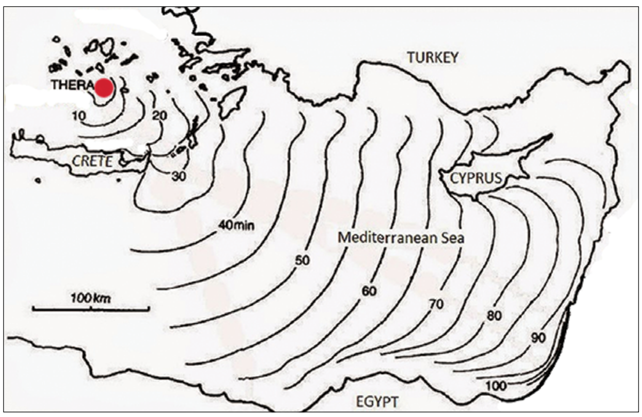


Fig. 18 / Reconstructed tsunami time-distance curves. (After Yokoyama 1978).

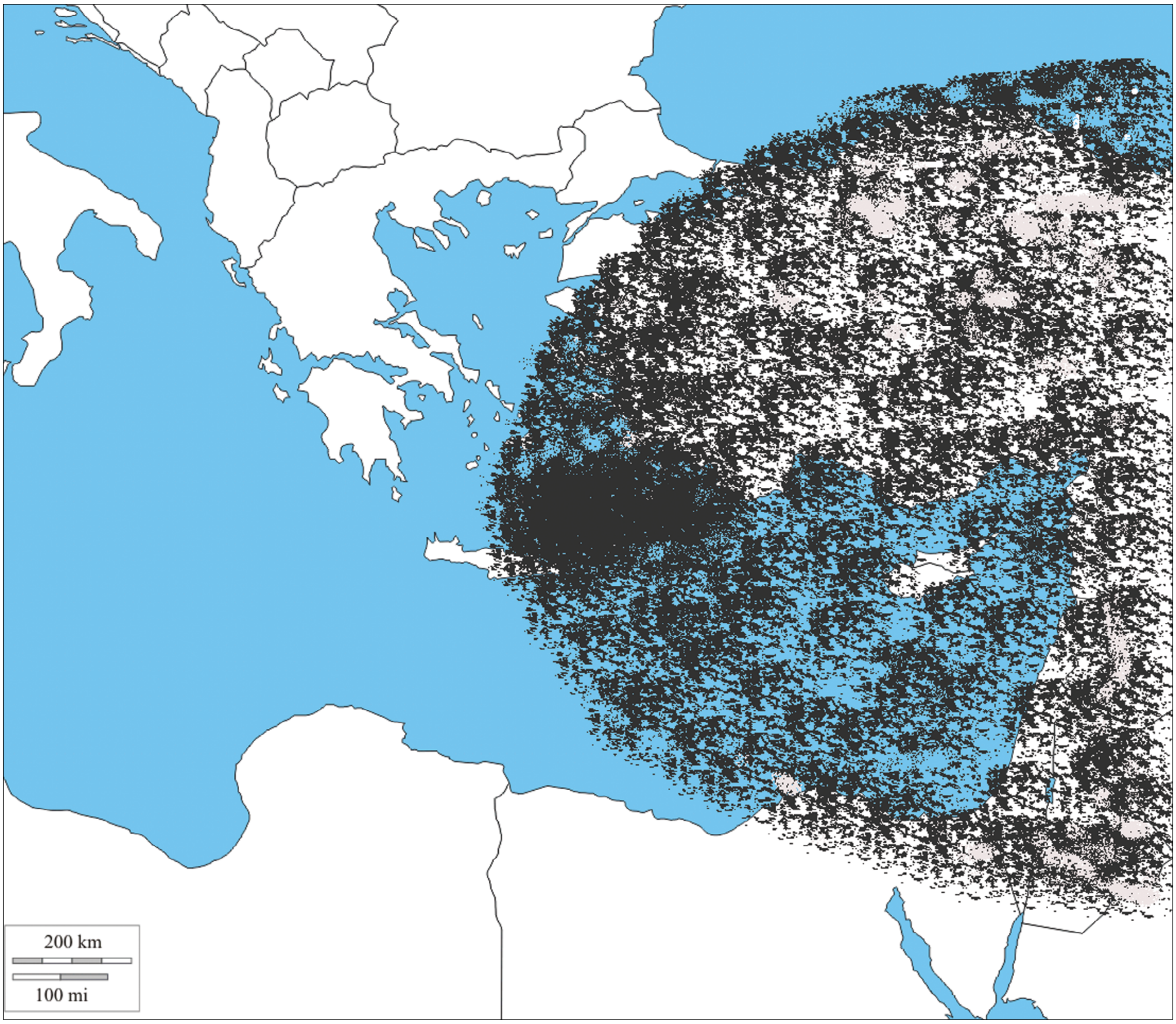


Fig. 19 / Santorini tephra dispersal pattern. (Illustration by author)

Anatolia the layers of ash are as much as 1m thick (Driessen and Macdonald 1997, 92). Among the more recently documented sites is Mochlos, where deposits of tephra, created at the time of the eruption and shortly after it, were found. Buildings there were destroyed by earthquakes associated with the eruption, or possibly by the ash fall itself, but there were also new LM IB buildings erected in the settlement immediately after the eruption. The excavators pointed out that these new houses display many architectural features that are typical of the houses of Thera, which are not to be found in the neighbouring LM I settlements e. g. at Gournia or Pseira, and expressed a hypothesis that they may have been built by refugees coming from Thera itself (Soles 2009, 108–114). An LM IA house on Pseira, another tsunami victim, was also rebuilt and Theran ash was worked into the agricultural soil making it even more fruitful (Betancourt 2009). Another very clearly recognizable ash layer was found in Papadiokampos where the ash layer sits immediately on top of Minoan cultural remains (Brogan and Sofianou 2009). Other tsunami deposits were studied in Priniatikos Pyrgos where the site was abandoned after the Santorini event (Molloy et al. 2014) and at Palaikastro (MacGillivray et al. 2009; Höflmayer 2012). Yet another ash deposit has recently been discovered on the island of Telos (Irene Nikolakopoulou, *pers. communication*).

This catastrophe must have impacted on all neighbouring regions: in the Aegean, Crete, the west coast of Asia Minor and other regions closer to or farther from Santorini. If the impact was not direct, the secondary effects would surely have been felt. The dramatic events on Santorini must have been visible from Crete, maybe even the Delta, from where the eruption would have been also heard, felt and smelt. It would have been announced by brilliant glows towards the northwest, particularly at night, daytime darkness, sounds like cannons firing and tsunamis, climate changes and, for a few seasons, spectacular sunsets. Over and above the physical effects, such an event could not fail to affect both individual and collective psychology (Driessen and MacDonald 1997, 94; McCoy 2009, 89–90).

1.3 Synopsis of the history of research

Based on results of early excavations and classical comparative archaeological typological and stratigraphical chronology, the date the Santorini volcano erupted in the Late Bronze Age was originally established as 1450 BC and this date was not really challenged until the 1970s. According to the stratigraphy of Cretan settlements, the eruption occurred at, and probably defined, the transition from the LM IA to the LMIB period, or LHI to LHII. This is the period following the horizon of the Mycenaean shaft graves, whose dating is a very important issue for central European archaeology. Many analogies and influences from the Mycenaean world are documented across Europe and artifacts (e.g. bronze nails, amber beads), imported from Northern parts of the continent were also found in the shaft graves (Harding 1984, 213–5). It was the first time when Europe, as a whole, was in active contact with regions which had already passed into the state stage, ergo producing literary documents or even elaborate calendars. At least such was the deduction of the first European archaeologists trying to determine absolute dates for the European Early Bronze Age (BA and BB phases of Reinecke's scale). The available Egyptian chronology was accepted as an almost perfect scale and the connections between the Aegean and Egypt observable on imports/exports were treated as adequate evidence for absolute dating. (Tab. 1)

The first calibrated radiocarbon dates, obtained not only from Santorini itself but also from Crete and the mainland, were not in agreement with historical chronology and suggested a date earlier than 1530 BC for the event. Discussion about who is wrong, archaeologists or physicists, started immediately. Initially, the radiocarbon method was mostly dismissed as not being secure for this period. However, the first calibrated radiocarbon dates were followed by dates obtained by dendrochronology and glaciology. Both shifted the event even further back, closer to the mid 17th century BC, and showed that there really was a serious need for detailed revision of Aegean Late Bronze Age dating. Dating of the Santorini eruption began to be one of the most discussed issues of Aegean prehistory and, in the 1980s and 1990s, there were intensive and systematic efforts to cast light on the problem.

One could wonder why, given that the Santorini catastrophe is one of the most discussed and studied issues in Mediterranean prehistory and the many scientific methods used to help establish its precise date, undisputed results and arguments generally or at least widely accepted have still not been presented. In the beginning, at least up to the 1990s, the majority preferred the 'low' (later) historical dates. Currently the 'high' (earlier) dates of the mid 17th century BC are generally privileged, except within Egyptology, where the arguments in favour of the accuracy of their historical chronological scales continue to hold sway. Contemporary monographs of Aegean prehistory sometimes present both dates as possibly correct (Shelmerdine 2008, 4–5), others present only the high chronology (Manning 2010, 23, Table 2.2.), while others instead prefer the low approach (Dickinson 1994, 19, Fig. 1.3). The only matter on which the majority agrees is that there is not a clear agreement for absolute dating of the early phases of the Aegean Late Bronze Age.

The Santorini event (probably the most dramatic and catastrophic event of the last 10 000 years in the Eastern Mediterranean, and, possibly, the Northern hemisphere (Manning 1999, 7)) was crucial for thousands of people then living in the region. Today it presents a test for science; on how to deal with complex questions and with inconsistent data, how to apply the theory of error and how to test results produced by the humanities and natural sciences where experiments or reconstructions are not possible.

I am sure that nobody will doubt the importance of the absolute time setting of the event. Causal and contextual questions taken out of their chronological frame make little sense. But why in particular is the absolute date of the so-called Santorini catastrophe so important? What would it mean to have fixed this date? Firstly, the Santorini eruption occurred in a period which is very important for the absolute chronology of Northern European regions because, as mentioned above, just shortly before it, at the horizon of the Mycenaean shaft graves, European prehistory had its first "meeting" with history (e.g. Vandkilde et al. 1996). Furthermore, this was the period when Cretans (Minoans) passed into the stage of creating a centralized state and it is probable that the Santorini catastrophe was the key event which stopped or disrupted this process (Klontza-Jaklová and Klontzas, *in print*). Determination of the absolute date is vital to help synchronize local chronologies with historical scales in the Eastern Mediterranean.

To find the reason for the error is also important for natural science and could be a precedent for other dating issues. Attribution of 'blame' – to science or the humanities – is pointless. Both are part of the one story. Solving the question is not a competition but the creation of new knowledge.

The goal I have set for this volume is not only to present a detailed overview of the contemporary state of investigation from the point of view of Aegean prehistory, Egyptology and physical science but also to pick up and underline the areas where solutions and errors may lie hidden.

E. Cline, in his book about Bronze Age collapse (2014, 139), suggested (albeit using a quote from Sherlock Holmes[15]) working with average data and M. Wiener (2009b, 288) with the most probable theory. But such approaches cannot be deemed wholly scientific. Science is not 'Gallup' and these are not election polls. Evidence is necessary. Average values document only our 'average opinion' or an average probability and not historical reality.

The problems with the Aegean Late Bronze Age absolute chronology demonstrate clearly that, in some cases, science and the humanities simply must work together. Each must be ready to present arguments to the other and to accept that it is possible those arguments may be wrong.

The island of Santorini was, from an archaeological perspective, 'discovered' between the years 1859–1869, during the exploitation of pumice used in construction of the Suez Canal (Manning 1999, xxvii), and as a result of the opportunity presented by the relatively minor eruption of its volcano in January 1866 (Fouqué (trans) 1998). Ferdinand André Fouqué, a French geologist, visited the island at the time and as a result of his research he dated the Bronze Age eruption within the interval between 2000 and 1500 BC. Given the methodology, data and instruments he had, this was an excellent conclusion (Manning 1999, 12).

The importance of the Minoan site buried under a massive (at some points over 10m high) layer of tephra was beyond dispute but the technical options available at the time precluded large scale excavations. Only smaller test trenches and pits were placed within the Akrotiri *intravillane*. The dramatic course of Greek history up to the 1970s made it impossible to develop a large scale archaeological project in Santorini. Systematic excavation eventually started in 1967 on the cape of Akrotiri where erosion had created easier access to archaeological contexts close to the coast. The first director of the Akrotiri excavation was Professor Spyridon Marinatos, of the Athenian University.

The Santorini eruption has been cited as the reason for the destruction of Minoan administrative centers during the LM IB period. The first to connect the eruption with those destructions, in which he saw the total collapse of Minoan civilisation, was J. Schoo (1937–1938). His theory was largely ignored by his contemporaries and it was S. Marinatos who became known as the author of this theory, which he published in Antiquity (1939). Schoo's original contribution was finally acknowledged when mentioned by Jan Driessen and Colin Macdonald (1997).

More recent archaeological evidence means that this theory of the collapse of Minoan civilisation due to the Santorini eruption is no longer current and the LMIB destructions cannot be related directly to the event (summary in Driessen and Macdonald 1997). In defence of both its proponents it must be said that, at the time, the chronology of the Late Minoan period was not known in as much detail as it now is and that the synchronism of some particular destruction horizons was unclear. It was also automatically assumed that the destructions at Knossos and other administrative centers would have been contemporary and would have resulted from the same causes. S. Marinatos not only excavated at Akrotiri but also at the site of the Knossian harbour in contemporary Amnissos on North Crete, which was totally destroyed by tsunami invoked by the Santorini eruption. Marinatos thought that the destructions of other Minoan sites documented in LM IB and the destruction of the harbour in contemporary Amnissos were of same date and all were related to this particular eruption. Albeit the concrete results of his research cannot be accepted any more, we cannot deny that S. Marinatos was one of the first to lay the foundations of modern comparative archeology and in essence we are still using his methodology (Doumas 2009, 263–264), which has not, thus far, been criticized or doubted. S. Marinatos studied imports from Egypt on Crete and Minoan and Mycenaean imports in Egypt and combined these data with the absolute chronological scale reconstructed for Egypt, based mainly on later literary sources. At least in one aspect he was clearly correct. It was he who correctly established the relative chronology of the Santorini volcanic eruption when he placed it between LM IA and LM IB. He also synchronized the event with the Eighteenth Dynasty in Egypt. This deduction is nowadays much discussed (i.e. Manning et al. 2002, 742). Within the framework defined by this methodology, he dated the Santorini catastrophe to around 1500 BC (Marinatos 1939). It is notable that Arne Furumark dated the equivalent ceramic phases of Mycenaean pottery to the same period (Furumark 1941a, b; 1950, summary in Manning 1999, 13–16), which provided something of a cross-check and meant that his date was not viewed as problematic and was broadly accepted.

It is self-evident that this is a key date for the European Bronze Age and one wonders why no effort was made to review the arguments for almost half a century. Until the 1980s the interval of 1500–1450 BC was generally adopted (e.g CAH II, 1, 558, or, in the Czech bibliography of ancient history: Pečírka et al.1989, 348, or European prehistory: Gimbuntas 1956; Pleiner (ed.) 1978; Buchvaldek, Sláma (eds.). 1982; Buchvaldek (ed.) 1985; Furmánek et al. 1991; Podborský (ed.) 1993).

Overviews of European and Aegean prehistory published in the 1990s had already begun to mention that the dating of the Santorini event was not so certain and that there was some disagreement on the subject between archaeologists and scientists (i.e. Dickinson 1994, 17–20; Furmánek et al. 1991; Podborský (ed.) 1993).

It was at the end of the 1970s and beginning of the 1980s that the data derived from stratified snow layers preserved in regions with permanent ice cover, particularly in Greenland, were presented. The method is called ice-core dating, but the first results surprised almost everybody. Anomalies had been found in the conductivity of ice layers which could have been caused by acid compounds, probably volcanic products spread by the Santorini eruption into the stratosphere and atmosphere. However the dates for these anomalies came out around 1390 ± 50 BC.

At the same time an attempt to apply thermoluminiscence dating provided dates in the interval of 3600 ± 200 bp, a range too large to be useful.

The majority of archaeologists assumed that the radiocarbon method was, for some reason, insufficiently accurate for the period concerned and merely reverted to the 'low' conventional dating. (Hood, S. 1978, 688; Manning 1999, 19–21)

In the 1970s some archaeologists had started to argue that the eruption could not have happened during the Eighteenth Dynasty in Egypt but during the Second Intermediate Period. They supported their conclusions by reference to particular archaeological comparisons and noted the silence of literary sources (Pomerance 1978, 797–804).

A publication by two dendrochronologists, Valmore C. La Marche and Kathrine K. Hirschboeck, in 1984 could be described as a breakthrough. They stated their empirical findings that any large scale volcanic activity releases substantial amounts of SO_2 and SO_3 into the atmosphere. These compounds are formed during the decay of sulphuric acid (H_2SO_4), which volcanos produce, and, when spread in high concentrations through the atmosphere and stratosphere, they create aerosols limiting the penetration of solar radiation to the Earth's surface. On examination of data for contemporary eruptions and those from the recent past, they have documented that volcanic eruptions can cause a decrease in average annual temperatures of about 0.4–0.7°C in the following years. This fact is then mirrored in the thickness of the new tree rings in the wood of long-lived species. Both scientists concluded that the date of the Santorini volcanic eruption fell between 1628 and 1626 BC (LaMarche and Hirschboeck 1984; Pyle 1990, 68). V. LaMarche had already proposed this date in the 1970s and published this conclusion in National Geographic (Matthews 1976), but Aegean prehistorians had completely ignored it. It was Peter Warren (1984) who brought these data to the attention of Aegean prehistorians and started a serious debate on them. His opinion, which was very important at that time, was that radiocarbon, dendrochronological and glaciological 'high' dates could no longer be ignored but must be reviewed and compared with historical and archaeological data. He further expressed the opinion that the data were impossible to explain away and that it was not scientific procedure on the part of archaeologists to blame the methodology of physical science for the discrepancy and simply to push the results to one side just because they were not coherent with previously created models. This gave the appearance that they were prepared to assert that the techniques of physical science are less accurate than those of the humanities in solving physical problems. He called for intensive and organized efforts to solve the problem. Warren's article can be described today as a classic; it presents a real threshold of long term debate, which still continues along the lines he predicted. (Warren 1984)

The next important point was the year 1987 when the Danish glaciologists revised their previous results, derived from the Greenland ice-core, and presented a series of the corrected data, which this time placed the relevant date to 1644 ± 20 BC (Hammer et al. 1987). More archaeologists became ready to consider the 'high' dating of the event. For example Gerald Cadogan, who, until some years previously, had been convinced that the absolute chronology of Aegean prehistory was stable and no radical change could be expected (1978), had to concede that a date of 1500 BC was no longer acceptable and that the date for the Santorini catastrophe should be sought before 1520 BC at least (Cadogan 1987). Martin J. Aitken (1988), on consideration of radiocarbon dates, reached the same conclusions: that the archaeologists and scientists should look for the correct date somewhere between 1670–1520 BC. Around the same time the Irish dendrochronological team published 1627 BC as the most probable date according to their analyses (Baillie and Munro 1988). Philip Betancourt (1990) for the second time contributed to the debate and it was he who first tried to compare the archaeological data (the particular archaeological finds and contexts) with historical absolute chronology and with chronology obtained by scientific methods. His conclusion was that the most probable date for the Santorini eruption seems to be the period around 1610 BC[16].

Even earlier, in 1980, a volume on Minoan pottery in second millennium Egypt was published by Barry J. Kemp and Robert S. Merrillees, who studied the Cretan and Mycenaean imports in Egypt and, without including the radiocarbon or dendrochronological dates in their assumptions, concluded that the Late Minoan period should have ended between 1600–1570 rather than starting in that period, as asserted by the then conventional dating. This finding provided some 'independent' support for the scientific dates.

Towards the end of the 1980s Sturt W. Manning added a comparative study of East Mediterranean chronology (1988). He didn't dispute the scientific results and supported that dating approach – he retains this position today (i. e. Manning et al. 2014). ,

Publications of the 1980s formed part of a major debate, which not only concerned the dating of the Santorini eruption and the chronological systems of the entire East Mediterranean, including Egypt, but also the security of the scientific and archaeological dates. It became obvious that the time had come to collect all the participants round the table in order to review the state of the argument. A conference, attended by many of the major players, was duly held in Göteborg in 1987 (Åström (ed.) 1987; 1987; 1989) and this really moved the debate forward. The 1500 BC date for the Santorini catastrophe was deemed incorrect, or, at best, minimally probable. Since this conference the question has at least been informally shortened to "high or low" (Fig. 20). More importantly perhaps, the participants set up an ongoing strategy to pull together further evidence to help fix the Santorini eruption date with greater accuracy, within the interval from 1648 to 1580 BC.

The debate at the Göteborg conference became so animated and epic that two years later yet another scientific panel was organized to revisit the topic (Hardy and Renfrew (eds.) 1990), during which the state of current knowledge was summarised, the disagreements were set out and questions meriting further research were defined.

At the end of the 1980s, at the Canaan site of Tel Kabri, Wolfgang-Dieter Niemeier (1990) recovered some destruction debris of Middle Bronze Age II date. This debris yielded an absolute date around 1600 BC. The debris came from the destruction of a habitation complex and covered the remains of painted floors, whose

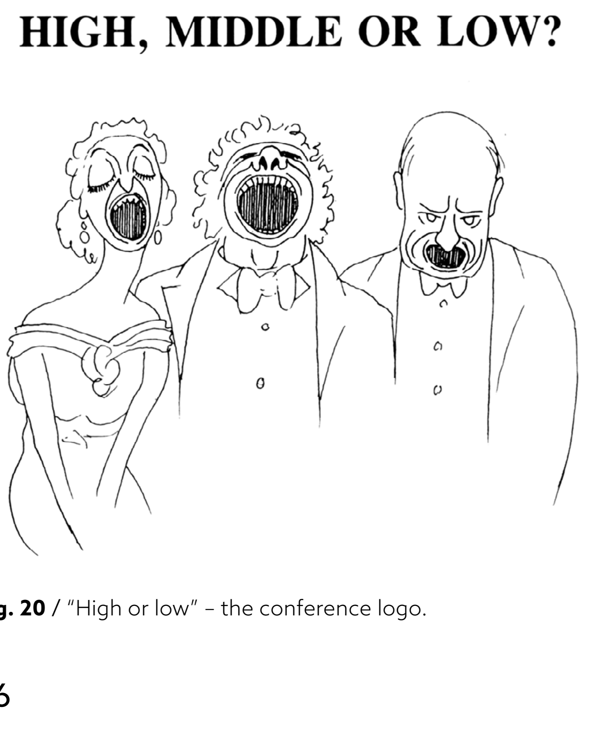


Fig. 20 / "High or low" – the conference logo.

decoration parallels the style of Aegean frescoes of Late Minoan I period. Niemeier has therefore concluded that Cretan LMI and Near Eastern MBII are contemporary and placed both phases in the 17^{th} century BC. He also tried to synchronize both chronological systems (Aegean and Near-Eastern) with the Egyptian chronological system and expressed his conclusion that the destruction of the palace in Tel Kabri happened before the Eighteenth Dynasty in Egypt.

At the same time the glaciologists returned to the debate with information that they had found documenting two sulphur compound anomalies in the ice sediments which probably mirror two different volcanic eruptions in the second half of the 17^{th} C BC, dated around 1627 and 1645 BC. (Bietak 2000, 30).

Debate continued and escalated during the following decade with the main battlefield moving to the pages of the journal Archaeometry. There, the frequently dramatic clashes between individuals brought about the creation of robust datasets. At the start of the 3^{rd} millennium James Muhly (2003, 17–23), possibly having been moved to exasperation by the combative positions being taken, expressed the not unreasonable opinion that the archaeologists and scientists could not continue as opposed teams but must cooperate.

The majority of academics, across the disciplines of science, archaeology and history began to prefer the 17^{th} century BC as the most probable period for the catastrophe.

However, since the very start of discussion about the absolute date of the horizons carrying the signature of the Santorini volcanic eruption, there have been authors who ignored the debate and simply avoided the question of absolute chronology in their analyses and syntheses (e.g. Schachermayer 1976a, b, Duhoux 2003).

Another key point, closing and summarizing one stage of the debate, was the publication of a detailed study "A Test of Time. The Volcano Thera and the chronology and history of the Aegean and East Mediterranean in the mid second millennium" written by S. Manning (1999). He clearly and consistently supports a 'high' chronology, placing the Santorini catastrophe in the second half of the 17^{th} century BC.

At the end of the millennium M. Bietak established an interregional and international project "The Synchronization of Civilization in the Eastern Mediterranean in the 2^{nd} Millennium B.C. (SCIEM 2000, http://www.oeaw.ac.at/sciem2000/index.html) with the intention to create a broad database of all relevant data. The SCIEM project was dedicated to the establishment of clear links across the Aegean and Eastern Mediterranean at this time. A number of publications have been produced within the framework of this project. This large scale project was sorted into 19 chapters covering the main topics (establishing the Project in

Bietak (ed.) 2001).[17] Detailed results of the project are discussed in the appropriate chapters.

Another milestone was the finding of olive branches in the Fira quarry on the edge of the Santorini caldera in 2003 and 2007. The branches, burned during the early phases of the Bronze Age eruption, had remained in situ in tephra (Friedrich and Heinemeir 2009; Friedrich et al. 2009; Heinemeier et al. 2009). Their dating provided the motivation to organize a further conference dedicated to the discussion of 'Low or High' chronology (Warburton et al. (eds.) 2009). It was clearly agreed that there is a significant gap between classical archaeological comparative dates and the dates obtained by radiocarbon methods and that neither discipline can define a reason for the discrepancy (Warburton 2009, 295). At the beginning of the 21st century the arguments for a low chronology of the event were resurrected and dates around 1530 BC again became part of the debate (i.e. Wiener 2009a, b; MacGillivray 2009; Warren 2009).

Among the latest organized efforts to help settle the issues, is the Aegean and Near Eastern Dendrochronology Project directed by Prof. S. Manning at Cornell's 'Malcolm and Carolyn Wiener Laboratory for Aegean and Near Eastern Dendrochronology'. Their *"key long-range goal is to build long multi-millennial scale tree-ring chronologies in the Aegean and Near East that will extend from the present to the early Holocene to cover, broadly speaking, the last 10,000 years of human and environmental history. Our raison d'être is to provide a dating method for the study of history and prehistory in the Aegean that is accurate to the year. This kind of precision has, up to now, been lacking in ancient studies of this area. Indeed, few archaeological problems stimulate as much rancor as chronology, especially that of the Eastern Mediterranean. The work of the Aegean and Near Eastern Dendrochronology Project aims to help to bring some kind of rational and neutral order to Aegean and Near Eastern chronology from the Neolithic to the present."* (http://dendro.cornell.edu/projects/aegean.php)

There were also ERC projects at Oxford university "Radiocarbon-based Chronology for Dynastic Egypt" (Shortland and Bronk Ramsey 2013).

Other small projects are in progress e.g. a project, wherein the author is involved, examining the problem of volcanic, so called "old" CO_2 contained in plants in volcanic regions (Fernandes et al., *in print*) (Fig.21).

But the debate continues. No agreement seems to be on the horizon. The discrepancies between historical-archaeological and scientific dates have still not been bridged and the complexity of the problems appears actually to have increased.

Fig. 21 / Plants (Curry plant, Helichrysum Italicum) sampled on Nea Kameni. (Photo by author)

2. THE INDIVIDUAL DISCIPLINES

2.1 'Hard' Science

"Nevertheless, the hard sciences and the social sciences are in closer contact than ever, though this relationship requires a lot of work if it is to continue to open doors between disparate disciplines." (Knappett 2011, 48)

2.1.1 Radiocarbon dating

Radiocarbon dating is, today, the most frequently employed method for determining absolute chronology during the East Mediterranean Bronze Age. However, some of the results appear diametrically opposed to those derived from archaeological and historical dating methods. Simply, the radiocarbon data from the Santorini volcanic destruction and from contemporary strata around the East Mediterranean seem to provide earlier dates than those expected from use of comparative historical and archaeological data. Archaeologists and historians have often argued that the radiocarbon method is not accurate enough, meaning that the chronological intervals provided by physical methods are effectively wider than those provided by historical dating. Furthermore there are too many extraneous factors affecting the results and the ^{14}C 'clock', although based on a well-established physical law (radiocarbon decay), is absolute only in laboratory circumstances and requires detailed knowledge of the ^{14}C content of the atmosphere before the clock of decay started running (i. e. Wiener 2009a, 199; 2009b; 2012; Kutschera 2012, 420).

