Liste erstellt am 2016-03-26

References

Baillie 2010

M. G. L. Baillie, *Volcanoes, ice-cores and tree-rings*, *One story or two?* Antiquity **84** (2010), 202–215.

Good archaeology relies on ever more precise dates – obtainable, notably, from ice-cores and dendrochronology. These each provide year-by-year sequences, but they must be anchored at some point to real historical time, by a documented volcanic eruption, for example. But what if the dating methods don't agree? Here the author throws down the gauntlet to the ice-core researchers – their assigned dates are several years too old, probably due to the spurious addition of 'uncertain' layers. Leave these out and the two methods correlate exactly ...

Keywords: dating | dendrochronology | ice-core | calibration

Baillie 2013

Mike Baillie, *Radical thinking on the Thera debate.* In: Harald Meller & Hans-Rudolf Bork (Hrsg.), *1600 – Kultureller Umbruch im Schatten des Thera-Ausbruchs? 4. Mitteldeutscher Archäologentag vom 14. bis 16. Oktober 2011 in Halle (Saale).* Tagungen des Landesmuseums für Vorgeschichte Halle 9 (Halle 2013), 65–75.

The date of the eruption of Thera has been the subject of debate for many years and several of the best known dating estimates have become entrenched; particularly ice estimates in the 1640s B. C. and tree-ring estimates in the 1620s B.C. In preparing this paper a list of tree ring minima and frost ring dates was compared with all the volcanic signals in the main Greenland ice cores, namely GISP2 and Dye 3/GRIP/ NGRIP. Simple pattern matching suggested that the best fit of the tree-ring dates versus the ice dates involved moving the ice dates back in time by 25 years; a possibility that would not normally have been considered. Subsequent decoupling of the two main ice records showed that the optimum solution to relating volcanoes – as indicated by ice acidities – to environmental effects – as indicated by tree ring minima and frost ring occurrences – was to retain the GISP2 published dating and move only the Dye 3/GRIP/NGRIP dates. The solution suggested by this data movement would show six environmentally effective eruptions between 1595 B.C. and 1695 B.C. and one eruption, probably Aniakchak, in the 1660s B.C. that had no obvious environmental effects. A curiosity is that the original GISP2 1623 B.C. acid layer, which contained controversial tephra, seems to only show up in that core. The outcome of this speculative analysis is that, based on radiocarbon evidence, Thera could be related to any one of the five volcanoes that have left evidence in ice core and tree ring records between 1650 B. C. and 1595 B. C. With the exception of the GISP2 1623 B.C. layer, none of the others have been searched for tephra from Thera.

Der genaue Zeitpunkt des Vulkanausbruchs des Thera wird nun schon seit vielen Jahren debattiert und einige der bekannten Datierungsvorschläge haben sich in der Forschung fest etabliert. Dies betrifft besonders die Eiskerndatierungen in die 1640er Jahren v.Chr. und die Jahrringdatierungen in die 1620er Jahre v. Chr. Für den vorliegenden Beitrag wurde eine Liste mit Jahrringminima und Frostringdatierungen mit den Vulkanspuren in den wichtigsten Eiskernen aus Grönland

– GISP2 und Dye j/GRIP/NGRIP – verglichen. Die Suche nach einem bestimmten Muster legte nahe, die Eiskerndatierungen um 25 Jahren nach hinten zu verschieben, um die Jahrring- und Eiskerndaten einander anzupassen – eine Möglichkeit, die man normalerweise nicht in Erwägung ziehen würde. Die folgende Entkoppelung der beiden wichtigsten Eisdaten zeigte als optimale Lösung, um Vulkanausbrüche (durch Säuregehalte im Eis angezeigt) und Umweltauswirkungen (durch Jahrringminima und Frostringe angezeigt) miteinander zu verbinden, die GISP2 Datierungen beizubehalten und nur die Datierungen der Dye 3/ Grip/ NGRIP zu verschieben. Das Ergebnis dieser Datenverschiebung würde sechs Vulkanausbrüche mit Umweltauswirkungen zwischen 1695 v. Chr. und 1595 v. Chr. zeigen und einen Ausbruch (wahrscheinlich des Aniakchak) in den 1660er Jahren v. Chr. ohne auffallende Auswirkungen auf die Umwelt. Eigenartig ist, dass die ursprüngliche GISP2 Säureschicht von 1623 v.Chr., die kontroverse Tephra enthielt, lediglich in diesem einen Eiskern vorkam.

Das Ergebnis dieser etwas spekulativen Analyse ist, dass aufgrund von Radiocarbonbefunden der Theraausbruch mit jedem der fünf Vulkanausbrüche in Verbindung gebracht werden könnte, die in Eiskernen und Jahrringen zwischen 1650 v.Chr. und 1595 v.Chr. Spuren hinterlassen haben. Mit Ausnahme der GISP2 Schicht von 1623 v.Chr. wurde keine andere auf Tephra von Thera hin untersucht.

Baillie 1988

M. G. L. Baillie & M. A. R. Munro, *Irish tree rings, Santorini and volcanic dust veils*. nature **332** (1988), 344–346.

There has recently been renewed interest in the dating of the violent eruption of the Aegean island of Santorini in the second millennium BC, both by its possible effects on tree-ring growth in the United States (suggesting a date of 1628–1626 BC), and by acidity peaks in ice cores from South Greenland (suggesting 1645 BC). We now show that oak trees growing on bogs in Northern Ireland produce significant concentrations of extremely narrow rings within a few periods less than 20 years long and that these periods correspond to the dates suggested by other methods for major volcanic eruptions. In particular, one of them, corresponding to a short period beginning in 1628 BC, was probably caused by Santorini. This date is qualitatively better than those derived from carbon-14 or ice cores, because it is based on an absolute tree-ring chronology.

Betancourt 1998

Philip P. Betancourt, *The Chronology of the Aegean Late Bronze Age, Unanswered Questions*. In: Miriam S. Balmuth & Robert H. Tykot (Hrsg.), *Sardinian and Aegean Chronology: Towards the Resolution of Relative and Absolute Dating in the Mediterranean, Proceedings of 'Sardinian Stratigraphy and Mediterranean Chronology', Tufts University, Medford, MA, March 17–19, 1995*. Studies in Sardinian Archaeology 5 (Oxford 1998), 291–296.

These pieces of evidence suggest a chronology such as is shown in Fig. 29.3. A major point is the length of LM IB (and the contemporary LH IIA). This period was originally assigned a length of only 50 years by Evans (1921-35: IV, 881). Although it was not well represented in his excavations at Knossos, other sites have shown it is a substantial period with several architectural phases and an enormous volume of ceramics. Its total length is difficult to judge, but it must surely be well over a century. At Pseira, for example, it is represented by several building phases, and it is long enough to incorporate changes in architectural style.

The large quantities of LM IB pottery and other objects suggest it is longer than LM IA.

The problem is that the discovery of the absolute dates is not as important as the question of the relative chronology. For historical conclusions, moving an event a hundred years forward or back in time is not as important at our present level of knowledge as understanding its relevance to other events from approximately the same time.

Radiocarbon dating operates the same way in the Central Mediterranean as it does in the Eastern Mediterranean. In comparison with the "late chronology" of the Aegean, radiocarbon dates always suggest an earlier trend. One cannot mix one's classes of evidence and date Mycenae and Crete based on the traditional chronology of Egyptian synchronisms and the rest of Europe based on the radiocarbon dates, and then draw meaningful conclusions. For parts of Europe and the Mediterranean that are themselves dated by radiocarbon, one must use the "high Aegean chronology" in order to understand the proper historical correlations.

BIETAK 1998

Manfred Bietak, *The Late Cypriot White Slip I Ware as an Obstacle to the High Aegean Chronology*. In: MIRIAM S. BALMUTH & ROBERT H. TYKOT (Hrsg.), *Sardinian and Aegean Chronology: Towards the Resolution of Relative and Absolute Dating in the Mediterranean*, *Proceedings of 'Sardinian Stratigraphy and Mediterranean Chronology', Tufts University, Medford, MA, March 17–19, 1995*. Studies in Sardinian Archaeology 5 (Oxford 1998), 321–322.

Therefore I see little or no chance for the high Aegean chronology to last. No proof has been produced so far that the Theran eruption is responsible for the 1628 BC tree ring anomaly. One kind of proof would be the identification of the origin of particles of volcanic ash from dated Greenland ice deposits by scientific methods. Another kind would be to probe for volcanic ash in Egyptian stratigraphic deposits. Both possibilities will be exploited in the near future. With the evidence of the appearance of White Slip I-Ware at Tell el-Dab'a from the early 18th Dynasty onwards, I doubt very much that samples from a deposit around 1628 BC would reveal the fingerprints of the volcano of Thera.

It will give me great pleasure to have the lines above read in 10 years!

BRONK RAMSEY 2004

Christopher Bronk Ramsey, Sturt W. Manning & Mariagrazia Galimberti, *Dating the volcanic eruption at Thera*. Radiocarbon **46** (2004), 325–344.

