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Biblical Radiocarbon Dating the Minoan Eruption to the Exodus

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Abstract

Dating of the Minoan Eruption of the Middle Bronze Age has been an elusive goal of archaeologists since at least the 1970s. An absolute date would make this eruption a timestamp for ancient sites throughout the Mediterranean world since tephra from the eruption is a common finding in these ruins. But with no historical record of this greatest volcanic eruption in human history, investigators are left with the indirect dating methods of pottery seriation, stratigraphy, and radiocarbon, which have so far been unable to resolve a 100 to 150 year discrepancy between the secular radiocarbon date and the archaeological date for the eruption. Biblical radiocarbon dating offers the prospect of resolving this discrepancy by overturning secular radiocarbon dating with its uniformitarian assumptions and affirming the younger archaeological date for the eruption. Biblical recalibration of the radiocarbon ages of ancient carbons associated with the Minoan Eruption supports the idea that this major volcanic event occurred at the time of the Exodus in 1446 BC. Therefore, the Minoan Eruption may have contributed to the plagues that fell from God on Egypt during the Exodus.

Keywords: Minoan Eruption, Santorini, Akrotiri, Exodus, radiocarbon, tree rings, tsunami

Introduction

The citizens of the ancient city of Akrotiri likely knew they were living on a volcano. The cluster of earthquakes and the outgassing of several new vents on the island of Thera may have provided an oracle of doom that caused an abrupt evacuation of the city. Most of the citizens probably escaped to the island of Crete, which lay less than 160 km (100 mi) south across the azure Mediterranean Sea. Imagine a vast flotilla of sailing ships, overloaded with terrified people, leaving the greatest port city in the ancient world. Likely, no one remained to see the andesite peak in the center of the caldera beginning to expand, nor the gases bubbling up from the surrounding waters inside the crater rim. Then, with the energy of a thousand thermonuclear warheads (Pang, Srivstave, and Keston 1989), a mountain of rock and lava, a dense rock equivalence of 31 km^3, exploded into the sky (Karstens et al. 2022). The island split into three as a towering plume of black ash mixed with fire climbed to the upper stratosphere. The caldera collapsed further beneath the waters. A tsunami swept across the now grey sea, destroying the north coast of Crete and killing many of the refugees who had fled from Thera to escape the eruption, only to be swept away by the massive wave (Lespez et al. 2021).

The Minoan Eruption of the island of Thera, modern Santorini, is the greatest volcanic event witnessed in human history (Friedrich 2013). Yet there are no written accounts like that of Pliny the Younger, who described the much smaller Vesuvius eruption of AD 79, which destroyed Pompey and its inhabitants. With its towering ash column, Pliny's description of that cataclysm has defined these most massive volcanic events as "Plinian" eruptions. Modern investigators claim the Minoan Eruption is the greatest of all Plinian eruptions. The geology of Santorini, the tephra deposits spreading 1000 km to the east, and the ruins on the north of Crete provided undeniable evidence that the Minoan Eruption dwarfs all volcanic events in recorded history (Kuethe 2018; Pearson et al. 2023). Absent a written record, it is unsurprising that many have attempted to correlate the Minoan Eruption with ancient Near Eastern accounts of unusual weather events. Some attribute the eruption to the collapse of the Minoan civilization, which once dominated the Aegean (Freewalt 2013). Others have associated the event with the biblical Exodus, possibly recorded in the chronicle of Ahmose (Wood 2006), the first pharaoh of the eighteenth dynasty of the Egyptian New Kingdom. Some have even related the collapse of the caldera and its central island to the destruction of the mythical Atlantis, which sank into the sea (Howells 2024). While there are many competing scenarios, most agree that an event of this proportion must have profoundly affected the civilization of the eastern Mediterranean in the second millennium BC. However, the lack of an eyewitness written account of the Minoan Eruption has prevented the accurate dating of the event. This is unfortunate since tephra marking the eruption is found in archaeological sites throughout the Middle East and Egypt (Manning et al. 2006). A firm date for the Minoan Eruption would provide an invaluable timestamp for biblical and ancient Egyptian chronology. This is why the dating of the eruption continues to be the focus of intense discussion among all who are interested in the history of the second millennium BC.