The humanities and natural sciences approach the problem differently. The archaeologist starts with the event and looks for its date within a 'known' material cultural or historical sequence. Should the answer determined scientifically not be in agreement with such interpretations they tend to assume the method is faulty. Natural scientists usually provide the date and then test if it is unconditionally valid. They do not usually comment on the historical interpretation. However, radiocarbon dating is often the only and, generally, the most accurate dating method available for most events during the Aegean Bronze Age.

The first efforts to use samples of organic material obtained from archaeological contexts were made in the 1950's. In 1958 it was A. G. Galanopoulos who was the first to use charred wood from the quarry south of Fira on Thera for this purpose. Organic material was collected and analyzed systematically from the earliest seasons of the Akrotiri excavation, which started in 1967. (Friedrich and Heinemeier 2009, 59).

In the 1970s' archaeologists generally expected that the radiocarbon dating method would only prove and confirm the chronological systems previously derived from and based on "stratigraphie comparée" but the radiocarbon dates were earlier than expected (Manning et al. 2006, 565–566). The chronology of Aegean prehistory was connected to the Egyptian historical chronology by cross-checking imports and exports in each region. This method is the basic chronological tool of prehistorians (MacGillivray 2009, 155) and relies on the assumption that single artifacts or groups of artifacts were in use and became part of the archaeological record at the same time in the regions of origin and deposition.

The first results related to the Santorini samples were published years after the samples were collected and it came as a shock when Pennsylvania University in 1977 presented a series of dates from the Aegean calibrating the value of 1500 bc to 1626 BC (Kuniholm 1990, 13; original publications: Michael 1976, 1978; Betancourt and Weinstein 1976; Fishman et al. 1977 ad.). The initial reaction of Aegean archaeologists was that the samples must be contaminated. These objections, however, did not stand scrutiny. P. Betancourt and H. N. Michael (1987) showed that there was a homogenous group of 15 samples, the dates of which had been accurately presented.

By then more laboratories had become interested in the topic and were producing dates: e. g. Simon Fraser University in Burnaby (Nelson et al. 1990) or Copenhagen laboratory, which presented dates in the range between 1690–1610 BC with 89% probability and 1560–1530 BC with 11% probability. Data from the Oxford laboratory were similar: 1690–1600 BC, P=71%, and 1560–1530 BC, P=29%. (Manning 1999, 32–39). Among all the interested laboratories there was no difference; the results were absolutely consistent. Certainly, by the early 1990s', it had become clear that something more fundamental than a simple error or contamination was happening because not just one but all the laboratories were presenting dates derived from their different Aegean Late Bronze Age samples, which were, from an archaeological/historical viewpoint, 'unexpected'.

When M. Bietak, at the end of the 20th century, established his first chronological project, there were already more than 30,000 samples, from across the whole Eastern Mediterranean, dated by many different laboratories (Kutschera and Stadler 2000, 70–71; Manning et al. 2006). By then the laboratories were already able to measure the amounts of isotopes in extremely small volumes (Bietak (ed.) 2000, 68–69). High-precision Accelerator Mass Spectroscopy (AMS) radiocarbon laboratories today can measure the radiocarbon content of a single sample to within a 60-year range BP, prior to calibration against a decadal measurement of a tree with rings of a known dendrochronological date. (Manning 2006–2007, 54–60; Wiener 2009b, 280).

Organic material from Cretan sites (Agia Triada, Myrtos Pyrgos and Chania), from Rhodes and from Akrotiri on Santorini, analyzed by the Oxford laboratory, were presented and summarized in Manning et al. 2002. The authors conclude that the period LM IA ends approximately between 1610–1590 BC and not by 1480 BC, as traditionally presented, and that the Santorini event itself dates to 1650–1620 BC. They exclude the period of 1520–1500 BC as a possibility. They date the end of the LM IB period to the late 16th C, 1522–1512 BC. (Manning et al. 2002, 733–744; 2009). S. Manning's interpretations are criticized by M. Wiener (2009; b) who blames Manning's team for choosing only those values which prove the high chronology and ignoring the peripheral ranges of the dating intervals.

In 2003 an olive branch, 1m long, was discovered, buried alive in the pumice of the eruption (Friedrich et al. 2006). The layer was a few meters thick, as much as 4–5 m over the trees (Friedrich and Sigalas 2009, 97). The researchers describe this event as a "lucky incident" (Friedrich and Heinemeir 2009, 59) because it was the first time we had a "witness" of the event. Dates extracted from it fell in the span 1613 ± 13 BC after Friedrich et al. (2006). Another branch, 183 cm in length and 13–15cm in diameter, was found by the same team in July 2007, about 9m from the first one. The main stem of the tree has disappeared into the caldera due to erosion of the caldera slope. Both branches were sealed in layers about 150 m above contemporary sea level. They were growing close to a man-made Bronze Age wall. A layer of buried leaves and roots was identified under the burnt trees, but it was impossible to sample this as it had been reduced to dust by a hot volcanic blast which hit the south-western part of the island ring in the initial phase of the eruption. As a result, the leaves of the trees instantly dried, fell and were embedded in the white pumice dust covering the surface. The researchers are convinced that the tree was alive at the moment of the eruption. The tree (or trees) had reached an age of at least 72 years before the event. (Friedrich and Heinemeir 2009, 59–61). The branch was therefore not only suitable for radiocarbon dating but also, with more than 70 rings, suitable for dendrochronology (more in chapter 2.1.2). Radiocarbon dating provided a date between 1627–1600 BC and this was supported by dendrochronology. (Friedrich et al. 2006, 509, 548) The findings from those branches provided the impetus to organize a conference in Copenhagen to discuss the absolute chronology of the Santorini eruption from different points of view (Warburton (ed.) 2009). Another conference was held in Halle in 2011 "1600–Cultural change in the shadow of the Thera-Eruption?" (Meller et al. (eds.) 2013). While the conference in Copenhagen gave weight to both opinions, the Halle conference participants tended to concentrate on radiocarbon dating.

In the last 25 years many other projects were established, many sites have been sampled and much data obtained. In general all the dates obtained from samples from Santorini and Crete lead to the conclusion that the Santorini eruption occurred in the last three decades of the 17th century BC. Similar results were provided by cross regional projects. E.g. samples from Jericho (Tell es-Sultan), extracted mainly from carbonated wood, were dated by the laboratory in Groeningen and were compared with samples from Egypt, Santorini and North-Eastern Sinai. Some of the samples could be tested by dendrochronologists at the same time (Bruins, van der Plicht 2003, 35–37).

Large amounts of data were obtained from Egyptian sites. It is presumed that the Santorini eruption left its finger print in Egypt in depositions of pumice, which were mainly in Tell el-Dabᶜa and connected with the Early Eighteenth Dynasty, up to the reign of Thuthmosis III. These strata (C/2) are dated by scarabs of Ahmose, Ahmose-Nofretari, Amenhotep I, Thutmose III and early Amenhotep II (Bietak et al. 2009). Even this *terminus ante quem* for the Santorini eruption shows 120 years offset between archaeological data and results of radiocarbon data (Kutschera et al. 2012; Höflmayer 2012; Bietak 2013a).

Today data are available not only from Santorini itself, particularly the short/lived samples from the volcanic destruction level (VDL), but from other regions (Crete, Greek mainland, Anatolia, Near East). This dataset provides a consistent series of results, which show that a point in time shortly before the eruption was in the second half of the 17th century BC (e.g. Höflmayer 2012, 36). However, there are authors (e.g. Wiener 2009a; b) who argue that, although the probability of the Low chronology is small, it exists and cannot be excluded simply on the basis of an appeal to the statistics. Some argue that the data obtained from Tell el-Dabᶜa should be excluded because they disagree with reconstructed historical chronology (Kutchera et al. 2012; contradicted in Manning et al. 2016, 21-22)

Scholarship related to radiocarbon methods is now focused in two directions: examining the method and accuracy of calibrating radiocarbon dates and the problem of environmental factors influencing the ^{14}C decay process (summary in Wiener 2009a; 2009b; 2012).

2.1.1.1 Calibration problems

The calibration curves currently in use are built up from the dendrochronological sequences which are supported by the series of tree ring of the American sequoias and long living oaks and pines from Ireland and Germany. It can obviously be argued that these regions are very far from the Aegean and that this could have an impact on the accuracy of calibration when applied to Mediterranean or Aegean samples. A contemporary dendrochronological sequence derived from wood from the site of Porsuk in Anatolia (about 840 km North of Santorini), which seems to be more appropriate to the region [Bietak (ed.) 2000, 71], has lately been specified by use of dendrochonological/radiocarbon dates obtained from other Anatolian sites (Kültepe, Kakahöyük and Acemhöyük) (Manning et al. 2016). Even this is quite distant and the climate in Anatolia is very different from that in the Aegean. Moreover, this scale currently ends at 1573 BC and, therefore, it is impossible to use it for 17th century BC data (Wiener 2009b). Efforts continue to collect remains of wood in order to create local dendrochronological sequences but the deposition circumstances in the East Mediterranean and Aegean are not favourable for wood preservation.

The IntCal calibration model weights the probabilities exhibited around a particular interval. It favours the main trend evident and downplays any odd outlying minor values. (Manning et al. 2009b, 305).

The accuracy of radiocarbon dating is expressed in the shape of the calibration curve. The current internationally accepted radiocarbon calibration curve for the Holocene is IntCal04, built on the data set of dendrochronological dates from Germany and Ireland (Reimer et al. 2004). It uses a combination of old data and new data obtained by high-precision laboratories.

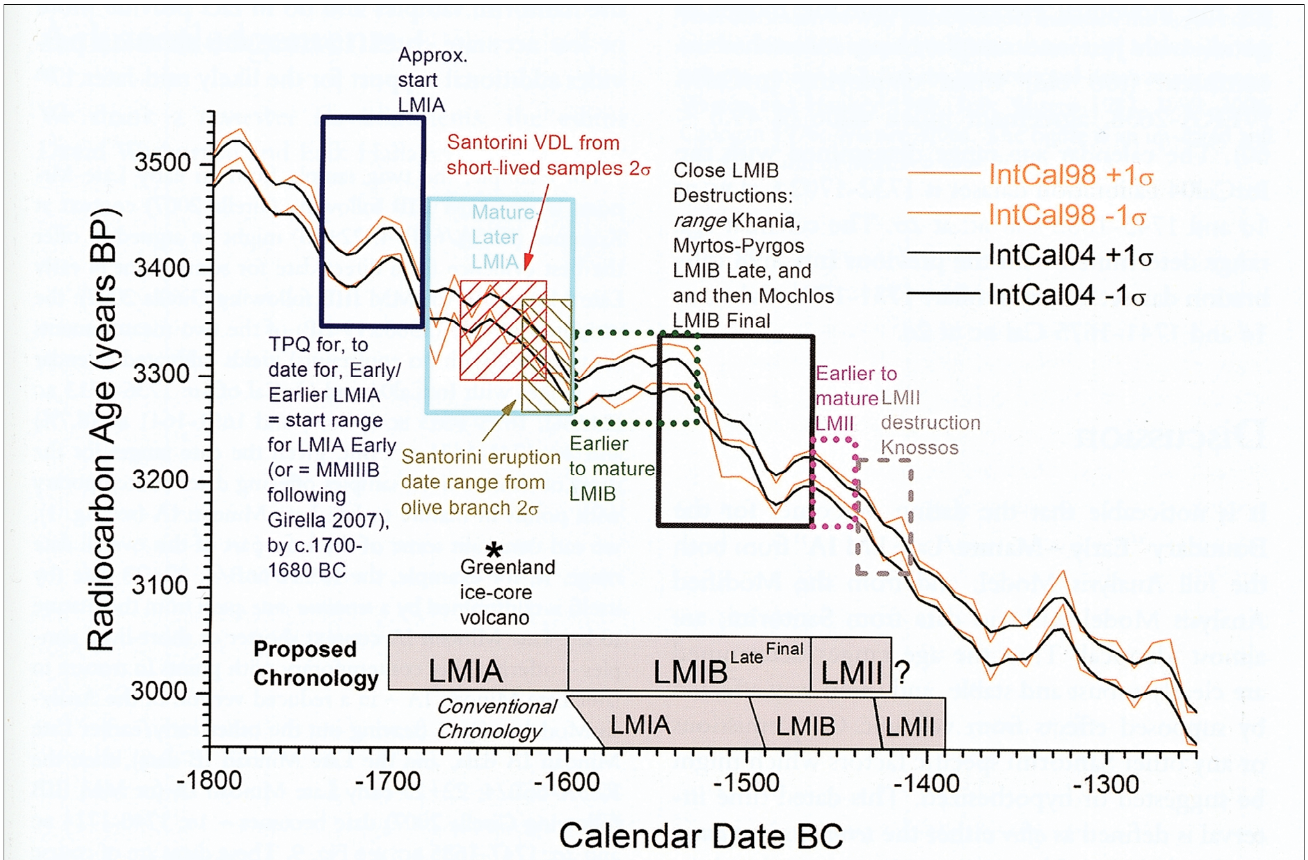


Fig. 22 / Calibration curves IntCal104 smd IntCal98 with the major evens mentioned in the book. (After Manning and Bronk Ramsey 2009a, Fig. 10)

The previous standard curve was IntCal98 (Stuiver et al. 1998), which was based largely on a similar database, but new data have since been added. The IntCal04 curve (Fig. 22) gives an estimated five-year resolution, employing a sophisticated random-walk model which smooths the inherent noise in the raw calibration datasets. The IntCal98 curve provides ten-year resolution and merely averaged the dates in that interval to achieve a data point for the calibration curve. Thus IntCal04 is a smoother curve (Manning 2006–2007, 54; Wiener 2009b, 283). However, IntCal98 may offer slightly better results in some conditions for some periods before AD 1510. IntCal04 better describes the 16th century BC raw data than IntCal98 but in the 17th century BC there is a question if a real and significant underlying variation in the period 1690–1640 BC exists which IntCal04 is perhaps overly smoothing away. If applied to data from Gordion juniper the curve exhibits some extra variations (Manning et al. 2009b, 305, Figure 5).

There is not a unique agreed calibration curve. The curve most often used was that of Stuiver and Becker (1986). B. Weniger (1990) used his own curve and points out that there are significant differences between single calibration systems. Betancourt and Michael (1987) calibrated their data around 1500bc to 1619 ± 20 BC according to the „bidecade curve“ of Pearson and Stuiver. Then M. Stuiver and B. Becker used the decade curve and got almost the same dating, 1680–1600 BC, as the so called „2σ range“ method, which gave 1687–1575 BC. (Weninger 1990, 219–223)

A calibration curve is sometimes viewed as an a priori perfect fixed and immutable tool but in fact it is a construct permanently "under construction". S. Manning (1995, 128) points out that it is not really a curve but a probability band.

I would add here some personal doubts about the general accuracy of the calibration curves. I am convinced that global climate fluctuations can be stamped into the annual growth rings of long lived trees and that such anomalies can fix some chronological points to the calibration curve but we cannot exclude the possibility that microclimatic factors cause anomalies in tree rings laid down in a particular affected region (to microclimatic shocks in Mediterranean: Grove and Rackham 2003, 27–29).

2.1.1.2 Contamination by ^{14}C-deficient carbon

Another question is the purity and rate of possible contamination of tested samples, both past and present. Nowadays efforts are made to test short lived organisms (vegetation or animal bones) in order to estimate in a particular very short interval. However, there can still be anomalies, e,g. wood from a thirty year old oak gave a dating range 1757–1685 BC (Manning and Bronk Ramsey 2003, 112–114), or the plants can be affected by other factors, such as contamination by volcanic CO_2..

One often cited proposition is the possibility of contamination of Santorini vegetation by volcanic CO_2 emissions. It has been experimentally proved that the vegetation growing close to a source of CO_2 can provide very low dates due to the larger than natural amount of so called "old" CO_2. E.g. the data from contemporary vegetation growing directly by a CO_2 source in the Eifel region of Germany showed the same ratio of carbon isotopes as samples dated to 1500 bc but about 100m farther away, where the concentration of CO_2 in the air was normal again, the samples behaved normally. (Hubberten et al. 1990, 180–186; Weninger 1990, 218; 2012, 424).

M. Wiener (2009a; b; 2012) is convinced that so called "old" CO_2 could affect the samples on Santorini although it has been proved that even the plants growing very close to the volcano do not contain any old CO_2 and only those plants growing in the volcano itself have produced higher concentrations of it. (Fernandez et al., *in print*). He says – and we should bear it in mind – that, although the concentrations are now normal, just before the eruption there could have been many more sources of ^{14}C-deficient carbon open, which could have affected the plants growing then. S. Manning (2012; Manning et al. 2014, 1170) and Kutschera et al. (2012, 419) argue that, if the old CO_2 concentration had been higher in the period of eruption, it would have affected the samples of the plants which died during the eruption and not the plants from the earlier layers or the plants from other regions where such sources are unlikely to have existed, as proved by the experiments of R. Fernandez and his team who have sampled and analyzed annual plants collected across the islands of Santorini and Crete (Fernandez et al., *in print*).

We should also take into account the so called 'upwelling effect' of ocean water (Fig. 23) which, at substantial depths, can store CO_2 containing higher concentrations of ^{14}C-deficient carbon. It is probably one of the reasons why the radiocarbon dates of the southern hemisphere are higher than the dates from the northern. The Mediterranean is virtually a closed basin where the water exchange is very slow and the factor of sea upwelling can play its role (Keenan 2002). As mentioned above it seems that, at least today, it is having little measurable effect (Fernandez et al., *in print*).

Today, there are other smaller projects in progress; e.g. in a project examining the problems of so called old CO_2, dry plants collected in Egypt and stored in herbals of the 19th century were tested for possible old CO_2 contamination. The resulting dates were 19±5 years earlier than the recorded dates. (Dee 2013a)

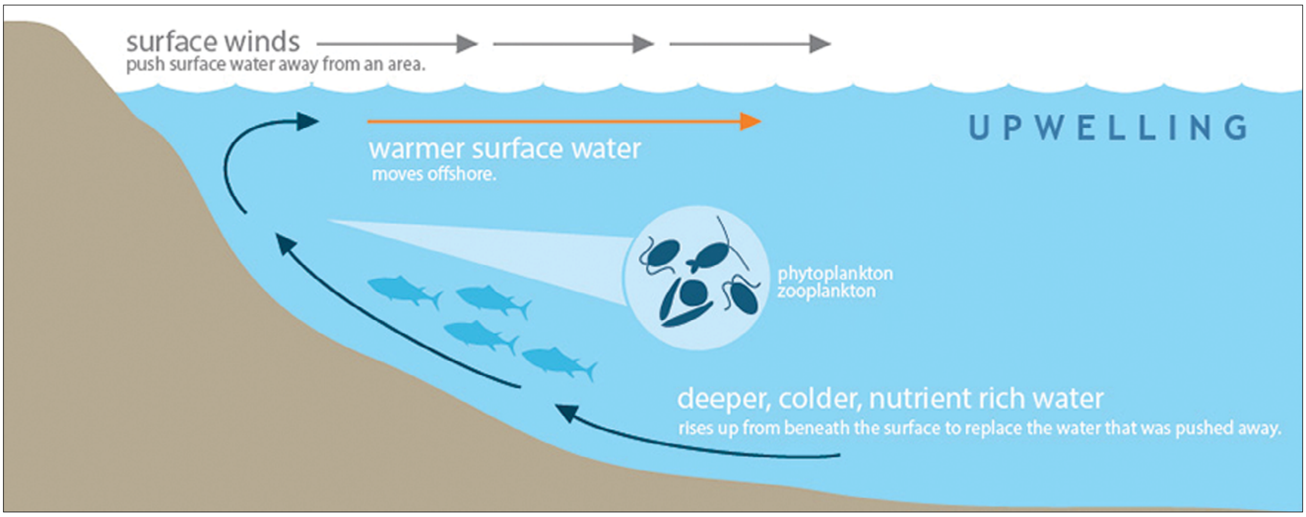


Fig. 23
Upwelling effect. (After National Ocean Service, National Oceanic and Atmospheric Administration, U.S. Department of Commerce, http://oceanservice.noaa.gov/facts/upwelling.html)

2.1.1.3 Other possible reasons for inaccuracy

Given the large numbers of samples tested it is hardly surprising that there are some anomalies which are difficult to explain; how, for instance, does a sample extracted from one context (such as a sealed vessel containing carbonated figs) provide dates with a range of 200 years (Friedrich et al. 1990, 193–195) und why are the range and standard deviation, which this method provides so large (Nelson et al. 1990, 198–206, Housley et al. 1990, 213–214). The blame, in these cases, is generally attributed to laboratory error.

The accuracy of an individual determination from a single laboratory has, indeed, been blamed quite often (examples in Wiener 2009b, 280–281). It is now common practice that one example is tested in several high-precision laboratories and it is believed that repeated analyses can exclude or, at least, reduce the probability of mistakes and inaccuracies, Short-lived samples, which came directly from the volcanic destruction layer (VDL) of Akrotiri, were tested in different laboratories and provided consistent results for a point of time shortly before the Minoan eruption in the second half of the 17th century (Höflmayer 2012, 436).

Inter-annual variance is another variable sometimes identified as a possible problem. Annual data do scatter around the longer term average trend reflected by the curves and it is fair to suggest this issue could create a little noise. An increase of the sample standard deviation was calculated as 0.1% or 8 ^{14}C years for single-year samples, before calibration. (Stuiver and Braziunas 1998). In practice, this has no substantive effect since it typically means 0,5 to 1,5 ^{14}C years' increase in the standard deviation for the relevant samples and has almost no observable impact on the analyses and outcomes reported. (Manning et al. 2006, 2009). Clearly, the changes are very small and insignificant and merely slightly enlarge the date ranges we reported before.

D. J. Keenan (2002) alleged that Mediterranean ^{14}C dates in the Bronze Age are some 100–130 years older due to upwelling. Manning believes that this assertion is not supported by any positive evidence (Manning et al. 2009b, 305–306). D. J. Keenan suggested that the Mediterranean Sea, because of its particular mode of formation and development, is very rich in "old" air and water and this probably affects local radiocarbon dating. It is questionable that this could give rise to sufficiently high concentrations of old ^{14}C in the atmosphere, where plants obtain the majority of their carbon, or, indeed, in the bedrock and water sources.

However, there are differences between calibration curves from the north and south hemispheres and the greater volume of water, and the more intensive upwelling effect in the south, is likely to play a role in this (Manning et al. 2009, 305–306).

2.1.1.4 Radiocarbon data from other regions

The date of the Santorini eruption is not determined solely from samples obtained from the relevant layers in Santorini. Contemporary samples from other regions and from periods which stratigraphically precede and post-date the eruption must also be tested. Layers of vocanic ash and tsunami debris are very good indicators of accurate relative chronology.

Destruction debris of the LM IB period from Chania and Myrtos-Pyrgos in Crete has been tested. The data from Myrtos-Pyrgos gives a 1σ calibrated age range of 1514–1492 BC (42.5% probability) and 1476–1460 (25.7% probability) and a 2σ range of 1522–1451

BC. The Chania samples (8 dates from 4 samples) give a more open spread. One of the values is an outlier but the remaining 7 provide an average 1σ calibrated range of 1607–1570 BC (41.5%), or 1560–1546 BC (14.9%), and a 2σ range of 1615–1520 BC. This data set is, however, older than the Myrtos-Pyrgos data. (Manning et al. 2006, Manning et al. 2009b, 308). Jeffrey Soles (1999) expressed an idea, supported by radiocarbon dating, stratigraphical, typological and theoretical studies, that the LM IB destructions proceeded from west to east. These destruction dates cover almost all the 16th century. They clearly represent the *terminus ante quem* for the eruption but some scholars don't accept them as evidence because, if the destructions occurred in the second half of 16th century, there remains time for the eruption to have happened during the 16th century, even in its second half (Wiener 2009a, 203–205; 2009b, 286–288).

However, tsunami debris in Palaikastro gave dates overlapping with the high chronology, which, even though some organic material from tsunami debris could have been old when it became part of the context (Bruins et al. 2008, 207, Table 4; Höflmayer 2012, 437), can be seen as supporting an earlier date for the eruption.

A few samples of charcoal found in Trianda on Rhodes were dated using both radiocarbon and dendrochronology. Their contexts were archaeologically dated to the LM IA period but some argue that they are somewhat earlier and represent the final phase of the Middle Bronze Age. However, the dates obtained from these samples suggest the period shortly after 1736 BC (Manning et al. 2006, Manning et al. 2009b, 307). M. Wiener suggests that it is impossible to pull these samples into the debate because the context is unsecure (Wiener 2009a, 204).

There is also a significant set of radiocarbon data from Egypt. Some 47 seed samples from Tell el-Dabᶜa, from the strata supposedly contemporary with the Santorini eruption and historically interpreted as from the early period of the reign of Ahmose, have been dated. The dates obtained by radiocarbon methods are about 100 years earlier than Egyptologists expected. (Kutschera et al. 2012, 411–414; Bietak 2013a).

In Central Europe, as mentioned below, authors proposed that the radiocarbon dates obtained from their Early Bronze Age contexts seemed to be too early in comparison with the Aegean conventional chronology and were inclined to conclude that, for some unknown reason, the method was producing errors. However, contemporary radiocarbon dates are not doubted by European prehistorians and many of the data sets are supported by dendrochronological dates, which place a large part of the Central European Early Bronze Age before 2300 BC and shift the beginning of the Middle Bronze Age back to the mid 18th century (Jiráň 2008, 28–29 with other related bibliography; Furmánek et al. 2015, 15–16). This horizon should be contemporary with the advanced LH I (Klontza-Jaklová and Toth, *in preparation*)

The radiocarbon dates obtained by the numerous laboratories provide a very consistent chronological picture of the dates supposedly contemporary with the Santorini volcanic event. (Höflmayer 2012, 436)

2.1.1.5 Discussion of radiocarbon dating

Up to this day, it seems (I am currently tending towards saying it seemed), the problem with radiocarbon dates lies between 1700 and 1500 BC and that the issue must be more general because it is not only in Santorini and its immediate surroundings that the expected radiocarbon dates and historical archaeological dates fail to match (Manning et al. 2009, 183). Radiocarbon dates for the Middle Helladic period produce a tight and coherent sequence with a good correspondence between absolute and relative dates (Voutsaki et al. 2009, 159). Furthermore, absolute and relative chronology of LH III, the Amarna period, are again in absolute agreement with historical expectations. The Amarna period is the best cross-dated horizon of the Near East and the East Mediterranean Late Bronze Age. Due to the numerous written documents from Amarna and from other Near Eastern archives, a dense network of historical connections has been created and the archaeological stratigraphies, the imported goods, the radiocarbon and dendrochronological dates fit within it almost perfectly (Manning et al. 2009, 181).

Today, we know that the radiocarbon dating method has its limits which are very difficult to define at some points. The method, by its very nature, cannot provide us with a linear function where there is a one to one correspondence between actual and radiocarbon dates. There are also problems with the accuracy of the calibration curve. Its flattening in the interval between (approximately) 1600 and 1500 BC (Fig.23), presumably means something. (But then one wonders why we, the archaeologists, usually approach typology as though it were purely a linear process.) Here, I would like to note, but would ask the reader to bear in mind that what they will read is a just first idea and has not beent tested, that the radiocarbon curve seems to flatten, more or less always, before the climate changes to warm. Another clear example can be observed in the period following the Fall of Rome.

We still don't fully understand the process of the break-up of cosmogenic isotopes, or the fluctuation of cosmic rays, but the dating method has been studied and refined intensively for decades. Thus far radiocarbon methods have been subjected to much more intensive criticism than archaeological typology and historical chronological scales.

If there were a problem in the method itself, it would produce errors in other periods as well. However, radiocarbon outcomes are robust, sample treatment is standardized and contamination of the samples can be almost excluded and laboratories are able to measure very tiny amounts of carbon isotopes with significant accuracy.

It is also clear that the results of both methods contradict each other in the case of 18^{th} – 15^{th} centuries BC.

Although the data obtained by the radiocarbon method are consistent (Höflmayer 2012, 436) they are not universally accepted, especially by Egyptologists (Manning et al. 2016, 21). The problem of the divergence between Egyptian chronology and radiocarbon dates during this period remains largely unsolved.