The eruption of the volcano at Thera (Santorini) in the Aegean Sea undoubtedly had a profound influence on the civilizations of the surrounding region.The date of the eruption has been a subject of much controversy because it must be linked into the established and intricate archaeological phasings of both the prehistoric Aegean and the wider east Mediterranean. Radiocarbon dating of material from the volcanic destruction layer itself can provide some evidence for the date of the eruption, but because of the shape of the calibration curve for the relevant period, the value of such dates relies on there being no biases in the data sets. However, by dating the material from phases earlier and later than the eruption, some of the problems of the calibration data set can be circumvented and the chronology for the region can be resolved with more certainty.

In this paper, we draw together the evidence we have accumulated so far, including new data on the destruction layer itself and for the preceding cultural horizon

at Thera, and from associated layers at Miletos in western Turkey. Using Bayesian models to synthesize the data and to identify outliers, we conclude from the most reliable 14C evidence (and using the INTCAL98 calibration data set) that the eruption of Thera occurred between 1663 and 1599 BC.

Bronk Ramsey 2010

Christopher Bronk Ramsey et al., *Radiocarbon-Based Chronology for Dynastic Egypt*. science **328** (2010), 1554–1557.

s328-1554-Supplement.pdf

Christopher Bronk Ramsey, Michael W. Dee, Joanne M. Rowland, Thomas F. G. Higham, Stephen A. Harris, Fiona Brock, Anita Quiles, Eva M. Wild, Ezra S. Marcus, Andrew J. Shortland

The historical chronologies for dynastic Egypt are based on reign lengths inferred from written and archaeological evidence. These floating chronologies are linked to the absolute calendar by a few ancient astronomical observations, which remain a source of debate. We used 211 radiocarbon measurements made on samples from short-lived plants, together with a Bayesian model incorporating historical information on reign lengths, to produce a chronology for dynastic Egypt. A small offset (19 radiocarbon years older) in radiocarbon levels in the Nile Valley is probably a growing-season effect. Our radiocarbon data indicate that the New Kingdom started between 1570 and 1544 B.C.E., and the reign of Djoser in the Old Kingdom started between 2691 and 2625 B.C.E.; both cases are earlier than some previous historical estimates.

Bruns 1980

Michael Bruns, Ingeborg Levin, K. O. Münnich, H. W. Hubberten & S. Fillipakis, *Regional sources of volcanic carbon dioxide and their influence on ^{14}C content of present-day plant material*. Radiocarbon **22** (1980), 532–536.

14C measurements were made on present-day plant material with short integration times (tree leaves and sprouts) in the Eifel area, western Germany, where ancient volcanism produces gaseous emanations of considerable yield. Plants growing near sources emanating 14C-free CO2 show a significant depletion in the period of their growth. The same effect is found in the 14C content of recent samples from the Thera (Santorini) Archipelago/Greece. This mixing of "dead" CO2 may lead to pseudo ages in archaeologic or geologic samples of up to 1600 years in samples from the vicinity of C02 emanating sources.

Cherubini 2013

Paolo Cherubini et al., *Olive Tree-Ring Problematic Dating, A Comparative Analysis on Santorini (Greece)*. PLoS ONE **8** (2013), e54730. DOI:10.1371/journal.pone.0054730.

Paolo Cherubini, Turi Humbel, Hans Beeckman, Holger Gärtner, David Mannes, Charlotte Pearson, Werner Schoch, Roberto Tognetti & Simcha Lev-Yadun

Olive trees are a classic component of Mediterranean environments and some of them are known historically to be very old. In order to evaluate the possibility to use olive tree-rings for dendrochronology, we examined by various methods the reliability of olive tree-rings identification. Dendrochronological analyses of olive trees growing on the Aegean island Santorini (Greece) show that the determination of the number of tree-rings is impossible because of intra-annual wood density fluctuations, variability in tree-ring boundary structure, and restriction of its cambial activity to shifting sectors of the circumference, causing the tree-ring sequences along radii of the same cross section to differ.

Cherubini 2014

Paolo Cherubini et al., *Bronze Age catastrophe and modern controversy, Dating the Santorini eruption*. Antiquity **88** (2014), 267–291.

The date of the volcanic eruption of Santorini that caused extensive damage toMinoan Crete has been controversial since the 1980s. Some have placed the event in the late seventeenth century BC. Others have made the case for a younger date of around 1500 BC. A recent contribution to that controversy has been the dating of an olive tree branch preserved within the volcanic ash fall on Santorini. In this debate feature Paolo Cherubini and colleagues argue that the olive tree dating (which supports the older chronology) is unreliable on a number of grounds. There follows a response from the authors of that dating, and comments from other specialists, with a closing reply from Cherubini and his team.

Keywords: Santorini, Thera, Minoan eruption, radiocarbon dating, tree-rings

The olive-branch dating of the Santorini eruption

Paolo Cherubini, Turi Humbel, Hans Beeckman, Holger Gärtner, David Mannes, Charlotte Pearson, Werner Schoch, Roberto Tognetti & Simcha Lev-Yadun

The olive branch chronology stands irrespective of tree-ring counting

Walter L. Friedrich, Bernd Kromer, Michael Friedrich, Jan Heinemeier, Tom Pfeiffer & Sahra Talamo

Radiocarbon and the date of the Thera eruption

Manfred Bietak

The Thera olive branch, Akrotiri (Thera) and Palaikastro (Crete): comparing radiocarbon results of the Santorini eruption

Hendrik J. Bruins & Johannes van der Plicht

The difficulties of dating olive wood

Peter Ian Kuniholm

A disastrous date

J. Alexander MacGillivray

The olive tree-ring problematic dating

Paolo Cherubini & Simcha Lev-Yadun

Downey 1984

W. S. Downey & D. H. Tarling, *Archaeomagnetic dating of Santorini volcanic eruptions and fired destruction levels of late Minoan civilization*. nature **309** (1984), 519–523.

Archaeomagnetic dating on the Minoan ash horizons of the Santorini volcano and on fired destruction levels at late Minoan sites on Crete demonstrates that the basal (Plinian) air-fall ash of the first 'Minoan' pumice is contemporaneous with the destruction levels on central Crete, while the higher 'Minoan' ashes are contemporaneous with the destruction levels in extreme eastern Crete. These destruction levels were almost certainly caused by seismic activity, rather than the ash fall. The determination of a time gap between these events lead to a reappraisal of the archaeological evidence and is important volcanologically.

Eggert 1987

Manfred K. H. Eggert & Hans-Peter Wotzka, *Kreta und die absolute Chronologie des europäischen Neolithikums*. Germania **65** (1987), 379–422.

Das Ergebnis unserer Untersuchung ist eindeutig. Es läßt sich in einem Satz ausdrücken: Das von Milojcic errichtete System der absoluten Chronologie des ägäischen und kontinentalen Neolithikums ist eine Fiktion. Die von ihm aufgestellte Beweiskette für eine angeblich solide Fundierung der absolut-zeitlichen Ansätze muß in toto und ohne jede Einschränkung zurückgewiesen werden. Dies gilt nicht nur für die direkte, über Kreta führende Verbindung, sondern – wie in einer anderen Arbeit gezeigt wurde — auch für jenen Weg, der über Mersin und Mesopotamien nach Ägypten führt. Das Fazit ist somit klar: Die absolute Chronologie des ägäischen und kontinentalen Neolithikums hängt an einem in spätneolithischem kretischen Kontext gefundenen Bodenfragment eines ägyptischen Zylindergefäßes, das in die Zeit der 1. bis 6. Dynastie datiert. Die mit diesem Importstück gekoppelte Datierungsunsicherheit umfaßt somit eine Zeitspanne von mindestens 700 Jahren.

Es bleibt nur noch darauf hinzuweisen, daß die hier für mehr oder weniger tragfähig erachteten "Fixpunkte" nicht nur durch den ihnen inhärenten absolutzeitlichen Unsicherheitsfaktor die an sie gestellten Ansprüche nur sehr unvollkommen zu erfüllen vermögen. Sie unterliegen darüber hinaus der generellen Problematik des Prinzips der kleinen Zahl, das jedwede auf einer derartigen Basis getroffenen Schlußfolgerungen ganz erheblich relativiert. Dies gilt zweifellos in einem ganz besonderen Maße für das komplexe Feld von Importbeziehungen.

Die Implikationen der vorliegenden Abhandlung reichen über unser hier im Vordergrund stehendes Anliegen einer Überprüfung der Basis der historischen, komparativ-stratigraphischen absoluten Datierung des Neolithikums hinaus. Sie transzendieren auch das parallele Problem der entsprechenden Fundierung der Chronologie der Bronzezeit. Es ist offenbar, daß nunmehr der heute weithin akzeptierte, jeweils zugunsten der einen oder der anderen Seite entschiedene Widerspruch von Radiokohlenstoff- und komparativ-stratigraphischer Datierung in einem gänzlich neuen Lichte erscheint. Das auf letzterem Wege gewonnene Chronologie-System fällt als historisches Korrektiv der Radiokarbon-Datierung aus.