Attempts to date the Minoan Eruption have produced several symposia (Bruins, van der Plicht, and MacGillivray 2009; Fischer 2009; Friedrich and Heinemeier 2009; Friedrich, Wagner, and Tauber 1990), library shelves filled with dusty volumes (Hardy et al. 1990; Warburton 2009), and a long list of scientific articles from archaeologists and Egyptologists (Bietak 2003), biblical chronologists (Eames 2021; Harris 2014; Jackson 2014), and scientists of august radiocarbon laboratories of major universities in Europe and America (Manning et al. 2006). Historically, investigators fell into two main camps. Those in the "high date" camp of mostly radiocarbon scientists date the eruption to 1700 to 1600 BC. Those in the "low date" camp, mostly archeologists and Egyptologists, date the eruption to 1600 to 1500 BC (Höflmayer 2012; Manning et al. 2014). A third group, too small even to be called a camp, favors a very low date of the 1400s BC associated with the biblical Exodus. A truce in this decades-long war has yet to be signed, but the radiocarbon scientists have won the greatest gains. Armed with accelerator mass spectrometers and dressed in white lab coats rather than dirty jeans, the radiocarbon specialists present a hard science of numbers against traditional archeologists' softer descriptions of pottery and stratigraphic layers. The archeologists designated pottery buried by the eruption in Akrotiri as Middle Bronze Aged and correlated to Egyptian chronology between the Twelfth and Eighteenth dynasties, from 1550 to 1500 BC (Bietak and Höflmayer 2007; Cherubini et al. 2013). However, the radiocarbon camp, aided by the precise dendrochronology of the IntCal radiocarbon curves, coalesced around 1650 to 1600 BC. Several decades ago, the difference between these camps appeared to be irreconcilable. But now, many old-school archeologists are falling in line with the high date camp (Höflmayer 2012), unable to resist the intimidating radiocarbon numbers with attached Bayesian probability distributions.

This paper proposes a novel solution to this age-dating controversy by overturning the accuracy of all the radiocarbon dates associated with the Minoan Eruption. The main thesis presented here is that secular radiocarbon dating, based on a major uniformitarian assumption, may be precise but is not accurate. When recalibrated to the biblical timescale, the radiocarbon dates of ancient carbons used to date the Minoan Eruption will be shown to be from the mid-fifteenth century BC, near the time of the Exodus. The recalibration of the Minoan Eruption date and its association with the Exodus are discussed below. But first, a biblical radiocarbon scale (Jordan 2024) and its assumptions will be described.

Radiocarbon Dating with a Biblical Timescale

While radiocarbon dating is a useful tool for dating carbons younger than 3,000 years before the present (BP), its accuracy falls off for older carbons until it fails as a dating method. This can be seen in the Intcal20 radiocarbon calibration curve published by the IntCal Working Group (Reimer et al. 2020), which purports to present tree-ring carbon-14 (C14) values extending back to 14000 BP. This date is incompatible with the biblical record of the global Flood, which is thought to have wiped the earth clean of all its trees about 4,500 years ago, burying them in sediments to form the coal seams of the world. As a result, there are no tree rings older than 4500 BP. Yet for dates younger than 3000 BP (about 1000 BC), radiocarbon calibration with the IntCal20 curve is accurate, as attested by many archeologists, with a notable exception, which we shall now consider.

The destruction of Nineveh in 612 BC is a well-dated event by historical records. However, the C14 dating of human remains associated with that destruction "indicated an age a little less than two centuries too old" using the Intcal radiocarbon curve according to Taylor et al. (2010). These archeologists from the Cotsen Institute of Archeology at the University of California offered several possible explanations for the too-low C14 value, including site contamination and dietary reservoir effects (a seafood diet has reduced C14), but could not decide the cause. They did note that a slight increase in the observed C14 content of the bones would move the C14 age forward (younger) about 80 years into the Hallstatt plateau, a mid-first millennium BC region in the Intcal radiocarbon calibration curve where a C14 age has a 200-year uncertainty. That would put the date of the human remains between 750 and 550 BC, encompassing the date of Nineveh's destruction in 612 BC. To test whether other seventh century historical artifacts date too old with radiocarbon, Porter and Dee (2013) obtained C14 dates on textiles wrapping the mummy of Shepenese, a woman who lived in the first half of the seventh century BC. They found that the date was "fully compatible with estimates made on historical grounds." This suggests that the Nineveh anomaly is due to some local problem and is not due to a miscalibrated Intcal radiocarbon curve during the seventh century BC.

