The full citation of this article is: "Overview and Assessment of the Evidence for the Date of the Eruption of Thera" in D. A. Hardy and A. C. Renfrew, eds., *Thera and the Aegean World III: Proceedings of the Third International Congress, Santorini, Greece, 3-9 September 1989*. Vol. III "Chronology" (London: The Thera Foundation 1990) 13-18.

Overview and Assessment of the Evidence for the Date of the Eruption of Thera

---

Introduction:

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.

1. Marinatos's 1939 evidence for a 1500 BC eruption.

It is fitting that we meet on the 50th anniversary of Professor Marinatos's (1939) paper in which he proposed a date of 1500 BC for the eruption. Upon re-reading his paper, I submit that the key pieces of his evidence were the synchronisms with Egyptian material such as had been found just a few years earlier by Xanthoudides (1924) in reused tombs in the Mesara. While this may not seem like "hard" evidence, it was the best Marinatos had at his disposal fifty years ago. It does presume that Egyptian chronology was and is in good order and that the tombs' use and reuse did not continue for too long a time. If the diagnostic pottery was deposited with earlier burials, and the scarabs were deposited with later burials, for example, decades or more later, then the alleged synchronisms lose much of their value.

2. Additional archaeological evidence since 1939.

It is frustrating that a half-century's excavation throughout the Aegean and eastern Mediterranean has shed so little additional light on the date of the Theran eruption. Indeed, Marinatos's declaring for 1500 BC so early in the archaeological game has often meant that everybody else has adjusted his dates to fit the, by now, canonical 1500 BC. In the 1970's, following the publication of the first Thera radiocarbon dates (see below), there were a few questions, notably those voiced at the 1977 Archaeometry Meeting in Philadelphia (Hood 1978), but not until the last five years, in which there has appeared a spate of papers discussing and re-discussing the subject, has there been a serious question of this conveniently round figure, even though in off-the-record discussion some excavators will admit that firm evidence is lacking.

3. The first University of Pennsylvania radiocarbon dates: 1625 BC+.

The first serious effort at applying the then relatively new radiocarbon dating method to 16 samples of carbonized material from Thera (Michael 1976; Betancourt and Weinstein 1976; Fishman, Forbes, and Lawn 1977) yielded excellent uncalibrated results (approximately 1500 BC) and disturbing calibrated results (approximately 1625 BC or one or two years earlier, depending on whose calibration table one uses). The group of samples was remarkably homogeneous, and the one outlier (about a millennium too old) was explained away as possibly an inner ring of a very old tree. People who did not believe in calibration said the bristlecone pine calibration technique was thereby disproved. People who believed in calibration, on the other hand, were forced to conclude that something was possibly amiss with Aegean Bronze Age chronology. A third group tried to rationalize the discrepancy by saying that 14C dates from volcanic areas are contaminated by gases and are therefore corrupt, or that there had been possibly some kind of laboratory error. The gas theory I have never felt competent to judge, but I do not understand how 15 dates could have clustered together so neatly purely on the basis of a laboratory error. A recent study (Betancourt and Michael 1987) in which undersized samples are excluded from the calculations makes the cluster look even better.

4. The second Pennsylvania radiocarbon dates: all over the map.

A second batch of Thera samples was analyzed at Pennsylvania in 1976ff., presumably as a control upon the first batch (I suppose we could ask Professor Doumas what his motives were for submitting it), with horrible results for all parties concerned (Betancourt, Michael, and Weinstein 1978; Weinstein and Michael 1978). The dates ranged all the way from the Early Bronze Age to the end of the Late Bronze Age. The very few reasonable dates fell into both early and late camps. Indeed, the authors themselves pointed out that "the Series II radiocarbon dates are of little or no value for Minoan chronology." Here a claim of laboratory or some other kind of error is, I believe, allowable. Moreover, no statistical analysis is capable of sorting out the good and bad dates, although there have been some valiant recent efforts (Manning 1988; Aitken 1988). The wonder is that Professor Doumas was willing to agree to any kind of 14C analysis at Akrotiri again after such an unpromising beginning.

5. The new radiocarbon dates from Simon Frazier University: high or low?

The radiocarbon dating impasse was commented upon by Professor Doumas during the 1986 Archaeometry Meeting in Athens, and a third 14C study resulted. This will be reported on during this Congress, and I defer to Dr. Nelson, hoping that he is at last in a position to resolve the radiocarbon dating problem for us.