Fantuzzi 2007

Tiziano Fantuzzi, *The debate on Aegean high and low chronologies, An overview through Egypt.* Rivista di Archeologia **31** (2007), 53–65.

One of the most important problems which affect the reconstruction of the Aegean Late Bronze Age (LBA), and its significance in the Mediterranean world, is the absolute chronology of the Minoan LM I-II periods, and, in turn, the absolute dating of the mature LM I A Theran eruption, and their relationships with the Egyptian and Cypriote relative chronologies. Since the last three decades, the traditional chronology has been challenged by radiocarbon results obtained from a few key sites, which, during the late 1990's seemed to be confirmed by several other dating techniques. In turn, an impressive amount of new data, often supporting the traditional view, has been obtained from the (re)analysis of the Aegean, Cypriote and Egyptian assemblages, which have yielded good evidence for their chronological correlation. As a consequence, the archaeologists face with an impasse, given that none of the two parts involved in the debate can rely upon conclusive arguments, or be confident of the outcome. However, a slightly modified version of the traditional "Low" chronology might be put forward, maintaining both archaeological and radiocarbon evidence. It is interesting to point out that the radiocarbon results, when individually calibrated, do not seem homogeneous enough to justify a shift of some 120 calendar years in the traditional chronology.

Fischer 2009

Peter M. Fischer, *The chronology of Tell el-'Ajjul, Gaza, Stratigraphy, Thera, pumice and radiocarbon dating.* In: David A. Warburton (Hrsg.), *Time's Up! Dating the Minoan eruption of Santorini, Acts of the Minoan Eruption Chronology Workshop, Sandbjerg November*

2007. Monographs of the Danish Institute at Athens 10 (Århus 2009), 253–266.

Cross links between Tell el-'Ajjul and other sites and areas have been discussed at length in several publications.53 As far as the evidence from Tell elDabca is concerned, Bietak (pers. comm.) pointed out that certain vessels of Egyptian origin or Egyptianizing vessels from H5A at Tell el-'Ajjul54 belong to the Tuthmoside period (no further precision), viz. from around 1500 bc or later. Hein55 again classiied an Egyptian shallow bowl from H7 at Tell el-'Ajjul as belonging to the Hyksos period, which is in line with our observation deduced from a juglet in H8 that has parallels from the irst half of the Hyksos period at Tell el-Dabca (see above).

Another very important piece of information which does not usually receive the necessary attention in archaeological reports and discussions concerns the temporal aspects of the lengths of various layers of occupation. In order to meet the radiocarbon results one would have to adapt and possibly "stretch" the lengths of the occupational horizons at Tell el-'Ajjul. Let us assume a theoretical occupational length of 30 years for each of the cultural horizons at Tell el-'Ajjul.56 Let us put the end of H5A, from which there are (almost) complete Egyptian imports, around 1500 bc (give or take a few decades).57 H5B would then last from 1560-1530 bc, and H6 from 1590-1560 bc. This hypothetical back-counting would lead us fairly close to the radiocarbon-based chronology of the Theran eruption which is obviously not acceptable to our Egyptian colleagues, in particular.

There is hardly anyone in the two opposing "camps" who would deny the importance of Tell el-'Ajjul in connection with chronological discussions because of the unparaleled amount of imported material and numerous inds of Theran pumice. It is the hope of the author (and all the others involved in this discussion) that the excavations at Tell el-'Ajjul can be resumed shortly.

FOSTER 2009

Karen Polinger Foster, Johannes H. Sterba, Georg Steinhauser & Max Bichler, *The Thera eruption and Egypt*, *Pumice, texts, and chronology*. In: DAVID A. WARBURTON (Hrsg.), *Time's Up! Dating the Minoan eruption of Santorini*, *Acts of the Minoan Eruption Chronology Workshop, Sandbjerg November 2007*. Monographs of the Danish Institute at Athens 10 (Århus 2009), 171–180.

Our INAA results with respect to the pumice from Maiyana and the Tomb of Maket are entirely consistent with the sourcing picture that has emerged from the Thera Ashes project, namely, that Minoan eruption material is not present in pre-Dyn. XVIII contexts, from palatial complexes to modest graves. At the same time, our re-examination of the Tempest Stele of Ahmose raises anew the question of its relevance and signiicance. An eruption date falling exactly within the chronological horizon of the stele finds support in archaeological and analytical evidence that is highly suggestive but still inconclusive.

Our work has raised many questions, of which we pose here three. How would an Ahmoside eruption date aid our understanding of the Aegeanizing items connected with his reign, such as the ceremonial weapons he gave his mother, Queen Ahhotep? What is the meaning of her unparalleled title, "Mistress of the Littoral"? And what relation is there between the artists and workshops responsible for the Thera frescoes and those who painted the walls of early Dyn. XVIII palaces at the former Hyksos capital? We look forward to further investigations with keen anticipation.

Foster 1996

Karen Polinger Foster & Robert K. Ritner, *Texts, Storms, and the Thera Eruption*. Journal of Near Eastern Studies **55** (1996), 1–14.

Many have posed this question: if the Thera eruption was so cataclysmic, why is there no mention of it in texts from neighboring literate areas? As many have answered, the problem is that in both Mesopotamia and Egypt, the eruption occurred inopportunely during periods for which there is a dearth of historical documentation. Nevertheless, later Mesopotamian omen texts may provide us with indirect glimpses of the spectacular atmospheric phenomena that must have been engendered by Thera. More directly, Ahmose's Tempest Stele of about 1530 B.c., with its straightforward description of storms, darkness, noise, and damage throughout Egypt, may very well stand as an eyewitness account of the Thera eruption. If so, Ahmose not only expelled the Hyksos and founded the Eighteenth Dynasty, but also led Egypt through the greatest volcanic event of the Bronze Age world.

Friedrich 2006

Walter L. Friedrich, Bernd Kromer, Michael Friedrich, Jan Heinemeier, Tom Pfeiffer & Sahra Talamo, *Santorini Eruption Radiocarbon Dated to 1627–1600 B.C.* science **312** (2006), 548.

s312-0548-Supplement.pdf

MacGillivray 2009

J. Alexander MacGillivray, *Thera, Hatshepsut, and the Keftiu*, *Crisis and response in Egypt and the Aegean in the mid-second millennium bc*. In: David A. Warburton (Hrsg.), *Time's Up! Dating the Minoan eruption of Santorini*, *Acts of the Minoan Eruption Chronology Workshop, Sandbjerg November 2007*. Monographs of the Danish Institute at Athens 10 (Århus 2009), 155–170.

If we accept that the Thera eruption occurred at the outset of Hatshepsut and Thutmose III's ifth regnal year, the following dates combining the high Egyptian chronology and calibrated 14C dates for the ifteenth century bc may be proposed:
1572 -beginning of LM IA
1500 -Thera eruption in Mature LM IA
c.1495 -start of LM IB
1483 -Hatshepsut's death
1482 -Battle of Megiddo
1463 -Hatshepsut's proscription begins; – Mycenaean conquest of Knossos and start of LM II there
1450 -death of Thutmose III
1448 -revolt at Knossos; start of LM IIIA1 there.
c.1390 -beginning of LM IIIA2 in Crete

Hammer 1987

C. U. Hammer, H. B. Clausen, W. L. Friedrich & H. Tauber, *The Minoan eruption of Santorini in Greece dated to 1645 BC?* nature **328** (1987), 517–519.

The eruption on Santorini (Thera: 36.40° N, 25.40° E) in the Aegean Sea during Late Minoan time is considered the most violent volcanic event in the Mediterranean in the second millennium BC. The eruption buried a number of developing Bronze Age settlements on the island (one of which is presently being excavated at

the village Akrotiri1) and spread huge amounts of tephra over the eastern Mediterranean and adjacent lands. This event is therefore an important time marker both for archaeologists and Earth scientists. A dating of the eruption has previously been attempted by archaeological inference and by radiocarbon dating, but the two methods have tended to give ages that deviate by up to 150 years. Here we present a new ice-core dating of the eruption, which suggests an age of 1645 BC based on variations in acid fallout in the annual ice layers in a core drilled at the site Dye 3 (65.18° N, 43.49° W) in South Greenland.

Heinemeier 2009

Jan Heinemeier, Walter L. Friedrich, Bernd Kromer & Christopher Bronk Ramsey, *The Minoan eruption of Santorini radiocarbon dated by an olive tree buried by the eruption.* In: David A. Warburton (Hrsg.), *Time's Up! Dating the Minoan eruption of Santorini*, *Acts of the Minoan Eruption Chronology Workshop, Sandbjerg November 2007.* Monographs of the Danish Institute at Athens 10 (Århus 2009), 285–293.