2.1.2 Dendrochronology

Dendrochronology is able to provide perfectly accurate absolute dating but only if the circumstances are optimal. One obvious difficulty is the geographical limitation of the method but it should be possible to trace some radical global changes across regional systems (LaMarche and Hierschboeck 1984)[18]. The crucial assumption is that abnormal volcanic activity, which influences climate over a large region or even globally, must also induce global change in tree growth. The climate after each intensive volcanic event becomes colder during the next few years. This causes growth stresses which can be seen in the tree ring patterns of long lived species. Studies of 4000 year old sequoias[19] looked for growth anomalies around 1500 BC, on the assumption that this was probably very close to the correct date for the Santorini eruption, but no growth stress was found. The first anomalies were found much deeper, at around 1627 BC. (Kuniholm 1990, 7).

A similar acid anomaly, in the interval of 1644 ± 20 BC, was documented by Baillie (1990, 160–166, Baillie, Munro1988, 344–346) when studying the Irish oaks. Baillie expressed the view that this was the result of a very strong volcanic event.[20] Similar data were provided by pines from the White Mountains in California. Indeed, it can be said that all dendrochronological tests of long lived woods provide evidence of growth anomalies between 1626 and 1628 BC. Baillie notes that not all trees react the same way or with the same intensity. Some species are less sensitive or, and this is a key factor, cold weather can be balanced by the richness of the soils where the trees are growing. Trees in regions with very poor soils have stronger, more sensitive reactions to each temperature change or blip.

A European dendrochronological scale has been built on comparison of the scales derived from long lived trees from Ireland, England and Germany. This produces a few gaps between 3196–1682 and 1584–970 BC. J. Hillam has discovered a group of oaks in England which cover the period between 1687–1362 and there are again acid anomalies around 1620 BC.

In Germany the longest lived tree species grow mainly in regions with very rich soils and the anomalies are less distinctive but, even so, there are anomalies around 1628–1620 BC which suggest a series of cold summers.

Comparisons of the Californian, Anatolian and Fennoscandian tree-rings suggest that the rising temperatures and the increased rainfalls in the late 17^{th} and 16^{th} centuries and the downturn in the 13^{th} and 12^{th} centuries BC were probably global phenomena (Baillie 1998).

It can be accepted as a fact that for some months after the Santorini volcanic eruption global temperatures were lower (Sears et al. 1987). It should also be kept in mind that microclimatic circumstances, fertility of the soil and other factors could have sustained normal tree growth in the short term and the drop in temperature only provoked growth stresses some seasons later. Dendrochronologists, working on a global scale, document that between 1630–1627 BC something short-term and intense happened to the worldwide climate. They have combined their data with glaciological results and blamed the Santorini volcano. (Baillie 1990, 165). Tilia had been absent from the Cretan pollen record for 3000 years (Moody 2005, 460–463; MacGillivray 2009, 159) and grows only in temperate zones but its pollen appears within the post-eruption strata in Crete, testifying to a fall in temperature and increase in humidity. Similar results were obtained from Turkey.

M. Wiener (2009b, 280) and J.S. MacGillivray (2009, 159) note that there are also very narrow tree rings on bristlecone pine samples in California and Nevada between the years 1524–1486. As is evident from Irish trees[21] an event which affected climate occurred between 1530 and 1500 BC.

There are also local dendrochronological scales made for the Eastern Mediterranean. The majority of them are based on Lebanese cedar found in Egypt. The scale is then compared with American sequoias but there is still not continuity from today to the Bronze Age; there are only some sections "floating" in time. We have about 1503 years for the Bronze Age, following on from 570 years for the Neolithic, and the scale is almost continuous from 362 AD to the present (Bietak (ed.) 2000, 12). The development of this scale continues but samples from the 2^{nd} millennium BC are very limited (Cichocki 2003, 43–46).

The most important discoveries for Santorini were made in 2003 and 2007, when the olive branches, mentioned above, were found in the volcanic deposit in the Thera quarry. Friedrich and his team have presented the radiocarbon data and dendrochronological data as being in agreement and dating the event within the interval 1613 ± 13 BC and argue that the branches were alive at the moment of eruption. (Heinemeier et al. 2009, 285). These data are subject to doubt, not because of the method but because of the species. Olive trees are not ideal for dendrochronological dating because they don't always grow from one central stem, they tend to rot from the centre and even live trees can keep dead branches for a long time[22]. (Wiener 2009a, 204–205, 2009b, 280; Cherubini et al. 2014; Cherubini and Lev-Yadun 2014; Kuniholm 2014). Friedrich avoids this problem by using X-ray tomography which allows him to recognize as many tree rings as possible (Friedrich et al. 2006) and H. J. Bruins and J. Van der Plicht suggest that the dendrochronological records of olive wood need not always be viewed so pessimistically (2013).

Recently concluded research, focused on dendrochronological and radiocarbon dating of a bulk series of wood (mainly juniper) samples from Anatolian sites (Kültepe, Karahöyük and Acemhöyük) has provided a very accurate local calibration curve between approx. 2100–1200, and 600 BC. Although the project was not aimed at the "Santorini problem", it is strongly related. One of the most important results, along with the absolute chronology and the synchronism of Mesopotamian and Anatolian chronologies in the first half of 2nd millennium BC, is an ascertaitment that the tree rings anomalies of the Porsuk dendrochronological scale, which were related with Santorini event, are now dated to 1681- 1673 BC, with 68.2% probability, which makes them some 20 years earlier than previous assessments. (Manning et al. 2016). This means that the massive Minoan eruption didn't affect the growth rhythm of the Porsuk trees and that this dendrochronological scale is no longer floating in relative time. It also underlines the need to approach dendrochonological scales on a local basis in the first place and to examine all the data we already have through such a prism.

2.1.3 Glaciology ("ice-core" dating)

The principle of this method is based on the way polar glaciers are created. Snow falling onto glaciers doesn't melt and keeps its own particular chemical characteristics, which vary year by year according to climatological and other factors. These seasonal layers can be recognized and their chemical trace measured. The ice blocks are drilled up to 3000 m deep, which corresponds approximately to 200.000 years. Drilled-out "carrots" are tested with electrodes to measure changes in resistance and any anomalies are also tested chemically. Higher concentrations of H_2SO_4, SO_2 or SO_3 have an impact on conductivity and reduce resistance. Their presence mirrors their higher concentrations in the atmosphere where they can appear as a consequence of intense volcanic activity. (Friedrich 2000, 91). The Bronze Age Santorini eruption shot volcanic material rich in sulphur compounds up into the stratosphere and thus enriched stratospheric aerosols in acid elements (Pyle 1990, 68) which fell with the rain or snow to the Earth's surface. These layers, rich in sulphur compounds, were documented in the Greenland glacier and connected to the period following the eruption of the Santorini volcano.

As mentioned above, the glaciologists had already entered into the discussion about the absolute dating of the Santorini eruption in the 1970s' (see also chapter 1) but their first results were later revised and the samples were re-dated, with the acid layers being placed within the interval of 1645 ± 20 BC (Kuniholm 1990, 8).

There are nowadays three glaciological bases in Greenland (GIPS2, GRIP and NORTH GRIP) which have shown the existence of acid horizons and they are in agreement about its absolute dating within the interval of 1623 ± 36 BC. More detailed measurements document two different but chronologically close anomalies (Bietak (ed.) 2000, 30), which complicates their identification with the Santorini event.

The main, or it can be even said the only, source of atmospheric sulphur compounds during the pre-industrial era was volcanic activities, which supply the atmosphere with more than 60% of those compounds.[23] Magma is naturally acidic and can contain 4–7% of sulphuric acid. However, some doubts have been expressed about any simple or automatic connection between the measured anomalies and the Santorini eruption. (Pyle 1990, 167–172)

Not every volcanic eruption has sufficient power to impact the stratosphere, or even the upper atmosphere, and consequently to leave traces within the ice in Greenland. If the volcanic explosivity index (VEI) is higher than 4, an eruption can impact the stratosphere.[24] Statistically speaking it would be expected that only one eruption of the 20–30 each century would have a VEI greater than 4 and only one in three of these would have a VEI of 5. (Friedrich 2000, 70).

Using modern parallels, the Santorini eruption's VEI was reconstructed as 6.9, representing a truly exceptional event. (Hammer, Clausen 1990, 175).

Glaciologists C. U. Hammer and H. B. Clausen (1990, 174–179) are convinced that the absolute dating reconstructed by the Danish glaciological base on Greenland (DYE 3) can date particular levels within an accuracy of 10 years. This base doesn't just measure sulphur compounds but also other compounds produced by volcanic activity (e.g. HCl, HF etc.). The Dye3 base was looking for anomalies which could be connected with volcanic activity between the years 1900–1300 BC and has discovered only one sulphur compound record which could be equated with a VEI greater than 6. It was within levels dated to 1645 ± 7 BC and both C. U. Hammer and H. H. Clausen assert that it could result from the Santorini eruption.

Petrographic analysis indicates that the Santorini volcano was very rich in sulphur.

The approximate difference of 20 years between the samples from the GRIP and Dye3 expeditions are explained by the geologists as either due to a belated reaction of long lived trees to the climatic stress or incorrect measurement by one of those expeditions, though the distance between the volcano and Greenland may also have played a part. The sulphur compounds could have spread in the stratosphere for some time before being deposited as rain/snow. (Manning et al. 2001, 2532–2534; Hammer et al. 2003, 87–92; Muscheler 2009, 276–279).

The initial claim of a rare-earth element, Europium, anomaly in both the Greenland ice around 1645 BC and Theran tephra (Hammer et al. 1987, Hammer et al. 2001) was withdrawn by the investigators (Hammer et al. 2003, 93). Subsequently it became clear that major differences in the bulk components of the Greenland ice and Theran tephra made a common source practically impossible (Keenan 2003) and that the trace elements were not closely comparable (Keenan 2003; Pearce et al. 2004; Wiener 2007)

There is no reason why every Northern hemisphere eruption should leave an acid signal in every square meter of the Greenland ice (Wiener 2003; 2009b, 280) and some glaciologists assumed that the ice-core anomaly was due to another eruption elsewhere, for which evidence had not yet been found or which had left no archaeological or historical trace. This assumption now seems plausible, given the discovery of a contemporary eruption of an Alaskan volcano, Aniakchak, in the Aleutian Chain (Pearce et al. 2004; Denton and Pearce 2008), whose chemical signature is akin to that found in the Greenland ice-core and whose ejecta would have been far more likely to reach Greenland than those from Thera, given the prevailing wind patterns. However, others argue that both anomalies are related to one eruption because the tephra trapped in the ice layers was not only rich in sulphuric acid but also in calcium, which would be expected from a Santorini origin (Vinther et al. 2008).

The case of the Minoan Santorini eruption has also been investigated by calibrating dendrochronological dates, radiocarbon dates and ice-core dating. This method can also be used to cross-check different independent chronologies. The comparison can be done via cosmogenic radionuclides in tree rings and ice cores. Cosmogenic radionuclides are particles produced in the Earth's atmosphere by the interaction of galactic cosmic rays with atoms of the atmosphere. Variations in the galactic cosmic ray flux produce a global signal in cosmogenic radionuclide records that can be used to compare different time scales because contemporary samples must contain the same record of those cosmogenic radionuclides. Isotopes of ^{10}Be and ^{14}C contained in the branch of olive tree burnt during the Santorini eruption were compared with ice-core samples from Greenland. Due to the influence of climate change on both isotopes a perfect match cannot be expected. However, the method can establish the probable maximum error for each method – radiocarbon and ice-core dating. It seems that each method could have an error no greater than 20 years. After taking into account all the possible error margins and variables, the suggested date for the Santorini BA eruption is 1620 BC. (Muscheler 2009, 275–284).

2.1.4 Other scientific dating methods used in the case of the Santorini eruption

As briefly mentioned in the first chapter, the thermoluminescence dating technique was previously also applied to evidence from Santorini but with not very accurate results. The method's error (of 5–15%) represents a potentially quite large distortion for the Bronze Age. (Schoch 1995; Liritzis et al. 1996).

Palaeomagnetology, which works on the principle that the orientation of the earth's magnetic field is conserved if the medium was heated above 500°C, has also been used but this method cannot provide values which are any more accurate and thus does not help elucidate the problem of the absolute dating of the Santorini Bronze Age eruption. (Taling and Downey 1990, 146–159).

Other methods, such as the decay of cosmogenic isotopes such as Si-32, Cl-36, Ar-39, Ionium-Protactinium, electro-resonance, or measurement of exoelectrical emissions, are also still not sufficiently accurate to contribute to the solution of this particular dating problem.

2.2 Archaeological and historical dating

The pioneers of East Mediterranean prehistory (e.g. Evans, Pendlebury, Marinatos etc.) had, from the outset, correctly identified imports from Egypt present in Cretan palatial contexts as well as material of Cretan provenance found in other regions around the Aegean and Eastern Mediterranean basin. Interpretations of the frequency of such links tend to have been somewhat subjective. Some have asserted that it is sufficient to imply that contacts were systematic and commonplace. (Warren 1995, 1). Others suggested that the chronologically useful Egyptian items in Crete, and any Aegean items in Egypt, are rare (Manning et al. 2014). I would prefer, before drawing inferences from the relative frequencies of such cross cultural finds, to assess the material itself and to consider what its presence actually means. The first, indeed the main, question is, if the method is correct, what the imports say chronologically and how to deal with the disparity between the moment of production of the particular item, its export/import and finally its deposition.

However, the traditional methods depended on relatively simple assumptions concerning the transfer of objects and stylistic characteristics between regions and these are still quite commonly used. E. g. European pre-historians use dated parallels with the Aegean to date their contexts and, in the same way, Aegean prehistory uses the evidence of exchanges to connect its chronology directly with the chronological systems of regions which have entered the phase of literary history. The procedure does look overly simplistic, particularly in the case of the Eastern Mediterranean, where the archaeological artefacts document a wide contact network between various regions in various combinations. (i. e. Dickinson 1994, 16–17; Cline 2014, 22, 24, 60). These contacts can be traced during the entire Middle Minoan period (e.g. imports of fine polychrome pottery – 'Kamares' wares – in Egypt) but, although there was a later period of intense contact between Crete and Egypt during the Amarna horizon (LM III A – B in Crete) (McGovern 2000, 79; Karetsou and Andreadaki-Vlazaki 2001), Minoan influence reached its apogee in LM IA. This period was even termed the 'Minoan Thalassocracy' (for a comprehensive view to Minoan Thalasocracy see Hägg and Marinatos (eds.) 1983).

This term does not, of course, mirror the real situation at that time but reflects rather the fact that the first excavators in the Aegean tended to interpret history from a viewpoint based in heroic myth. The term was still in use until a few decades ago and the need to re-evaluate it provoked a conference confined to the discussion of this term and its historical conditionality. (Driessen et al. 2002). However, what is clear is that, at least during LM IA, the early Minoan 'state' was actively broadening its sphere of interaction and trading. (Klontza-Jaklová and Klontzas, *in print*)

Although efforts to use comparative typology to synchronize, at least in relative terms, the strata from individual regions in the East Mediterranean are very intensive, the issues involved are far from simple. Material was often in use for a long time and it is very difficult to say how long that time was, either for a group of similar or related artefacts or for an individual item. We must also deal with cases which may involve heirlooms, re-creations of elite material culture, past or present, and even ancient forgeries.

The topic of contacts, both physical and conceptual, is often discussed in contemporary archaeology and approaches tend to oscillate between the concept of a network of intensive contacts encompassing a very wide area and an understanding of prehistoric societies as considerably more introverted (for the Aegean compare Bouzek 1985; Kristiansen and Larsson 2005; Dickinson 2006).

2.2.1 Problem of distance in the Bronze Age

The questions most frequently put concern attitudes towards physical distances. The main doubts expressed concern the long distances involved and the slowness of the means of transport (Knapp 1998). It should be recognized that such concerns, rooted in modern attitudes, may not be wholly relevant. It is entirely possible, indeed likely, that people in the past understood distance, space and time rather differently (Klontza-Jaklova 2011). We often say that distances in the Mediterranean or Europe in general, are too great, forgetting that people, without the benefit of modern technology, successfully travelled across the Pacific (Diamond 2005, 120–135). Therefore I think it may prove both meaningful and helpful to attempt to discuss distances in the eastern Mediterranean as a man of the past may have understood them.

Evaluation of the intensity of 'international' Bronze Age contacts requires consideration of the ease and speed of the required journeys. A simple and rapid route between two regions greatly increases the potential for intensive connections, influences, contacts and, for archaeological purposes, synchronization of the regions concerned. The main areas we need to consider here are Egypt, Crete and their contacts. Crete is an island and therefore it is crucial to understand how the Cretans could connect to an East Mediterranean network.

Distance is subjective; what may appear far away to some individuals may seem quite close to others. Add to this the fact that attitudes to the sea, in my experience, differ markedly between islanders and mainlanders. For the latter the sea often seems a problem, a boundary or a barrier while to islanders it tends to represent a 'bridge' to the wider world.

This duality finds a reflection in the attitudes of Bronze Age archaeologists towards contacts, connections and relations between different regions. One group tends to dismiss the concept of intensive contact because the distances were large, technology poor and journeys risky. The other group takes the view that the peoples of the old world were connected from the Near East and Egypt, or at least from the Aegean, as far as Scandinavia. There is, for example, Baltic amber in Mycenae and Cretan pottery in Egyptian Thebes. It must therefore be possible that people could and did negotiate such distances.

This opens up further questions: Over what distances were the artefacts moved, and in how many stages? How frequent were the contacts? Why were these particular materials traded? To avoid lengthy discussion of topics not directly relevant to the current purpose I propose to accept, for the present, the explanation that the Bronze Age was a period when populations across a wide area were connected by their interest in a few strategic raw materials (mainly copper, tin and

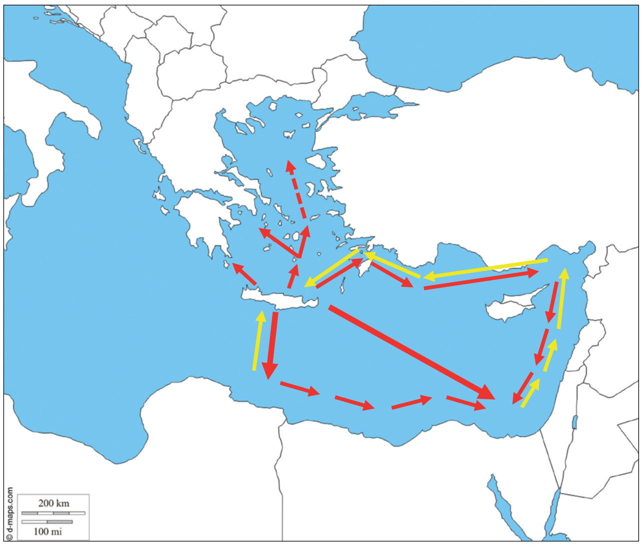


Fig. 24
Map of reconstructed-sea routes of the Bronze Age Eastern Mediterranean. (Illustration by author)

gold). (Kristiansen and Larsson 2005; Kostrhun et al. 2014) In this part of the book we will try to reconstruct how quickly and how far the people of the Bronze Age Mediterranean could travel. This will help to evaluate the information provided by the imported/exported or exchanged items, goods or ideas.

Minoan culture had a tendency to penetrate other regions. There were major centres of civilization surrounding Crete: Egypt, Babylon, the Hittites and the new and growing power of the Mycenaean polities. At the same time there was also a lot of space around the Minoans. Minoans must travel... and they did.

It will not surprise anybody that the Minoans had intensive contacts with other Aegean islands or the mainland. Such traditions must have been present since the Palaeolithic and, even by the early Bronze Age, evidence for these contacts is very clear. It was not difficult to move from island to island in the Aegean.

Evidence for contacts with Egypt and Palestine also exist. We will try to reconstruct the particular routes. (Fig. 24) The shortest way from Crete to the Nile Delta goes from Southeastern Crete directly to the Eastern Delta or South Palestine. There are 560 km of the open sea without island or visible mainland on the horizon. In classical antiquity such distances were dangerous and risky due to difficulties of navigation, orientation and also lack of possible help in case of an accident.

Another option is the route from South Crete to Cyrene. This has less than 300 km of open sea and then a further 500 km eastward along the North African coast to the Delta, making a total journey of some 800 km. Some scholars have inferred use of this route due to the pictures of Libyan fauna in Akrotiri, where, on the south wall of the West House, there was a fresco which depicted an African landscape and animals which live only in Libya (antilopa *oryx beissa*) (Fig. 24).

It is known that this route was in regular use in Roman times. The Roman consul governed the province of Crete and Cyrene from the south coast of Crete, meaning that practical contact was not only possible, it was a fact. Indeed, in summer the prevailing winds in South Crete are very favourable for such a journey. (Kemp and Merrillees 1980, 268–269). However, we should keep in mind that the marine technology of the Roman period was different and that LBA boats were not able to sail against the wind. (Wachsmann 1998, 253–254), meaning that this route could not then be in year round regular use.

Early writings, mainly using information from classical antiquity, when coastal navigation was preferred, state that the Minoans were not able to cross the open sea between Crete and Palestine or the Delta. What might happen, what troubles might be encountered by anyone who lost his bearings is clearly depicted in Homer's Odyssey. On the other hand Cretan fishermen and sailors state that the route to Palestine is the most natural way and the winds and currents direct boats right there. It is possible to sail there in one week or even less. The journey back is difficult because the boat must then go against the wind and currents. It is possible to wait for favourable conditions to go to Libya (Cyrene) and travel northwards from there to the southern coast of Crete. The other options were the journey along the Levant coast to Cyprus, or along Anatolian coasts to the west and then from island to island to Crete or the Greek mainland. Although there is a complete lack of primary evidence, the arts of navigation, meteorological observation and geography must have been well developed. Contacts were probably quite frequent and widespread, as demonstrated by the cargo of the Uluburun shipwreck, the origins of which encompassed almost all regions of the Old World (Manning et al. 2009, 163–164). Secondary sources indicate that knowledge then of how the world looks were quite accurate. The best example of this is probably the so-called 'Navy' fresco from the West House in Akrotiri. The fresco probably depicts Santorini itself (McCoy 2017, Fig. 6). There are plenty of boats depicted and it seems that movement across the sea was an everyday issue. There are also many wrecks known, demonstrating that the technology of boat construction, navigation, meteorology and cargo placement were not always predictable and to travel by sea was still risky.

There is another argument, touched on above, which must be evaluated and that is the security of traveling. The aim was not only to get somewhere but to get there safely and to return. Merchants needed to strike a balance between efficiency (how much cargo, how fast) and security. From this point of view the journey from Crete (ergo the Aegean) to Cyprus, passing the islands of Kassos, Karpathos, Rhodes and

Kastelorizo, to Cape Gelidonia, then along the South Anatolian coast to Cyprus and onward to Syria (Ur) and, finally following the Levantine coast to Palestine and the Delta was the most secure, although long and expensive. This journey was really very long, 1440–1800km, but it would have been possible to engage in other transactions en route and archaeological finds seem to support the theory that this itinerary was in use during the Bronze Age, as well as featuring in literary sources concerning the historical period (Kemp and Merrillees 1980, 274). Similar reconstructions of Bronze Age routes crossing the East Mediterranean basin and connecting the various regions around it are presented by C. Knappett (2011, 25).

There is little information on the speed of the LBA boats but it has been assumed that the journey from Crete to the Delta or to Palestine could be made in 2–3 months if going overland. (Raban 1988, 129; Wachsmann 1998, 254) As in later periods (e.g. Greek, Roman, Byzantine or Viking) overland routes were unlikely to be preferred. They were extremely slow and cargo would have had to be limited, rendering them expensive as well. E.g. for ancient Romans sea cargo was 28–56x cheaper than that transported via land routes (Tainter 2009, 177). The Vikings, for example, were able to transport tons of cargo with 6 or 7 people on board a sailing boat and the Uluburun shipwreck could have been operated by a crew of 4–6 people (Parker 1992, 20).

But contacts between particular regions were not only operated by merchants and were not always peaceful. A wall fresco painted on the north wall of the West house in Akrotiri presents a naval battle and landing of troops in full armour (e.g. Kemp and Merrilees 1980, 217). In general the Neo-palatial period is interpreted as a time of peace. In archaeological contexts there are few finds indicating warfare. In Crete the first period where evidence for combat, attacks and destructions is widely documented is LM IB (see summary of bibliography and contemporary theories in Klontza-Jaklova 2013, 237–295). The first warrior graves in Crete (Isopata) are dated to the latter half of the Neo-palatial period (Younger and Rehak 2008, 172). Nonetheless, it is possible – and the Santorini frescoes seem to support it – that the Minoans could have had significant forces at their disposal.

However, the overall picture presented implies that everyday contact was not generally possible. The interval from the moment of departure to the moment of arrival could be extremely long. As we know from the Vikings, from pirates or even from the seafarers of the 19th century AD, sailors often had to stay in harbour for months awaiting favourable weather. But people and goods were on the move around the Eastern Mediterranean and the people of the region probably had a good grasp of its geography. E.g. Egyptian sources speak about Crete, calling this island Keftiou (Dynasty XVIII) and also they also knew how Cretans looked (Rekhmire's tomb). Sargon I. of Akkad mentions Crete as Kap-te-ra (the biblical Kapthor) in the 24th century BC. An Akkadian inscription was found on the island of Kythera

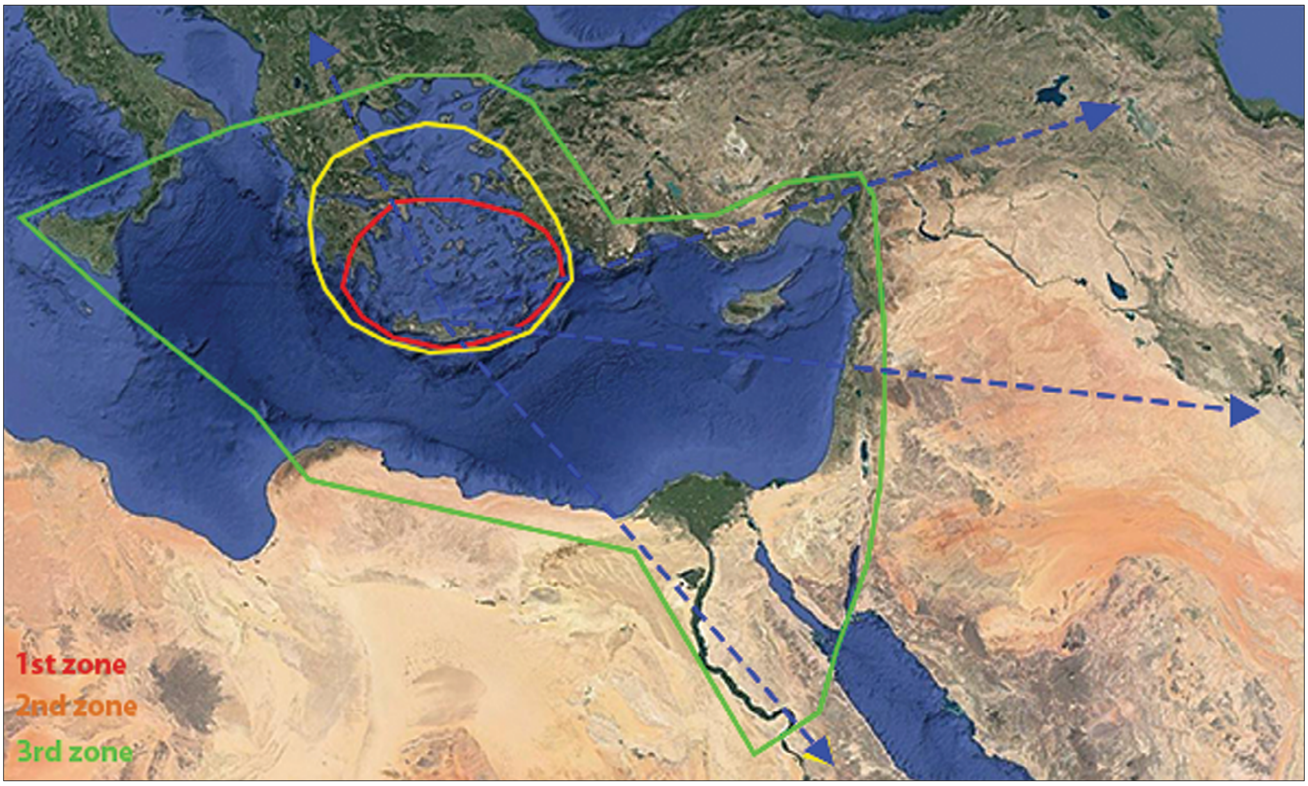


Fig. 25
Map of Minoan impact zones. (Illustration by authors)

and is dated to the 18th century BC, while in Platanos in the Messara plain a cylindrical seal of the 18th century BC has been found. In the royal archive in Mari there is mention of Crete, as a place where precious metals come from and where an ambassador was delegated. (Raban 1991, 129–147). But these contacts did not automatically mean that everyone had an accurate impression of how distant other regions were. E.g. the king of Mesopotamia complained to the pharaoh that he didn't know that couriers' journeys between their kingdoms took months (E. Cline, *pers. comm.).*

I would also like to underline that we tend to approach the societies we study as something isolated in time and space, as people who must discover everything from scratch, but the people of the Mediterranean, as mentioned before, had knowledge about the space around them. Their knowledge and traditions were inherited from generation to generation for thousands of years.

