[Slide 1]

KEYNOTE ADDRESS

THE STATE OF SCIENCE IN MEDITERRANEAN, EGYPTIAN AND NEAR EASTERN CULTURES, CLIMATE AND CHRONOLOGY

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May I begin by saying how pleased I am to be here today. Some months ago I vowed never to speak at a conference again, for the simple reason that I have reached the age of 75, and if I live to 90 and retain most of my marbles I still will not have time to publish all my research and proposals concerning the rise, florescence, and collapse of the formative civilizations of the Old World. Your invitation was irresistible, however, for the project on which you are about to embark represents the fulfillment of a major wish—the combination of a great dendro lab, a great radiocarbon lab, and specialists in other scientific disciplines including climatology, geology, geochemistry, volcanology, osteology and DNA analysis, with anthropologists, archaeologists and prehistorians in seeking to unravel the story of the human experience, including the chronological relationships of the formative Old World civilizations.

Let there be no doubt that major questions involving the history of humankind await our efforts. For example, just when anthropologists and prehistorians thought that they had something of a grip on the main outlines of human history, with a hunter-gatherer stage followed by a Neolithic era of agriculture and animal husbandry, with the first permanent settlements appearing between about 9,500 and 8,000 BC, along came an astonishing discovery at a site called Göbekli Tepe, near Urfa in southern Turkey just north of the Syrian border. **[Slide 2]** The site contains massive stone pillars weighing many tons, some carved with images of various wild animals, accompanied by a few radiocarbon measurements indicating dates from an upper level around 9,000 BC, but with significant older levels beneath. There is no indication at the site of cultivated cereals or domesticated animals, however. Perhaps further evidence will be forthcoming from surrounding areas, although much has been lost to the waters from the new Atatürk dam, but at least for the moment it appears that large work groups and monumental architecture preceded agriculture and animal husbandry, instead of following in their wake. Radiocarbon determinations, you will note, are a critical component of the discussion. More are urgently needed, accompanied by a sobering knowledge of the inherent limitations of radiocarbon dating, a topic to which we shall return shortly.

In my own area of specialty, the Bronze Age, intense interdisciplinary coordination is required to enlarge our understanding of the major desertification event encompassing large areas of the Near East which began around 2200 BC and lasted for more than a century. **[Slide 3]** The event affected many cultures including, I believe, those of the Aegean, if partly as a second order effect stemming from the incursions of the "intrusive ware" or "Kastri" folk at the end of the Early Bronze Age.

Of course it was the University of Arizona which set the example of close collaboration between tree-ring and radiocarbon experts, as anyone who has read the Leavitt and Bannister paper on the conference website will know. In Egypt, the Near East, Anatolia and the Mediterranean we do not have a continuous sequence from generally well-behaved and very long-lived trees such as bristlecone and foxtail pines native to this region, or the oaks of Germany and Ireland, but we have junipers which grow a good number of years, radiocarbon measurements, and historical information to anchor the sequence. **[Slide 4]** The result is known as the Anatolian Floating Chronology. A continuous 918 year-long sequence ends with massive beams from what is known as the Midas Mound Tumulus at Gordion, now thought to be earlier than the reign of Midas, and perhaps the tomb of his father, called Gordias in one text, about whom nothing is known. **[Slide 5]** More importantly, we have a number of logs from a temple at Ayanis in Urartu built by Rusa II which contains a long inscription describing his deeds. The dates of Rusa's reign from about 685 to 645 BC are well established historically, and the inscription must come late in his reign. Accordingly the inscription and hence the many logs of identical felling date used to build the temple can be dated within a decade, thus establishing an end date for a sequence of overlapping wood segments that now stretch back 2,009 years before the date of the Ayanis temple. **[Slide 6]** Wiggle-matching of radiocarbon measurements of decadal segments of the Anatolian wood with the continuous, precisely dendro-dated German/Irish oak sequence produced the generally convincing fit you see depicted on the chart. Note, however, that at times the fit disappears, as in the 8th century BC. A solar minimum resulting in a cold period affecting differently Anatolian and German trees has been suggested as a possible cause for the disparity, but this is hardly more than an educated guess. Certain decades in the 14th and 13th centuries BC also do not match, and there are peculiar leaps at other points, such as at 1675 BC. Even within one regional sequence, there are strange differences between measurements on trees of known dendrochronological dates, particularly around

1580–1550 BC, perhaps just before the notorious eruption of the volcano on the island of Thera. We have much to learn and much to do.