6. The 1390 BC Danish ice-core date: (now withdrawn).

In 1980 an apparent confirmation of the conventional date for the Theran eruption appeared in the Greenland ice cores (Hammer, Clausen, and Dansgaard.) The date as published was 1390 + 50 BC. This date has now been withdrawn by its authors although it lingers in the literature. As I understand it,

the crucial core was broken just above the large acidity layer that was thought to represent the Theran eruption, and, since the eruption was thought to be more or less around 1500, the layer was therefore assigned its date.

7. LaMarche and Hirschboeck's bristlecone pine frost rings in 1626 BC.

Shortly after he began work on bristlecone pines from the upper timber line, that is to say over 4000m. altitude, the late V. LaMarche knew he had a correspondence between frost rings and volcanic activity throughout the world. The governing principle seems to be that in years when the dust veil index is high, solar radiation bounces back into outer space, and the mean temperature of the earth drops enough so that these trees are damaged by frost. In 1974 when I first visited LaMarche's laboratory in Tucson he showed me how he had looked at the 1500 BC tree- ring to see what evidence there was for frost damage: nothing. He then looked a hundred years on either side of 1500 BC, and again: nothing. But in 1626 BC he had evidence of a volcanic explosion somewhere, several magnitudes that of Krakatoa. Of course this blast did not have to be from Thera. It could have been from anywhere in the world, but no one has yet proposed a reasonable alternative to Santorini. LaMarche asked whether this was going to get him in trouble with Aegean archaeologists, and I assured him that it would. He mentioned it casually in a National Geographic Magazine interview in 1977 and then published it formally in 1984 (LaMarche and Hirschboeck). Note that LaMarche's date has no plus-or-minus factor. It is correct to the year 1627 BC. (LaMarche's computer was programmed to include a year 0 between 1 BC and AD 1. Thus his 1626 BC with a year zero = 1627 BC without a year zero.) The event that caused this frost ring would have taken place a year earlier in 1628. Note that LaMarche's high-altitude bristlecone pine chronology replicates Ferguson's from lower altitudes, which, by the way, does not have these frost rings, but the crossdating is secure.

8. M.G.L. Baillie's 1626 Northern Irish bog oak rings.

As Dr. Baillie will no doubt be saying in his presentation to this Congress, after LaMarche's paper appeared, he examined the 22 bog oak samples from this period in Northern Ireland which were by then part of an absolutely dated 7,272 year long chronology. He found that on a number of samples the years 1628-1626 BC were the narrowest rings in the entire lifetime of the tree (Baillie and Munro 1988). On two trees the rings after 1628 were so small that they were totally unmeasurable. Corroborative evidence for the volcano-narrow ring relationship includes singularly narrow bands at AD 540, 207 BC, and 1153 BC, dates when it is believed significant volcanic activity took place. In the Irish bogs the mechanism for the abnormality is different from that of the frost rings in the American southwest: volcanic activity triggers both cold and possibly flooding, and the result is an extremely narrow band of rings which can continue for some years after the event. The Northern Irish oak chronology, replicated by several German laboratories, is also accurate to the year as is the bristlecone pine chronology. 1628 BC, then, and the years immediately following, were bad years in areas as widely separated as California, Northern Ireland, the Aegean (presuming Thera was the culprit), and even, perhaps, China.

9. The revised Danish ice-core dates: 1645 + 20 BC.

The Danes have now published a new date based on a new, intact core from the Dye 3 deep sounding in south Greenland (Hammer, Clausen, Friedrich, and Tauber 1987). They note a high acidity signal at 1644 BC and suggest a 1645 BC eruption with an estimated standard deviation of + 7 years and an estimated error limit of + 20 years. Note that 1628-1626 is well within the limits of the ice core evidence as revised. I am not in a position to judge the reliability of these error estimates, and I look forward to hearing from the authors as to their confidence in the date.

10. D. Sullivan's Theran ash near Sardis & his 14C dates for it.

Sullivan (1988) has found a 12cm. thick layer of Theran ash in Gölcük, a small lake above Sardis in western Asia Minor. He has a radiocarbon date of 7,400 + 120 BP on peat from well below the tephra and another of 3,110 + 160 BP from a peat layer 30cm. above the tephra. This is not immediately helpful to us, because the time range includes everything from about 5000 BC down to about 1420 BC, and we have no idea how long it took for the 30cm. of material to accumulate above the tephra layer. But Sullivan is setting an example for the rest of us. The Gölcük work has two significant aspects: a) the Theran fall-out must have affected western Asia Minor in much the same manner as Denys Page (1970) posited for eastern Crete; and, b) once these strata are identified and isolated, and, if organic material can be recovered both from above and below the tephra and submitted for radiocarbon dating, we will have a time control far removed from any contaminating volcanic gases.