There has been much discussion about how many direct imports we have in archaeological contexts and how much was transferred by third parties (for statistics from each period: Kemp and Merrillees 1980, 278–279).

It has been widely accepted that Crete (or any other region) operated within three zones, according to the mechanism of the so-called Versailles effect (Wiener 1983; Melas 1988). (Fig. 25)

The first zone can be described as the habitation zone. For Neo-palatial Crete it would comprise the Cycladic islands, Samos, Kythera, some regions of the South Peloponnese, Dodecanese including the island of Rhodes and the southwest coasts of Asia Minor. Within this zone there was probably real Minoan 'colonization'; it could be said that they were the Minoan regions. How Minoan material culture, Minoan identity or even Minoan life style, or the Minoan economic system were transferred and exported is another question. Most scholars regard it as the result of a natural emigration of merchants or craftsmen. It is also possible that these regions adopted and accepted the successful Minoan social and economic models along with the material culture. There is no obvious evidence of the extended wars or dangerous increases in population, which could have led to mass migrations. There is, instead, evidence of trade colonization (e.g. Betancourt 2004, 27; 2008, 217). The hypothesis has been put forward that the limited area of agricultural land in Crete may have played a role in this as the inhabitants could well have needed a means of finding and financing additional food supplies. (Melas 1988, 48–56)

The second zone includes those regions where there were important and direct contacts but which are considerably more distant. Here we would place the regions of South Greece, Laconia, Messenia, Argolid, Attica, Boeotia, Euboea, Thessaly, Aegina, Skopelos, Lemnos and Asia Minor. A dense network of trade and strong influences of Minoan material culture (imitations, fashion, imports of luxury goods) are archaeologically visible in this zone.

The third zone represents the region of inter-regional contacts and trade. Here we speak of the entire Eastern Mediterranean. The main items traded across this zone would have been luxury goods. Contacts were probably made by transfer and were mediated. Apart from the few most prominent merchants, there were also artists and highly skilled craftsmen, couriers and diplomats who travelled so far afield. This was the scale of distance across which relationships between power centres or even states were brokered (Melas 1988, 56–68) though there may have been 'personal' contacts between rulers (Cline 2014, 25).

The heyday of Minoan culture can be placed in the Neo-palatial period, mainly its first half. The settlement of Akrotiri on Santorini – probably one of the most important emporia – was established at the beginning of the LM period. But, as the latest excavations have documented, the tradition of habitation there goes back to the Early Bronze Age. The island of Santorini and its advantageous position on the route to the Aegean, with the additional benefit of its natural port in the caldera, had been known for many centuries. The expansion of Minoan culture was the background to the origins of the Theseus myth (Melas 1988, 56–68).

The influence of Minoan culture was so pervasive in archaeological contexts of the East Mediterranean that archaeologists, as mentioned above, used to speak of the 'Minoan thalassocracy' and the spread of those influences as a'conquista'. These terms have now been abandoned and the more neutral expression, 'large zone of influence' has been substituted. (Summary of the topic in Hägg and Marinatos (eds.) 1988)

This extended analysis of the meaning of distance in the Minoan Late Bronze Age provides us with the necessary background against which we can weigh up the relative importance and meaning of cultural parallels, and imports, allowing us to interpret and date them and to evaluate each as the result of its own particular history.

Early in the twentieth century A. Evans and J. Pendlebury were already using imports from Egypt as a basis for their chronological assumptions. They connected the strata containing imports from Egypt with Egyptian historical chronology but, because Egyptian imports were not found everywhere they had to combine this method with theoretical calculations of how many generations were needed for a change in style. (Schoch 1995, 29–49, 52–68) The mass of the layer represented for them the "mass" of time needed for its creation. This method can be used only in very specific situations, as today no archaeologist doubts, but it was still used by M. Popham (1990) almost a century later.

Albeit the majority of publications agree that the Santorini catastrophe broadly coincided with the change from LM IA to LM IB, the question continues to be discussed. This time division was defined according to the appearance of particular signs within the material culture which don't appear at the same time across the wider region. (Niemeier 1980, 80; Betancourt 1985, 122–148). E.g. on the island of Mochlos, under the layer containing the volcanic dust, there is only pottery classified as LM IA material, while on Karpathos and on Santorini itself there is also pottery which on Crete appeared only after the catastrophe, in the LM IB phase. (Soles and Davaras 1990, 89–95; Manning 1988, 21–24, 57; Betancourt 1985, 122–148).

The periodization of the past, and especially of the non-literary past, the division of history in order to separate clearly the archaeological phases, cannot work. It can only assist our endeavours to follow the phenomena, their context and complexity. This system was intensively criticized, e.g. by I. Hodder (1991, 80): *'The usual way in which archaeologists discuss developments over long spans of time is to divide up their data into phases and to discuss the reasons for change between the phases. History is thus a discontinuous process, whether the approach being followed is culture-historical (even the discontinuities are invasions and so on), processual (systemic, adaptive change) or Marxist (change from contradiction and crisis).'* We should bear in mind, when evaluating the chronological data and dealing with periods defined by us, that periods are not pottery styles (MacGillivray 2009, 156). And this truth is appropriate for the Santorini catastrophe, for which is important to know when it happened, in the absolute meaning of time, in order to understand how the world looked at that critical moment and what impact the geological event had. Furthermore, it is important to know which periods pre- and post-dating the event are contemporary, what contacts existed and how they functioned at each point in history.

It can be concluded that the distances of the Eastern Mediterranean basin were not inappreciable. But that to organize such journeys was within the power of the elite strata of each society. For unprivileged people the world was probably much smaller. I would also agree that there were 3 main zones within which people and goods circulated. And it is through such prisms that we should view the imports in each region.

2.2.2 Contacts with Egypt

As mentioned above, the pioneers of Cretan archaeology could not have failed to spot items of Egyptian provenance in Minoan archaeological contexts. Since the first days of Minoan archaeology, the contacts between the regions were scrutinized in order to understand the intensity and the character of those contacts. These connections between Crete and Egypt are the first evidence for contact between European prehistory and state civilization (although Crete, during LM IA, was exhibiting state-like characteristics and the palaces of the Proto-palatial period were polities; Knappett 1999; 2011; Klontza-Jaklová 2013, 220–236; Klontza-Jaklová and Klontzas, *in print*.) It seems that the Santorini eruption had a direct impact on the crystallization of the state. This process, on Crete, was interrupted (except at Knossos palace) as a consequence of the Santorini volcano eruption. (Driessen and Macdonald 1997, 108; Klontza 2013, 255)

This method of "cross-checking" or the "mirroring" of Minoan archaeological finds in the Egyptian chronology would appear reasonable. The next question is, how accurate is the Egyptian absolute chronology for the period? In what follows the main finds which can help answer such chronological questions and, perhaps, establish the accuracy of the chronological systems for the wider region are presented and analysed.

2.2.2.1 Egyptian absolute chronology (Table 1, 2)

	High chronology (^{14}C)	Middle (Conventional)	Low (Historical)	Extra Low
SIP starts	1800–1790	1780–1770	1674–1669	1658–1638, or even 1630
Dynasty XVIII stats	**1577–1570**	**1541–1520**	**1542/40 -1530**	**1480**

Table 2
Overview of Egyptian chronologies.

Despite all the reservations, Egyptian chronology is the most accurate historical chronological system in the Eastern Mediterranean of the Late Bronze Age. But this system was not given ready-made to the Egyptologists. It is the product of intense and continuous research and is based on a very wide range of sources (Table 3). Thus the results are extremely complex (Shortland 2013).

King lists	Palermo stone (Fifth Dynasty – circa 2400 BC) Hall of records, Temple of Amun, Karnak (Thutmosis III) Temple of Abydos (Seti I – circa 1250 BC) Turin Royal Canon (circa 1200 BC) Tomb chapel of Tjunuroy (official of Ramesse II) at Saqqara
Other Genealogical Lists	
Archaeological objects	
Synchronism	
Astronomy	Solar eclipses Lunar observations Sothic dates

Table 3
List of sources for Egyptian absolute chronology. (After Kitchen 2013; Shortland 2013)

Radiocarbon dates for the Second Intermediate Period and Dynasty XVIII are always put to one side because of the significant offset of 50–120 years for this period (Kutschera et al. 2012; Höflmayer 2012; Bietak 2013a, contradicted by Warburton 2009; Manning et al. 2016). The method of combining all historical and archaeological data and thus calculating the absolute chronology is called "dead-reckoning". This method was borrowed from geography where unknown points are predicted according to their established relationship with a known, fixed point. The counting of years starts with a date which has been established beyond doubt (here 664 BC) and proceeds backwards, deducing other less well established or unknown dates (e.g.Kitchen 2002). The dead-reckoning system offers an absolutely minimal framework based on the count of the pharaohs, high officials and events. (Krauss 1985; Hornung et al. 2006; Krauss and Warburton 2009, 125–126). From this point of view radiocarbon then offers the maximal framework. The periodization of Egyptian history which is currently in use copies the periodization by Manethon of Sebennyt, who, in the first half of the 3rd century BC, wrote the Egyptian history for Ptolemius I Soterus. From this opus, unfortunately, only notes survived – mainly the lists of kings. These notes were repeatedly copied in the works of later, mainly Christian, authors, such as Julius Africanus, Eusebius, Synkellus and Josephus Flavius. Other important sources are the Palermo table from Dynasty V, the List of Karnak written around 1500 BC, the Abydos list from the period around 1300 BC, the Saqqara list from 2 generations later and the Royal Cannon of Torino, which seems to be the most complete. This list was copied on papyrus during Ramesses II's reign from another king list, also written originally on papyrus, but both documents had different formats leading to errors in copying and the state of preservation is also very bad. On the lower edge of the document the names of 6 Hyksos kings could be recognized. This fragment of papyrus is not completely preserved and there are different readings of the length of their reign. The readings range from 108 to 140 years. It can be said with some certainty that the Hyksos king named Apophis ruled for 33 years. (Redford 1986, 1997; Krauss and Warburton 2009, 131) but the period of his reign is floating in the second half of the SIP.

These lists are not complete and don't provide a perfect match. Egyptologists also work with genealogies, private and public documents, correspondence, synchronisms with rulers of Mesopotamia, Syria and Anatolia, with archaeological typology, radiocarbon dates and astronomical events. (Krauss and Warburton 2009, 125; Wiener 2009b, 278)

The discrepancies are so significant that Egyptologists work with three different scales: The so called high chronology dates the beginning of Dynasty XVIII to 1577–1570 BC, the medium system about 20 years later and the low chronology goes as far as 1542/40–1530 BC. (Manning1988, 25; Ward 1992; Weinstein 1995, 85; Warren 2009). The majority of Egyptologists use the scale defined by K. A. Kitchen (1987; 1991; 1996; 2000) who prefers the low data. But there is also a significant group of scholars which prefer the high chronological scale (Weinstein 1995, 85; Höflmayer 2012, 444).

Although Egyptology has plenty of literary sources which refer to very early stages of Egyptian state, these are not complete and in agreement each with other. Also their authors were writing centuries later than the periods they describe. There are further complications which arise from situations such as the presence of different pharaohs in Upper and Lower Egypt, or when there was more than one dynasty or pharaoh contesting the crown over a considerable period. At times it is not known how many years some of the pharaohs ruled. It can be said that the chronology seems to be accurate to within a year from the 7th century BC onward (some authors would say from the Persian campaign in 525 BC – e.g. Bietak; Kopetzky 2000, 22–27; others from 664 BC – e.g. Krauss and Warburton 2009; Kitchen 2013).

The gaps and overlaps of the literary sources are not the only problems of Egyptian chronology. The problems start with how Egyptians understood and counted time. Their month counting and placing of the start of each year were not astronomically perfect. The calendar was created differently. An Egyptian month was 29.5 days long and was counted from each new moon, the observation of which can itself introduce discrepancies or errors. The Egyptian year had 365 days, which means that the quarter of a day, missed in the yearly calendar, caused cumulative discrepancies. (Manning 1999, 369–371; Bietak and Kopetzky 2000, 22–27). The year, for ancient Egyptians, began with the promise of renewed fertility due to the annual Nile inundation. Its harbinger, the star of Sirius, was the brightest body in the sky. Sirius disappeared from the horizon for circa 70 days and, shortly before the flood season, it re-appeared. The day when Sirius was observed in the sky again for first time was the beginning of the New Year. It is obvious that the possibility of perfect measurement was limited and it is astonishing that the Egyptian astronomists were so accurate. An additional complication is caused by the visibility of Sirius differing between Upper and Lower Egypt. Observations from Thebes were not, for example, the same as those from Memphis. Today we can use the models of the visible sky at each moment in time for each part of Egypt in order to correct the historical calendar (Firneis and Rode–Pautzen 2003, 47–85). It is certain that the end/beginning of the astronomical and calendar year were different. When this became obvious, one extra month was placed in the calendar. This was done by estimation.

The Moon and Sirius meet at one point in the sky once in every 1460 years. This cycle is called the Sothis cycle. The Roman author Censorius informs us that this phenomenon was observable on 20th of July 139 AD. Theon writes that it happened just 1605 years before Diocletian's reign started (29th of August 294 AD). Both these observations agree with the start of a Sothic cycle in the year 1321 BC (Manning 1999, 370–371; Krauss 2003, 175–197). Albeit that Egyptian astronomy was extremely accurate, given the state of their technology, just taking account of possible, and probably relatively small, mistakes in observation, assuming these could occur in 15% of cases, could create an error of 70 years in the date of the Santorini event (Krauss 2003, 175–197; Krauss and Warburton 2009, 133).

We also must bear in mind that the ancient Egyptians had different ways of understanding and approaching time. Our dealings with the calendar are mediated through highly accurate instrumentally measured global time but for ancient societies time was connected to the gods' rhythms and had special and not necessarily absolute meaning. The years were not numbered from one conventionally set year but they were labeled by the number of years reigned by a particular pharaoh. This leaves scope for interpretation; "bad" pharaohs, for example, could be rejected from the record and overlaps, as mentioned above, could cause confusion. The consequent lack of accuracy could, quite simply, be explained as being the will of the gods (Luft, U. 2003, 199–200).

I am not competent to define where there can plausibly be mistakes in Egyptian chronology, (or) if there are any. But it is necessary to provide an overview of the period in which we are interested in order to evaluate the possible level of accuracy.

2.2.2.2 Overview of historical development in Egypt during the Second Intermediate period and early 18th Dynasty, up to Thutmose III

This period represents, perhaps, the most problematic phase of ancient Egyptian history, and not only when speaking about absolute chronology. Some authors describe this period as a dark age of Egyptian history (Redmount 1995, 61). During the SIP the continuity of Egyptian pharaohs was disrupted and the literary sources are extremely limited. Opinions about this period are not fixed but are still being modified and changed in the light of each new research finding (Oren 1997).

The low chronology proposes the year 1795 as the entry point of Dynasty XIII and the year 1479 as the beginning of Thuthmose III reign (Kitchen 2000, 49). The SIP starts with Dynasty XIII, as Manethon's tradition says, when *' In his reign, for what cause I know not, a blast of God smote us; and unexpectedly, from the regions of the East, invaders of obscure race marched in confidence of victory against our land. By main force they easily overpowered the rulers of the land, they then burned our cities ruthlessly, razed to the ground the temples of the gods, and treated all the natives with a cruel hostility, massacring some and leading into slavery the wives and children of others. Finally, they appointed, as king, one of their number, whose name was Salitis. He had his seat at Memphis, levying tribute from Upper and Lower Egypt, and leaving garrisons behind in the most advantageous positions. Above all, he fortified the district to the east, foreseeing that the Assyrians, as they grew stronger, would one day covet and attack his kingdom'.* (Manethon, Aegyptiaca, frag. 42, in Oren 1997, xix). These invaders are referred to by later sources as the *Heka chasut*, meaning "rulers from foreign lands" and today we call them Hyksos (Oren 1997, xix). These days they are not viewed as a nation and their impact in Egypt in this particular period is described as the Hyksos culture, Hyksosian pottery, Hyksosian period etc. The Hyksos must be understood as a foreign dynasty designated as the Dynasty XV and of simultaneous minor dynasties, who took the title ***Hq3w H3swt*** (Bietak 2010, 139). This was not a homogenous group of people but a conglomerate created from the local Egyptians and different immigrants coming in, generally from the East, whose origin is not clear at all. The Hyksos of Egyptian sources probably were a new elite layer of society, after a violent overthrow of the previous rulers. A few texts describe their entry to Egypt and in a few texts from the period of their reign in Egypt there can be found names of non-Egyptian gods, providing evidence that those who believed in them were not of Egyptian origin. According to those names these groups used Semitic languages, though, as mentioned above, the written sources are extremely limited (summary of them in: Redford 1997). Some of the names may have a Western Semitic origin. Temples, shrines and donkey' burials in Canaan style have been found. (Bietak and Marinatos 2000, 40) It was believed that the elite of Hyksosian period probably originated in Canaan but, after M. Bietak (2010, 150–153, 163), their origin should be sought not in the South Levant but in North Syria, in the regions of Byblos and Ugarit.

During the final phases of the Middle Kingdom people from the Near East were already penetrating to Egypt (Bietak and Marinatos 2000, 40; Bietak 2010, 139–143). The way this process started, why and how they were settling in Egypt, are much discussed topics. The structure of the society, power and politics of the Hyksosian ruling dynasties are unclear and the borders, or even the size, of the region under their control is not certain (Oren 1997, xxi – xxii).

For many decades, under the influence of ancient sources, the Hyksos were accepted as a homogenous tribe or nation (Redmount 1995, 61–63). But the reality is clearly more complex. A stream of individual migrants and groups, both small and large, travelling from the Near East to Egypt has been documented in the final phases of the Middle Kingdom and it became very intense and probably organized. These groups targeted the Delta, where they created their own state structures (Redford 1992, 101–102).

The result of these migrations is clearly written in the history and archaeology, but it is more difficult to determine the reasons for their decision to move from their original homes. This stream was not a short-lived phenomenon, instead it seems that the people were moving to Egypt, and mainly to the Eastern Delta, at least from late in Dynasty XII (Bietak 2010, 139, 143). The Near East was then passing through a period of significant development, which, logically, would have led to growth of population and competition in access to resources. Part of society was clearly forced to abandon the region. At first this migration was confined to individuals or families but finally the movement became organized, sometimes with the use of armies. It is plausible that Western Asiatic populations were settled in Tell el-Dab^{c}a and some of them may even have served in the Egyptian army (Bietak 2010, 141). The names of the kings of the SIP, written in the Torino list and Manethon, remain Semitic. All later sources speaking about this period contain differences in the lists of kings' names. Manethos, Eusebius, Africanus and Joseh Flavius agree only in some points and their chronological disagreement is between 108–511 years for the government of Hyksos dynasties. Only 6 names of the Fifteenth Dynasty are unambiguously identified and 6 more were discovered by the study of inscriptions on monuments and scarabs. Their names were not Egyptian and they did not even have additional Egyptian names (Redford 1992, 103–111).

The Hyksos had regular contacts with regions in many different directions; those with Cyprus, for example, were intensive. During the 18th and 17th centuries they were organizing expeditions and conquests back into Western Asia. Many king scarabs of this period were found on the way to Nubia as well (Redford 1992, 113). Trade contacts with the Near East were documented too (Oren (ed.) 1997), as were contacts with Crete, which will be discussed further below.

The capital city of Hyksos Egypt was Avaris, probably later Peru Nefer (contemporary Tell el- Dab^{c}a[25], more in chapter 2. 2. 1. 3), in the East Delta. Aside from this, other Hyksos centers have also been discovered; e.g. Tell el-Maschúta, close to Tell el-Dab^{c}a, sited on a caravan path crossing the valley of Wadí Tumílát and connecting Sinai with the East Delta (Holladay 1982). Another site is Tell el-Jahudíja located south of both the sites mentioned above.

Due to the almost total lack of literary sources the form of Hyksos rule in Lower Egypt is rather obscure and we also have relatively poor information about Hyksos religion. At the summit of their Pantheon was the Semitic god Baal, meaning The Lord. The equivalent of the Egyptian goddess Hathor, and Baal's female partner, was the so-called Mistress of Two Trees. The traditions of this religion were clearly very strong since they remained visible in much later periods. The Ramses stela (the so-called Stela of 400 years) in Avaris shows evidence of the Baal cult.

Under the pressure of immigrants and expeditions from the East the Egyptian royal dynasties had to retreat south to Upper Egypt and this marked the start of the SIP. During the period of maximum expansion in Hyksos hegemony, clashes with Egyptian royal forces placed in Thebes, fighting for the control over the Delta, started. The first recognized Egyptian pharaoh mentioned in this context was Sekenenre Tao of Dynasty XVII who was in conflict with the Hyksos ruler called Apopi. Sekenenre Tao's successor – probably his son – was Kamose, who reached the fortification wall of Avaris. Hyksos rulers were constantly trying to open a second front to the South by pushing their Nubian allies to attack the Egyptians based in Thebes. But in the period of Kamose all Nubia was under his control already. (O'Connor 1997, 45; Redford 1997, 68–69) As the pressure on the Hyksos continued, it was Ahmose, probably Kamose's brother, who finally managed to overthrow the Hyksos dynasty and reinstate an Egyptian royal Dynasty on the Egyptian throne. Ahmose is understood to be the founder of Dynasty XVIII. Egyptian historiography places this event to 1540 BC (O'Conner 1997, 45, 48–52, 60–63; Kitchen 2000, 44, 49).

The last Hyksos king, according to the Torino Royal Cannon was Khamudi. Avaris must have fallen in year 11 of Khamudi, which is probably equivalent to the 18th/19th year of Ahmose. This date has been reconstructed as 1504 (Table 4; Krauss and Warburton 2009, 137–139).

Last Hyksos King	Early Dynasty XVIII
Khamudi (1515–1504 BC)	Ahmose c. 1524–1499 (or 1–3 years later)
	Amenhotep I c. 1498–1477 (or 1–3 years later)
	Thutmose I c. 1476–1470 (or 1–3 years later)
	Thutmose II c. 1469–1468
	Thutmose III c. April/May 1468–Nov. 1415

Table 4
Overview of the late Hyksos period and early Dynasty XVIII. (After Krauss and Warburton 2009, 138–139, Table 1)

As well as the general historical vagueness of this period the specific chronological problems are obvious too. The absolute chronology of the Middle Kingdom is connected to lunar observation of the 7th year of Senusret's III reign. However, it is not clear where the observation was made; if it was made in Memphis then this year would be dated to 1872 or 1866 BC and the end of Middle Kingdom is then dated to 1801 BC (or a few years later in 1796–1793 BC). The Middle Kingdom finished when the Hyksos took over the capital city Memphis (Krauss 2003, 177–180). The first two pharaohs of Dynasty XIII were sons of the last Dynasty XII pharaoh, known as Amenemheta IV but there is not any certain chronological point for this period. According to some scholars Memphis was captured by the Hyksos king Dudmose II but his name does not appear in all the lists of Hyksos rulers and it is possible that this personality did not actually exist or that his status is hypothetical. Dynasty XIII probably lasted for around one and a half centuries and is dated to 1851–1643 BC (Manning 1999, 367–412) or to 1795–1631/27 BC (Kitchen 2000, 49).

2.2.2.3 Avaris and its stratigraphic sequences

Ancient Avaris, contemporary Tell el-Dab^c^a, probably also identifiable, under the New Kingdom, as Peru Nefer (c.f. Bietak 2009a, 2009b; 2010, 167; MacGillivray 2009, 165), was discovered near the end of the 19th century (1885) by Swiss Egyptologist Henri Édouarde Naville. Between 1941 and 1942 Labib Habachi, an Egyptian Egyptologist, put forward the idea that the site could be identified with Avaris. Systematic excavation, by the Austrian Archaeological Institute, started in 1966–69 and has continued, with a few short breaks, to this day. The site is within the Eastern Delta and formed a hub for the markets of the region. It was not first established and occupied by the Hyksos as it was already in existence during the Middle Kingdom. There are even finds of Protopalatial pottery from Crete mentioned as having been found there. Its original name should probably be pronounced ***Ḥaʔat-Wūrat**, Avaris being a Greek name for the city. The Hyksos, however, developed the site and it became a centre for their kingdom. The city is 250ha in area and it was the largest urban center in the Eastern Mediterranean (Bietak and Marinatos 2000) at the time. The site is not only important for the Hyksos period but its chronological framework documents the continuities of Egyptian history from the Twelfth to the Eighteenth Dynasties. (Weinstein 1995, 84). Ultimately, virtually all of the archaeological arguments against the ^{14}C date of 1627–1600 BC for the Santorini eruption are based on the stratigraphy and finds from Tell el Dab^c^a (Krauss and Warburton 2009, 139).

The stratigraphy of the site is very complex and further complicated by the fact that the soil is extremely wet and water must be pumped from the trenches. These difficulties have hampered the efforts of the excavators to synchronize chronological and stratigraphic units and there is often reason for criticism (Warburton 2009; Manning et al. 2016). (Fig. 26)

The excavators tend to accept the explanation of Josephus Flavius that the siege of Avaris lasted for a very long time and the inhabitants reached a compromise solution that they should leave the city and go to Southern Palestine. This would then explain the hiatus between the debris from the fall of Avaris and the reoccupation during Dynasty XVIII. (Bietak 1996, 67)

A new royal (Dynasty XVIII) citadel was built on the destroyed Hyksosian strata (Fig. 27a). It was constructed on a platform (Fig. 27b) which incorporated late Hyksosian elements within its structure and even reused parts of the Twelfth Dynasty architecture. (Bietak 1996, 68–72).