[Slide 7] The study of texts and interconnections is also ongoing. For example, this week I sent to press a paper proposing a significant revision of what Professor Kenneth Kitchen wittily called the "currently traditional" Egyptian chronology. My paper, by the way, is titled "Oh, No—Not Another Chronology!," the response of Dr. Dorothea Arnold, the distinguished Egyptologist and honorand of the Festschrift in which the article will appear, when I told her of my proposal.

The problem runs as follows. The "currently traditional" Egyptian chronology gives Horemheb, the army commander who seized power after the Amarna period and the short reign of King Tut, a reign of 28 years, based on the reading of three texts. One of the texts is probably a forgery, however, and the readings of the other two are highly problematic. Recently the reexcavation of the tomb of Horemheb at Thebes revealed 254 inscribed sherds comprising at least 60 wine dockets which were once attached to jars, of which 40 had a year date, including 22 of Horemheb Year 13 and 8 of Year 14, but none of any later year. Two other sites contain wine dockets from various years of Horemheb, but again none later than Year 14. The documented career of Horemheb's chief of police, who goes on to serve until at least Year 21 of Ramses II, would require the chief to serve in the post for 40 years, until the age of 75 to 80 at least, if Horemheb reigns for 28 years. A reduction of 14 years in the duration of Horemheb allows a similar reduction in the duration of service and age of the police chief, surely a more likely prospect. Finally, as the great Egyptologist Wolfgang Helck noted long ago, it seems unlikely that in so well-documented a period and reign as that of Horemheb, we should have 14 years of silence. Accordingly, I believe we must accept a 14-year reign for Horemheb.

How to fill the Horemheb 14-year gap? Obviously one must either lower the dates of preceding pharaohs or raise the dates of succeeding ones. My preferred solution is to raise the accession date of Ramses II by 11 years from 1279 BC to 1290 BC, and pick up the remaining three years by some combination of eliminating proposed coregencies from the confused immediate post-Amarna period and/or adding a year or two to other reigns. But why not raise the accession date of Ramses II by 14 years? It is because of our knowledge of Egyptian astronomy. The surviving Egyptian Sothic and lunar observations, as we understand them, give us a choice of 1279, 1290 or 1304 BC for the accession of Ramses II, but none of the years between. I might add that the first sizable, coherent set of radiocarbon measurements of Egyptian material, published recently by Chris Ramsey of the Oxford lab, strengthens my disinclination to fill part of the Horemheb gap by lowering the accession date of Thutmosis III from 1479 BC to 1468 BC as Krauss and Warburton suggested, inasmuch as the lower band of the two-sigma range of the Oxford dates ends at c. 1475 BC, although I base my argument on textual/historical grounds.

[Slide 8] How we resolve these questions has important knock-on effects, not only for Near Eastern, Anatolian, and Aegean chronology, but for the Western Mediterranean as well. Italy has no Aegyptiaca—that is to say, no scarabs with the cartouches of Egyptian pharoahs with closely known dates, for example—but it does have quite a bit of Mycenaean Greek pottery, whose phases, which we call Late Helladic IIIA2, IIIB and IIIC, are dated by their appearances in Egypt in the reigns of successive pharaohs. Hence any change in Egyptian chronology has a wide impact throughout the ancient world.

In the Near East we have what is still the longest textual chronology in the world, the Assyrian, which takes us back safely to 911 BC, and before that, administrative and taxation records of various named years which bring us to around 1400 BC with dates within a range of ±15 years at the most. Moreover, Near Eastern rulers correspond with Egyptian pharaohs, and some of the correspondence is preserved on tablets. If two rulers correspond, then their reigns must be conclusively presumed to overlap. Such overlaps also support raising the beginning of the reign of Ramses II to 1290 BC. The Assyrian account of a great battle at Qarqar in 853 BC between their forces and a coalition led by Ahab provides a critical anchor for Biblical chronology as well. Differences of a few decades matter, for it is hard to write history unless one knows what happened first and what happened next.