In 2006 we published a radiocarbon dating, 1613 bc, for the Minoan eruption on Santorini with an unparalleled precision of ±13 calendar years.1 It was based on the unique find in the caldera wall of Santorini of a branch of an olive tree that had been buried and preserved in an upright, life, position by the pumice of the eruption. 72 tree rings were identified by X-ray tomography, and the high precision was achieved by wiggle matching the 14C results of the time series of four contiguous sections of tree rings to the radiocarbon calibration curve. Since the trees were growing at an altitude of 150 m above sea level and at a distance of more than 2.5 km from the active volcanic zone on Santorini, it is unlikely that the radiocarbon values published in 2006 could have been affected by old CO2. Because of the clear association of the tree and its outermost growth ring with the geological/archaeological event of the eruption, the date represents the best combination of directness and precision in any attempt so far of a science based chronology of the Minoan eruption.

While in broad agreement with other science dating attempts, there are some who claim that it is completely irreconcilable with the traditional archaeological dates of the late 16th century bc, or later, based on cultural linkage (pottery typology) and Egyptian Chronology. To resolve the conflict, we need to take a careful look at the implicit and explicit underlying assumptions in the two methods. As we do not possess the expertise to evaluate the results of the archaeological approach, this paper will deal with the details of the find of the olive branch and its radiocarbon dating by wiggle matching as well as a balanced assessment of the possible sources of error.

Höflmayer 2009

Felix Höflmayer, *Aegean-Egyptian synchronisms and radiocarbon chronology.* In: David A. Warburton (Hrsg.), *Time's Up! Dating the Minoan eruption of Santorini*, *Acts of the Minoan Eruption Chronology Workshop, Sandbjerg November 2007.* Monographs of the Danish Institute at Athens 10 (Århus 2009), 187–195.

Based on Aegean material found in Egypt and vice versa, Aegean relative chronological phases can be synchronized with the Egyptian historical chronology. As has been shown above, Minoan and Mycenaean pottery turns up in Egypt in the same sequence as in the Aegean. It can be assumed that these imports are not heirlooms as it would be hard to think that all these goods were exported with more or less the same time-lag of one or two generations after they were in use in the Aegean. On the other hand, it is known that stone vessels were in use for several generations and that these objects might even have been traded as antiques. The case of the re-worked stone vessel from shaft grave V shows that one cannot assume a short interval between production in Egypt and deposition in Mycenae, thus creating an argument for an end date of LM IA well after 1550 or 1524 (beginning of the New Kingdom).

Nonetheless, radiocarbon evidence cannot be put aside in chronological discussion. The work in this field by Sturt Manning, Walter Friedrich and others has stimulated critical reviews of the conventional chronology. Nevertheless the conclusions based on the evidence put forward above make an eruption date in the second half of the 17th century virtually impossible. Neither is an end-date of around 1500 for the LM IB-period likely, whereas the end of LM II and the dates for LH IIIA2 seem compatible with current understanding of archaeology and history of the Eastern Mediterranean.

Today it is still not possible to achieve a consensus regarding the absolute chronology of the early Late Bronze Age. Archaeology and natural sciences still come down to different results. Future work in both fields may shed more light on areas still not so well understood. We still lack sound archaeological arguments for synchronizing MM III with the Egyptian chronology and likewise recent radiocarbon dates for Aegean Middle Bronze periods are insufficient as well. However, such work might be useful in order to establish the point in time where the difference between archaeological interpretation and radiocarbon dating starts and perhaps to finally solve the debate around the absolute date of the Aegean Late Bronze Age.

Höflmayer 2012

Felix Höflmayer, *The Date of the Minoan Santorini Eruption: Quantifying the "Offset"*, *Proceedings of the 6th International Radiocarbon and Archaeology Symposium*. Radiocarbon **54** (2012), 435–448.

Despite many recent attempts to settle the dispute concerning the absolute date of the Minoan Santorini eruption, there are still differences between some archaeologists and scientists on the absolute dates and the reliability of radiocarbon dating. The recent publication of over 200 new 14C dates for dynastic Egypt rules out a major flaw in the historical chronology of Egypt and proves the reliability of 14C dating in the Nile Valley. Therefore, the student of Aegean archaeology and eastern Mediterranean interconnections is still confronted with an archaeologically based conventional, or "low," chronology and a 14C-backed "high" chronology. New 14C determinations from different sites of the Aegean support the high chronology for the Late Minoan (LM) IA, while recent re-evaluation of LM IB determinations are slightly higher but more or less in agreement with archaeological estimations. The present contribution reviews archaeological and scientific data for the LM IA period and argues that a reduced (≈30 to 50 yr) offset between archaeological and 14C dates for the Minoan Santorini eruption may be possible, thus offering new perspectives for potential solutions for this problem.

Höflmayer 2016

Felix Höflmayer, Jens Kamlah, Hélène Sader, Michael W. Dee, Walter Kutschera, Eva Maria Wild & Simone Riehl, *New Evidence for Middle Bronze Age Chronology and Synchronisms in the Levant*, *Radiocarbon Dates from Tell el-Burak, Tell el-Dabʿa, and Tel Ifshar Compared.*

Bulletin of the American Schools of Oriental Research **375** (2016), 53–76.

We report a set of radiocarbon data for the Middle Bronze Age monumental building at Tell el-Burak in Lebanon, dating it to the 19th century b.c., and summarize the relevant archaeological information concerning the stratigraphy and dating of the building. he radiocarbon data from Tell el-Burak is consistent with the high Middle Bronze Age radiocarbon dates recently reported for Tell el-Dab'a in the eastern Nile Delta and with radiocarbon dates for Middle Bronze Age Tel Ifshar in the coastal plain of Israel. A comparison of these radiocarbon dates questions the current (low) Middle Bronze Age absolute chronology of the southern Levant, which is largely based on the stratigraphic sequence of Tell el-Dab'a. Due to open questions in the archaeological dating of Tell el-Dab'a, we argue against using a single site as a main reference for dating the Middle Bronze Age in the Levant and argue for adopting a comprehensive and independent approach based on archaeological, historical, and radiocarbon evidence from all relevant sites.

Keywords: Tell el-Burak | Middle Bronze Age chronology | radiocarbon dating | Tell el-Dab'a | Tel Ifshar | southern Levant

HUNGER 2009

Hermann Hunger, *How uncertain is Mesopotamian chronology?* In: DAVID A. WARBURTON (Hrsg.), *Time's Up! Dating the Minoan eruption of Santorini*, *Acts of the Minoan Eruption Chronology Workshop, Sandbjerg November 2007.* Monographs of the Danish Institute at Athens 10 (Århus 2009), 145–152.

Most scholars are convinced that Mesopotamian chronology of the second millennium bc is uncertain. I shall try to present the so-called foundations of this chronology, which I think are reliable. I shall then go beyond this and describe the less reliable parts which concern the second millennium. Mesopotamian chronology is conventionally based on texts: eponym lists; king lists; dated documents; synchronisms; royal inscriptions; etc.

In conclusion I regret to say that there is conflicting evidence for Mesopotamian chronology: pottery development suggests a relatively Low Chronology, tree rings (assuming they are correctly interpreted) a somewhat higher, and astronomy (if P. Huber is correct) a very high one. At the moment, a decision seems to me impossible, but I hope for better data.

KEENAN 2003

Douglas J. Keenan, *Volcanic ash retrieved from the GRIP ice core is not from Thera.* Geochemistry Geophysics Geosystems **4** (2003), 1097.

Tephra found in an ice core from Greenland (GRIP) has been claimed to be from the Minoan eruption of Thera (Santorini), Greece. If true, this would date the eruption, thereby resolving a decades-long debate in chronology. Herein, it is shown that the methods used to match the Greenlandic tephra with Thera are flawed and that the geochemical data imply the tephra is not from Thera.

Keywords: Tephrochronology | Thera | Santorini | ice core

KLONTZA-JAKLOVÁ 2007

Vera Klontza-Jaklová, *Datierung der Katastrophe von Santorini, Kurze Zusammenfassung des bisherigen Standes der Forschung und vorherrschende Tendenzen.* Anodos (2007), Supplementum 4, 13–57.

Auch trotz sehr intensiver Forschung, die viele Probleme beleuchtete und ans Tageslicht viele neue Feststellungen gebracht hatte, wurden bisher folgende Fragen gerade hinsichtlich der ägyptischen Chronologie nicht eindeutig beantwortet:
1. Ist es zu der Katastrophe von Santorini während der Zweiten Zwischenperiode oder in der Zeit der Regierung der frühen 18. Dynastie gekommen?
2. Ist die Periode LMIA chronologisch zeitgleich mit dem Schluss der Zweiten Zwischenperiode oder übergreift sie in die frühe 18. Dynastie?
3. Ist es möglich, dass die ägyptische Chronologie länger sein könnte und die 18. Dynastie trat früher als wir heute denken?

Vorläufig ist der Streit zwischen der hohen und niedrigen Chronologie eindeutig nicht entschieden.

Knappett 2011

Carl Knappett, Ray Rivers & Tim Evans, *The Theran eruption and Minoan palatial collapse: new interpretations gained from modelling the maritime network*. Antiquity **85** (2011), 1008–1023.