A painted wall in Aegean style (Fig. 28) is an important chronological marker for Avaris. It was published as having been found in the strata of the "transition between the Hyksos period and the 18th Dynasty" (Bietak 1995, 23, 26) but later the excavators re-examined that conclusion and connected the citadel's platform to the period following the fall of Avaris (Bietak 1996, 67–68). The most important fresco was found during the excavation of the Citadel, particularly in its west part, in 1992. The fresco fragments were spread through more strata but the main debris seems to be connected with stratum C3 which is now synchronized with Thutmose III or Thuthmose II, ergo 1479–1425 BC (Bietak 1997; Bietak and Marinatos 2000). Significant amounts of pumice were also deposited in this layer (Bietak 1995; 1996; Manning 1999, 32) and it is, therefore, looked upon as the layer contemporary with or directly following the moment of the Santorini eruption. Stylistically the fresco was characterized as a wall painting of the LM IA period by the excavators (e.g. Bietak 1995, 1997, 117; Morgan 1995; Bietak and Marinatos 2000, 40–45, 95; MacGillivray 2009, 157) but there is not full agreement on this and an alternative opinion places the fresco later and within the style of LM IB wall paintings. The argument is that the bulls are painted in profile and not "en face" (Niemeier and Niemeier 1998, 90). I am not personally convinced that the evidence for stylistic dating of this fresco, or indeed other frescoes, is other than weak. There are just scattered pieces of frescoes from all of the Late Bronze Age – these are not an LM IA fresco from Knossos. It is also questionable how these fit in with the frescoes of Santorinian Akrotiri. We cannot define how the fresco painting styles developed in the Aegean so any effort to identify close parallels for the

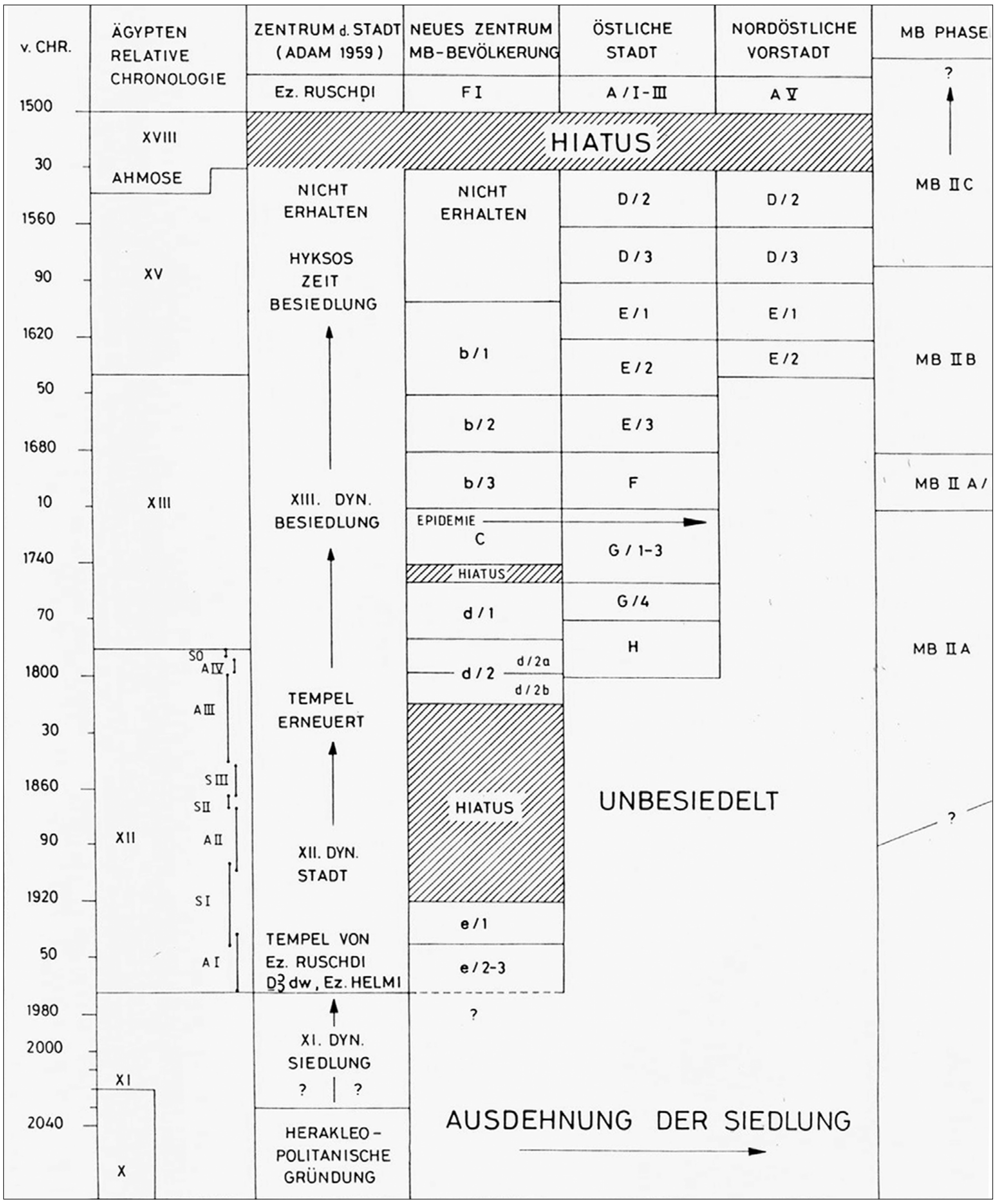


Fig. 26
Chart of Tell el-Dab[c]a stratigraphy (Bietak 1992, Abb. 1).

Avaris wall paintings remains somewhat tentative. As the bibliography cited above shows, it is possible to find elements which can be connected with both the earlier and later phases of Neo-palatial Crete.

When the contexts with frescos were found they were originally dated to the Hyksos period and were interpreted as decoration of the Hyksos citadel (Bietak 1995, 1996). Dating and interpretations were revised and the excavators now conclude that the previous stratum, designated D2, belongs to the period when the city of Avaris was taken over by the Egyptian pharaohs (Bietak 1995, 23, 26; Weinstein 1995, 89; Bietak 1997, 115–117; Bietak and Marinatos, 2000, 41–42).

If the fresco was made during LM IB and it was part of Thutmose III or II citadel, then the Santorini catastrophe must have happened in the first half of the 15[th] century BC, which seems an extremely late date. If the Egyptian chronology is as accurate as we suppose and if the strata where the fresco was found are really Thutmosian, then the fresco cannot be contemporary with the LM IA period.

However, an art object, such as this fresco, evokes questions of forms, characters and the intensity of Minoan / Egyptian contacts. Some scholars propose that the Avaris frescoes were made by an artist who travelled in the train of a Cretan princess, who married the Egyptian pharaoh. (Bietak and Marinatos 1995, 61) M. Bietak himself has expressed the opinion that this pharaoh can be identified. Originally he offered some of the Hyksos kings but later when the chronological and stratigraphical contexts were revised, he identified Ahmose, the founder of Dynasty XVIII (Bietak and

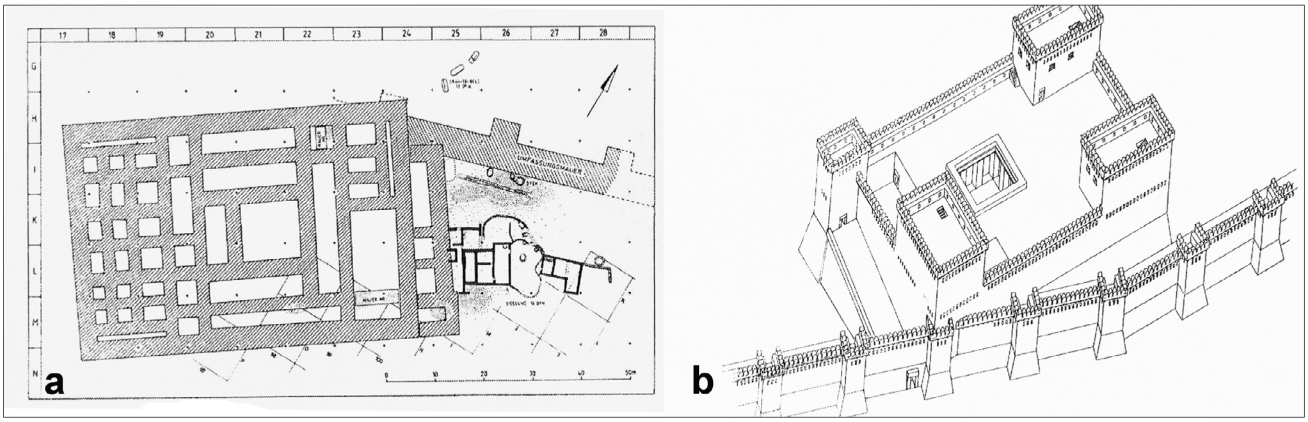


Fig. 27
Ahmose's citadel at Tell el Dab^{c}a: a) platform, b) reconstruction. (After Bietak 1996)

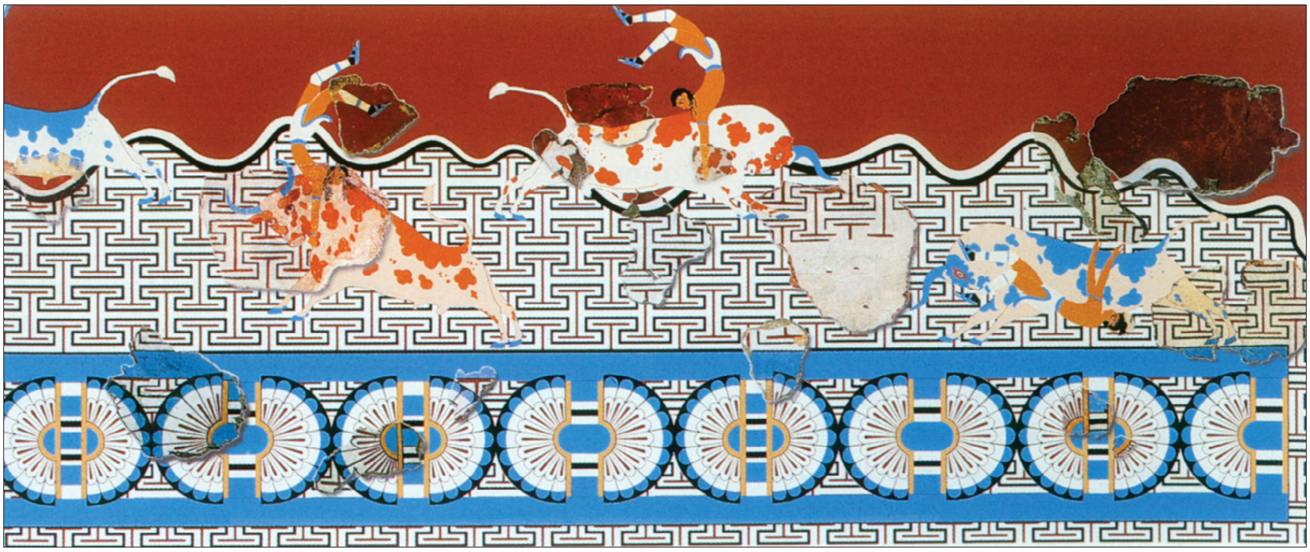


Fig. 28
Reconstruction of one of the Tell el-Dab^{c}a frescoes. (After Bietak 20013b, Fig. 8)

Marinatos 1995, 61; Niemeier and Niemeier 1998, 95), as the pharaoh in question. We can imagine circumstances which bring about an increased desire for good diplomatic relationships on the highest level. Although it is of course hypothetical, it is possible that Ahmose, faced with some uncertainty immediately after his very recent victory, would have wanted to cement alliances with his potential allies. If this happened in the LM IA period, when Crete was in its zenith and it was one of the most important players on the political scene of the Eastern Mediterranean, then such an alliance would be highly beneficial. LM IB Crete would be a more problematic ally due to destabilization of the situation there then (MacGillivray 2009; Klontza-Jaklová 2013; Klontza-Jaklová and Klontzas, *in print*). Politically speaking, the context seems to make sense and the synchronism of the LM IA early Cretan (Knossian) state with the Egypt of early Dynasty XVIII, exchange between both regions, including diplomatic marriages and travelling artists, could work. The Santorini eruption would have disrupted this picture. The only problem is the radiocarbon dates from LM IA Santorini and Crete were not in accord with dates from Avaris layers D2 and C3, which seem to support the Egyptian historical chronology (Kitchen 2000, 49), but new dates from layers E1–D3 are about 100 years earlier than expected (Kutchera et al. 2012; Bietak 2013a).

There are more objections which must be discussed and borne in mind. The Minoan style fresco fragments in Avaris were scattered over several layers. It has also been shown in Knossos that the frescoes found in destruction levels were much earlier that the destructions themselves. It is logical therefore to pose the questions: When were the frescoes painted? For how long did they, undisturbed, decorate the palace walls? And when did they finally become part of the destruction debris? Pieces contained within layers D2 and C3 could have been part of a fresco created a hundred years earlier than the creation of the debris (Krauss and Warburton 2009, 139–140).

However, Avaris has more than just a fresco to help with our chronological conundrum. There was a significant amount of pumice in the excavation areas designated H I, II and III. Pumice found in Avaris was tested using neutron activation analysis, and it proved to have originated in Santorini (Foster Polinger and Bichler 2003, 431–437). It seems that this pumice must have become part of the context after the Santorini event (Bietak 1995, Fig. 1).

How did the pumice get into these Avaris contexts? Clearly the Santorini volcano produced a lot of pumice which not only covered the island but was also left floating on the surface of the sea. According to contemporary observation chunks of pumice can move with sea currents at speeds of 9 km per day. Eastern Mediterranean currents and winds in the South Aegean generally move floating objects to either the Palestinian coast or the Nile Delta. Pumice could have travelled from Santorini to Egypt in approximately three months (Foster Polinger and Bichler 2003, 437). Santorini pumice was found not only in northern Egypt but also much further south, in Thebes, Maiana and Kahún, in graves of Dynasty XVIII up to the period of Thuthmose's III reign (Foster and Bichler 2003, 433–436). In the graves of the cemeteries at Thebes, Maiana and Kahun, the pumice was found mainly in contexts dated as late SIP or early Dynasty XVIII. The strata in Tell el-Dab^{c}a and in Tell el-Ajjul produced the same picture. Contexts prior to Dynasty XVIII contain pumice of earlier Aegean eruptions, such as Kos, Gialis, Nisyros, and earlier Santorini eruptions but not from the Minoan eruption, whereas many early Dynasty XVIII sites contain Minoan eruption pumice in overwhelming quantities. A simple interpretation of this evidence would be that the eruption occurred at the beginning of the Eighteenth Dynasty, around 1530 BC or even later. (Foster Polinger et al. 2009, 171–175)

Pumice not only moved "passively" on the sea but was a material 'harvested' for use both in everyday activities and in ritual. Pumice was used for weaving weights or as fishing net floaters. Pumice could be collected in the Delta and transported south. Santorini is continuously eroding and even today, as I can, myself, attest, there is plenty of pumice washed up on the Cretan coast in stormy weather. It is possible today to ascertain whether pumice found spread around the Mediterranean is or is not from Minoan eruption of the Santorini volcano but not to determine how and when it came to the place, wherein it was finally deposited.

Before turning our attention to the most obvious archaeological find – to pottery – we should discuss the evidence provided by literary sources. One can ask if the Egyptians mentioned the event in their written documents. As noted above, the eruption was huge and the people must have noticed its effects at the time, e.g. tsunami, ash fall, maybe darkness, storms etc. Later on the disruption of relations with Crete and other regions must have become obvious and there may even have been reports in circulation from those who witnessed the catastrophe. Those, who accept that the eruption occurred in the period of Ahmose, generally believe that the so-called Tempest (or Ahmose) stela reports the event. (Fig. 29, Foster and Ritner 1996, 1–14; Foster Polinger and Bichler 2003, 436; Manning 2012, 469). This stela, which is traditionally dated to 1530 BC, was first connected with the Santorini eruption in the publication of Ellen N. Davis (1990). The inscription on the stela speaks about Ahmose's special abilities to calm even volcanos. The interpretation of the text on this stela is not generally accepted by all scholars. The translation of K. Foster Polinger and M. Bichler (Foster Polinger and Bichler 1996) is not widely agreed and the majority of scholars use the translation of James P. Allen (Wiener and Allen 1998) who does not believe that the stela describes this particular event. A new translation (Fig. 29), was published by R. K. Ritner and N. Moeller (2014) and the authors expressed the view that the document could be describing the Santorini eruption, even though there are some chronological discrepancies.

Ahmose's stela was found in Karnak in 1947–1951 by French Egyptologists and the text was first published in 1967 (Vandersleyen 1967). Aegean archaeologists met the text one generation later (Davis 1990). The main problem with the inscription is that not all the events as described could have been seen from Egypt. It mentions earthquakes, an eclipse etc. and, had the observations been made and written in northern Crete, this would not present any great difficulty. Santorini is 1300 km from Egypt and it questionable if such detailed descriptions could have been documented so rapidly. These inscriptions, wherein the pharaoh or other ruler is described as a person with god-like abilities are often used in Egypt, and elsewhere. These are symbolic metaphors underlining the 'unique' attributes of each person thus described (summary of opinions in Manning 1999, 192–202). We are unaware of any volcanic eruption which the Egyptians could have observed in their own territory. The only volcanoes which behave that way and are not impossibly remote, are Santorini and the volcanos of Sicily and the Apennine peninsula. The only exception is the so-called Avellino eruption. This occurred most probably in the 20th/19th century BC (Sevink et al. 2011), within a Bronze Age society which was prehistoric, agricultural and exhibits no evidence whatever of any contacts or relationships with the East Mediterranean. Santorini, at the time of the Minoan eruption, was much

Long live (?) the Horus "Great of Manifestations," He of the] Two Ladies "Pleasing of Birth," the golden Horus "Who binds the Two Lands," King of Upper and Lower Egypt, Neb-pehty-Ra, son of Ra, Ahmose, living forever.

Now, His Majesty dwelt in the town of Sedjefatawy ("Provisioner of the Two Lands") [in the district just to] the south of Dendera.

Now then, A[mon-Ra, Lord of the Thrones of the Two Lands,] was in Heliopolis of Upper Egypt (= Thebes).

It was His Majesty who went south ("upstream") in order to [give to him bread, beer and everything good and] pure. Now after the offering, [. . .] their(?) [. . .]. Then attention was given in33 [. . .] this [dis]trict. Now then, the cult image [of this god . . .] [. . .] as his body was installed in (lit. "united with") this temple

while his limbs were in joy.

[. . . Now then,] this great god desired [. . .] His Majesty [. . .] while the gods complained of their discontent. [Then] the gods [caused] that the sky come in a tempest of r[ain], with [dark]ness in the condition of the West, and the sky being in storm without [cessation, louder than] the cries [lit., "voices"] of the masses, more powerful [than . . .], [while the rain howled] on the mountains louder than the sound of the underground source of the Nile that is in Elephantine.

Then every house, every quarter that they (scil. the storm and rain) reached [. . . their corpses(?)] floating on the water like skiffs of papyrus outside the palace audience chamber for a period of [. . .] days [. . .] while no torch could be lit in the Two Lands.

Then His Majesty said: 'How much greater this is than the wrath of the great god, [than] the plans of the gods!' His Majesty then descended to his boat, with his council following him, while the crowds [on] the East and West had hidden faces, having no clothing on them after the manifestation of the wrath of the god. His Majesty then reached the interior of Thebes, with gold confronting gold of this cult image, so that he received what he desired.

Then His Majesty began to reestablish the Two Lands, to give guidance (or "a conduit") for the flooded territories. He did not f [ail] in providing them with silver, with gold, with copper, with oil and cloth comprising every bolt that could be desired. His Majesty then made himself comfortable (= seated himself) within the palace (life! prosperity! health!).

Then His Majesty was informed that the mortuary concessions had been entered: the tomb chambers collapsed, the funerary mansions undermined, and the pyramids fallen – what had been made rendered non-existent (lit., "what had not been made").

Then His Majesty commanded to restore the temples that had fallen into ruin in this entire land: to refurbish the monuments of the gods, to erect their enclosure walls, to provide the sacred objects in the noble chamber, to mask the secret places, to introduce into their shrines the cult images which were cast to the ground, to set up the braziers, to erect the altars, to establish their bread offerings, to double the income of the personnel, to put the land into its former state. Then it was done in accordance with all that His Majesty had commanded.

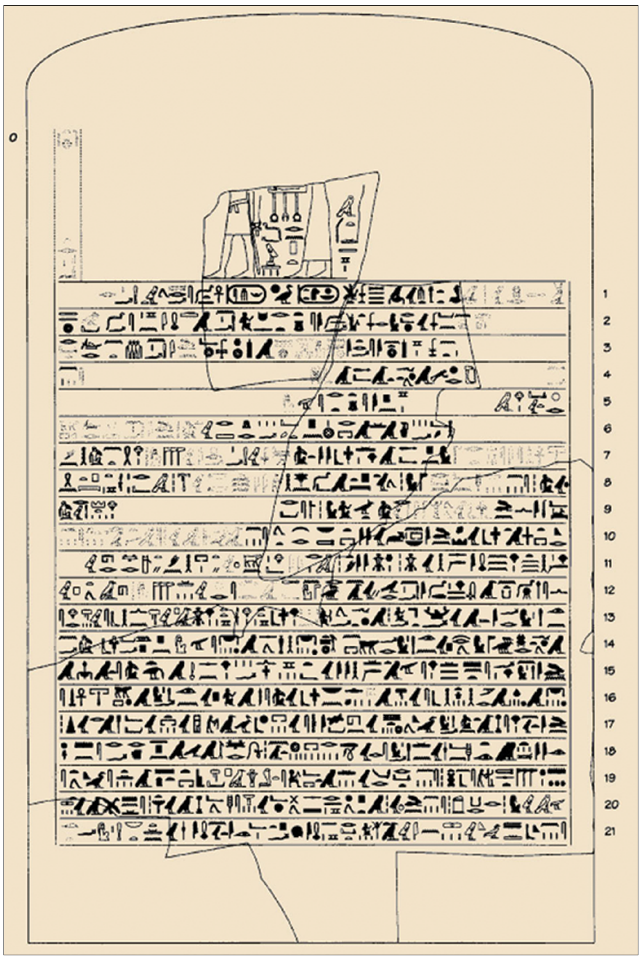


Fig. 29
The Ahmose Tempest Stela and its transtlation. (After Wiener and Allen 1998)

closer to Egypt, both physically and in political and economic organization.

Descriptions of such events can survive for a very long time even in the oral tradition. The Indians of Klamath, for instance, maintained a 'myth' about a volcanic eruption, with consistent and credible details, for almost 8000 years (Barber and Barber 2004, 1–15). On the assumption that the people of Bronze Age did not separate "current" time from "past" time, it would follow that they did not have a linear view of history, such as we now have. They had ancestors and shared their space and time with them, meaning that, in their perception, time was organized in a circle (Lévi-Strauss 1962; Eliade 1969; Sádlo et al. 2008, 205; Klontza-Jaklová 2011). Many authors, including most who subscribe to this theory, don't believe in the authenticity of the inscription and warn that it cannot be used as chronological evidence or a primary narrative source (Wiener and James 1998).

Ahmose' stela could be a contemporary report about a particular event, it could be a story which survived from an earlier time or it could even be a literary device, surviving in celebration rituals. Just to indicate how archaeology and history should, in an ideal case, work with other sources: if the stratigraphy, the radiocarbon data and the historical data were in agreement, we would not doubt that the Tempest stela describes the Minoan eruption.

Similar arguments were used by J.A. MacGillivray (2009, 159–161) when connecting one of Hatshepsut's best-known dedications found in the rock-cut temple to the lioness goddess Pakhet near Beni Hasan in Middle Egypt. The inscription is known as the "Great Speos Artemidos Inscription." It was interpreted as a description of the acts of Hatshepsut, which demonstrated her absolute power. According to the inscription she evoked storms and total darkness in the temple. These effects were first connected with the Santorini eruption by H. Goedicke (2004). If the connection made were valid, the eruption must have happened after her accession to the throne, in the second or seventh year of her reign. (MacGillivray 2009, 159). H. Goedicke (1992) connects this inscription with another one, which is placed on the el-Arish shrine, built in the Ptolemaic period (3rd –

2nd century BC) on the Levantine coast. This refers to an event during Thutmose III's reign saying that, *"there was no exit from the palace for the space of nine days. Now these days were in violence and tempest: none, whether god or man, could see the face of his fellow."* (MacGillivray 2009, 160). If these stories describe the Santorini eruptions and the darkness created by the clouds of tephra and ash covering almost all the East Mediterranean (Johnson et al 2012) and were recorded by direct witnesses, they would, particularly the latter, be advocating an extremely Low Chronology. My own opinion would be that all of them, by their appearance over such a substantial spread of time, tend to support the theory that these stories were universal, used each time the necessity arose to mark a particular occasion. There are many examples illustrating the use of similar 'model' stories. The el-Arish description was, if not actually fictional, created very much later than the event it described. Darkness during the day can be also explained as the result of a solar eclipse. However, there are other events placed within Thutmose III's reign, such as the Deukalion flood (by Manetho), which has been connected with the tsunami by J.A. MacGillivray (2009, 160–161). He also mentions many other descriptions of different disasters which occurred in Thutmose III's reign and he suggests that the Santorini volcano erupted during his 5th regnal year. As mentioned above, it is extremely difficult to connect such descriptions with particular events, while, on the other hand, a particular event can be memorized and handed down unchanged for years (Bouzek and Kratochvíl 1994; Barber and Barber 2004).

On further consideration of the evidence, I would add another possible interpretation of events, which may support the placing of the Minoan eruption to the SIP. The eruption could have played the same role in Hyksosian Egypt as it did in Minoan Crete, where it seems to have destabilized the fragile Knossian hegemony over the island (Driessen and Macdonald 1997; Klontza-Jaklová and Klontzas, *in print*). The weakening of the not fully centralised power of the so called Hyksosian rulers, could have given decisive advantage to the representatives of traditional Egyptian power. It is possible that Ahmose underwent the volcanic catastrophe but that, at that stage, he had not yet become the pharaoh and Hyksosian power still existed. Although the Minoan eruption didn't affect Egypt primarily, it affected climate, economy, transport, trade and the psychology of people. It must surely have been discussed and passed on as important and shocking news, undoubtedly much exaggerated. So, the Ahmose tempest stela could refer to the Minoan eruption and Ahmose could have been its witness (coeval) but the events could have taken place before he was on the Egyptian throne.

The majority of archaeologists working with finds or in the field use pottery imports and influences in order to evaluate the contacts between populations, which impact the pottery styles and movement of vessels from region to region and provide criteria which help to re-create the networks of the time. A lot of imported pottery was found in Avaris. The main bulk comprises imports of Cypriot White Slip Ware (chapter 2.2.3.1.1.) (Oren 2001, 139–140, Manning 1999, 325), causing many authors to infer intensive contacts with Cyprus, and Cypriot pottery was found in contexts together with Aegean fresco fragments and pumice.

The other main ceramic group used to synchronize regions is pottery of Tell el-Jahudíja type (shortened to TY Ware), which was named after the eponymous site. This pottery was once accepted as typical for its time but today it is clear that the style was very popular and was used for a very long period, from the 12th to 18th Egyptian dynasties in Egypt, the Levant, Syro-Palestine and Cyprus. (Merrillees 1978; Artzy and Asaro 1979; Kaplan et al. 1984; Manning 1988, 27; Redmount 1995).

2.2.2.4 The Pacheia-Ammos-like vessel from el- Lisht and other pottery from the cemetery in Abydos

Other important groups of finds are the ceramic vessels from the cemetery at Abydos in Upper Egypt, an important point on the map of Egypt and a secret place dedicated to Horus, son of Osiris, and from the site el-Lisht (there particularly grave No. 879).

The El-Lisht vessel (Fig. 30), a jug, was decorated in Tell el-Jahudíja technique. It has a white encrustation on a dark surface. There were dolphins and pelicans depicted on the vessel, a strong Minoan tradition. The closest parallel for its decoration motive seems to be a jug found in Pacheia Ammos (Fig. 31) on East Crete, which is dated to MMIII – LM IA. Other finds from the grave belong to the Middle Kingdom and to the second intermediate period (Kemp and Merrillees 1980, 220–225). Stylistically, the vessel was also dated to the early Neo-palatial period (MMIII) (Betancourt 1990, 20). The El-Lisht vessel belongs to Dynasties XII and XIII which are dated to 1801–1650 according to the High chronology, 1786–1649 according to the Low chronology and to 1785–1606 according to the extremely Low chronology (Manning 1988, 26).

There were two graves containing Minoan pottery found in Abydos. In grave number 137 was an alabastron painted with black pigment. Unfortunately the shape of the vessel can be dated from LMIA to LMIIIA. The painted motif is very common in the LMIB period. This grave is dated to Dynasties XVIII – XIX.

In grave number 328 a bowl fragment typical of the LM IB period was found. It could also be from the Greek mainland. This was also the grave in which the Abydos stela was found. (Kemp and Merrillees 1980, 226–240).