What, then, are the principal problems you will face in the world you are about to enter? Let us begin with the trees. There are no well-behaved bristlecone and foxtail pines, no German or Irish oaks, as I have already noted. True, we have junipers in Anatolia as you have heard, but their growth is mainly affected by climate conditions from the area of the Black Sea, unlike Mediterranean trees which are subject to the prevailing westerlies. Hence we are reduced to looking for signature years, in which the effects of a major storm can be traced as it moves across Europe and the Mediterranean. Accordingly, we have a precautionary rule of thumb which states that no comparison between two wood segments should be considered unless each segment represents at least 80 years. We also have the cedars of Lebanon, which Cichocki reports cannot be crossdated satisfactorily even within relatively small geographic areas; moreover, objects examined in Egypt such as chests are often constructed from pieces of cedar from various areas, which in most cases are reused in any event. Of course wood was routinely reused, for it was difficult to obtain and to transport to its intended destination. From Egypt itself we have many sycamores, which are apparently completely useless for chronological dating.

[Slide 9] Of course in the Aegean and parts of the Near East, we have the ubiquitous olive tree. The olive tree has generally been regarded as useless for dendrochronological purposes. Indications of growth of any sort are generally invisible, but may be detected by a technique known as x-ray tomography. Dr. Paolo Cherubini of the distinguished Zurich dendro lab has distributed x-ray tomography photos of branches of olive trees of known planting date and age to various dendro labs, no two of which agreed on the number of indications, or pseudo-rings, they had observed. Furthermore, a single year may see the appearance of several rings, and a number of other years, none at all. Moreover, olive trees, as anyone who has observed them in the Aegean knows, are generally covered in dead branches, which the owners are reluctant to remove for fear of damaging the tree. The two leading authorities on Mediterranean olive trees, Professor Oliver Rackham at Cambridge University and Prof. Harriet Blitzer at Buffalo, report that living trees sometimes carry branches that have been dead for a century.

[Slide 10] These discouraging circumstances were not sufficient to deter the recent publication of a startling claim that radiocarbon measurements of an olive branch from a tree buried under the volcanic tephra on Thera provide a secure date for the eruption. The analysis by Friedrich et al. has been published in leading scientific journals including *Science*, and now in a lavish and heavily subsidized book published by the Danish Institute in Athens.

[Slide 11] The publications state that the olive branch provides "year"—that is, annual—rings that can be counted to an accuracy of ±3 years for each of the four segments of the branch (but unfortunately no other specialists have been invited to see the photographs), and that radiocarbon measurements from four segments of the olive branch can thus be curve-fitted to the INTCAL calibration curve to produce a date for the eruption about 90 years earlier than historical chronology would allow.

The question of whether the branch measured was alive at the time of the eruption is addressed by stating that the tree was alive, but the question concerns the branch, not the tree. The statement is also made that trees do not absorb earth-borne carbon lacking the carbon 14 isotope through their roots, but without any supporting reference and in the face of seven studies of which I am aware that show that trees and plants do indeed absorb carbon through their roots. Much is made also of the fact that the four successive segments of the branch measured produced determinations which descend in order, but that would be the case if the branch had died earlier and/or had absorbed continuing amounts of ^{14}C-deficient carbon from the soil or atmosphere.

[Slide 12] That brings us to the particular problems of radiocarbon dating in the Aegean. Welcome to the world of seasonal–regional offsets and reservoir effects par excellence.

Intra-year seasonal variation in the production of ^{14}C affects radiocarbon measurements. The difference between the summer high and winter low today generally ranges between eight and thirty-two radiocarbon years, and may exceed this range.

Seasonal variation prior to the impact of industrialization on the atmosphere may have been greater. Radiocarbon measurements of seeds of known date collected in Egypt between AD 1700 and 1900 disclosed an offset of 19.5 ±5 calibrated years earlier than calibration curve dates for this period. The result raises the question of whether an adjustment with respect to Aegean measurements is required as well. In addition, radiocarbon measurements of decadal tree segments with years of greatly varying ring thickness may have only a loose connection to measurements of seeds which have a brief growing season within a single year.