What was the effect on Late Minoan civilisation of the catastrophic destruction of Akrotiri on Thera (Santorini) by volcanic eruption? Not much, according to the evidence for continuing prosperity on Crete. But the authors mobilise their ingenious mathematical model (published in Antiquity 82: 1009-1024), this time to show that the effects of removing a major port of call could have impacted after an interval, as increased costs of transport gradually led to ever fewer routes and eventual economic collapse.

Keywords: Aegean, Minoan, Crete, Thera, Santorini, Akrotiri, Bronze Age, maritime communications, network analysis

Krauss 2009

Rolf Krauss & David A. Warburton, *The basis for the Egyptian dates*. In: David A. Warburton (Hrsg.), *Time's Up! Dating the Minoan eruption of Santorini*, *Acts of the Minoan Eruption Chronology Workshop, Sandbjerg November 2007*. Monographs of the Danish Institute at Athens 10 (Århus 2009), 125–144.

Dead-reckoning, supplemented by the synchronisms, the kinglists, the archaeological data, and lunar dates allows us to conclude that the conquest of Avaris and the defeat of the Hyksos by the irst king of Dyn. XVIII took place around the end of the 16th century bc. The end of Dyn. XII can be estimated as having been at least two centuries earlier.

The Sothic date from Illahun allowed us to estimate that year 7 of the reign of Sesostris III fell between 1881 and 1826 bc. The lunar dates from the Illahun papyri mean that year 1 of Sesostris was 1837/36 bc. Thus the year 7 Sothic date of Sesostris III can be pinpointed at 1830 bc. Dyn. XII would have ended around 1760 bc.

The relationship between the Illahun Sothic date and the Sothic date in the calendar of P. Ebers allows the regnal year 9 of that papyrus to be placed in the years 1506 to 1498 bc. Taking account of the lunar date, this regnal year 9 must be 1506 bc. If year 1 of Thutmose III was 1468 bc, then dead reckoning means that this year 9 cannot be that of Amenhotep I, as this cannot have fallen before 1490 bc. It follows that we revive the doubts about the reading of the royal name (as that of Amenhotep I), and instead read this as the throne name of the last Hyksos king.

The end of Dyn. XIII and the beginning of the Hyksos Dyn. XV would have been around 1650 bc. The elimination of the Hyksos would have taken place

roughly 1504 bc. The year 1613 bc would lie towards the beginning of the Hyksos period.

Kutschera 2012

Walter Kutschera et al., *The Chronology of Tell El-Daba, A Crucial Meeting Point of ^{14}C Dating, Archaeology, and Egyptology in the 2nd Millennium BC.* Radiocarbon **54** (2012), 407–422.

Walter Kutschera, Manfred Bietak, Eva Maria Wild, Christopher Bronk Ramsey, Michael Dee, Robin Golser, Karin Kopetzky, Peter Stadler, Peter Steier, Ursula Thanheiser & Franz Weninger

Radiocarbon dating at the Tell el-Daba site in the Nile Delta has created an enigma for many years. Despite great efforts, the difference of about 120 yr between the chronology based on 14C dates and the one based on archaeological evidence linked to the Egyptian historical chronology has not been solved. In order to foster open discussions on this discrepancy, we present here the results of 40 14C accelerator mass spectrometry (AMS) measurements on short-lived plant material assigned to 14 different phases of the Tell el-Daba excavation, spanning 600 yr (about 2000–1400 BC). On the one hand, the recently established agreement between 14C dates and dynastic Egypt (Bronk Ramsey et al. 2010) makes it unlikely that the problem lies in the 14C dates and/or the Egyptian historical chronology. On the other hand, the extensive archaeological evidence from Tell el-Daba linked to many different cultures in the eastern Mediterranean and to the Egyptian historical chronology provides strong evidence for an absolute chronology shifted by about 120 yr with respect to the 14C dates.

Kuniholm 1990

Peter Kuniholm, *Overview and Assessment of the Evidence for the Date of the Eruption of Thera.* In: D. A. Hardy & A. C. Renfrew (Hrsg.), *Thera and the Aegean World III, Vol. 3: Chronology, Proceedings of the Third International Congress, Santorini, Greece, 3–9 September 1989.* (London 1990), 13–18.

What I propose to do is to survey some of the heterogeneous evidence for the dating of the eruption of Thera and, where possible, give my subjective assessment of the validity of each bit of evidence, both individually and collectively. I should add that I have been extremely skeptical of 'big-bang' approaches to history, but I now believe that in certain circumstances, especially when there are multiple, converging lines of evidence, one is sometimes justified in looking for 'big bangs' and their effects.

Although at least one scholar (Betancourt 1987) has voiced open support for a higher dating system for the Aegean late Bronze Age, for many other colleagues the jury is still out. I, for one, find it difficult to believe that something as cataclysmic as the Theran eruption could have taken place without causing world-wide tremors or reactions and am therefore inclined to favor the earlier date because of what I believe to be the more than accidental clustering of the bristlecone pine frost rings, the extraordinarily narrow bands in the Northern Irish oak, the acidity layer in the Greenland ice cores, and the bulk of the radiocarbon determinations, all around 1628-1627 BC, possibly corroborated by the silence from Egypt and more distant events commented on by Kevin Pang (1985) who believes that the 1628 event is the same one that ushered in the beginning of the Shang Dynasty in China, as reported in the Bamboo Annals for 1618 BC: 'yellow fog, a dim sun, then three suns, frost in July, famine, and the withering of all five cereals.' The Chinese evidence is not entirely secure as to its date, the Annals having been

found, lost, and then recovered, and the question of the Shang Dynasty and its dates really depends on one line in the text (information from Professor Martin Bernal at Cornell), but these phenomena are symptomatic of a large volcanic eruption such as the one which now preoccupies us and which certainly must have had a global rather than a purely local impact.

LaMarche 1984

Valmore C. LaMarche Jr & Katherine K. Hirschboeck, *Frost rings in trees as records of major volcanic eruptions*. nature **307** (1984), 121–126.

New data about climatically-effective volcanic eruptions during the past several thousand years may be contained in frost-damage zones in the annual rings of trees. There is good agreement in the timing of frost events and recent eruptions, and the damage can be plausibly linked to climatic effects of stratospheric aerosol veils on hemispheric and global scales. The cataclysmic proto-historic eruption of Santorini (Thera), in the Aegean, is tentatively dated to 1628-26 BC from frost-ring evidence.

Manning 2002

Sturt W. Manning, Christopher Bronk Ramsey, Christos Doumas, Toula Marketou, Gerald Cadogan & Charlotte L. Pearson, *New evidence for an early date for the Aegean Late Bronze Age and Thera eruption*. Antiquity **76** (2002), 733–744.

The authors report on radiocarbon data derived from carefully selected organic material from Late Minoan IA and IB contexts. The results suggest that the accepted chronology of the period should be revised by 100 years and that the eruption of Thera/Santorini most likely occurred c. 1650–1620 BC.

Keywords: radiocarbon, Late Bronze Age, Thera, Late Minoan, chronology

Manning 2006

Sturt W. Manning, Christopher Bronk Ramsey, Walter Kutschera, Thomas Higham, Bernd Kromer, Peter Steier & Eva M. Wild, *Chronology for the Aegean Late Bronze Age 1700–1400 B.C.* science **312** (2006), 565–569.

s312-0565-Supplement.pdf

Radiocarbon (carbon-14) data from the Aegean Bronze Age 1700–1400 B.C. show that the Santorini (Thera) eruption must have occurred in the late 17th century B.C. By using carbon-14 dates from the surrounding region, cultural phases, and Bayesian statistical analysis, we established a chronology for the initial Aegean Late Bronze Age cultural phases (Late Minoan IA, IB, and II). This chronology contrasts with conventional archaeological dates and cultural synthesis: stretching out the Late Minoan IA, IB, and II phases by ≈100 years and requiring reassessment of standard interpretations of associations between the Egyptian and Near Eastern historical dates and phases and those in the Aegean and Cyprus in the mid–second millennium B.C.

Manning 2014

Sturt W. Manning et al., *Dating the Thera (Santorini) eruption, Archaeological and scientific evidence supporting a high chronology*. Antiquity **88** (2014), 1164–1179.

Sturt W. Manning, Felix Höflmayer, Nadine Moeller, Michael W. Dee, Christopher Bronk Ramsey, Dominik Fleitmann, Thomas Higham, Walter Kutschera & EvaMaria Wild

The date of the Late Bronze Age Minoan eruption of the Thera volcano has provoked much debate among archaeologists, not least in a recent issue of Antiquity ('Bronze Age catastrophe and modern controversy: dating the Santorini eruption', March 2014). Here, the authors respond to those recent contributions, citing evidence that closes the gap between the conclusions offered by previous typological, stratigraphic and radiometric dating techniques. They reject the need to choose between alternative approaches to the problem and make a case for the synchronisation of eastern Mediterranean and Egyptian chronologies with agreement on a 'high' date in the late seventeenth century BC for the Thera eruption.