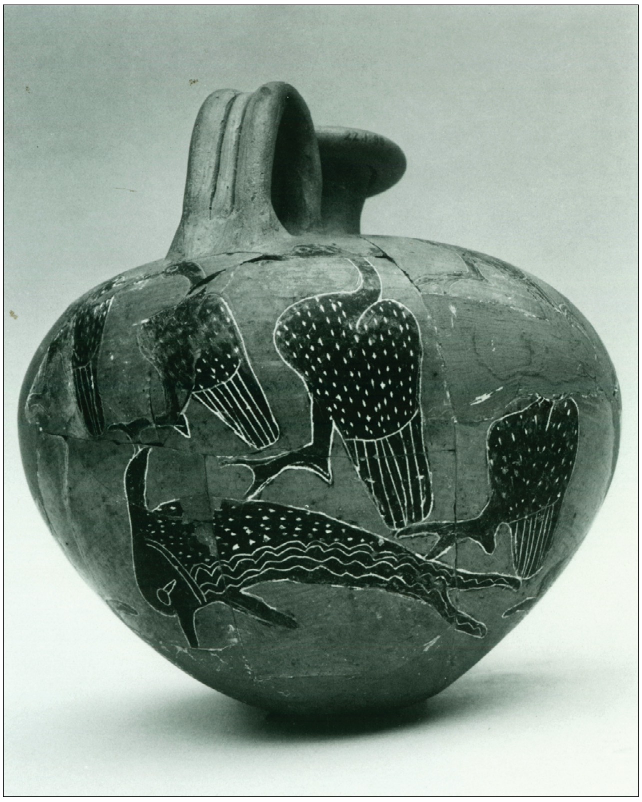


Fig. 30 / El- Lisht: TY Ware jug. (After Kemp and Merrillees 1980)

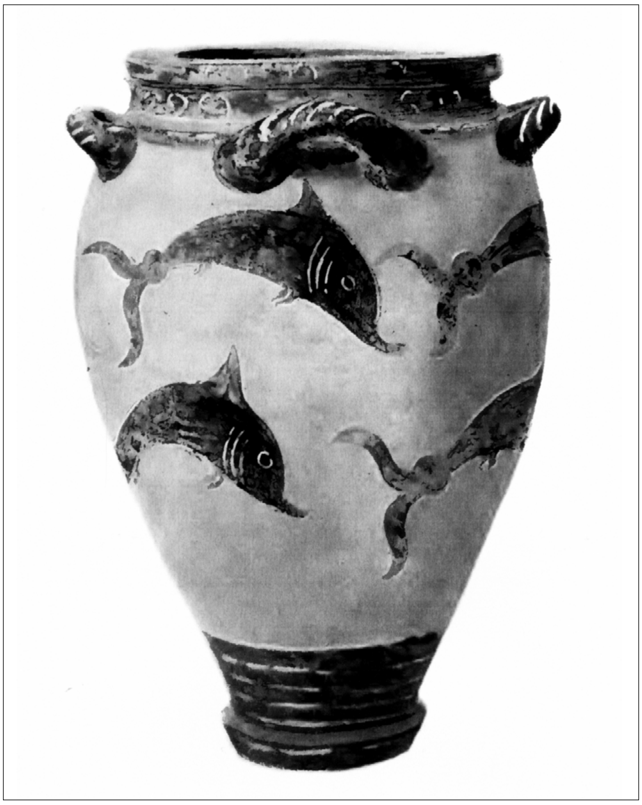


Fig. 31 / Pacheia Ammos MM III – LM IA painted pithos. (After Seager 1916)

Aegean pottery was also found in Aníba, Kerma and Sidman. In Grave Number 59 from the Sidman cemetery a vessel decorated with a picture of a reddish-brown octopus was recovered. The shape of the vessel is again common from LMI to LM IIIB and can be from Crete or the mainland. This grave should be dated to the early Ramessian period.

All the listed finds come from old excavations with poor documentation. Grave collections were not stored in one place but spread around different institutions. Some of them cannot be physically located and are known only from filed note books. (Kemp and Merrillees 1980, 238–240)

Kemp and Merrillees (1980, 267) based their chronological conclusions on those finds and first radiocarbon dates and, using the historical data, they offered the following chronology (Table 5):

MM IB	Post 2000 -
MM II	– 1775/1750
MM III	1775/1750–1675/1650
LM IA	1675/1650–1600/1575
LM IB	1600/1575–1500/1475
LM II	1500/1475 –
LM IIIA	– 1375/1350
LM IIIB	1375/1350

Table 5
Absolute chronology of the Minoan Middle and Late Bronze Age. (After Kemp and Merrillees 1980)

TY Ware was recovered in large amounts at Tell el-Dab^ca in strata E/2–D/2. Some of the vessels were decorated with birds and fish (Bietak 1979, 254, 258–259, 262–263). Due to the presence of Cypriot imports in those layers, the synchronism with this island was obvious. Stratum E2/1 was contemporary with the beginning of LC IA and should be contemporary with MMIII/LM IA. Egyptologists date this horizon to 1640–1590.

TY Ware found in Tell el-Dab^ca is parallel to the jug from el-Lisht, mentioned above. The style of these vessels remained highly characteristic of Minoan pottery for the LM IA period from Crete or from Santorini. It seems that the correlation of LM IA and MB IIB periods may be correct or at least highly probable, as stated by S. Manning (1988, 27–29). It seems also to correlate with an Egyptian faience vase found in Knossos in LM IB strata. (Cadogan 1983, 517).

Grave collections must be approached differently from those found in habitation levels. Looked at en masse they can contain obscure mixtures of items from different periods which were kept for generations before being excluded from living culture (Pomerance 1984; Kemp and Merrillees 1980, 253; Manning 1988, 25; Warren 1990, 24–26 etc). The philosophy underlying the creation of such collections and the reason why each was put together in its own particular way are generally not matters we can interpret with any clarity. Obviously the latest item will give us a terminus post quem for each grave context but our knowledge of material culture is not that precise, despite its having been studied for such a long time. For instance White Slip Ware, whose dating was once thought of as fixed, was produced for a much longer time than had been supposed. Moreover, even the dates of its initial and final phases are unclear (for more details see chapters 2.2.3.1., 2.2.3.2.). A similar scenario applies to TY Ware. Aspects of pottery dating and its chronological sensitivity will be discussed in Chapter 3 of my final conclusions.

Pottery of TY Ware's style was imported to Cyprus but not, as would be expected, from Syro-Palestine but from Egypt where it was produced from Dynasty XII to Dynasty XVIII (Arzy and Asaro 1979). This type of pottery was very popular throughout the Near East, in Egypt and Cyprus, though not a single frafment was found on Crete or on the Greek mainland. It is obvious that the transformation of parallels can be very dangerous when the region and chronological range is so wide. There were contemporary workshops of TY Ware in Lower Egypt as well as in Syro-Palestine. The presence of this pottery is more important for tracing a common cultural area or zone of close contact than for chronology.

2.2.2.5 Cartouche of Khajan (Fig. 32, 33)

An alabastron disc, 103 mm in diameter with inscription: "*Good god Seuserenre, son of Re, Khajan*", was found at Knossos in 1901. A. Evans has said about this find that *"No discovery made in the whole course of the excavations at Knossos can rival in historic interest the finding of this record of the king who seems first to have united the whole of Egypt under the Hyksos dynastic sceptre*" (Evans 1921–1935: I, 420). He was right and the dating of the context where the disc was found would prove crucial for synchronizing the two regions. Unfortunately information from the field note book is not in agreement with the contextual material with which the disc is stored. The original note book speaks about a stratum which dated the artifact to MMIII but today the item itself is stored with material from a context which also contains sherds dated to LMIIIA. (Betancourt 1990, 20–23; 1997, 430), (original report: Evans 1921–1935: I, 419, fig. 304 a, b). However, the date in the MM III period has largely been accepted (Macdonald 2005, 134; Manning et al. 2014, 1171) because dating it to LM IIIA (ergo the Amarna horizon) renders it impossibly late.[26] Khajan seals were found in layers D = E/1 and D3 in Tell el-Dab^{c}a and they should be comparable with the Late Babylonian Kingdom (with 100–150 year discrepancies in its dating as well; Manning et al. 2014, 1171; 2016, 1).

This cartouche could have been part of a diplomatic gift from a Hyksos ruler to his Knossian partner (Bietak 1994, 207; Niemeier, Niemeier 1998, 97).

2.2.2.6 Closing notes to contacts between Crete and Egypt

Contacts between both regions were obvious to students of Aegean archaeology from the outset and their later confirmation has not come as a surprise but their frequency and intensity in each period are less clear and interpretation of single finds can be somewhat

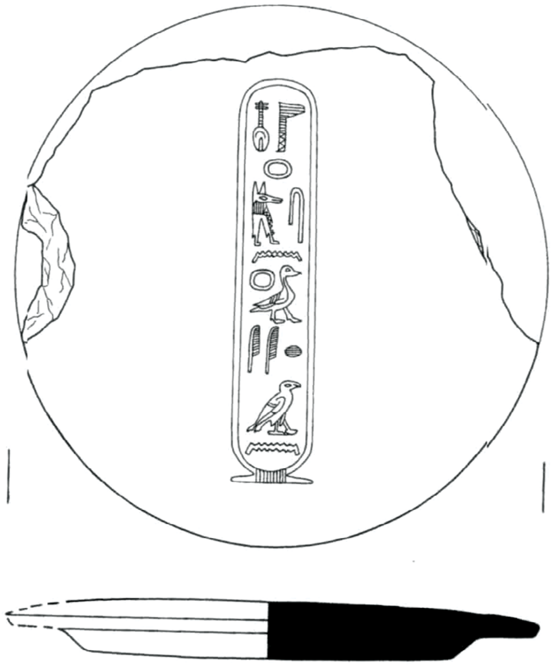


Fig. 32 / Cartouche of Khajan. (After Karetsou 2000; 2001)

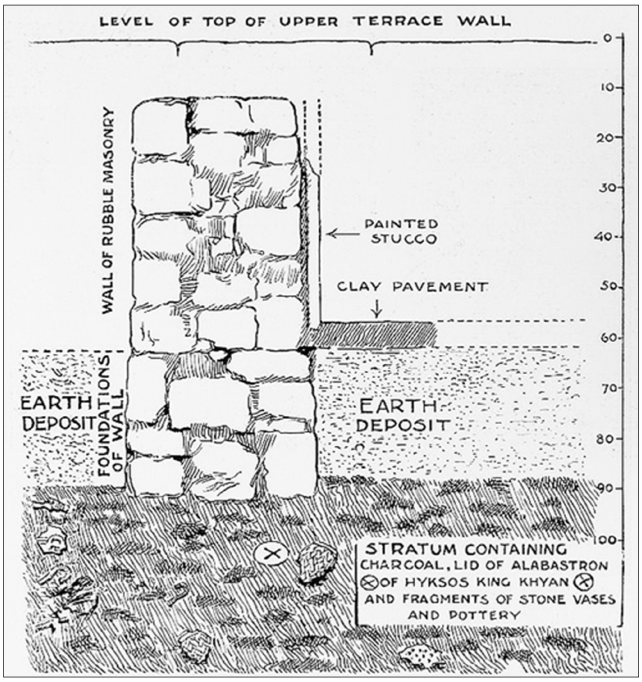


Fig. 33 / Find spot of the Khajan cartouche: in the base layers of the lustral area. (After Evans 1928–1935, 1st volume, p. 418)

hypothetical. They cannot be relied upon too heavily. In the 1980's many scholars realized that not only the general approach but also the individual finds must be reviewed. P. Betancourt (1987, 45–49) pointed out that synchronism is often supported by finds whose production and use phases were very long. He was the first who said that the synchronism of LM IB with Thuthmose III is impossible, and placed the Santorini catastrophe into the SIP and deduced the following chronological sequence (Table 6):

Crete	Greek mainland	Absolute chronology	Egypt
LM IA	LH IA	c. 1700 –1610	
LM IB	LH IIA	c. 1610–1550	
LM II	LH IIB	c. 1550–1490	
LM IIIA:1	LH IIIA:1	c. 1490–1430/10	Amarna horizon
LM IIIA:2	LH IIIA:2	c. 1430/10–1365	Ahkhenaten
LM IIIB	LH IIIB	c. 1365–1200	

Table 6
Synchronism of the Aegean Late Bronze Age and Egypt. (After Betancourt 1987)

Imports from Egypt in Crete and Cretan imports in Egypt and other evidence of contacts between the two regions are more frequent in the MM period and during the advanced Dynasty XVIII and Amarna horizon in Egypt and the Cretan Neo-palatial period (Driessen and Macdonald 1997, 80–82; Karetsou and Andreadaki-Vlazaki 2001) The link between numbers of imported artefacts found and intensity of contacts is, of course, open to question. Some, e. g. Phillips (2008, 220), would take the view that the low absolute number of imports implies that contacts were very limited. The alternative view, that contacts were much more intensive and we have either found only a tiny proportion of the imports or media other than imported artefacts were more important, is taken by some other authors (e.g. Karetsou, A. and Andreadaki-Vlazaki 2001; MacGillivray 2009; Marinatos 2010; Cline 2014, 19, 22, 59). This topic was, and still is, approached very individually and the research field remains much more a forum of pros and cons. One method which could help introduce more objectivity to interpretation of the data is the reconstruction of networks (e. g. Knappett 2011).

It is eminently feasible that we are still missing contexts in Egypt which would confirm or document the precise moment of the Santorini eruption. However, our current efforts to synchronize both regions hit the following difficulties:

1) Deviations in Egyptian absolute chronology for the end of the Middle Kingdom, SIP and New Kingdom,

2) Grave assemblages which contain chronologically insensitive pottery and pottery from different periods,

3) Pottery from settlements with long term duration and different times of use and deposition.

These discrepancies allow us to create more or less probable models but, for the moment, none of the evidence is unambiguous. The radiocarbon dates, despite all their uncertainties, remain the most scientific we have and are thus less subject to interpretive bias. E.g. M. Bietak, according to Tell el-Dabᶜa stratigraphic levels, strongly suggests that the period MM IA is contemporary with the Early Middle Kingdom, MMIB with Dynasties XII and XIII and LM IA with Dynasty XV to early Dynasty XVIII, which latter is then contemporary with the LM IB period (Bietak 1995, Fig. 1).

S. Manning (2002, 742) synchronizes both regions differently, deeper in time. He asserts that LM IA cannot be connected with Dynasty XVIII but only with Hyksosian SIP. He supports his assumptions by using the radiocarbon dates and suggests that LMIA lasted from 1689/1680 to 1610/1590 and not to 1480 BC.

The stratigraphic sequences in Avaris support the classical dating and a different overlap of the single phases of both regions. It is generally true that Minoan archaeologists and European prehistorians tend to accept the deeper (high) radiocarbon dates while Egyptologists prefer the conventional (younger, low) ones.

We also cannot place excessive reliance on the imports from the Aegean into Egypt and Egyptian items in Crete. Although they prove that there was contact between elites, and it is especially important for Crete, the Aegean was at the periphery of Bronze Age state civilization. Contacts between Egypt, the Near East and Cyprus were much more intensive and those regions effectively formed one cultural *koine* as can be inferred from the intensity of interchange of artefacts. Even so, the synchronism of these regions is not as simple as it may look. There are methodological problems; how to evaluate the imports, how to understand the forms and intensity of the contacts, how to consider their dating (more about the method in Chapter 3). Here, I would like to mention the opinion of Prof V. Kruta who is facing similar problems with dating single items placed in Celtic graves. He considers that it is necessary to date the cemeteries as a general context because each item bears witness to something different, had a different pathway into the grave context, and it is reasonable to assume that the people who placed all the items into the graves were not necessarily directed by the age of the things. The meaning, the importance, the sense of each item lay in different spheres for them.

I also agree with the opinion, expressed in Manning et al. 2014, 1165, that chronologically useful Egyptian items are, in fact, very rare in the Aegean during the relevant period.

2.2.3. Minoan contacts with Asia Minor and the Near East

H. Kantor (1947) first raised questions concerning second millennium contacts between Eastern Mediterranean regions. Following in her footsteps, more than half a century later, the topic was explored at a number of international meetings (Cline and Harris-Cline 1998; Mynářová 2010; Mynářová et al. 2015). However, evaluations of the intensity and importance of such contacts tend to be rather subjective. There is a limited number of definitively Minoan objects in the Near East (Sørensen 2009, 267), and objects of Near Eastern origin are even more rare in the Aegean region, despite appearing as early as the MM period (Betancourt 1998, 7). However, it seems that the Minoans dominated Aegean trade with the Near East and Egypt during the Second Millennium B.C. (Bass 1998, 184–185; Cabet 1998, 106–108). The character of those contacts is still defined mainly on hypothetical and theoretical criteria. Items which have survived in archaeological contexts were probably very rare objects from the trade between East Mediterranean and Aegean elites. They were moving, trading and exchanging items related to the metal industry, from raw materials to elaborate objects, and other luxuries, such as textiles and musical instruments. At the same time, non-material values, such as symbols, aesthetics and ideas, and people, especially skilled craftsmen, artists, astronomers, engineers etc., also moved around the trade routes. However, only a very small section of society, including couriers, merchants and maybe even artists, actually travelled regularly (Betancourt 1998, 8; Barber 1998, 16; Caubet 1998, 106–108). The existence of an international fashion, iconography and also language, shared by the local elites of the region, may be presumed (Betancourt 1998, 7; Caubet 1998, 109–110). Crete was probably mentioned in Mesopotamian archive records (Niemeier 1991, 199 with references to original sources in supra 89–92).

The evidence for these contacts once again provides an opportunity to investigate the potential for synchronization of the regional chronologies in order to find some chronologically fixed points.

Mesopotamian chronology is conventionally based on texts, eponym lists, king lists, dated documents, synchronism with other regions and royal inscriptions. The Near Eastern texts are less accurate before 1000 BC and the absolute chronology is based on assumption and deduction. Two different systems were created and both are in use – a high and a low chronology with quite large discrepancies, e.g. the dates for the reign of Hammurabi of Babylon, according to the high and low chronologies, are about 150 years apart[27] (Hunger 2009, 145–149).

The experts working in the field agree that there is conflicting evidence for Mesopotamian chronology. Pottery development, as we understand and interpret it, suggests a relatively low chronology, dendrochronology a higher and astronomy a very high one. For the moment, it is impossible to decide which is correct and why (Hunger 2009, 152).

The reference chronological system for all the Near East is the Babylonian absolute chronology. The Babylonian calendar was built according to observations of the planet Venus, which couldn't always be absolute or perfect and it is necessary to deal with even larger deviations than for Egyptian chronology. Discussion about the accuracy of Near Eastern chronology is still ongoing, which is not surprising given that, for some periods the difference between the high and low chronology can reach as much as 200 years.

As mentioned above (Chapter 2.1.1), a new dendrochronological/radiocarbon project has recently been published. The authors conclude that the Middle- and Low-Middle Mesopotamian chronological scale is correct. They place the death of Šamši Adad I in 1776–1768 BC (Manning et al. 2016).

Where the general chronological difficulties of the second millennium BC relate directly to the problem of determining an absolute date for the Minoan eruption, there are two sites cited as crucial or, at least, very important: these are the palace of Alalakh in South Asia Minor (contemporary Turkey) and the urban center of Tel Kabri (contemporary Israel) where frescoes and painted floors of Aegean style were recovered.

2.2.3.1 Palace of Alalakh

Fragments of frescoes of Minoan style (Fig. 34) were found by the excavation of the site Tell Atchana in South Turkey on the Syrian border, which was identified as the ancient Alalakh. Excavations there started quite early. Leonard Woolley excavated the site from 1936–1939 and from 1946 -1949 but the quality of field work and final publications were affected by the events of World War II (a preliminary report was published in the Illustrated London News, 2. 12. 1939/833; Wooley 1953, 1955). Much later, in the late 20th century, a team sponsored by the University of Chicago started surveys again and has conducted excavations, led by K. Aslihan Yener, in the early 21st century. She is now leading work sponsored by Mustafa Kemal University and the Turkish government (http://www.alalakh.org/intro_alalakh.html).

The palace of Alalakh was situated on the periphery of the Hittite Empire but was not a part of it. However, the location was favourable nor only for permitting but also for facilitating contacts with Hittites, Cyprus and the Aegean. Alalakh was mentioned in many literary sources produced in other centres but significant literary documents were also found on the site itself. One of the most important sources is the so-called Alalakh Codex found in strata IV and VII which belong to Near Eastern LBA – MBA (Gates 1987, 60; Niemeier and Niemeier 1998, 69 -71; Manning 1999, 341–360).

Very fragmentary frescoes were found in LBA contexts of strata IV and VII. The frescoes of stratum VII are made in Aegean style (Fig. 14) and are traditionally classified as Cretan LM IA style painting but efforts to date wall paintings accurately seem to be futile due to the fact that only a few small fragments were found. The problem of destruction horizon dating, or the dating of the moment when the frescoes were consigned to the archaeological record, is usually quite clear, at least on a relative scale[28], but the moment of a fresco's creation is a huge problem. Firstly, for how long was each fresco displayed? They could be repaired and/or repainted several times, as were the Knossos Throne Hall frescoes. We also do not have a sufficiently large collection of well dated frescoes to be sure that we can date according to the stylistic features presented on them. It is certainly more correct to say that the Alalakh frescoes reflect the Minoan wall painting style of MMI B – LM II periods rather than to date them accurately (Niemeier and Niemeier 1998, 69 -70; Blakolmer, *pers. comm.).* The frescoes in the palaces documented the wealth, prestige and power of their owners. (Brysbaet 2008; Cline et al. 2011) I am, therefore, convinced that we cannot assume that they were only used for a short time.

However, it is not only the frescoes which make stratum VII so important for the synchronism of the Near East and Aegean, literary documents were also found there.

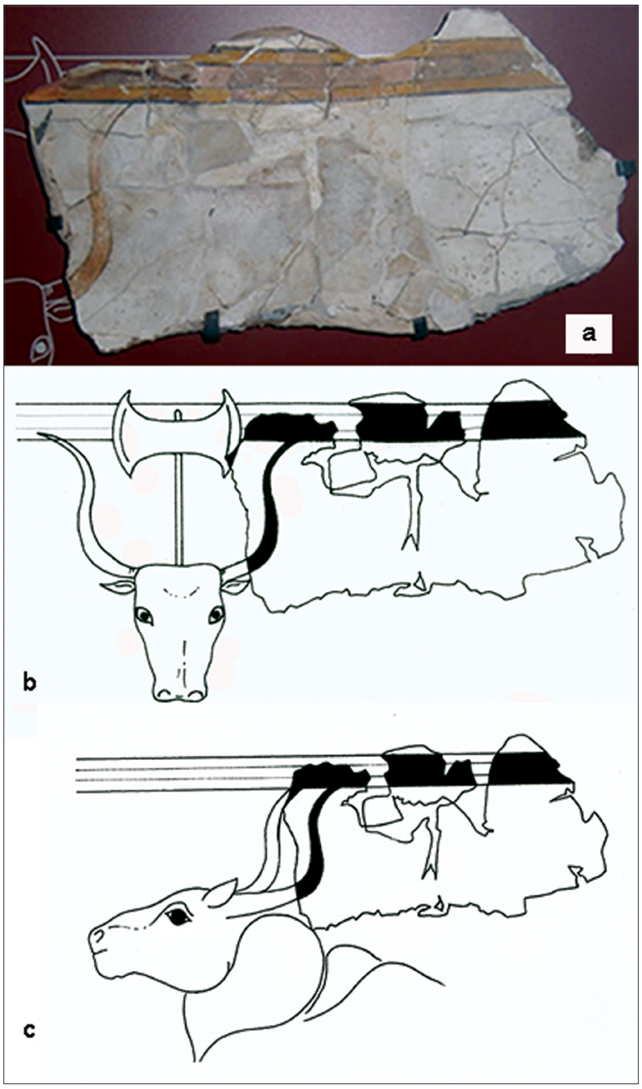


Fig. 34 / Possible reconstructions of an Alalakh Aegean style fresco: a) fragment as found, b) Niemeiers' reconstruction (Niemeier and Niemeier 1998), c) other possible reconstruction. (Illustration by author)

How, then, can these strata be dated? A combination of typological and historical dating methods has been used to try to place the Alalakh stratigraphy within the historical frame of the region. L. Woolley dated stratum VII to 1780–1730 BC, ergo to the period of the 1st Babylonian dynasty's reign. But it seems today that he was probably wrong and this dating would be too early (Niemeier and Niemeier 1998, 69 -70).

The name of Yarim-Lim, who was probably a grandson of Yarim-Lim I of Yamhad, appears in the cuneiform records of Alalakh stratum VII as ruler. This dynasty can be chronologically compared with the Babylonian King Hammurabi and Zimri-Lim of Mari but both of these are at least one generation earlier.

A seal of King Šamshi Adad I,.which is likely to be contemporary with Phase IB of the period of Waršama of Kültepe, was found at the site of Sarikaya in Turkish Acemhöyük. The palace of Sarikaya was built around

1725 and the Waršama palace in Kültepe around 1810 BC. These dates broadly overlap with the range of possible dates for Hammurabi of Babylon's accession to the throne in 1848 (high chronology), 1792 (middle chronology) or 1728 (low chronology) BC. According to literary sources, lists of kings, genealogies and archaeological comparisons, dates for the reign of Šamshi Adad I are 1864–1832 or 1808–1776 or 1744–1712 BC. New re-dating of the second millennium BC in Anatolia and Mesopotamia based on radiocarbon and dendrochoronological cross dating suggests that Šamši Adad I died between 1776–1768 BC (Manning et al. 2016, 22). The sources inform us that he was on throne for 33 years and his last year in power was contemporary with the 17th year of Hammurabi's reign. The cuneiform tables from Kültepe fix the date of his 1st year on throne to 1810 BC. The historical evidence makes it almost certain that Hammurabi of Babylon was a contemporary of Zimri-Lim of Mari, Šamshi-Adad I of Assyria and Yarim-Lim I of Yamhad. The latter's successor was Hammurabi I of Yamhad and he was succeeded by Abba-El I who was a contemporary of but slightly older than the Yarim-Lim of Alalakh VII, who was probably his brother (Manning 1999, 350, Fig. 65).

The synchronism of the various Near Eastern regions is a complex issue and efforts to determine the correct absolute chronology via dendrochronology have been made (Manning 1999, 345). General syntheses for the Near East try to combine historical and archaeological dates with astronomical observations (Gasche et al. 1998).

King lists and genealogies seem to indicate that Yarim-Lim ruled at Alalakh from 1681/1651 to 1657/1619 BC, giving a terminus post quem for Alalakh stratum VII, which, according to L. Woolley, represents 50 or, at most, 75 years (Wooley 1955, 385). Other writers seem to accept a similar timespan: i.e. 1661–1591 or 1637–1559 BC (Gasche et al. 1998) but some would extend it beyond 75 years to as much as a century (Niemeier and Niemeier 1998, 70).

This information can be compared with sources of Hittite provenance which document that the Hittite king Hattusilis I destroyed Alalakh and later on invaded Syria. The dating of those events has not been generally agreed and we should bear in mind that Hittite chronology is under revision to this day (Müller-Karpe 2003, 383; 2009). The reign of Hattusilis I was dated approximately to 1595–1550 (Kühne 1987) but. T. Bryce (1998) uses a chronological system which shifts it to about 3 generations earlier: 1650–1600 BC.

It should be underlined that the events which resulted in stratum VII lasted for a long time and the frescoes could have been made at any time during this period (Cline et al. 2011, 256–257), and that the different scales of Mespopotamian chronological frames and scales are floating within 150 years.[29]

The historical dates can be combined with chronological scales, deduced from archaeological evidence of typological progression and stratigraphy, which confirm the relative chronology and sequences of the single phase and support the connections mentioned in the literary sources.

There is characteristic burnished pottery, the so called Bichrome Ware, imported from Cyprus, within Alalakh's stratum VII.

The typological phases of Bichrome Ware on Cyprus have been worked out in detail. The first phase of Bichrome Ware production can be placed in the Middle BA with an overlap into the Late BA. This type of pottery was also present in deposits of stratum D/2 in Tell el-Dabᶜa. This would make Alalakh VII contemporary with the Hyksos period in Egypt, probably with the last century of Hyksosian hegemony over the Lower Egypt. It could, therefore, be expected that White Slip Ware would also be present in stratum VII but it is totally absent, as is TY Ware. Only in stratum VI were two atypical fragments found and there was one rhyton fragment in stratum VII. The ceramic assemblage of Alalakh VII can be dated to the Syrian MB II period on a relative basis (Gates 1987, 66).

This means that the absolute dating of stratum VII in Alalakh remains open. S. Manning (1999, 341 and farther) tried to fix the ceramic sequences using Cypriot ceramic chronology and concluded that Alalakh VIA which follows stratum VII, should be contemporary with the end of LC IA and early IB. He worked mainly with Red Slip Ware and Bichrome Ware. In absolute chronology we can settle on the end of the 17th C after Manning (1999, 341 and farther).

Stratum Alalakh VIA was assumed to be contemporary with Syrian MBII and Alalakh VII with the late phase of MBII. Syro-Palestinian MB II should align with LCIA and LM IA (Gates 1987, 66 -71; Manning 1999, 341–366,).

It is extremely difficult to synchronize the Near Eastern chronology with Hittite chronology, where there are also several chronological systems in use, from High to Low, as is the case throughout the region, e.g. the options for Hattushilis I's reign range from 1575 -1540 BC (e. g. Kühne 1987) to 1650–1610 BC (Bryce 1998, summary of opinions Müller-Karpe 2003, 383–394, spec. Fig. 1)

Scarabs of Hyksos kings were found in stratum VI at Alalakh, which further corroborates synchronization with the Hyksos period, ergo SIP. (Gates 1987, 80).