Unresolved disparities in measurements of trees of known dendrochronological date occur among logs from the same site (for example, Gordion in Turkey for the years 1580, 1570 and 1560 BC); within measurements from trees in the same geographic area (for example, two forests near the Rhine River at 1550 BC); and between the trees from Germany which form the backbone of the calibration curve and the trees from Gordion in Turkey in a number of periods (for example, c. 1325 and 1225 BC, 1080–990 BC and especially between 850 and 750 BC, when the *average* offset is 28.8 ±26.3 radiocarbon years). When radiocarbon measurements of trees of the same known dendrochronological date differ markedly, at least one of the measurements has provided an erroneous date, whereas agreement between two measurements provides no guarantee against error in both, whether due to reservoir effects or other factors.

As recently as five years ago, large differences in radiocarbon measurements between major high-precision laboratories of samples of the same age divided between them were a significant problem. For example, Manning et al. (2006, 5) reported that

> [o]verall, comparing the Oxford versus Vienna data on the same samples…, we find an average offset of -11.4 ^{14}C years. The standard deviation is, however, rather larger than the stated errors on the data would imply at 68.1 [uncalibrated radiocarbon years]. This indicates that there is an unknown error component of 54.5 ^{14}C years.

Recent years have witnessed a major improvement, if the laboratory intercomparison project just completed by the laboratory here at the University of Arizona in collaboration with the Weizmann laboratory at Rehovot in Israel, the Groningen laboratory in the Netherlands and the Aarhus laboratory in Denmark is any indication. Measurement differences of divided seed clusters from four sites in Israel were minimal. Of course if the samples are affected by contact with ^{14}C-deficient carbon contained in volcanic soil, gas emission fields, carbonate rocks or the rivers that flow over them, or from other sources—what are known as reservoir effects—then measurements from samples divided between laboratories may be consistent, but consistently older than true dates.

Problems arise, however, with the process of calibration of the measurements, however accurate and precise, against decadal or semi-decadal segments of trees of known dendrochronological date. Many of the measurements in the calibration curve data bank were made before the period of high-precision determinations and are of poor quality. Moreover, the weeks or months of seed sample life may be poorly represented in the decadal segment, and regional/seasonal offsets between the location of the samples and of the calibration curve trees come into play.

[Slide 13] Now for the reservoir effects. For the non-radiocarbon aficionados in the audience, I should perhaps state that the carbon 14 isotope is formed by the interaction of cosmic rays with nitrogen in the atmosphere, and is then absorbed by living organisms until they die, at which point decay begins at a measureable rate. Carbon within the earth lacks ^{14}C. For every 1% of ^{14}C-deficient carbon in a sample, the measured age for a sample which dies in 1500 BC, for example, is reported as about 80 years older than the true date.

[Slide 14] The critical sources of ^{14}C-deficient carbon include volcanic and non-volcanic gas vents, geothermal fields, and general soil degassing. In Italy the area of terrestrial CO_2 emissions stretches from Tuscany to Sicily, and from the Tyrrhenian Sea to the Apennines. Similar emissions have been observed in areas of southern Italy, and on the volcanic island of Stromboli. Reported radiocarbon dates from Italian sites whose historical contexts are clear are frequently 100–300 years too early. At Sulphur Banks on Hawaii, three living tree ferns and one Ohia leaf growing one to five miles from a volcanic vent gave radiocarbon ages between 81 and 303 years. Basalt weathering has been proposed as the cause of impossibly early radiocarbon dates from Ethiopia and the Sudan. In addition, in areas such as the Aegean we must contend with what is called the "hardwater effect." Groundwater that has been in contact with soil degassing or with rocks such as limestone, a notorious source of ^{14}C-deficient carbon, if absorbed by plants or consumed by living creatures, often affects radiocarbon measurements which accordingly provide dates that are older than true dates.