Given the technical difficulty of radiocarbon dating, such as site contamination and stratigraphic uncertainty, it is not surprising that inaccuracies may increase going back in time. This is especially true for dates falling on the Hallstatt plateau, described above. Still, radiocarbon dating in the first millennium BC with the Intcal curves has been accurate in many cases, like that of the mummy of Shepenese. Another example of accurate radiocarbon dating in the first millennium BC is the work in Iron Age Jerusalem by Regev et al. (2024). By careful stratigraphy of the burn layer from the destruction of Jerusalem in 586 BC, they calibrated the radiocarbon curve for "high precision dating in the Hallstatt Plateau." Their offsets to the Intcal20 curve were 14 to 21 years, within the acknowledged measurement error for C14, showing that the amended Intcal20 curve can be made more accurate even in the Hallstatt Plateau.

These examples show that the Intcal radiocarbon curves can be useful if properly calibrated with C14 values from carbons of known age. But for dates older than 1000 BC the radiocarbon calibration goes completely "off the rails." This requires an explanation. Why does radiocarbon calibration with the IntCal20 curve work reasonably well back to 1000 BC and then totally fail for earlier dates? The answer to this question is that the dendrochronology was constructed using carbons of known age, such as textiles wrapping a mummy of known age, charcoal from a burn layer of known age, or beams from historical buildings of known age (Arnold, Howard, and Litton 2003; Arnold and Howard 2014; Baille 2009). But there are no carbons of known age or buildings of known age before 1000 BC. To extend the dendrochronology further back in time, "sub-fossil" trees are used. These are trees buried in gravel along rivers, such as the German Oaks (Becker 1993; Friedrich et al. 2004), trees buried in peat bogs, such as the Irish Oaks (Baille 2009), or dead trees lying around on a mountainside, such as the Bristlecone pines (Michael 2000). These sub-fossil trees are placed in the developing master chronology based on C14 measurements that are used to approximate the tree's age (Speer 2010, 254–255). This circular reasoning makes a major uniformitarian assumption since the C14 age is determined from the C14 measurement using the standard "Libby age" formula. This uniformitarian assumption is that the C14 content of the atmosphere at the time the ancient tree lived was about the same as today. This method will undoubtedly surprise many readers who have assumed that the ages of the tree rings were always and solely determined by counting the rings. For a variety of reasons, it is not possible to accurately count rings for thousands of years in a series of pattern-matched dead trees (Sorensen 1976). The rings are often very thin, and even neighboring live trees may have ring patterns that differ. Furthermore, clusters of well-matched tree ring series provide "floating" chronologies that must be bridged to anchor a master series to the calendar. This bridging can be difficult, resulting in "fictitiously long multi-millennial chronologies" (Woodmorappe, 2018). Carbons of known age, including beams from historical buildings are an absolute requirement for constructing a dendrochronology for accurate radiocarbon calibration. When these carbons of known age are not available, that is, for dates older than about 1000 BC, the chronology fails due to the uniformitarian assumption described above.

For a discussion of the many dubious assumptions that allow scientists to construct dendrochronology extending back to nearly 14,000 years BP, before the world was created according to the biblical record, see Hebert, Snelling, and Clarey (2016). Suffice it to say that creationists should not be intimidated by secular claims to have found ancient trees that are tens of thousands of years old. With this understanding of the failure of the IntCal20 radiocarbon calibration curve for carbons older than 1000 BC, we will now briefly review the construction of the biblical radiocarbon calibration curve.