Finally the fresco found in stratum VII, mentioned above, was dated stylistically as characteristic of the Neo-palatial fresco style and the absolute dating of this stratum was put at 1650–1575 BC (Niemeier and Niemeier 1998, 70). This option appears possibly to have been chosen in order to support the early dating of the LMIA period and the Santorini catastrophe. It is a possible date, but for the moment there is little real evidence. The chronologies of all the kingdoms and other polities of the region are still quite "fluid", their chronological systems have serious "plasticity", or are not actually fixed in time at all. It can be concluded that, till now, all the regions mentioned are "fighting" with the absolute chronology of the 17th and 16th centuries BC. It seems reasonable, therefore to conclude that, far from the Alalakh stratigraphy providing help with absolute dating of the 17th – 16th centuries BC in the Eastern Mediterranean, the dating of the Alalakh stratigraphy is itself in need of help.

2.2.3.2 Tel Kabri

The site of Tel Kabri (Kempinski et al. 2002, Cline et al. 2011), a city, placed in a prominent position, which was a gateway community and the most powerful polity in northern Canaan, can be compared with Hazor or even Tell el-Dab^{c}a (Cline et al. 2011, 258) and may be one of the most important elements for synchronism and absolute chronology of the 17th and 16th centuries BC in the Eastern Mediterranean. Tel Kabri is placed in West Galilee and it is possible to identify it with Biblical Rehob. It lies on an important trading route later known as the Via Maris. The first fortified urban center is dated to the MBA and already was about 32 ha. in area. It was destroyed and abandoned in Palestinian LBA IIB.

Painted floors imitating floor tiles were recovered in the central yard of the palace. **(Fig. 35)** The fresco technique was used and the decorative pattern is made in red, yellow, brown, grey, black and blue colours. Analogous decorative motifs, colour ranges and techniques are known from Crete and Santorini and spectrographic analyses have shown that the pigments have the same composition. The floor surface was significantly disturbed but some parts were still well preserved or could be reconstructed. The painted squares, imitating ceramic tiles, are circa 40 × 40 cm. Yellow and white tiles are placed as on a chessboard. The earliest such painted floors are known from the 'Room of the Loom Weight Deposit' in Knossos and are dated to MMII – III. Painted floors were recovered in Aktrotiri as well, where they are dated to LM IA and, in Knossos dates of LM IB are quite usual. The floors found in Tel Kabri belong to the destruction horizon of MB IIB. Motifs used there – crocuses or lilies – were very popular as late as the LM IA period. It is unlikely that such a similar combination of technique, motifs, colour range and composition would be the result of just simple inspiration or imitation; a more probable explanation would be that the floor was made directly by Cretan artists (Niemeier 1991, 196–199; Niemeier and Niemeier 1998, 72–73).

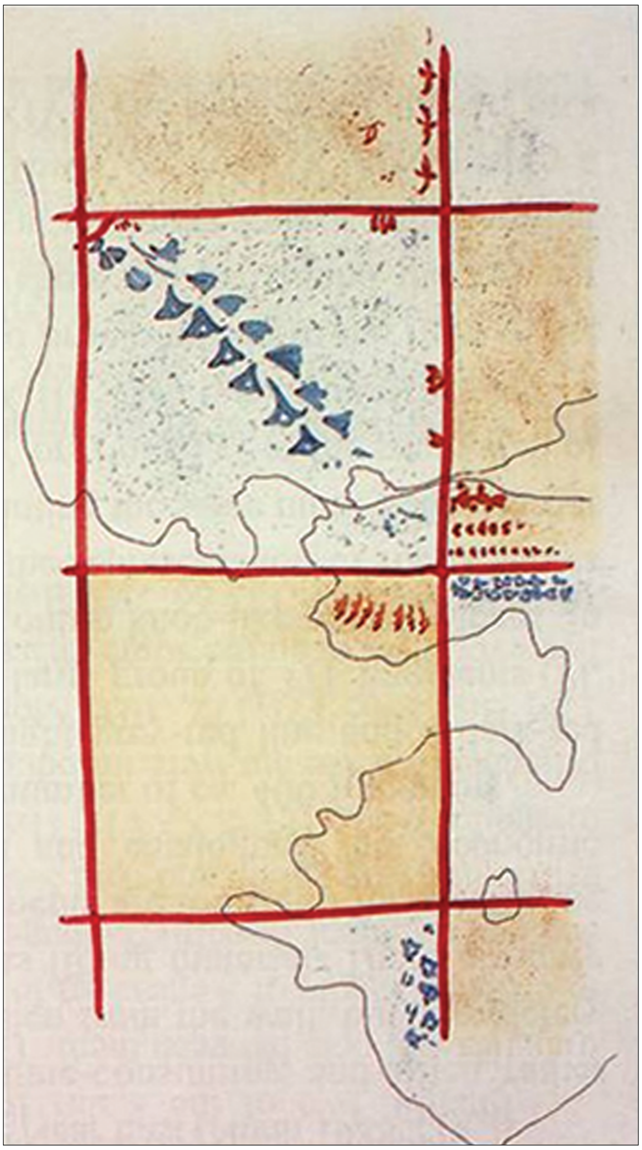


Fig. 35 / Reconstruction of painted floor from from Tel Kabri. (After Niemeier 1991 and https://digkabri.wordpress.com/excavations/)

During the excavations in 2008 and 2009, more than 100 new fragments of wall and floor plaster were uncovered (Cline et al. 2011). The first group, which was found in the area D-West, comprises small fragments covered in green and brown paint. The excavators suggest that they come from the depiction of a hilltop within the landscape illustrated in a miniature composition and that they follow the Aegean conventions for depicting landscapes. They correlate them with Theran art. Other fragments from area D--South are also covered by multi-coloured painting, done with great precision. The authors of the painting were excellent artists, who used the real fresco technique, with multiple layers of colours "just as would have been done in the Aegean", according to the excavators (Cline et al. 2011, 251). They recognize parallels in Knossian frescoes. The fragments covered in blue paint may have originally come from a picture of a griffin, wing of a bird, flying fish or hand with long fingers and nails. Some of the fragments were painted in various colours, outlined in black, which is a characteristic element for Aegean depictions of architecture. (Cline et al. 2011, 252–256). Unfortunately, the Kabri fragments in blue are too fragmentary to be read with certainty but their finding is very important in relation to the chronological framework. Fragments found in the D-West area, the north part of the palace, appear to have been found in situ but not in their original position. They too are fragmentary and some are lying with the painted side down. They were probably reused as a temper within mudbrick material during the rebuilding of the last palace. As we know, this last palace was undecorated and its final destruction occurred in the later MB II phase (Kempinski et al. 2002, 120). The plaster fragments were accompanied by a fair amount of Cypriot White Panted ware, typical for the MB period, but the frescoes cannot be dated to the final phase of the palace (after Kempinski et al. 2002 phase 3c). Instead, all belong to a preceding phase (Kempinski's 3b), at the end of which an extensive renovation program took place. The frescoes were made during the 17th century BC. (Cline et al. 2011, 254–257)

The questions remain if it was possible that Cretan artists came to Tel Kabri palace and, if so, how, why and when they came. Literary sources seem to be very helpful in this point. Around 1800 BC the king of Ugarit sent one of his "young men" to Mari with reports about a spectacular palace of Zimri-Lim, which was decorated with frescoes (Niemeier 1991, 199). In Zimri-Lim's palace similar floors were also found (Niemeier 1998, 73; original publication: Parrot 1958, 109).

Ugarit was known to Cretans. They obtained tin there, according to tales from Mari, which also spoke of metal vessels and weapons manufactured on Crete. Such luxury goods were mentioned in the time-frame encompassing the reign of Zimri-Lim to the Mesopotamian kings. (Niemeier 1990, 120–124; 1991, 195–196).

Cretan imports were found on many sites of the Near East: e.g. two silver chalices in Byblos, Proto-palatial polychrome pottery in Ugarit, Quatna, Hasor and Byblos (Niemeier 1991, 196)

The Ugarit mythology speaks about the great fame of the Cretan artists. The goddess Anat is said to have sent a courier called Cadesh a Amur from Byblos on a long overseas journey to find the god of craftsmanship – Koshar a Chasis – and to invite him to decorate the palace of the god Baal with the most special artistic items. Koshar a Chasis was supposed to have reigned in the land of *KPTR*, read as Kapthor, which is usually identified as Crete. The tablets where this story was written are later in date, from the first half of the 14th century BC, but the myth can be significantly earlier. The god's name Koshar a Chasís has been translated as Master Builder and Caster. (Niemeier 1991, 199 with references to original sources in supra 89 – 92). This personality could be connected to the myth about the Cretan Talos, the iron man destroyed by Theseus, according to Greek classical mythology.

It seems that Cretan artists and craftsmen had an international reputation due to their abilities and there is plenty of information in literary sources about the traveling artists, who were sent from king to king to provide their services. These exchanges were part of diplomatic conntacts (i. e. Niemeier 1991, 199–202; Bietak 2008; Cline et al. 2011).

Tel Kabri, according to its excavators, was finally destroyed and abandoned shortly before 1600 BC and the floors must surely have been painted before that date (Niemeier 1990, 120–126; Niemeier 1991, 197), or, more probably, in the preceding phase (3b), as indicated by the new excavations, cited above.

Does this chronology for the Kabri frescoes have an impact on Aegean chronology at all? The answer should be yes. Kabri is to date the only site in the ancient Near East that continues to yield Aegean style frescoes dating to the Middle BA. The LB AI stratum in Kabri predates the advent of the New Kingdom in Egypt. The frescoes must have been made deep in the 17th century BC. (Cline et al. 2011, 257–258). Kabri is one of the key sites for the synchronism of Aegean, Asia Minor's, Near Eastern and Egyptian Bronze Age chronology. However, it cannot add primary data to the problem of the absolute dating of the Santorini eruption. This event left no traces in palace of Kabri. W.-D. Niemeier (Niemeier and Niemeier 2002, 266–267) is convinced that the Kabri stratigraphic sequences support the high chronology, though some other authors are more wary, saying that it is too early to answer that question (Cline et al. 2011, 259).

2.2.3.3 Closing notes on Aegean – Near East contacts and chronology

Frescoes found in many of the Near Eastern palaces are very important, albeit their chronology remains significantly uncertain and spreads over a lengthy timespan.

Allow me to repeat here that the Tell el-Dab'a frescoes decorating palace F and part of palace G, in their early palace phase C/3 (stratum d) were made in the Aegean style and are now dated by the excavators to the early part of the reign of Thutmose III, ergo 15th century BC (Bietak 2007a, 38).

Frescoes in Quatna were made in both Aegean and local styles and belong within the Late Bronze Age; in absolute chronology the 16th and 15th centuries BC (Bietak 2007b, 280–282; Brysbaet 2008, 99 -100, Pfälzner 2008a, 2008b, 2008c).

Only the Alalakh – stratum VII frescoes can possibly be contemporary with those at Kabri. It is very difficult to match the historical and archaeological records in order to reach a close fitting absolute dating for those frescoes (Manning 1999, 349).

However, the frescoes do help to synchronize the chronological systems of Crete and the Near East and this may eventually be used to establish an absolute chronology for the Santorini eruption. It is impossible to date them perfectly but all can be classified as frescoes of MMIII – LM IB style (Neo-palatial; Cline et al. 2011, 259, 280). It should be kept in mind that artistic styles and fashions could have survived for a long time, while the different abilities of each individual artist and the probable lengthy display of each fresco make accurate dating extremely difficult. However their presence demonstrates the existence of a relatively stable network of power elites across a large region. Knowledge of how societies were operating and co-operating helps to evaluate the relative chronological options and instead – and mainly so – establish the absolute chronological frame, which is necessary if we want to compare the different entities directly.

The chronological synchronism and the character of connections between Crete, the Aegean, Asia Minor and the Near East are crucial to our understanding because they created the circumstances from which the Iron Age societies of the region arose. Unfortunately, even nowadays, these correlations remain “very shaky” (Cline et al. 2011, 259).

2.2.4 Cyprus

Cyprus was one of the main players in the second millennium East Mediterranean. Intensive contacts are traceable in all directions from this island, which enjoys a strategic location in the basin of the Eastern Mediterranean, and, although it is not, strictly speaking, central, the majority of sea routes must cross it. Cyprus was rich in raw copper which gave it an economic advantage and fixed its pre-eminent position in the international trade network, on what was then a ‘global’ level, during the entire Bronze Age. Cyprus was constantly in contact with Asia Minor, the Near East, Egypt, the Aegean and also the Western Mediterranean.

Despite the position of Cyprus within the inter-regional trade network in raw materials, there are relatively few items of foreign provenance found in Cyprus and not many exported artifacts from the island have been found in other regions: there are certainly fewer than expected and those which have been found are not chronologically sensitive at all, despite the great hopes attached to special types of Cypriot pottery, called White slip ware and Bichrome ware, and their imitations and derivatives. These pottery types connect Cyprus with Egypt and the Near East and have been found on almost all excavated centres throughout the Eastern Mediterranean. However, in the Aegean and on Crete there were literally only a few fragments, on Santorini one complete bowl, as mentioned below (Wiener 2003, 367 with further bibliography mentioned in *suprae 11, 16, 17*). The largest collections outside Cyprus were found in Tell el-Dab^{c}a (Avaris) (Maguire 1995) and in in Tell el-Ajúll (Fischer 2009) but there are about 40 sites in Levant and Egypt where Cypriot pottery was imported during the Middle and Late BA (Maguire 1990, 92).

On the other hand pottery from Egypt and the Near East was found in Cyprus (Manning 1999, 323–325). Bilateral contacts existed during the entire MC III – LC IB period (~ LM IA – II, LH I – LH IIB, Dynasties XII – XVIII, Syro-Palestinian MB IIB – LB).

Until quite recently the chronology of Cypriot prehistory was very vague and also extremely complicated. Only a limited number of stratified settlements had been recognized and excavated and the political situation in Cyprus has prevented intensive research in the north for a long time. Despite the continuing political problem, the archaeological situation is now changing. A large settlement, i. e. Maroni-Vournes (Cadogan et al. 2001, 75–88), and the shorter period settlements of Enkomi and Toumba tou Skourou (Eriksson 2001, 61) have been excavated and studied. Comparative studies with sites in the Delta (Tell el-Dab^{c}a), the Sinai (Tell el--Ajjúl) and the Hittite Empire have been undertaken. The need for a detailed Cypriot chronology and synchronism with other regions remains very real. Methodologically, Cypriot luxury pottery from the wider region is placed within relative chronological scales, absolutely dated from the contexts in Egypt and the Near East, wherein it was found, these data are applied to parallel material in Cyprus and then the Cypriot absolute chronology is again used to cross-check Egyptian and Near Eastern chronological scales. This reduces the methodology to a circular argument and renders it, or at least the final step in it, useless. The Cypriot pottery can be only used as an indicator of relationships in the wider frame of relative chronology.

2.2.4.1 Specifics of White Slip Ware and related pottery types

The main characteristic of this pottery type is dark painting on a light surface, which was a common fashion of Aegean painted pottery of the Late Bronze Age. White painted ware, the precursor of WSW, is characteristic of the Middle Bronze Age and belongs to a pottery family, which, on Crete, is called Light-on Dark, with which it is contemporary. WSW, which is the same as Dark-on-light Aegean pottery, concludes in the mid 12th century BC. WSW is very uniform throughout its existence. The main vessel type is a semi-globular bowl, around 20cm in diameter, with horizontal chicken-breast shaped handles. From the earliest phase, the vessels were covered in white or buff slip and painted with orange, red and, later, brown linear ornaments 'hanging' from the rim and, later, in vertical bands. WSW of the early phases (Proto-WS) was fired at a relatively low temperature and was quite porous. WSW I and II pottery was instead fired very high (1080 °C). Experimental evidence indicates that this was probably pottery used for serving food. The porous matrix absorbs liquids and even the well fired vessels cannot retain liquid for more than 7 hours. Moreover, their size seems to be more convenient for eating than drinking. (Karageorghis 2001, 9–11). These bowls are usually found in large numbers in public rooms, together with bones of birds, fish, sheep and goats. In later phases other shapes were also made: these were craters and jugs which were then either used as burial goods or were used during funeral drinking rituals, in the same way as the craters and jugs of Mycenaean culture (South and Steel 2001, 65–69).

WSW has been divided into three phases: Proto--WS, WS I and II. Proto-WS ware was defined by V. Karageorghis (1965), but this pottery was already known in the 1930s when the Swedish archaeologist E. Gjerstad studied the transition phase between White Painted and WSW obtained during excavations in Pendayia and Akhera. Proto-WSW is known from cemeteries in the Paphos region (Anarita and Kedare).[30] It should be dated to LC IA:1 with an overlap into LC IA:2 when WSI starts to appear (Åström 2001, 49–50).

One of the most important sites related to WSW is Sanidha lying on the slopes of the Trodos Mountains circa 520m a.s.l. in central South Cyprus. Evidence for the manufacture of WSW II was actually found in Sanidha. (Todd and Pilides 2001, 27–41).

This pottery was very popular and often exported but was produced for a very long time. There is also some question as to how this pottery was distributed and produced in Cyprus itself. S. Manning believes that the island can be divided into two regions with different development during the Bronze Age. East and South Cyprus were more developed due to intensive contacts to the East and the trade in copper. The North and West parts of the island were more isolated and retarded. (Manning 1999, 323–325; Wiener 2003, 368). According to him, when Enkomi was established, WSW was in regular use in North Cyprus. Enkomi was probably one of the trade centers facilitating contacts between the Near East, the Delta and Cyprus. (Manning 1999, 119–129, 125). However, there is no stratigraphic evidence to show that one region was producing pottery earlier than another and the explanation of a two-speed regional development remains merely a theoretical model. It is hard to believe that sites circa 80km apart, albeit divided by a mountain, would maintain a completely different material culture for 4 or 5 generations. (Wiener 2003, 368) but it cannot be excluded as impossible.

It seems, at least, to have been well established by stratigraphic sequences in Egypt and Cyprus that Proto-WS is contemporary with the Hyksos period and WS I with the early New Kingdom. (Bietak and Hein 2001, 174–191; Wiener 2003, 369)

2.2.4.2 White Slip Ware from Tell el-Dab^{c}a (Avaris)

Proto-WSW was found, sporadically, in Tell el-Dab^{c}a (Avaris) but mainly in poorly defined or disturbed contexts. One fragment was found in area A II, in grave 1. This was a child's pithos burial which should be contemporary with stratum D/2. (Eriksson 2001, 59–60). The most significant concentration of WSW was documented in stratum D/3. It was defined as WS I style and it should be correlated with LM IA (Bietak 2003, 23–27). The Cypriot pottery in Tell el-Dab^{c}a is not represented by WSW only. Other Cypriot ceramic types were buried within the Avaris stratigraphic sequences, particularly Red-on-Black Ware, plain wares, Cypriot Bichrome Ware and their imitations. (Maguire 1990; 1995, 54)

2.2.4.3 White Slip Ware from Tell el-Ajjúl

Tell el-Ajjúl, probably the Canaanite "Sharuhen", lies in Sinai and was first excavated in 1930-1934, by W. M. F. Petrie, and later, in 1952, by E. H Mackazie and M. A. Murray. A new excavation campaign started in 1999 but this lasted for only 2 seasons because of the political situation in the Gaza region. (Fischer 2009, 253)

The site produced the greatest number of scarabs from anywhere in the Levant. It also yielded a very large number of various imports, particularly from strata H1–8, where 941 ceramic imports, which document contacts with Mesopotamia, Cyprus, the Levant and even with the Aegean, were found. Pumice, shown by neutron activation analyses to be probably from Santorini, was identified on the site mainly in strata H1–5 with the most significant concentration being in H5, below which it is entirely absent. H5 can be therefore be accepted as the period during which the eruption almost certainly occurred.

Radiocarbon dates were obtained from each layer and the layer predating the eruption, stratum H6, was dated before 1600 BC. Also the dates obtained from stratum H6 (ends around 1600), H5A (mid 16th century), H4/3 (around 1500) agree fairly well with radiocarbon dates from the Minoan sites. They are about one generation earlier than we would expect when using Egyptian historical scale. (Fischer 2009, 263)

Red and Black Slip, Bichrome Wheel Made and, White Painted wares were found in stratum H6. When synchronizing with other regions we are dealing here with the end of MC and very early LC IA:1 and the period around Dynasty XV of the Hyksosian domination during the SIP.

The H5 stratum contained the largest quantity of Cypriot imports (87% of all imports are Cypriot). There are WSW, Bichrome Wheel Made Ware, Black Lustrous Wheel Made Wares, Chocolate-on-White Ware, ergo pottery of LC IA:2 phase. If this stratum dates the eruption, the high chronology seems again, to be more probable. There are, inevitably it would seem, discrepancies in the classification of stratum H5, which is classified as Hyksosian by some scholars or as contemporary with Thutmose III. (Fischer 2009, 265).

There is a very long tradition of Palestine Cyprus contacts documented covering, at least, the entire Hyksos period up to Dynasty XVIII (Bergoffen 2001, 145 –155; Fischer 2003, 263–290; 2009, 253–265).

2.2.4.4 White Slip Ware from other sites of Asia Minor and the Near East

Pottery of Cypriot provenance was found on Alalakh mainly in strata XII – VII but has still not been published (Bergoffen 2003, 395 –396).

A large collection of Proto-WSW was found in Megiddo in stratum X (Eriksson 2001, 60–61) and on other Canaan sites (all of them are listed in Oren 2001, 127–136).

WSW was also found in Cannatelo on Sicily, in a settlement of Thapsos culture, where.even fragments of Aegean pottery were deposited among the local wares (Vagnetti 2001, 101–103).

As far as I know, none has, to date, been found on Crete.

2.2.4.5 White Slip Ware bowl from Santorini

An optimist would expect then that Cypriot pottery in Aegean contexts would be found in sufficient quantity for the pieces of the puzzle to fall into place. Whatever the reasons, see discussion below, this is not the case, though there are a very few outstanding exceptions. One complete bowl, classified as WSW I, was found at Akrotiri, in the volcanic destruction layer (Fig. 36). Unfortunately, the bowl has not survived and, not only has it been lost but much of the information about its discovery is also missing. The bowl was first described by A. Dumont in 1872 and illustrated by J. Chaplain when they visited the French School in Athens. Other illustrations were made by the director of the French School E. Burnouf (in 1878) and by F. A. Fouqué (in 1879). Also in this year a photograph was taken by Adolf Furtwängler and Georg Loeschckee and they were the first to document its size: h = 11.7 cm. Maximal diameter = 23.7 cm, Rim diameter = 22.8 cm).

After World War II the bowl was never seen again (Merrillees 2001, 89–93).

R. Merrillees also discovered another WSW bowl, which was, plausibly, claimed to have been found on Santorini and was given to the Cairo museum. The bowl should have arrived at the museum in 1904 but today it too can no longer be found. Having consulted the surviving drawings in the museum catalogue R. Merrillees thinks that the bowls were not the same and that the Cairo bowl is stylistically of WSW II type.

The finding of the Santorini WSW bowl appears, potentially, to be very helpful for regional synchronization. The bowl was repaired in antiquity, meaning that it was probably in use for a considerable time and was treated as a special and valuable item (Merrillees 2001, 90). The bowl was classified as a very early import from Cyprus (Manning 1999, 119–129). However, although it fits into the relative chronological synchronism, it doesn't help with absolute chronology. A similar bowl was found in Hyksos stratum D/3 in Tell el-Dab[c]a but it was the later strata, containing pumice, which were thought to be associated with the Santorini eruption. If the bowl was in use for a rather long time, then synchronism between LM IA and early Dynasty XVIII cannot be excluded either.

Other fragments of WSWI were found in Phylakopi on Melos (Eriksson 2001, 61).

Considerable efforts have been made to find Cypriot pottery in Cretan contexts but without success. The

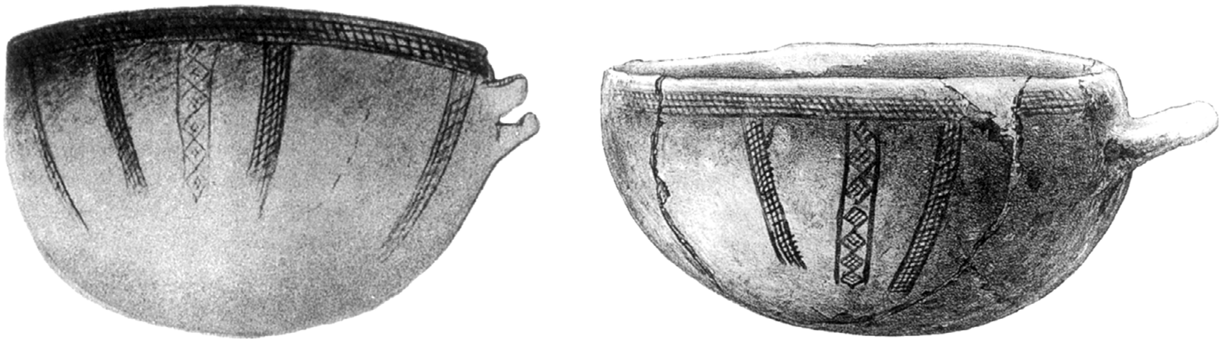


Fig. 36 / White slip ware bowl from the Akrotiri Volcanic Destruction Layer. (After Kemp and Merrillees 1980)

author has personally seen a small fragment of, possibly, Cypriot WSW among pottery from LMIA Papadiokampos. Even if this fragment proves to have come from Cyprus, it would represent an exception. It seems that Cretan pottery was traveling more to the North, to Mycenae, and that the contacts between Crete and the Eastern regions were accompanied by other goods: e.g ingots etc. (Betancourt 2008, 218).

2.2.4.6 Chronological conclusions from the Cypriot pottery

Today it seems that, after a long period of intensive research, the relative chronology has very probably been firmly established. The Proto-WSW period of LC IA:1 equates with stratum D/2 in Tell el-Dab^ca, stratum X at Megiddo and the SIP in Egypt. The absence of WSW I in the Aegean is connected with the disruption of naval connections in the period following the Santorini eruption. (Eriksson 2001, 60–64; Oren 2001, 139–140; Bergoffen 2001, 155, ad.)

Minoan imports in stratum Ic on the Maroni-Vournes settlement are accompanied by WSW I pottery, which supports the same synchronism: MM III ~ Proto WSW, LM IA ~ WSW I) (Cadogan et al. 2001, 78).

In the period when the Proto-WSW first appeared, contacts between Cyprus and Syro-Palestine already existed. It is also the period when the first real Cypriot urban centres started a rapid development (MC/LC), agricultural society became stratified and a class of rich merchants became established. Their wealth was created through a very profitable trade with the Near East and Delta. The main goods traded were probably Cypriot copper and timber. In the MC III period, centres such as Enkomi and Toumba tou Skourou were established, whose contexts provide evidence for contacts with Hyksosian rulers (Eriksson 2001, 52–53).

Another phenomenon of this period in Cyprus is the building of fortifications, which implies increased competition, a need to display both position and capabilities and the presence of dangerous rivals. That this period was probably dangerous may be inferred also from the presence of mass graves and the frequent appearance of weapons in archaeological contexts (Knapp 1986, 71).

Cyprus went through a period which mirrors that of the Mycenaean centres at exactly the same time. These transformations may have been brought about by influences from other regions but the results were the same.

The sparsity of evidence for Cypriot-Cretan contacts in LM I – II, mentioned above, is a very real problem. Cretan merchants were still using Cypriot copper during the Late Bronze Age but the Laurion quarries were probably the preferred source (Stos-Gale and MacDonald 1991; Stos-Gale and Gale 1992; Driessen and MacDonald 1997, 80; Gale et al. 2009)

2.2.5 Possible responses to the Santorini eruption from other regions

If the Santorini eruption had a global impact on climate then catastrophes would have arisen as a consequence of the eruption, which were certainly not perceived by the local populations. There is some information about particular effects and phenomena from even very far distant regions which could, at least in theory, be connected with the Santorini eruption. For example the so-called Bamboo Annals of the Chinese Emperor Chieh's period tell of disastrous hydrological events accompanied by very weird phenomena, such as dry fogs, dimming of the sun, frost in summer and abnormal cooling of the waters. There followed famines, crop failures, intense rainfall and floods. Many cities collapsed and, even 7 years later the level of water in the rivers was much lower than normal. These phenomena were supposedly observed 24 generations before 841 BC. If we allow 25 years for each generation, we would get a date of 1441 BC but climatologists set the date at 1600 ± 30 BC (Kuniholm 1990, 17; Friedrich 2000, 81). It is, of course, impossible to be sure that these phenomena can be connected directly with Santorini events and it stretches co-incidence to have a 200 year gap between historical dating and dating via natural science in China as well as the eastern Mediterranean.