[Slide 15] The island of Crete is composed largely of limestone—the White Mountains are not called that by accident. Homer says that the ancient Kydonians lived along the banks of the river Iardanos and its tributaries. The river empties into the Mediterranean 11 km west of Chania, the site of a Minoan palace, a fact worth bearing in mind in connection with four radiocarbon measurements of seeds from an LM IB destruction level there which gave dates earlier than other LM IB destruction deposits.

Before leaving Crete, let us consider a recent report of radiocarbon measurements from the opposite end of the island, at the major east coast harbor city of Palaikastro. Bruins et al., in a pair of articles for the *Journal of Archaeological Science* (2008) and *Radiocarbon* (2009), discuss measurements from two cattle bones, a marine shell, a goat/sheep bone and a tooth. Unfortunately, as Prof. Todd Whitelaw has forcefully noted, none had anything like a secure context. Indeed, the deposits are described as chaotic, disturbed according to the articles by the tsunami wave that accompanied the Theran eruption, as shown by the presence of tephra. The primary evidence, the two cattle bones, produced measurements of 3390 and 3310 BP respectively, which were accompanied by the conventional ±35 radiocarbon years for AMS measurements. You will note that 3390 minus 35 does not overlap with 3310 plus 35, thereby creating, all else being equal, a statistical likelihood of 89% that the two measurements do not represent the same event. Nevertheless, the two measurements were averaged as if they did and an average date of 3350 produced, but now with a plus–minus of 25! As Prof. Jull has observed, the combined measurement should have been plus–minus 40 years at best, and even that assumes that averaging the measurements was justified in the first place. When I described this work to Dr. Richard Garwin, a member of the Institute for Aegean Prehistory ad hoc Scientific Advisory Panel and a most distinguished scientist, he started to laugh as soon as I mentioned the two measurements and said, "Oh, I bet I know what they did—they divided ±35 by the square root of 2 and came up with ±25. That's absurd!"

Why is this relevant to the chronological debate? Because any measurement within the 3320s BP is potentially consistent with the well-founded historical chronology, due to an oscillation of the calibration curve. Samples dated 3350 ±40 BP would include 3320 BP. The measurement of 3310 ±35 BP from one cattle bone fell within the oscillation, and the other did not.

The articles in the *Journal of Archaeological Science* and *Radiocarbon* did not rely solely on the cattle-bone measurements, however. The articles also referred to a single measurement on a mollusk shell from the same chaotic deposit which provided a radiocarbon date 400 years earlier than 3350 BP, which was described as "very important." Dr. van der Plicht, the Director of the Groningen laboratory and one of the coauthors, elaborated on this point in a grant application to continue research submitted to a funding body, stating that the mollusk measurement was crucial, and that the marine sample offset in the Mediterranean was always exactly 400 years. In fact, the first attempt by Minze Stuiver of the Seattle lab to measure the amount produced a general estimate, *grosso modo*, of 400 ±200 years. Subsequent work has produced further adjustments upward for different oceans and seas. With regard specifically to shells from the Mediterranean, Reimer and McCormac examined the magnitude of the reservoir effect in recent Mediterranean shells and found an average Mediterranean offset of 458 ±85 years. Moreover, their research showed century-scale variations in the effect between different shells. As a further precaution, their study excluded shells thought to show a local influence of ^{14}C-depleted river water. Exactly this effect was suspected by Siani et al. on the basis of their study of radiocarbon measurements from mollusk shells found near Mediterranean river mouths, which found a greater offset still.

In addition, the reservoir effect in the Mediterranean varies in time due to upwelling instabilities. Roether et al. discovered that a stupendous flow of Aegean deep water began rather suddenly around 1988, and caused the upward displacement of older waters of the eastern Mediterranean. Such events in the past may have caused significant variations in the magnitude of the marine reservoir effect, as well as affecting terrestrial measurements. Rapp and Hill note that “upwelling of deep water occurs near many coastlines” and that it “is affected by the shape of the coastline and the bottom topography, local climate, and wind and current patterns.”