Based on the Masoretic text, the Flood was only 4,500 years BP, which is less than the half-life of C14 (5,730 years) and young earth creationists expect that coal should contain C14. And it does, but at levels vastly lower than expected for carbons only 4,500 years old. The coals of North America seem to have about the same amount of C14, which is less than 1% of the C14 concentration in the atmosphere today (Baumgardner et al. 2003). This suggests that the amount of C14 that prevailed in the atmosphere at the time of the Flood was less than 1% of the modern level. Because coal is a carbon of "known age" containing C14, it provides a starting point for constructing the biblical radiocarbon curve. A second carbon of known age is provided by the 1000 BC tree rings of the IntCal20 radiocarbon calibration curve since the IntCal20 curve is accurate back to about 1000 BC. A third carbon of known age is obtained by assuming the Joseph famine of Genesis 41 caused the "Neolithic Decline," a population collapse in Europe well attested by archeological findings and for which C14 values are available from human remains associated with that collapse. For details on the construction of this biblical radiocarbon calibration curve, see Jordan (2024). This biblical calibration curve, fig. 1, gives C14 values, measured today, for ancient carbons of age 2500 BC (The Flood) to 1000 BC.

Other attempts at biblical calibration have been made, including a recent one by Douglas Petrovich at the International Conference on Creationism (2023). After noting the increasing discrepancy between radiocarbon and archeological dates for events older than 1000 BC, he speculates that the decay rate of C14 may have been increased during and after the Flood. An increased decay rate would reduce the amount of C14 measured today in ancient post-Flood carbons even if the atmospheric C14 were the same back then as today. Also, in the years after the Flood, if the C14 decay rate were to decrease to

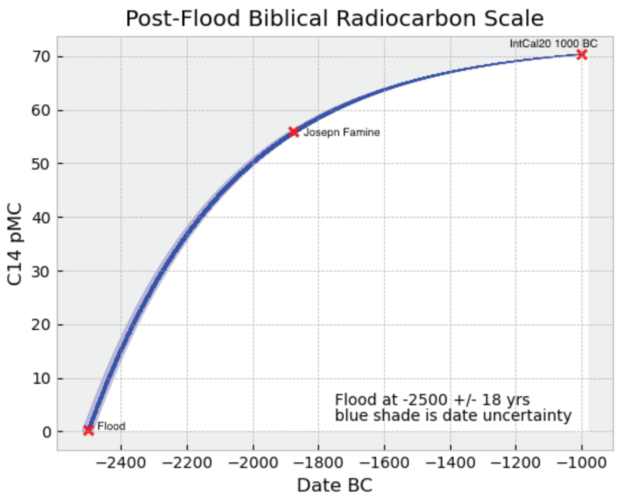

Fig. 1. The biblical radiocarbon scale. C14 versus date BC for dates between the Flood at 2500 BC and 1000 BC. Dates are written with negative sign to represent BC dates. The three carbons of known age use for the curve construction, indicated by the red crosses, are the Flood at 2500 BC, the Joseph Famine at 1875 BC, and the tree ring c14 values from the IntCal20 radiocarbon calibration curve at 1000 BC. Flood date uncertainty is ±18 years.

today's rate gradually over 1,500 years, the curve of fig. 1 might still accurately calibrate radiocarbon to the biblical timescale. Since the curve of fig. 1 is based on the very low measured C14 in coal and this could be due to either lower atmospheric C14 when the coal formed or a higher C14 decay rate after the coal formed, there is no way to distinguish between these two possibilities. The calibration curve of fig. 1 is an empirical model founded on the Genesis record of Noah's Flood. This biblical calibration will now be applied to the radiocarbon samples associated with the Minoan Eruption.

A conclusion of this paper is that the radiocarbon dating of the Minoan Eruption to the late seventeenth century BC is wrong because the IntCal20 radiocarbon calibration curve is wrong for dates older than 1000 BC. The error results from the uniformitarian assumption that atmospheric C14 concentration in ancient times was not lower than today's concentration. In what follows, the C14 values associated with the Minoan Eruption will be collected and recalibrated to the biblical radiocarbon scale, moving the event forward in time. This will show that the Minoan Eruption occurred in the mid-fifteenth century BC, about the time of the Exodus of Israel from Egypt, prompting speculation that the eruption may have contributed to the divine judgments recorded in the Bible.