Keywords: Santorini, Thera, Late Bronze Age, Minoan eruption, radiocarbon dating, chronology

Manning 1998

Sturt W. Manning, *Correction. New GISP2 Ice-Core Evidence Supports 17th Century BC Date for the Santorini (Minoan) Eruption, Response to Zielinski & Germani (1998).* Journal of Archaeological Science **25** (1998), 1039–1042.

In correction to the interpretation of Zielinski & Germani (1998), the tephra shards from the 1623 bc layer of the GISP2 ice-core do not discount the likelihood of a 1628 bc date for the Minoan eruption of the Santorini volcano. In fact, excitingly, they provide the first tangible evidence in strong support of a later 17th century bc date for the Santorini eruption. The 1623 ± 36 bc date is entirely compatible with the previous suggestions of a 1628/27 bc date from treering data (LaMarche & Hirschboeck, 1984; Baillie & Munro, 1988; Kuniholm et al., 1996) or a c. 1636 ± 7 bc or 1644 ± 7 bc (realistic error therefore c. ± 20 years?) date from other ice-core evidence (Hammer et al., 1987; Clausen et al., 1997), or the most likely date range from the radiocarbon evidence relevant to the eruption (Manning, 1995: 200–216). At this time a 1628 bc date for the Santorini eruption remains the best working hypothesis from all scientific data. This does not, of course, mean that it is correct. Further positive confirmation and replication must now be sought, both from the ice-core data (including traceelement analysis and if possible refractive index data), and also potentially from the establishment of a direct physical link between volcanic activity and tree-rings along the lines of the analyses of Hall, Yamaguchi & Rettberg (1990).

Keywords: Santorini | Thera | Ice-Cores | Tree-Rings | Dendrochronology | Volcanoes

Ossowski Larsson 2015

Petra Ossowski Larsson & Lars-Åke Larsson, *When was the Minoan eruption of Thera?* unknown (2015), preprint, 1–10. DOI:10.13140/RG.2.1.4942.1287.

The Minoan eruption of the Thera (Santorini) volcano provides an archaeological key marker for the Bronze Age chronology of the Eastern Mediterranean civilizations. However, the exact date for this large eruption is still unknown. Based on published tree ring and ice core chronologies, we investigate the candidates for major volcano eruptions in the middle of the second millennium BC.

Ice core analysis provides indication for the volcanic nature of prominent events which resulted in climatic downturns and which are therefore visible in the tree ring chronologies. Our conclusion is that there are only two candidates for a "supervolcano" eruption in the time range -1675 to -1450. Only one of them has so

far been scientifically considered as a candidate for the Thera eruption. Recent investigations seem to indicate it to be less likely that this candidate is Thera. But there is one unexplored candidate left!

The evaluation of which of the two eruption candidates is the most probable, is backed up by a re-investigation of the so called “Ugarit Eclipse”. We also suggest a new synchronization of tree ring and ice core time lines for the time range mentioned.

PEARCE 2004

Nicholas J. G. Pearce, John A. Westgate, Shari J. Preece, Warren J. Eastwood & William T. Perkins, *Identification of Aniakchak (Alaska) tephra in Greenland ice core challenges the 1645 BC date for Minoan eruption of Santorini*. Geochemistry Geophysics Geosystems **5** (2004), Q3005.

Minute shards of volcanic glass recovered from the 1645 ± 4 BC layer in the Greenland GRIP ice core have recently been claimed to originate from the Minoan eruption of Santorini [Hammer et al., 2003]. This is a significant claim because a precise age for the Minoan eruption provides an important time constraint on the evolution of civilizations in the Eastern Mediterranean. There are however significant differences between the concentrations of SiO2, TiO2, MgO, Ba, Sr, Nb and LREE between the ice core glass and the Minoan eruption, such that they cannot be correlatives. New chemical analyses of tephra from the Late Holocene eruption of the Aniakchak Volcano in Alaska, however, show a remarkable similarity to the ice core glass for all elements, and this eruption is proposed as the most likely source of the glass in the GRIP ice core. This provides a precise date of 1645 BC for the eruption of Aniakchak and is the first firm identification ofAlaskan tephra in the Greenland ice cores. The age of theMinoan eruption of Santorini, however, remains unresolved.

Keywords: Aniakchak | tephra | Minoa | Santirini | ice core

PICHLER 1978

H. Pichler & W. Schiering, *Der Ausbruch des Thera-Vulkans um 1500 v. Chr. Archäologische Datierung, Eruptionsverlauf und Auswirkungen auf die minoische Kultur Kretas*. Naturwissenschaften **65** (1978), 605–610.

The stylistic development of the painted pottery from the excavations of Akrotiri on Thera evidences that the great Late-Minoan eruption of the Thera volcano must be dated around 1500 B.C. The eruption had only minor effects on Crete which were not nearly so serious as has been supposed. The rate of ash fall and the height of the tsunamis did not play a significant role. After the Thera eruption Minoan trade and culture flourished as before. This means that the decline of the Minoan civilization was neither caused nor influenced by this volcanic event as suggested by the Marinatos theory. The Minoan decline was substantially initiated by great devastations in Crete which occurred, according to the ceramic chronology, around 1450 B.C. These destructions were the result of one or several violent regional tectonic earthquake(s) in combination with severe internal revolts.

RENNE 1997

P. R. Renne, W. D. Sharp, A. L. Deino, G. Orsi & L. Civetta, *$^{40}Ar/^{39}Ar$ Dating into the Historical Realm, Calibration Against Pliny the Younger*. science **277** (1997), 1279–1280.

Laser incremental heating of sanidine from the pumice deposited by the Plinian eruption of Vesuvius in 79 A.D. yielded a 40Ar/39Ar isochron age of 1925 ± 94 years ago. Close agreement with the Gregorian calendar-based age of 1918 years ago demonstrates that the 40Ar/39Ar method can be reliably extended into the temporal range of recorded history. Excess 40Ar is present in the sanidine in concentrations that would cause significant errors if ignored in dating Holocene samples.

RITNER 2014

Robert K. Ritner & Nadine Moeller, *The Ahmose 'Tempest Stela', Thera and Comparative Chronology*. Journal of Near Eastern Studies **73** (2014), 1–19.

From the press release: In 2006, radiocarbon testing of an olive tree buried under volcanic residue placed the date of the Thera eruption at 1621—1605 B.C. Until now, the archeological evidence for the date of the Thera eruption seemed at odds with the radiocarbon dating, explained Oriental Institute postdoctoral scholar Felix Hoeflmayer, who has studied the chronological implications related to the eruption. However, if the date of Ahmose's reign is earlier than previously believed, the resulting shift in chronology "might solve the whole problem," Hoeflmayer said.

The revised dating of Ahmose's reign could mean the dates of other events in the ancient Near East fit together more logically, scholars said. For example, it re-aligns the dates of important events such as the fall of the power of the Canaanites and the collapse of the Babylonian Empire, said David Schloen, associate professor in the Oriental Institute and Near Eastern Languages & Civilizations on ancient cultures in the Middle East. "This new information would provide a better understanding of the role of the environment in the development and destruction of empires in the ancient Middle East," he said.

For example, the new chronology helps to explain how Ahmose rose to power and supplanted the Canaanite rulers of Egypt—the Hyksos—according to Schloen. The Thera eruption and resulting tsunami would have destroyed the Hyksos' ports and significantly weakened their sea power. In addition, the disruption to trade and agriculture caused by the eruption would have undermined the power of the Babylonian Empire and could explain why the Babylonians were unable to fend off an invasion of the Hittites, another ancient culture that flourished in what is now Turkey.

RISCH 2015

Roberto Risch & Harald Meller, *Change and Continuity in Europe and the Mediterranean around 1600 BC*. Proceedings of the Prehistoric Society **81** (2015), 239–264.

Based on recent evidence from both archaeological and natural sciences, in this paper we would like to sketch a historical geography of Europe and the Mediterranean around the year 1600 BC and then discuss the changes observed during the 16th century BC in relation to a possible correspondence with the Thera eruption. Our point of departure will be the sequence of events that took place during the months and years just before, during, and immediately after the Thera eruption. The available archaeological evidence permits us to explore the response of the local and regional communities, the logistics that were mobilised, and the political decisions adopted in light of these events. From this local and regional scenario we will move on to discuss the changes occurring in Europe, the Mediterranean, and the Near East during the 16th century BC. At least four different socio-economic and political scenarios can be sketched, showing that the responses of Bronze Age societies were highly variable. At that point, we can ask how different political structures existing at the time reacted or were affected by the ecological and/or social dynamics. Basically, our itinerary concludes that the Thera eruption did not cause a severe climatic or environmental change, but touched the ideological realm particularly of those socio-political entities which were more dependent on complex ideological superstructures in order to legitimate extreme economic exploitation.