All of this, however, did not deter Dr. van der Plicht from stating that the marine offset for the North Atlantic and Mediterranean “is always 400” and that “for the marine environment, one can simply subtract 400 years from the measured BP date and subsequently calibrate the result.” In response to queries regarding the application for funding of further research, Dr. van der Plicht added that there was no reason to be concerned about possible reservoir effects with respect to the measurements of the cattle bones, since cattle do not eat fish. He did not mention the potential hardwater effect upon grass, which cattle do eat. A recent study by Ascough et al. showed large reservoir effects via plankton, grass and field horsetail.

The articles in question, and the subsequent response to requests for clarification, might simply be dismissed as preposterous, had not such research been published in respected, peer-reviewed journals, and were not the Groningen radiocarbon laboratory so prominent in the field, providing 4,000 measurements a year. The problematic nature of much peer review in scientific journals is a subject which deserves its own conference.

[Slide 16] So much for recent claims regarding radiocarbon measurements from Crete. What about Thera itself? The volcanic island suffered a devastating earthquake at the beginning of the Late Minoan–Late Cycladic period about 75–100 years before the great eruption, and has experienced recurring vapor emissions until the present. Several studies have shown that volcanic emissions in areas around a volcano increase in the years preceding an eruption. Those who discount any possibility of reservoir effects on Theran radiocarbon measurements say that the olive tree branch we have considered as well as the site of Akrotiri from which the seed measurements come are at a distance from the presumed epicenter of the eruption, as if reservoir effects could only affect samples in close proximity to a volcanic crater.

[Slide 17] This brings us to the critical radiocarbon measurements of Theran material. Of prime importance to the Theran debate are the 28 measurements of seeds found in the Volcanic Destruction Level at Akrotiri, which produced measurements whose reported central ages were as much as 250 years apart, with the total maximum width of the respective probability bands of course wider still. Measurements of the same species of seed provided central radiocarbon ages 215 radiocarbon years apart in the case of peas and 97 years apart in the case of barley. Incidentally, the underlying data just cited is not easy to access. The relevant data were relegated to the supplementary material. **Slide 18** presents the data as provided by Manning et al. in the Supporting Online Material for their 2006 article in *Science*. Two measurements of the same barley seed cluster with the same sample number gave discordant readings of 3400 BP ±31 and 3318 BP ±28. The two measurements were presented far apart from one another, indeed on separate pages, with no explanation concerning the measurements. One colleague observed that had the authors set out deliberately to mask the underlying data, they could not have done a more effective job. Few colleagues have the time to ferret out critical information presented in this manner. Editors of journals and the radiocarbon community in general should insist on clear presentation of data, accompanied by a full statement of problems encountered, uncertainties, and possible sources of error.

[Slide 19] From such ambiguous radiocarbon measurements of seeds from the Theran Volcanic Destruction Level, Manning et al. produced a remarkable conclusion—an eruption date of 3344.9 BP plus or minus 7.5 years, at 95.4% probability! The claimed precision reflects the unfortunate fact that the OxCal, Calib, and other calibration programs narrow stated error bands solely in response to the number of measurements made, irrespective of how consistent, inconsistent, or wildly incommensurate the measurements themselves are. Professor Timothy Jull, Dr. Elisabetta Boaretto of the Rehovot lab, and I have each independently noted this problem in our publications.

Chris Ramsey, the Director of the Oxford laboratory, has kindly responded to my inquiries by stating that there are two potential methods of addressing the problem within the OxCal program. The first is to insert what the investigator—for example, the archaeologist submitting the samples—regards as a minimum acceptable error range, based on her understanding of the nature of the database. In practice this is never done, given the intrinsic unquantifiability of such a minimum and the fact that archaeologists seldom understand the complex statistical issues involved. The second method suggested by Ramsey of addressing the problem inherent in the calibration program is to introduce an asymmetric adjustment to the error range (e.g., +10/-100) to reflect the excavator's understanding of the potential reservoir effects at the site. Such putative effects are also impossible to quantify, however, and no excavator would feel qualified to estimate them. Higham et al. note that measurement of bones poses particular problems with respect to reservoir effects, but that it is not possible to determine a suitable average correction factor.