The Minoan Eruption Radiocarbon Data

Attempts to find the absolute date of the Minoan Eruption using radiocarbon dating have centered around three sources of ancient carbon related to the event. 1) The remains of plants and charcoal buried in volcanic ash on the island of Thera. 2) Animal and plant remains buried in debris from the eruption tsunami, which devastated Crete and parts of coastal Turkey. 3) Plant remains associated with pumice from the eruption in archeological sites in Israel and Egypt. The samples collected from these three venues are now described.

On the island of Thera (modern Santorini) is the city of Akrotiri buried in ash, pyroclastic materials, and fragments of lava. There are no human remains. The people had ample warning of the eruption and escaped. Intense heat destroyed almost everything (Friedrich 2013), leaving burned fragments of short-lived plants (grasses, grains, and forbs) suitable for radiocarbon dating (Manning and Kromer 2012). C14 values from 11 samples of burned plant remains were obtained from the Oxford Accelerator Unit and the Vienna Environmental Research Accelerator (Manning et al. 2014; Manning et al. 2006). These are labeled "Akrotiri Manning" in fig. 2. Two olive branches were also found in the volcanic ash on Thera. The first olive branch, labeled "Santorini olive" in fig. 2, had C14 measurements on its 72 tree rings in four groups: rings 1-13, 14-37, 38-59, and 60-72 (Friedrich et al. 2006). A second olive branch, labeled "Therasia olive," had nine individual tree rings measured for C14, including the outermost bark ring (Pearson et al. 2023). Deep shafts dug in Akrotiri also allowed the collection of charcoal samples from buildings destroyed by the eruption (Maniatis 2012). C14 values from these 10 samples are labeled "Akrotiri Maniatis." The above samples total 31 radiocarbon

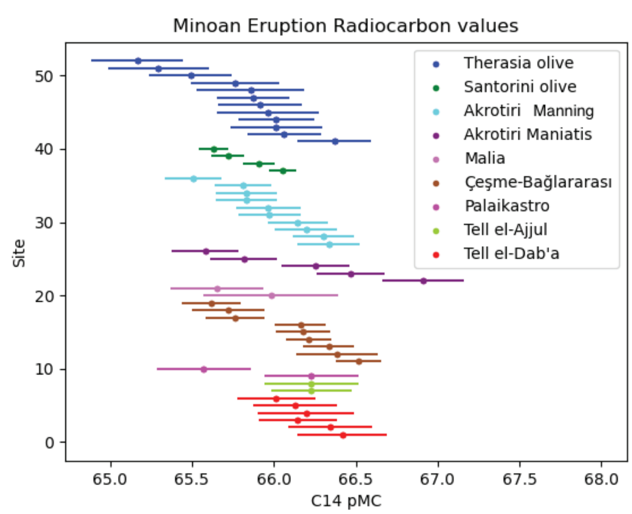

Fig. 2. A plot of the radiocarbon samples associated with the Minoan Eruption. Values of C14 in percent modern carbon are arranged from top to bottom on the vertical axis according to the legend. Descriptions of each group of samples are in the text of the paper. The bars represent one standard deviation.

values obtained from the Minoan Eruption on the island of Thera. They are listed in table 1.