Keywords: Thera 'Minoan eruption' | Bronze Age societies | Aegean prehistory | European prehistory

Rutter 1993

Jeremy B. Rutter, *Review of Aegean Prehistory II: The Prepalatial Bronze Age of the Southern and Central Greek Mainland.* American Journal of Archaeology **97** (1993), 745–797.

This review of a modest slice of mainland Greek prehistory is designed for twin audiences and has twin goals. On the one hand, it is targeted at archaeologists, ancient historians, Classicists, and others who, though they take an interest in Aegean prehistory and may even have some familiarity with it, hardly consider themselves specialists in this subdiscipline of Old World archaeology. For this audience, the purpose of what follows is to provide an outline, with helpful but by no means exhaustive references, to the principal discoveries made, questions addressed, and novel research strategies employed in the archaeology of roughly the first three-quarters of the Bronze Age on the southern and central Greek mainland. At the same time, this review is addressed to specialist Aegean prehistorians, not with the aim of making them aware of discoveries or intellectual currents about which they may be ignorant, but rather with the intent of encouraging them, through a consideration of the current state of our field, to take whatever future action they may feel is appropriate to improve upon the present state of our knowledge.

The spatial coverage undertaken for this review includes those portions of the Greek mainland south of a roughly east-west line connecting the mouth of the Spercheios River with the southeast corner of the Gulf of Arta (see below, fig. 3). Epirus, Thessaly, Macedonia, and Thrace are thus omitted from consideration, but Akarnania, Aetolia, the southern half of Eurytania, and the Ionian islands from Lefkas south are included. Also included, aside from the entire Peloponnese and the central Greek nomes of Attica, Boiotia, Phocis, Locris, and the southern half of Phthiotis, are the islands of the Saronic Gulf (most notably Aegina and Salamis), islands located just off the southeastern coast of the Argolid (such as Hydra and Spetses), and islands off the southwest coast of the Cape Malea peninsula (Elaphonisos and Kythera), but the large island of Euboea, since it was covered thoroughly in last year's review, is not considered here.

The period of time surveyed encompasses the entire Early and Middle Bronze Ages (EBA and MBA, respectively), known throughout the area in question as the Early Helladic (EH) and Middle Helladic (MH) periods, as well as the earlier part of the Late Bronze Age (LBA), variously termed the Late Helladic (LH) or Mycenaean period. The terminal date for my chronological coverage is provided by the construction, at some point during the LH IIB or LH IIIAl periods in the 15th century B.C., of the first Mycenaean architectural complexes generally recognized by the term "palaces" as the administrative seats of centralized kingdoms.

Shelmerdine 2008

Cynthia W. Shelmerdine (Hrsg.), *The Cambridge Companion to the Aegean Bronze Age.* Cambridge Companions Online (Cambridge 2008). DOI:10.1017/CCOL9780521814447.

This book is a comprehensive, up-to-date survey of the Aegean Bronze Age, from its beginnings to the period following the collapse of the Mycenaean palace system. In essays by leading authorities commissioned especially for this volume, it covers the history and the material culture of Crete, Greece, and the Aegean Islands from ca. 3000 to 1100 bce, as well as topics such as trade, religions, and economic administration. Intended as a reliable, readable introduction for university students, it will also be useful to scholars in related fields within and outside classics. The contents of this book are arranged chronologically and geographically, facilitating comparison between the different cultures. Within this framework, the cultures of the Aegean Bronze Age are assessed thematically and combine both material culture and social history.

Cynthia W. Shelmerdine is the Robert M. Armstrong Centennial Professor of Classics at The University of Texas, Austin. A scholar of Aegean Bronze Age archaeology and Mycenaean Greek language, history, and society, she has worked in the field with the University of Minnesota Messenia Expedition, the Pylos Regional Archaeological Project, and currently the Iklaina Archaeological Project. She is the author of many publications on Mycenaean culture.

Sterba 2009

Johannes H. Sterba, Karen Polinger Foster, Georg Steinhauser & Max Bichler, *New light on old pumice*, *The origins of Mediterranean volcanic material from ancient Egypt*. Journal of Archaeological Science **36** (2009), 1738–1744.

This paper presents and discusses the Neutron Activation Analysis (NAA) results newly obtained from pumice pieces found decades ago at the Egyptian sites of Maiyana, Sedment, Kahun, and Amarna – now in the collections of the Ashmolean Museum, Oxford, and the Petrie Museum of Egyptian Archaeology, London – which could be successfully related to several volcanic eruptions in the Mediterranean. The work contributes to the constant accumulation of knowledge concerning the first appearance of pumice from the so-called Minoan eruption of the Santorini volcano. In addition, it unexpectedly sheds more light on the long-distance trade of Mediterranean volcanic material in the Bronze Age world by disclosing another connection between Lipari and the Eastern Mediterranean.

Keywords: Neutron Activation Analysis | Pumice | Santorini | Minoan eruption | Bronze Age trade

Wardle 2014

Kenneth Wardle, Thomas Higham & Bernd Kromer, *Dating the End of the Greek Bronze Age*, *A Robust Radiocarbon-Based Chronology from Assiros Toumba*. PLoS ONE **9** (2014), e106672. DOI:10.1371/journal.pone.0106672.

pone09-e106672-Supplement.pdf

Over 60 recent analyses of animal bones, plant remains, and building timbers from Assiros in northern Greece form an unique series from the 14th to the 10th century BC. With the exception of Thera, the number of 14C determinations from other Late Bronze Age sites in Greece has been small and their contribution to chronologies minimal. The absolute dates determined for Assiros through Bayesian modelling are both consistent and unexpected, since they are systematically earlier than the conventional chronologies of southern Greece by between 70 and 100 years. They have not been skewed by reference to assumed historical dates used as priors. They support high rather than low Iron Age chronologies from Spain to Israel where the merits of each are fiercely debated but remain unresolved.

Warren 1984

Peter Warren, *Absolute dating of the Bronze Age eruption of Thera (Santorini)*. nature **308** (1984), 492–493.

On this evidence, it would seem there is little support for linking the White Mountains frost-ring event at 1626 BC specifically with the eruption of Thera. Moreover the link is not substantiated by archaeological data, nor strongly supported by radiocarbon evidence from Thera.

Weninger 1990

B. Weninger, *Theoretical Radiocarbon Discrepancies*. In: D. A. Hardy & A. C. Renfrew (Hrsg.), *Thera and the Aegean World III, Vol. 3: Chronology, Proceedings of the Third International Congress, Santorini, Greece, 3–9 September 1989*. (London 1990), 216–231.

An attempt will be made to reconcile the calibrated radiocarbon dates from Akrotiri with the traditional archaeological chronology of the Aegean Bronze Age, supporting the archaeological date of c. 1550-1500 BC for the LM IA period.

In the past decade a number of studies have led to the impression that the calibrated radiocarbon dates for the Aegean Late Bronze Age generally tend to be earlier than the archaeological dates. To explain the difference of 100-200 years between the archaeological dating of the Minoan eruption on Santorini (c. 1550-1500 BC) and the calibrated dates (c. 1700 BC) it has been proposed that the radiocarbon samples from Akrotiri were influenced by volcanic emanations, rendering them too early due to the photosynthesis of old CO2 deriving from fissures in the ground in the volcanic surroundings. On the other hand, on the basis of a reinterpretation of the archaeological evidence it has recently been argued that the archaeological correlations with the historical chronology of Egypt may well be consistent with the 'high' radiocarbon dating.

My paper will take a closer look at the radiocarbon dates from the Aegean Late Bronze Age and from Egypt. Using the new high-precision 14C calibration curve, it will first be shown that in Egypt the historical chronology and the radiocarbon dates agree within margins of error judged to be 1-3 decades at the time of Dynasties XVIII-XX. This is demonstrated by sequencing the radiocarbon dates according to the known age of the Egyptian samples. When fixed to the calibration curve by Archaeological Wiggle Matching (AWM) the 14C dates are in perfect agreement with the historical chronology and, furthermore, show the expected fine variations in atmospheric 14C content. Using the same method, it will be judged that the radiocarbon dates from Akrotiri do not necessarily disagree with the traditional archaeological date for the Minoan eruption. The dates may well calibrate to c. 1550-1520, though not later than 1500 BC. However, the calibration reading is not unique and a date 100 years earlier, supporting recent tree-ring and ice-core studies, cannot be excluded. To find a unique 14C date for the Minoan eruption, an effort was made to develop an AWM sequence for all the radiocarbon dates of the Aegean Late Bronze Age, but here the interpretation of the radiocarbon dates is heavily dependent on the rather poor archaeological information available for the samples.