11. Other reported Theran ash falls in the islands and in Anatolia.

Sullivan's work may be coupled with reports of Theran ash on Keos, Rhodes (Doumas and Papazoglou 1980), and elsewhere in western Anatolia. W. Voightlander (pers. comm.) has now found Theran ash mixed with LMIa and LMIb pottery on the Anatolian coast at Teichioussa. Sullivan reports more Theran ash at Köycegiz. More will no doubt be found as we learn what to look for.

12. Ralph Rowlett's thermoluminescence dates.

Rowlett (pers. comm.) has been doing a large number of thermoluminescence dates on Theran ash, but I have not yet seen printed results. The error margins for TL are such that under normal circumstances the prospects of resolving this particular problem would be unlikely. As I understand it, he hopes that by the sheer number of TL determinations (~1000) he will get a clustering that will be significant.

13. Dendrochronological evidence as of 1988 from the Turkish mainland.

In our laboratory at Cornell we have a floating, almost continuous dendrochronological sequence for the eastern Aegean that runs from the 23rd to the 8th century BC with only one gap, about thirty years long, in the late 17th century BC. Before September 1989 we will have returned to Gordion and Porsuk, two sites which ought to give us the material to fill this gap, thereby providing us with a 1500 year continuous floating chronology wiggle-matched by 26 radiocarbon dates of specifically-numbered rings. Measurement of the newly-collected wood will start in October 1989 as soon as we return to Ithaca, N.Y. There is no obvious anomaly in the Aegean tree-rings around 1500 BC, and as of June 1989 we do not yet have a ring for 1626 BC, so we are not in the position of either LaMarche or Baillie to make any claims about odd-looking rings, but give us several more months, and we will see. Our low-altitude (below 2000m.) Aegean wood does not exhibit the responses of either the high-altitude California wood or of the Irish bog oak, and, although we can point to some narrow rings following volcanic activity elsewhere in the world, I do not believe that these are statistically significant. Thera, being much closer, might have left a mark of some sort.

14. Dendrochronological non-evidence from Thera.

In 1982 Professor Doumas kindly invited us to look at the charcoal on Thera, of which he has several kilograms. The notion was to see whether we could find a ring-sequence which we could then try to crossdate with the long sequences from Anatolia. Interestingly, all that is preserved at Akrotiri is the charcoal from the hearths, and we discovered to our disappointment that the people of Thera did not burn their first-quality wood. Although we found several small flakes of conifer, the bulk of the charcoal is either olive or grapevine, neither of which are useful for dendrochrono-logical analysis. The restored beams that one sees in all the Thera photographs are modern reproductions of unburned beams that have long since rotted away. We have told Professor Doumas that the day he discovers a burned building at Thera with well-preserved charcoal from constructional timbers all he has to do is send us a

telegram and we will be on the next airplane.

15. The Hyksos and the argument from silence.

One oddity which proponents of the 1500 BC date have never been able to explain is why there is no mention of this catastrophic event in the Egyptian records. Thera ash has been excavated in the Nile Delta (Stanley and Sheng 1986), and surely the Egyptians should have left us some kind of comment. In the period of the Hyksos, however, internal Egyptian affairs were in sufficient disorder so that had the eruption occurred in 1628-1626 the lack of comment is explicable. It is of course illogical to say that, because we hear nothing from the Egyptians, something, therefore, must have happened, but the earlier date does make more sense from an Egyptologist's point of view.

16. Summary.

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.

ACKNOWLEDGMENTS: The Aegean Dendrochronology Project is supported by the National Endowment for the Humanities, the Institute for Aegean Prehistory, the National Geographic Society, the Samuel H. Kress Foundation, the A. N. Lindley Foundation, and a number of private contributors.

Bibliography:

AIKEN, M. J. (1988)
"The Minoan Eruption of Thera, Santorini: A Re-Assessment of the Radiocarbon Dates," in JONES, R. E. and CATLING, H. W., eds., *New Aspects of Archaeological Science in Greece, British School at Athens, Occasional Paper 3 of the Fitch Laboratory*, 19-24.

BAILLIE, M. G. L. and MUNRO, M. (1988)
"Irish Tree Rings, Santorini and Volcanic Dust Veils," *Nature* 332 (24 March) 344-346.

BETANCOURT, P. P. (1987)
"Dating the Aegean Late Bronze Age with Radiocarbon," *Archaeometry* 29:1, 45-49.