Carbons from three coastal sites devastated by the tsunami were also collected. On the north coast of Crete, a mere 120 km (75 miles) from Santorini, is the ruin of Malia, a Minoan archeological site abandoned in the late Bronze Age. A geomorphological survey of this site shows devastation from the tsunami produced by the Minoan Eruption extending 400 meters inland. The destructive waves brought sand mixed with marine fauna, mostly gastropods and foraminifera, to overlie a marsh to the west of the city. Immediately below this layer of tsunami debris is peat and gyttja, which provided carbon for dating the eruption. Two samples of this material were collected from cores drilled through the tsunami deposits (Lespez et al. 2021). Another archeological site devastated by the Minoan Eruption tsunami is Çeşme-Bağlararası, a western Anatolian/Aegean coastal archeological site lying 230 km (144 miles) northeast of Santorini. Encased in the debris of the tsunami are the skeletons of a human and a dog killed by the event for which C14 values have been measured. Additionally, C14 values were measured on seeds and charcoal fragments in the debris. A total of 9 samples were collected from this site (Şahoğlu 2022). Another Minoan archaeological site, Palaikastro on the northeast coast of Crete, has a tsunami destruction layer associated with tephra from the Minoan Eruption. Mixed in the debris are bones from two cattle for which C14 values were obtained (Bruins, van der Plicht, and MacGillivray 2009). From these three sites, 13 radiocarbon samples associated with the tsunami deposits are recorded in table 1 and displayed in fig. 2.

At coastal sites in Middle East evidence of the Minoan Eruption is found in the form of floating pumice which has been deposited on the shore. At Tell el-Ajjul, an archaeological site in the Gaza Strip, deposits of pumice were found and subjected to Instrumental Neutron Activation Analysis, revealing a trace element profile consistent with the Minoan Eruption. C14 values were obtained for two samples found below the pumice layer, that is, in stratigraphic layer H6 of the site, a position pre-dating the arrival of the pumice and presumably concurrent with the eruption (Fischer 2009). Another site where pumice is found is Tell el-Dab'a in the Nile Delta. This is the ancient city of Avaris, which is thought by many to be the home of the Children of Israel living in the Land of Goshen (Genesis 46:28). The city is inland, so the pumice at the site may have been blown in by wind from shore deposits a few miles away. Archeological excavations here reveal a sudden abandonment of the site at stratigraphic layer D1, dated to the Middle Bronze Age III. Above this abandonment layer, Thera pumice is found, suggesting that the abandonment was about the time of the Minoan Eruption. Samples for radiocarbon analysis were obtained from ryegrass (Lolium) seeds in the D1 layer (Kutschera et al. 2012). From these two pumice-associated sites, a total of 8 samples are recorded in table 1 and displayed in fig. 2.

Recalibrating the Data to the Biblical Timescale

A total of 52 C14 ages associated with the Minoan Eruption were obtained from the published studies of the above sites. The C14 ages were converted to C14 values, given as percent modern carbon-14 (pMC), using the Libby formula, (eq. 1), where "age" is the C14 age in years before the present (BP). These are recorded in table 1, along with one standard deviation, and plotted in fig. 2, where the variation of one standard deviation is indicated by the bars. For each site, a range of C14 ages was reported. For rings of the olive trees, the older ages are for deeper tree rings, and the younger ones are for the outermost rings, which correlate to the eruption date when the tree died. For tsunami deposits, where the destructive waves have mixed the debris, the range of C14 ages is due to variation in the collected samples. For the stratigraphic samples, deeper layers are older, and the younger C14 ages (higher C14 values) are closest to the time of the Minoan Eruption. Because a range is presented for each site, a simple average of the 52 sample C14 values will not give the radiocarbon age of the Minoan Eruption but will be too old. For each site, the younger values are closer to the time of the eruption and a weighted average of the samples will give a better estimate of the eruption date. For this reason, a weighted average of the 52 C14 values is appropriate. The C14 values were weighted by first placing them in a sorted list from lowest pMC to highest, that is, from older to younger. Then each value was weighted by multiplying it by its weight as assigned by the exponential function of eq. 2, where "i" is the index of the value in the sorted list. An exponential equation was selected for weighting in keeping with the method used by others (Höflmayer 2012; Manning et al. 2014) to account for the prior assumption that the later C14 ages and their higher C14 values are closest to the date of the eruption. The weighted mean of the 52 samples is 66.16 pMC. A standard deviation of 0.2201, the average standard deviation for the 52 samples, is assigned to this result.

$$\text{pMC} = 100\left(2^{(-\text{age}/5568)}\right) \qquad \text{(eq. 1)}$$

$$\text{Weight} = 0.1\, e^{.09\, i} \qquad \text{(eq. 2)}$$

The published biblical radiocarbon scale (Jordan 2024) was used to determine the biblical age of the weighted mean of the 52 samples by the following method. Eq. 3 is the biblical radiocarbon