The paper by Manning et al. has produced an unfortunate "Founder Effect" on subsequent papers. The article by Bruins et al. refers to the "amazing similarity" of the average date of their two cattle bones to the date obtained by Manning et al. for the Theran seeds, and the Friedrich et al. paper about the olive branch also invokes the support of the Manning et al. claim regarding the Theran seeds.

The paper by Bruins published in *Science* which is posted on the conference website speaks of a "scientific date" for the Theran eruption, differing by a century from the historical date. In claiming the existence of a scientific date, it would have been appropriate to consider all the scientific evidence, and not only that which is believed to support one's own view. **[Slide 20]** Consider in this regard the radiocarbon measurements and other evidence from site of Tell el 'Ajjul near Gaza, where in a single distinct destruction level there appear Theran pumice, Egyptian New Kingdom pottery, and Cypriot White Slip I pottery similar to a bowl recovered from the Theran Volcanic Destruction Level, plus five seeds not affected by Aegean reservoir effects whose radiocarbon dates center exactly on c. 1525 BC., a historically and archaeologically appropriate date for the eruption, while only touching the asserted Manning–Friedrich–Bruins–and van der Plicht eruption date of c. 1613 BC at the limit of the two-sigma range. Radiocarbon dates from Tell Abu al-Kharaz also agree with historical dating.

Even more telling, 415 samples of pumice and tephra from the Minoan eruption of Thera have been found at 19 sites in Egypt, the Levant, Cyprus and the Aegean, all of them from New Kingdom contexts after c. 1540 BC at the earliest, whereas the 27 examples of pumice from earlier contexts all come from the earlier eruptions of Nisyros and Gyali in the Dodecanese. The investigators note that if the Aegean Long Chronology were correct, "it would indeed be most peculiar a phenomenon that pumice from the Minoan Santorini eruption were abundantly available along the shores of the Eastern Mediterranean, yet for some reason had been left unnoticed and unused by the local inhabitants for 100–150 years."

We have considered various possible sources of error in radiocarbon measurements, most of which result in proposed dates which are earlier in time than true dates. These include the problems of pretreatment of samples, of inconsistencies in the measurement of ^{14}C, seasonal variation, regional variation, the uncertainties of the calibration curve itself, and the possibility of contact with ^{14}C-deficient carbon from the earth, seawater or groundwater. Let us recall that the bell-curve probability distribution only purports to state the probability that a particular set of radiocarbon measurements fits a particular segment of the calibration curve. In radiocarbon dating, and in statistic-speak generally, the term "probability" is used within a particular statistical paradigm, whereas in standard discourse the term "probability" implies that all contrary information, sources of uncertainty, and areas of insufficient knowledge have been considered. Indeed, the use of the term "probability" should perhaps come with a warning label, reading about as follows:

> CAUTION: The estimate of probability provided rests on the assumptions that the measurements have not been affected by 1) laboratory bias, that is, that other laboratories would have obtained very similar measurements, which is not necessarily the case; 2) seasonal/regional variation and/or problems of comparison between a short-lived plant growing in one climate zone against 5- to 10-year segments of oak trees growing in another; 3) the possible presence of ^{14}C-deficient carbon from sources in the earth or water, some of which may be absorbed through roots as well as through atmosphere by leaves, a problem which may be particularly acute in areas of known volcanic activity, gas-emitting fields, or formations of carbonate rocks such as limestone; and/or 4) the structure of the calibration programs, which narrow error bands solely in response to the number of measurements made irrespective of their consistency or inconsistency.

The chemistry and biology of sky, land, and water is not easy to capture in ^{14}C measurements and statistical probability models. The gaps in our knowledge, the sparseness of our observations in relation to the knowledge we seek, and the insufficiency of our explanations for the anomalies we observe in our measurements should induce caution in our conclusions.

As you will have gathered, I believe that much that has been published, and in leading peer-reviewed journals at that, is simply nonsense squared. There is much underbrush to remove. Bruins et al. conclude their paper in *Radiocarbon* by saying that it is important not to mix scientific and historical chronologies, as they exist in separate realms. Yet that is precisely what we must do, and what I see as the raison d’être for joining forces. With this bold initiative, the University of Arizona has the potential to become the world leader in an area of fundamental importance to the history of humankind.