The validity of the traditional chronology is, however, further supported by an analysis of the reasons why the Akrotiri dates appear to calibrate to 1700 BC, even though the samples may actually derive from c. 1520 BC. Calibration is essentially the task of transferring the 14C dating probability from the 14C time scale to the calendric time scale. Owing to the non-linear properties of this transformation, it is quite inevitable that the calibration readings are distorted. Model studies assuming precisely measured 14C dates for samples from 1550-1500

BC show that the mean value of the calibrated dates is necessarily c. 1650 BC, both for single dates and for larger date sets, irrespective of the actual age of the samples. This is because the calibration curve is essentially flat, with a few re-entry wiggles, from 1500-1700 BC. A further implication of the non-linearity of calibration is that all archaeological 14C chronologies based on large numbers of dates are fixed to artificial regions of the calendric time scale and will be distorted quite generally. The problems of the calibrated 14C dates at the site of Akrotiri thus have to be generalized. Because the calibration readings of all 14C dates adhere to specific time intervals it appears appropriate to look at radiocarbon dates in the general terms of what I like to call 14C Quantum Chronology.

WIENER 2001

Malcolm H. Wiener, *The White Slip I of Tell el-Dab'a and Thera: Critical Challenge for the Aegean Long Chronology*. In: VASSOS KARAGEORGHIS (Hrsg.), *The White Slip Ware of Late Bronze Age Cyprus*, *Proceedings of an International Conference in Honour of Malcolm Wiener, Nicosia 29th–30th October 1998*. Denkschriften der Gesamtakademie 20 (Wien 2001), 195–202.

In order to accommodate a 1628 BC date for the WS I bowl in the Volcanic Destruction Level at Thera, the Aegean Long Chronology would still require: (1) the deposit of the stratified PWS bowl from a Dab'a D/2 tomb (together with the other nine examples of PWS from that stratum) near the beginning of the time period encompassed by stratum D/2; (2) the production of the PWS bowl fifty years prior to the date of its deposition in Egypt, together with all of the PWS and WS I fragments found in D/2 and C respectively (unless they are survivals from earlier strata in which no such examples, but large numbers of MB Cypriote wares, were found); (3) the arrival of one of the earliest pieces of WS I at Thera not long before the eruption (notwithstanding some evidence that the bowl in question was repaired in antiquity, as noted by Merrillees, this volume); and (4) the existence of significant chronological overlap between PWS/WSI and White Painted V at least, if not the Pendent Line and Cross Line Styles of White Painted III/IV as well, notwithstanding the fact that such an overlap is not observable at any site in Cyprus, the eastern Mediterranean or the Nile Delta, and goes against the evidence at Toumba tou Skourou, Tell el-Ajjul and Tell el-Dab'a (Eriksson, this volume; Oren, this volume; Bergoffen, this volume; Bietak and Hein, this volume).

Each of these four propositions is individually unlikely, and the chance of all of them obtaining is slim indeed. The White Slip pottery from Tell el-Dabca and Thera accordingly presents a most critical challenge to the proposed 1628 BC date for the eruption of Thera and to the Aegean Long Chronology.

WIENER 2003

Malcolm H. Wiener, *Time Out: The Current Impasse in Bronze Age Archaeological Dating*. In: KAREN POLINGER FOSTER & ROBERT LAFFINEUR (Hrsg.), *METRON: Measuring the Aegean Bronze Age*, *Proceedings of the 9th International Aegean Conference New Haven, Yale University, 18–21 April 2002*. Aegaeum 24 (Liège 2003), 363–399.

This paper attempts to survey and critique both the current state of dating by Egyptian and Babylonian/Assyrian historical and astronomical chronologies and the current state of science-based dating by radiocarbon measurements, tree rings

and ice cores. The discussion will focus on the ongoing controversy concerning the date of the eruption of the volcano on Thera (Santorini). Proponents of the Egypto-archaeologically based Aegean Short Chronology place the event between 1560 and 1480 B.C. (at the outermost limits, with some preferring a date before 1530). Leading advocates of the Aegean Long Chronology now place the eruption between 1650 and 1643 B.C., in place of their previous advocacy of 1628 B.C. The 1650–43 B.C. range results from the area of overlap between the Manning et al. dendro-radiocarbon date range for the anomaly in the Porsuk section of the Anatolian floating tree-ring sequence of 1650 +4/-7 B.C. and the Hammer et al. ice-core date of 1645±4 B.C. (1645 +4 = 1649 B.C., with a year of leeway to 1650 B.C. to allow for the possibility of an eruption in the year prior to the year of the putative arrival of its ejected glass shards in the Greenland ice).

This paper thus addresses both the chronology of prehistory and the prehistory of chronology. The interrelated chronologies of Egypt, the Levant, Anatolia and the Aegean are considered against the background of emerging scientific methods of dating and the efforts of prehistorians trained in art history, classics, ancient history and/or anthropology to assess the contributions and limitations of scientific methods of dating and to incorporate appropriately the data provided. Of course interdisciplinary research requires informed communication between disciplines.

Wild 2010

E. M. Wild, W. Gauß, G. Forstenpointner, M. Lindblom, R. Smetana, P. Steier, U. Thanheiser & F. Weninger, *^{14}C dating of the Early to Late Bronze Age stratigraphic sequence of Aegina Kolonna, Greece.* Nuclear Instruments and Methods in Physics Research B **268** (2010), 1013–1021.

Aegina Kolonna, located in the center of the Saronic Gulf in the Aegean Mediterranean (Greece), is one of the major archaeological sites of the Aegean Bronze Age with a continuous stratigraphic settlement sequence from the Late Neolithic to the Late Bronze Age. Due to its position next to the maritime cross roads between central mainland Greece, the northeast Peloponnese, the Cyclades and Crete, the island played an important role in the trade between these regions. In the course of new excavations, which focused on the exploration of the Early, Middle and Late Bronze Age at Kolonna, several short lived samples from different settlement phases have been 14C-dated with the AMS method at the VERA laboratory. Bayesian sequencing of the 14C data according to the stratigraphic position of the samples in the profile was performed to enable estimates of the transition time between the cultural phases. The Aegina Kolonna 14C sequence is one of the longest existing so far for the Aegean Bronze Age, and therefore of major importance for the absolute Bronze Age chronology in this region. Preliminary results indicate that the Middle Helladic period seems to have started earlier and lasted longer than traditionally assumed. Further, at the present stage of our investigation we can give also a very tentative time frame for the Santorini volcanic eruption which seems to be in agreement with the science derived VDL date.

Keywords: Radiocarbon dating | Aegina | Aegean Bronze Age | Bayesian sequencing

Wiener 1998

Malcolm H. Wiener & James P. Allen, *Separate Lives*, *The Ahmose Tempest Stela and the Theran Eruption.* Journal of Near Eastern Studies **57** (1998), 1–28.

We may summarize by posing the following questions to those who would link the Ahmose Tempest Stela to the Theran eruption:

1. Why is the Stela interpreted as implying an unmentioned earthquake, given the presence of terms indicative of human destruction and neglect?
2. If the earthquake that struck Akrotiri an estimated three months to two years before the eruption also devastated Upper and Lower Egypt as Foster and Ritner appear to suggest, why were this earthquake and the supposed eruption-created tempest perceived as a single event?
3. Why were the tempest and darkness perceived in the west, when Thera lies mostly to the north and the direction of winds carried the tephra strongly to the east?
4. How does the description of the storm and its consequences differ from that which would be expected of a typical monsoon-induced storm and resultant Nile flooding?
5. How do the sections of the Stela describing the support of temples and restoration of order differ significantly from other restoration-of-order texts, so as to make the Stela uniquely a reference to damage from the eruption of Thera?

These questions lack convincing answers. Accordingly, it appears unlikely on balance that the Ahmose Tempest Stela refers to the Theran eruption.

Zielinski 1998

Gregory A. Zielinski & Mark S. Germani, *New Ice-Core Evidence Challenges the 1620s BC age for the Santorini (Minoan) Eruption.* Journal of Archaeological Science **25** (1998), 279–289.

Determining a reliable calendrical age of the Santorini (Minoan) eruption is necessary to place the impact of the eruption into its proper context within Bronze Age society in the Aegean region. The high-resolution record of the deposition of volcanically produced acids on polar ice sheets, as available in the SO4(2-) time series from ice cores (a direct signal), and the high-resolution record of the climatic impact of past volcanism inferred in tree rings (a secondary signal) have been widely used to assign a 1628/1627 bc age to the eruption. The layer of ice in the GISP2 (Greenland) ice core corresponding to 1623 ± 36 bc, which is probably correlative to the 1628/1627 bc event, not only contains a large volcanic-SO4(2-) spike, but it contains volcanic glass. Composition of this glass does not match the composition of glass from the Santorini eruption, thus severely challenging the 1620s bc age for the eruption. Similarly, the GISP2 glass does not match the composition of glass from other eruptions (Aniakchak, Mt. St. Helens, Vesuvius) thought to have occurred in the 17th century bc nor does it match potential Icelandic sources. These findings suggest that an eruption not documented in the geological record is responsible for the many climate-proxy signals in the late 1620s bc. Although these findings do not unequivocally discount the 1620s bc age, we recommend that 1628/1627 bc no longer be held as the "definitive" age for the Santorini eruption.

Keywords: Santorini (Thera) | Ice Cores | Tephra | Bronze Age | Minoan Civilization