Table 1. Radiocarbon data of samples associated with the Minoan Eruption. Carbon-14 ages and values of 52 samples associated with the Minoan Eruption. "#ID_Number" is the laboratory identification number. "Sample" is the type of plant material analyzed. "Species" is the taxonomic name of the plant sample. "c14_age" is the standary age of the sample based on the Libby formula. "1SD" is the standard deviation of the c14_age. "c14_pMC" is the c14 amount in percent modern carbon. "1sigma" is one standard deviation of the c14 pMC. "Reference" is the published study from which the sample data is obtained. "nan" means not provided.

#ID_Number	Sample	Species	c14_age	1SD	c14_pMC	1sigma	Reference
A/M4N003 rings 6-8	charcoal	Olea europaea	3446	39	65.117	0.3154	Manning et al 2006
C/M4N003 rings 7-8	charcoal	Olea europaea	3440	35	65.1657	0.2833	Manning et al 2006
E/M4N003 rings3-4	charcoal	Olea europaea	3424	38	65.2956	0.3082	Manning et al 2006
M10/23A N012	charred seed	Hordeum sp.	3400	31	65.491	0.2523	Manning et al 2006
M7/68A Noo4	charred seed	Hordeum sp.	3367	33	65.7606	0.2696	Manning et al 2006
D/M4N003 rings 5-6	charcoal	Olea europaea	3355	40	65.8589	0.3271	Manning et al 2006
G/65/N001/l2 ring2	charcoal	Tamarix sp.	3353	27	65.8753	0.221	Manning et al 2006
M2/76 Noo3	charred seed	? Lathyrus sp.	3348	31	65.9163	0.2539	Manning et al 2006
B/M4N003 rings 3-5	charcoal	Olea europaea	3342	38	65.9655	0.3113	Manning et al 2006
M2/76 N003	charred seed	? Lathyrus sp.	3336	28	66.0148	0.2297	Manning et al 2006
M31/43 N047	charred seed	Hordeum sp.	3336	34	66.0148	0.2788	Manning et al 2006
H/65/N001/l2 ring1	charcoal	Tamarix sp.	3330	27	66.0642	0.2217	Manning et al 2006
F/65/N001/l2 ring	charcoal	Tamarix sp.	3293	27	66.3692	0.2227	Manning et al 2006
Hd-23599/24426	tree rings 1-13	Olea europaea	3383	11	65.6297	0.0898	Friedrich et al. 2006
Hd-23587	tree rings 14-37	Olea europaea	3372	12	65.7196	0.0981	Friedrich et al. 2006
Hd-23589	tree rings 38-59	Olea europaea	3349	12	65.9081	0.0984	Friedrich et al. 2006
Hd-23588/24402	tree rings 60-72	Olea europaea	3331	10	66.0559	0.0822	Friedrich et al. 2006
AA111456	tree stem 88-1 inner	Olea europaea	3398	21	65.5073	0.171	Pearson et al. 2023
AA110272	tree stem 88-2 inner	Olea europaea	3361	21	65.8097	0.1718	Pearson et al. 2023
AA111458	tree stem 72-inner	Olea europaea	3358	23	65.8343	0.1882	Pearson et al. 2023
AA111459	tree stem 72-2 outer	Olea europaea	3342	24	65.9655	0.1968	Pearson et al. 2023
AA110273	tree stem-88-2 outer	Olea europaea	3341	23	65.9738	0.1886	Pearson et al. 2023
AA110271	tree stem 88-1 outer	Olea europaea	3320	22	66.1464	0.1809	Pearson et al. 2023
AA111457	88-3 inner	Olea europaea	3314	23	66.1959	0.1893	Pearson et al. 2023
AA110274	tree stem 88-2 bark	Olea europaea	3301	23	66.3031	0.1896	Pearson et al. 2023
AA110275	88-3 outer	Olea europaea	3297	23	66.3361	0.1897	Pearson et al. 2023
DEM-1615	charcoal	nan	3389	25	65.5807	0.2038	Maniatis 2012
DEM-1624	charcoal	nan	3360	25	65.8179	0.2045	Maniatis 2012
DEM-1311	charcoal	nan	3307	25	66.2536	0.2059	Maniatis 2012
DEM-1529	charcoal	nan	3281	25	66.4684	0.2065	Maniatis 2012
DEM-1607	charcoal	nan	3228	30	66.9084	0.2494	Maniatis 2012
Malia pre-tsunami	Gyttja	nan	3380	35	65.6542	0.2854	Lesprez et al. 2021
Malia pre-tsunami	peat	nan	3340	50	65.982	0.4094	Lesprez et al. 2021
OxA-38950	charcoal	nan	3384	22	65.6215	0.1795	Şahoğlu et al. 2022
D-AMS019172	charcoal	nan	3372	27	65.7196	0.2205	Şahoğlu et al. 2022
OxA-38881	nan	Bos taurus	3367	22	65.7606	0.1799	Şahoğlu et al. 2022