BETANCOURT, P. P., MICHAEL, H. N. (1987)
"Dating the Aegean Late Bronze Age with Radiocarbon: Addendum," *Archaeometry* 29:2, 212-213.

BETANCOURT, P. P., MICHAEL, H. N., and WEINSTEIN, G. A. (1978)
"Calibration and the Radiocarbon Chronology of Late Minoan IB," *Archaeometry* 20:2, 200-203.

BETANCOURT, P. P. and WEINSTEIN, G. A. (1976)
"Carbon-14 and the Beginning of the Late Bronze Age in the Aegean," *American Journal of*

Archaeology 80, 329-348.
DOUMAS, C. and PAPAZOGLOU, L. (1980)
"Santorini Tephra from Rhodes," *Nature* 287 (25 September), 322-324.
FISHMAN, B., FORBES, H., and LAWN, B. (1977)
"University of Pennsylvania Radiocarbon Dates XIX," *Radiocarbon* 19:2, 188-228.
HAMMER, C. U., CLAUSEN, H. B., and DANSGAARD, W. (1980)
"Greenland ice sheet evidence of post-glacial volcanism and its climatic impact," *Nature* 288 (20 November) 230-235.
HAMMER, C. U., CLAUSEN, H. B., FRIEDRICH, W. L., and TAUBER, H. (1987)
"The Minoan Eruption of Santorini in Greece Dated to 1645 BC?" *Nature* 328 (6 August) 517-519.
HOOD, M. S. F. (1978)
"Discrepancies in 14C Dating as Illustrated from the Egyptian New and Middle Kingdoms and from the Aegean Bronze Age and Neolithic," *Archaeometry* 20:2, 197-199.
LaMARCHE, V. C., Jr., and HIRSCHBOECK, K. K. (1984)
"Frost rings in trees as records of major volcanic eruptions," *Nature* 307 (12 January), 121-126.
MANNING, S. (1988)
"The Bronze Age Eruption of Thera: Absolute Dating, Aegean Chronology and Mediterranean Cultural Relations," *Journal of Mediterranean Archaeology*, 1:1, 17-82.
MARINATOS, SP. (1939)
"The Volcanic Destruction of Minoan Crete," *Antiquity* 13, 425- 439.
MICHAEL, H. N. (1976)
"Radiocarbon Dates from Akrotiri on Thera," *Temple University Aegean Symposium*, 7-9.
PAGE, D. L. (1970)
The Santorini Volcano and the Destruction of Minoan Crete. Society for the Promotion of Hellenic Studies, (JHS Supplementary Paper No. 12.)
PANG, K. D. (1985)
"Three Very Large Volcanic Eruptions in Antiquity and Their Effects on the Climate of the Ancient World," *EOS (American Geophysical Union)*, Vol. 66, No.46 (12 November), 816.
STANLEY, D. J. and SHENG, H. (1986)
"Volcanic Shards from Santorini (Upper Minoan Ash) in the Nile Delta, Egypt," *Nature* 320 (24 April), 733-735.
SULLIVAN, D. G. (1988)
"The Discovery of Santorini Minoan Tephra in Western Turkey," *Nature* 333 (9 June), 552-554.
WEINSTEIN, G. A. and MICHAEL, H. N. (1978)
"Radiocarbon Dates from Akrotiri, Thera," *Archaeometry* 20:2, 203-209.
XANTHOUDIDES, S. (1924)
The Vaulted Tombs of the Mesara: An Account of Some Early Cemeteries of Southern Crete. (London: University Press of Liverpool).

Discussion from the Conference

Peter Warren: I think, first of all, that the work that Dr. Kuniholm is doing gives the best hope that we shall eventually have an absolute date for Thera, if a tree ring from Thera can be found to match the dendrochronological sequence. I am interested to see that so far he hasn't a ring for 1628/26, nor for 1500. May I make the briefest of references to the paper of LaMarche and Hirschboeck, which was the original proposal for a 1628/27/26 date? There isn't time to repeat them now, but I gave numerous reasons in *Nature* (308 no. 5959) in 1984, using their own data, why the probability of a correlation between the Californian frost-ring event in 1627 and the Theran eruption, or indeed any volcanic eruption, is very low indeed.

Peter Kuniholm: I think the burden is really on Mr. Doumas: please find us a burned building.

Floyd McCoy: You said you found the ash at Troy?

Peter Kuniholm: On the basis of the distribution pattern, there ought to be about 7 cm of the stuff. Professor Korfmann has this in mind as the Trojan survey continues. Parenthetically, I do have rings for 1500, all the way back to 1552, but there's nothing unusual about them. But what goes on around 1626/7/8 remains to be seen.