The Santorini eruption and its consequences plausibly became part of some more or less contemporary, mythological stories. It is possible to identify the eruption and subsequent events with the prelude of the Exodus (i. e. Galanopoulos and Bacon 1969; Harris 2013) or as the driving force for the chain of events culminating in the departure of Hebrew populations from Egypt (i. E. Manning and Sewel 2002). The Santorini eruption has often been mentioned as a possible inspiration for the legend of Atlantis (Friedrich 2000; 2009). Such explanations have frequently in the past been employed by the authors of fantastic literature, popular culture, tabloid journalism and assorted mystics, cultists or even extremists, who have little knowledge of or respect for serious scientific topics.. But both legends, the Biblical exodus and the Egyptian legend reproduced by Plato, are part of the narrative tradition of ancient East-Mediterranean populations. The Bible was designed to convince the reader that the information which it contains is true and it has, in many cases, been confirmed that the events described were based in real contexts. Plato told the story about Atlantis around 360 B. C. The origin of the story according to the myth was in Egypt, where it was written down by a priest and was later read by Solon, who was the source for Plato.

The most common arguments against connecting the Santorini eruption with Exodus or the Atlantis myth usually say:

1. Events described in legends and myths are usually represented much more dramatically and as more catastrophic than they actually were. Thus they are not real descriptions of particular events because they are not objective, true and realistic. It is true that people often do describe natural events as total disasters. They usually describe what could have happened rather than what really happened. Their narratives are also full of fear and reflect deep-seated concerns. People have always feared nature, especially in times when little was known of how or why natural phenomena occurred. This was one of the prime motives for the creation of civilization, which appeared to establish control over and banish the vicissitudes of nature and its potential catastrophes. Mythology is full of stories about natural phenomena destroying civilization, i. e. floods, volcanos, winds, huge waves, marauding animals, diseases etc. (Torrence and Grattan 2002).
2. Events presented by legends or myths are usually applicable to any natural disaster and their chronological connection to any particular one is not possible. This argument could be applied to the description of catastrophes on the Ahmose Tempest Stele.

However, I am convinced that we generally do not work properly with mythology. The modern expectations of factual reporting providing answers to the questions of what, how, when and why are deeply ingrained and, when the expected data are not clearly presented, we doubt the entire concept. But such expectations are clearly inapplicable and legends and myths cannot be approached as "black and white". They are true but the truth is presented differently, understood and approached differently. The stories are not documentaries, they serve as metaphors, salutary and beneficial for the members of the society sharing them (Barber and Barber 2006). In the way the events are presented is displayed the way people understood time. It was a relative and transitory value and there was thus no necessity to place events precisely on a linear time scale. This approach to time is noticeable also in ancient treatments of the words of people, both alive and dead, the agricultural cycle of time and the creation of calendars etc. (Klontza-Jaklová 2011; Kruta 2015, 29–31, 174–184).

Certainly we can assume that the eruption of the Santorini volcano, as stored in the collective memory of the Late Bronze Age Mediterranean population, was a model of disaster, which was used in a whole series of admonitory stories indicating the consequences of 'incorrect' behaviour. Unfortunately, this topic, albeit both substantial and interesting, must be left aside because, at least for now, it cannot help elucidate our current concern with the absolute chronology of the event in question.

2.2.6 Correlation with other European regions.

Accurate dating of the Santorini eruption and with it the accurate dating of the LM IA and LHI periods has a very wide significance and is important for a large region. It is not a single, isolated problem within one small region but has impact on historical interpretations in the region of the Eastern Mediterranean and Aegean and thence to Central Europe (Makkay 1996). LM IA (~LHI) , the period when the eruption happened, follows the horizon of the shaft graves in Mycenae, which represents the main connection point of European and Aegean Bronze Age chronologies. Mycenaean culture had a significant impact on a very large area from the Balkans to Central Europe, and even as far as Scandinavia (Gimbuntas 1965; Harding 1984; Bouzek 1985; Kristiansen and Larsson 2005; Kostrhun et al. 2014), and the absolute chronology of those regions is almost entirely built on the Mycenaean chronological system. If we shift the date of LM IA and LH I one century deeper in time, we must then do same for the whole European Early and Middle Bronze Age. It is certainly notable that the monographs and synthesis of Moravian prehistory published in 1993 mention that the traditional dating of the Moravian Bronze Age was not supported by radiocarbon dates which are older (earlier) than expected (e.g.Únětice culture: Cezavy by Blučina: 1750–1600 BC, Věteřov culture: Buškovice: 1880–1530 BC, Blučina 1670–1660, 1640–1510; Velké Pavlovice: 1690–1590 BC and 1570–1530 BC). The authors of that book exclude these dates as wrong and prefer "fixed" Aegean absolute chronology. They explain the radiocarbon data as a statistical mistake and refuse to accept them at all (Podborský 1993, 237). The situation was similar in Slovakia where the authors of a similar monograph expressed the opinion that the radiocarbon dating method could not be attested or approved for this period because the dates were too early for the fixed Aegean chronology (Furmánek et al. 1991; 1999). In the latest volume summarizing the Bronze Age in Bohemia the authors accept the radiocarbon dates which were obtained from Early Bronze Age contexts and place the occurrence of the Early Bronze Age into the period 2350/2400–1750 BC. They ignore the archaeo-historical dates and clearly prefer the radiocarbon dates (Jiráň 2008, 28–29; the same applies to the last synthesis of Slovac Bronze Age: Furmánek et al. 2015, 15–16).

The simplified transfer of parallels from Mycenae to other European regions is not possible (Makkay 1996, 219–220, 225). Direct imports of items of Mycenaean origins are extremely rare in the Carpathian basin and Central Europe. Evidence is inferred from the possible transfer of technologies and ideas about the structure of power through mythological stories which are later observable in the use of symbols. (Kristiansen and Larsson 2005, Klontza-Jaklová 2012b)

3. GENERAL CONCLUSIONS

As shown above, the absolute chronology of the mid 2nd millennium BC is uncertain and represents one of the most complex problems of prehistory. The main question can possibly be simplified as: 'Does the problem lie in radiocarbon methods or in Aegean prehistory and Egyptology?'[31] The problem cannot be solved statistically: A higher probability cannot be directly interpreted as indicating a correct answer. It seems today that the majority tends to use the high chronology (= deeper dates) for the Santorini catastrophe, trusting the new radiocarbon dates obtained from a large number of Bronze Age sites, including those outside the Eastern Mediterranean. On the other hand it is impossible completely to exclude the arguments of classical archaeological methods and Egyptian absolute chronology reconstructed from historical sources. But what we really need is to be sure that the chronologies we use are correct and that means we need scientifically proven data. When saying "scientific" I refer to both physical and social sciences equally. As social scientists, we need to find methodologies and the type of finds and contexts which will allow us to test our interpretations and will produce results closer to the historical reality.

The actual questions can be defined as follows:

1. Did the Santorini eruption happen during the SIP or during the early Eighteenth Dynasty? In other words: Is the LM IA phase contemporary with the SIP or with early Dynasty XVIII?

2. Is it possible that Egyptian absolute chronology can have a larger deviation than has been assumed and, if so, when precisely does it begin to deviate?

3. If the Egyptian chronology is correct, why does the radiocarbon dating method provide incorrect dates?

Today there are basically two chronological charts (Table 7):

High chronology:

LM IA	Dynasty XIII – SIP
LM IB	Late SIP – early Dynasty XVIII
LM II – IIIA: 1	Tuthmose III. – Amenophis III.
End of LM IIIA:1	Amenophis III.

Low chronology:

MM III	Dynasty XIII – SIP
LM IA	Late SIP – early Dynasty XVIII
LM IB – LM II	Tuthmose III.
LM III A:1	Amenophis III.

With absolute dates for Crete:

High	CRETE	Low
1750 1700	MM III	1700 1600
1600 (eventually 1628)	LM IA	1500
1490	LM IB	1430
1430	LM II	1390
1390	LM IIIA1	1370/60
1300	LM IIIB2	1300

Table 7
High and Low synchronisms of Cretan and Egyptian relative chronologies.

Maybe the main problem is not when the event happened but where the mistake is; where lies the crossroads from which we took the wrong path. It is abundantly clear that an interdisciplinary and multidisciplinary approach is extremely important. Nevertheless, although physical science and the social sciences are in closer contact on the "Santorini issue" than ever, this relationship still requires a lot of work (Knappett 2011, 48).

After the analysis I have presented above, I am convinced that there are archaeologists who ought to revise their methodologies. We should reconsider the typological scales and entire system of parallels which have often been used automatically and mechanically. What has been dubbed "a common sense method" now seems to be giving rise to more and more special pleas and doubts appearing in the literature (i.e. Knappett 2010, 161, 213; Jung 2012; Cline 2014, 114). Although our relative typological scales are very precise we may well be failing in our understanding of how to use them in an actual historical process and it is fascinating how much work has been done on typologies and how little we understand their dynamics (Knappett 2011, 161). It seems that they don't "behave" in time and space as we expect (Knappett 2011, 213; Trnka and Lorencová 2016). A similar opinion was expressed more than 20 years ago by P. Warren: 'Absolute dating of these ceramic periods from artefactual evidence is far less precise than we would like.' (Warren 1994, 492) among others, e.g. Makkay (1996, 220), Muhly (2003, 17–23).

M. Wiener (2009b, 279) comments on the shapes of Aegean Bronze Age vessels: "Can each of these have been copied by Egyptian artists 50–75 years after they were superseded in the Aegean?" He implies that it is impossible, that it is too long a time lapse and thus that imports-exports represent quite precise points in time. But in archaeology, as in other disciplines, we cannot simply guess or estimate what seems to be plausible and what not. There are many examples today of major shifts of styles and fashions in time and space. We know that pottery made in Aegean in 12th – 13th century AD was copied by central European potters centuries later (in 16th century; Klonta-Jaklova, *in preparation*). Archaeologists divide the material into so-called chronologically sensitive types of artifacts and wares used for a long time. Changes in shapes and decorations have their logic but this logic is not universal, it is not valid for each type in each time and space. Some of them have incredible duration: e.g. trickle-decoration on Cretan Bronze Age pithoi, TY Ware in the Near East, transport amphorae from the Hellenistic period to the Middle Byzantine period and even later. The balance of benefit (not only in the economic meaning) must be very stable in those cases. But some other shapes and decorations can appear and disappear much more quickly and probably carry more sensitive symbolisms (Knappett 2011, 160). The point is: do we always understand which wares belong to the first and which to the second group?

As J. A. McGillivray (2009, 155) says: "for more than two centuries archaeologists have refined the Bronze Age Mediterranean historical framework by observing the relative order of superimposed levels on a series of sites. Next, they established inter-site relationships based on common cultural characteristics – primarily on ceramics, art and architecture. Nothing has changed. This is still how we verify our relative chronology." But maybe we should no longer do so without at least questioning its validity and applicability to the problem we address. Even this system, which looks so solid and with which we are all so comfortable, is not necessarily accurate and may not work linearly.

Today it is impossible to approach the problem as isolated and cut out from its context. Natural sciences and archaeological methods must look together for a united solution (French and Shelton 2009, 196–197). We must make every effort to understand the methodologies and limits of each discipline. Also we must be critical of our own methods and results; we must be strict with ourselves. What we are studying are people – individuals and societies –and people are not passive, they act, so the principles of human thinking are as important as the relative amounts of isotopes in their bones or the regularities of climate changes.

Going back to the Santorini issue, it is, firstly, essential to revise the earlier finds, since many mistakes are automatically transferred from publication to publication (Manning 1988, 24). However, it makes no sense just to keep discussing those same early finds so, as Manning (1999, 44) suggests, new finds and fresh stratigraphic evidence must be sought. The same stratigraphic sequences, from Tell el-Dab^ca (e.g. Bietak 2013a), Tell el-Maskhuta (Redmount 1995,), Tel Kabri (Niemeier 1990.), Alalakh (Woodley 1955; Niemeier 1991; 1996), Tell el-Ajjúl (Fisher 2009), are repeated again and again, including serious doubts about them (Krauss and Warburton 2009). It seems that it may be important to include more northern regions in the game, such as the Balkans or central Europe. One of the most important regions seems to be Macedonia with tells, such as Kastanas (e.g. Jung 2002) or Dikili Tash (Koukouli-Chryssanthaki et al. 2008)) and others.

Not only do we need new contexts and finds, we also need new methodologies. It seems that the way we currently work with parallels, imports and influences doesn't give always correct dates (Makkay 1996, 219–220) and connections and relationships, which mirror these, were more complex than we expect. Finds from rich graves are particularly problematic, as discussed above (Manning 1988, 24). Some years ago we were still using their ceramic styles as chronological and stylistic markers but it seems that the way past societies viewed this material, as producers and as users, is very different from the way we view it.

It is also notable, and far from logical, that the radiocarbon dates which we have obtained for prehistoric periods, are accepted without any doubts and yet for later periods, if they don't match with our assumptions, we tend to reject them as mistaken (Makkay 1996, 220; Guidi et al. 1996, 279). It is also true that the selection of only those opinions and results which fit a particular theory is commonplace (Manning et al. 2009b, 299).

Today it seems that the archaeological and historical scales are slightly shorter than radiocarbon based chronologies (e. g. for the Aegean: MacGillivray 2009, 156; for the Hittite Empire: Bryce 1998; Müller-Karpe 2003). The flow of time is one of the most important factors in history. Its understanding has immediate importance for contemporary societies and for predictions of the future. In the past, the correct chronological framework gives us the opportunity to study causal questions, both general and particular (Wiener

2003, 363). We cannot accept an approach which just rejects radiocarbon dates out of hand, nor can we take the opposite one and simply ignore archaeological methods or literary sources.

We might wonder that, in the case of dating the Santorini eruption and the problems of Late Bronze Age Mediterranean chronology, we can mobilize archaeological and literary sources, a quite dense network of regional interrelations, numerous dates obtained by scientists and still the issue remains such an open question.

This is not a fight, it is not a trial, nor is it a gamble; it is simply science. This means that we will know when we get to the correct answer because the method will give a result which we will be able to verify. However, for the present it is essential to remind ourselves that "Everything in archaeology is always momentary, fluid and flexible" (Hodder 1997) and that "archaeology is a continuously evolving field with new data and new analyses requiring the rethinking of old concepts" (Cline 2014, 118).

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1 Cornell University: Tree Rings, Kings, and Old World Archaeology and Environment. (Manning and Bruce (eds.) 2009); Copenhagen: Time's Up! Dating the Minoan eruption of Santorini. (Heinemeier and Friedrich (eds.) 2009); Halle: "1600–Cultural change in the shadow of the Thera Eruption?" (Meller et al. (eds.) 2013).

2 In Greek: Saint Prophet

3 In Greek: Big Hill

4 In Greek: Small Prophet Elijah

5 In Greek: Red Hill

6 In Greek: White Island

7 In Greek: Old burned (land)

8 In Greek: New/Young burned (land)

9 'Franks' in Byzantine literary sources are the Catholic western Europeans.

10 F. McCoy has expressed the opinion that the conditions for the eruption might have been established with the strong earthquakes during the MM period. A tectonic earthquake may have opened cracks as conduits for magma ascent from the melts deep in the crust at the subduction zone. About a century between these earthquakes and the eruption would be adequate for magma ascent of a viscous silica--rich melt to the surface. (2009, 89)

11 The time between intrusion and onset of the 1925–1928 eruption on Nea Kameni lasted 15–75 days (McCoy 2009, 79).

12 "*Tremor can be the final signal of an impending eruption, even for viscous magmas such as the rhyodacites of the LBA magma. They are an announcement that magma is in transit to the surface, and can continue throughout the eruption. Magma ascent rates for explosive eruptions can be of the order of 1- 3 metres per second, or only a few centimeters per second. For LBA Santorinini, Sigurdsoson et al. (1990) estimate a magma chamber 8–15 kilometers from the surface. Thus, once tremor started, the Bronze Age inhabitants may have had only hours before a vent opened and the precursor eruption started (assuming the more rapid ascent rate."* (McCoy 2009, 80)

13 "Tsunamis are not single waves, but sets, or packets, of perhaps five or eight waves within which one or two are larger and potentially damaging to coastal areas." (McCoy 2009, 86)

14 It the past estimates of erupted material were much smaller (e.g. Sullivan 1990, 114–119)

15 We must balance probabilities and choose the most likely. (A. C. Doyle, 1892: The Adventures of Sherlock Holmes)

16 P. Betancourt now concedes that the low (or lower) chronology is possible as well.

17 Project 1: „Co-ordination and Publication Office“, Project 2: „Data Management, Electronic Communication and Quantitative Methods“, Project 3: „Datum Lines by First Appearances“, Project 4: „Thera Ashes“, Project 5: „Chronological Data in Mesopotamia“**,** Project 6: „Astrochronology“, Project 7: „Dendrochronology“, Project 8: „Radiocarbon (^{14}C) Dating“, Project 9: „Egypt“, Project 10-11: „Israel/Palestine & Jordan „, Project 12: „Cyprus“, Project 13: „The Minoan Deposit Project“, Project 14: „The End of Mycenean Culture Project“, Project 15: „Stratigraphic Project Aigina (EH III-LH I)“, Project 19: „Stratigraphie comparée“ (http://www.oeaw.ac.at/sciem2000/index.html)

18 It is not automatically possible; local anomalies of microclimate or short time variations must be taken into account (Moody 2000, 52 Grove and Rackham 2003, 27–29)

19 Laboratory of Tuscon University

20 Baillie has only observed a similar extreme (shrinking of tree rings) 9-times in a 6000 year record.

21 J.A. MacGillivray (2009, 159) mentions that it corresponds with an acidity peak in a core obtained by the DYE3 station in Greenland absolutely dated to 1525±4 years but does not cite the original sourcet.

22 "I have explored the Thera quarries too, searching in vain for bits of pine or juniper, but when Friedrich's group did at last find a piece of wood, the Greek version of Murphy's low decreed that it had to be an olive tree." (Kuniholm 2014, 289).

23 Today other sources of S compounds include industrial pollution and nuclear explosions. These events are also traceable in glacier stratigraphy

24 VEI = the scale has 8 steps which are defined by the height of the column of tephra hurled up and the loudness of the eruption.

25 Recently written also as: Tell el-Daba or Tell el-Dab'a (Kutschera et al. 2012, 407) or Tell el-Dabca (Bietak et al. 2009).

26 But can the possibility that it was kept as an heirloom for a long time after its production and exported to Crete be excluded?

27 High Chronology: 1848–1806` Middle Chronology: 1792 – 1750; Low Chrornology: 1728–1686.

28 With some exceptions, such as the Tell el-Dabca layers containing fragments of painted plaster.

29 Ift the Manning et al. 2016 revision is correct and is accepted, the Middle-, or Low-Middle Scale will be valid for the region. However, this shift of Mesopotamian chronology doesn't support the very Low chronology of Tell el-Dabca.

30 See history of research in Maguire 1990, 22 – 33.

31 Kutschera et al. (2012, 407) pose the same question.

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5. LIST OF ABBREVIATIONS

BA: Bronze Age
EBA: Early Bronze Age
EH: Early Helladic period
EM: Early Minoan Period
LBA: Late Bronze Age
LC: Late Cypriot Period
LH: Late Helladic Period
LM: Late Minoan Period
MBA: Middle Bronze Age
MC: Middle Cypriot Period
MH: Middle Helladic Period
MM: Middle Minoan Period
SIP: Second Intermediate Period
TY Ware: Tell el-Yehudiyah Ware
VDL: Volcanic destruction layers

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7. SUMMARY

My primary aim in this work is to underline how vital detailed investigation, research and study of human activity continues to be in our efforts to reconstruct sequences and causality of historical events. Indeed, as the pace of change in our knowledge of the natural background to these historical events increases and is, in turn, affected by such research, its role could be described as crucial.

We operate with large datasets collected over almost 200 years of systematic archaeological activity but, despite the efforts of a veritable 'army' of scholars over the years, many of the so-called 'big' questions remain unanswered. I chose to focus here on the absolute chronology of the Late Bronze Age volcanic eruption on Santorini and its effects across the wider region. Why? We are all familiar with the event: a massive eruption of the Santorini volcano. Its relative chronology is also clear: (LM IA/IB). The primary impact, on the Aegean environment at least, can easily be documented. Yet we still cannot place the event within an absolute chronology and it is therefore impossible to establish how people reacted, or what changed in the social sphere, the economy and in the flow of history.

The absolute dating of the Santorini eruption is one of the most frequently discussed and studied topics of Aegean prehistory, especially since the mid 1970's, when the first radiocarbon dates from the region were published and the difference between those dates and archaeological/historical dates became clear. The question is much more than simply methodologically important; in this period in this region is a key point for understanding the Late Bronze Age in the whole of Europe.

I have, within this monograph, set out many arguments, facts and data and attempted to assess which are secure and which vague. I have tried to indicate where errors may possibly have arisen and identify those areas where there have been failures in aspects both of our research and comprehension.

As first there are presented chapters describing the natural circumstances, reconstruction and intensity of the eruption, together with an historical overview. Let us remember that the Santorini Bronze Age eruption has been evaluated as the most violent eruption of the last 10,000 years, with VEI = 6.9. The devastated island was not re-inhabited until the Geometric period, an hiatus of at least 800 years. The ash and tsunami deposits have been found on many sites on Crete and all the neighbouring regions, including Asia Minor, the Near East and North Africa, were impacted. Even the climate changed, for at least a number of years after the event.

This giant eruption left primary or secondary traces in archaeological contexts around the Eastern Mediterranean and it appears reasonable to suppose that determining its absolute date should be a simple issue. The eruption occurred at, and probably defined, the transition from the LM IA to the LMIB period. The absolute dates of the Aegean Bronze Age were connected to the Egyptian chronology and originally the eruption was dated to the mid-15th century BC but the radiocarbon dates suggested a much earlier ('higher') date, placing the event before 1600 BC. The first calibrated radiocarbon dates were followed by dendrochronological dates obtained from tree ring sequences and by glaciology studying Greenland ice stratigraphy. This problem is still with us and the arguments are summarised in the following table:

	Method	Suggested date of the eruption/chronology	Chronological accuracy		Chapters in the book
			"Pro"	"Cons"	
Hard Sciences	Radiocarbon	High	Large datasets from a wide region and from many and various labs. Great accuracy of measurement.	Calibration curve(s). Incomplete knowledge of impact factors (e.g. "old" C^{14}).	2.1.1.
	Dendrochronology	High	General accuracy of the method in particular circumstances. Good evidence of climatic events in global scale.	No local sequences. Olive wood used in Santorini.	2.1.2.
	Ice-core dating	High	General accuracy of the method in particular circumstances. Accurate for global events if chemically significant.	Unclear identification of the event(s) in the ice stratigraphy.	2.1.3.
Humanities	Egyptian chronology	Low	Literary sources. Historical calendars. Astronomical observations.	Gaps in literary documents. Different understandings of calendar. Discrepancies between historical and radiocarbon dates (17th – 15th century BC).	2.2.2.1.
	Literary sources	High & Low	Descriptions of volcanic events (e. g. Ahmose's Tempest Steal)	Unclear relationship with the Santorini events.	2.2.2.1., 2.2.2.2
	Cretan (and Aegean) and Egyptian exports/imports	High & Low	Aegean objects in Egypt and Egyptian ones in Aegean.	Longue durée styles and types. Problems of heirlooms. Old excavations with incomplete documentation.	2.2.2.4., 2.2.2.5.
	Cyprus chronology	Low	Cyprus pottery spread across the Near East and Egypt	Related to Egyptian historical chronology (cannot be accepted as independent).	2.2.4.
	Iconography	High & Low	Minoan iconography in Asia Minor, Near East and in Egypt	Impossible to date the so called Aegean frescoes stylistically.	2.2.3.1., 2.2.3.2., 2.2.2.3.
	Asia Minor's chronology	High	Literary sources and stratigraphy of Alalakh.	Synchronism with Aegean and Egypt.	2.2.3.1.
	Near Eastern chronology	High	Literary sources, astronomical observation.	Difficult synchronism with Aegean and Egypt mainly in SIP.	2.2.3.2., 2.2.3.3.
	European chronology	High	Large dataset of radiocarbon dates from independent measurements and laboratories.	Chronology depends on Aegean scales.	2.2.6.

Table 8
High or Low chronology? "PRO" and "CONS".

As shown above, the absolute chronology of the Santorini volcano eruption is still uncertain. There are serious doubts, mainly from the perspective of Egyptian historical dating scales. Although it seems today that the majority tends to prefer the high chronology, this cannot be directly interpreted as indicating a correct answer. In archaeology, as in other disciplines, we cannot simply present guesswork, or even a considered estimation of plausibility, as a result. This principle is accented in the book because it has, in the past, sometimes been overlooked by historians and archaeologists interpreting prehistory.

New radiocarbon dates obtained from a large number of Bronze Age sites, including those outside the Eastern Mediterranean, appear to exclude almost any date after 1600 BC. On the other hand it is impossible to exclude completely the arguments of classical archaeological methods and Egyptian absolute chronology reconstructed from historical sources completely. Stratigraphical sequences containing artefacts from different regions supporting both low and high chronologies cannot be rejected. All these discrepancies must be resolved since, logically, only one option is correct. This means that "someone" is wrong. But who and why? What do we know for sure and what remains unclear? From which point have we taken a wrong turn?

The actual questions can be defined as follows:

1. Did the Santorini eruption happen during the SIP or during the early Eighteenth Dynasty? In other words: Is the LM IA phase contemporary with the SIP or with early Dynasty XVIII?

2. Is it possible that Egyptian absolute chronology can have a larger deviation than has been assumed and, if so, when precisely does it begin to deviate?

3. If the Egyptian chronology is correct, why does the radiocarbon dating method provide incorrect dates?

And the main question can possibly be simplified as: 'Does the problem lie in radiocarbon methods or in Aegean prehistory and Egyptology?' I don't seek to denigrate the Egyptian chronology since I, as an archaeologist and prehistorian, am not competent to judge but, at present, it does seem that it may be necessary to consider its revision.

After the analysis presented in the book, I am convinced that at the moment there are archaeologists who ought to revise their methodologies – both prehistorians and Egyptologists. Although our relative typological scales are very precise we may well be failing in our understanding of their regularities, and how to use them in an actual historical process. Albeit we know that people don't operate within the simple universe described by Newtonian mechanics, and their cosmologies and mechanisms of deciding/resolving are much more complicated and complex, we still stick to the positivist interpretation of the artefact sets. We tend to ignore the inconvenient fact that the time conserved and expressed in the artefacts has a speed, is relative and it certainly does not constitute a direct proportionality. It seems that they don't "behave" in time and space as we expect. Similar opinions have also been expressed in the past but seem to have been little heeded.

There are many examples today of major shifts of styles and fashions in time and space and examples of longue durée pottery styles. Changes in shapes and decorations have their logic but this logic is not universal, it is not valid for each type in each time and space. Some of them have incredible duration: e.g. trickle-decoration on Cretan Bronze Age pithoi, TY ware in the Near East and transport amphorae from the Hellenistic period to the Middle Byzantine period and even later.

A major conclusion from the analysis must be that it is essential that we be critical of our own methods and results.

Returning to the Santorini issue, I suggest that not only should earlier finds be reviewed, since many mistakes have automatically been transferred from publication to publication, but also that new finds and fresh stratigraphic evidence must be sought. It is important to include more northern regions, such as the Balkans or central Europe, in the exercise. One of the most important regions seems to be Macedonia, where tells, such as Kastanas, Dikili Tash and others, may prove fruitful.

Not only do we need new contexts and finds, we also need new methodologies, new paradigms. It seems that the way we currently work with parallels, imports and influences doesn't always give us correct dates and connections and relationships. There are heirlooms, there are types and styles which survive, virtually unchanged, for centuries, styles which repeat and styles which are consciously resurrected, more progressive and conservative regions etc.; the people of the past would most probably, have had a very different approach to their material world, . Radiocarbon dates cannot simply be rejected when they do not match with the archaeological chronologies, the exponents of both methods should look for possible reasons for any discrepancy.

It seems, at present, that the archaeological and historical scales are slightly shorter than radiocarbon based chronologies.

The conclusions of the book should not be interpreted as judgments and do not imply that previous researchers were necessarily wrong. This has been an attempt to provide as complete as possible a summary of contemporary results, analysing the arguments concerning each method, and to create a threshold for further research which should be upgraded and enriched by new approaches and methods.

What's wrong?

Hard science and humanities – tackling the question of the absolute chronology of the Santorini eruption

Věra Klontza-Jaklová

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