OxA-38973	nan	Ovis aries	3318	19	66.1629	0.1563	Şahoğlu et al. 2022
OxA-38972	nan	Sus scrofa	3316	20	66.1794	0.1646	Şahoğlu et al. 2022
OxA-38857	nan	Olea europaea	3312	17	66.2124	0.14	Şahoğlu et al. 2022
OxA-38966	charcoal	nan	3297	19	66.3361	0.1567	Şahoğlu et al. 2022
D-AMS-019173	charcoal	nan	3291	30	66.3857	0.2475	Şahoğlu et al. 2022
OxA-38858	nan	Hordeum vulgare	3275	17	66.518	0.1406	Şahoğlu et al. 2022
GrA-30339	bone	Cattle	3390	35	65.5725	0.2851	Bruins, van der Plicht, and MacGillivray 2009
GrA-30336	bone	Cattle	3310	35	66.2288	0.2879	Bruins, van der Plicht, and MacGillivray 2009
VERA-1905	pumice	plant remains	3310	35	66.2288	0.2879	Fischer 2009
VERA-1904	pumice	plant remains	3310	30	66.2288	0.2469	Fischer 2009
VERA-3725-C/2-3	seeds	Lolium sp	3336	29	66.0148	0.2379	Kutschera et al. 2012
OxA-15957-C/2-3	seeds	Lolium sp	3322	31	66.13	0.2547	Kutschera et al. 2012
VERA-3031-D/1	seeds	Lolium sp	3314	36	66.1959	0.296	Kutschera et al. 2012
VERA-3724	seeds	Lolium sp	3320	29	66.1464	0.2384	Kutschera et al. 2012
OxA-15959-C/23	seeds	Lolium sp	3296	31	66.3444	0.2555	Kutschera et al. 2012
OxA-15958-C/2-3	seeds	Lolium sp	3287	33	66.4187	0.2723	Kutschera et al. 2012

curve, where t is the post-Flood years based on the C14 value, pMC. To eq. 3, an 18-year range of variation was applied to represent the Flood Date uncertainty. This 18-year variation is the difference in the Flood Date of 2500 BC, on which eq. 3 is based, and the estimated Flood date of 2518 BC derived by Thomas (2017). The uncertainty in the C14 value corresponding to the eruption date was modeled by a normal distribution based on the weighted mean and standard deviation. The product of C14 values from this distribution and the biblical calibration curve with its uncertainty gave the likelihood distribution for the date of the Minoan Eruption. The 95.4% likelihood probability range was 1515 BC to 1443 BC. The method is illustrated in fig. 3. Note that the 95.4% likelihood range includes the range of 1450 BC to 1446 BC when the Exodus occurred, according to many biblical chronologists (Habermehl 2023; Osgood 2022). Thus, the Minoan Eruption may have made its contribution to the plagues God used to judge Egypt. We will now proceed to discuss this interesting possibility.

$$t = \left(-1/.002361\right)\ \ln\left(1-\left(\frac{\text{pMC}-.292}{72.112359}\right)\right) \quad \text{(eq. 3)}$$

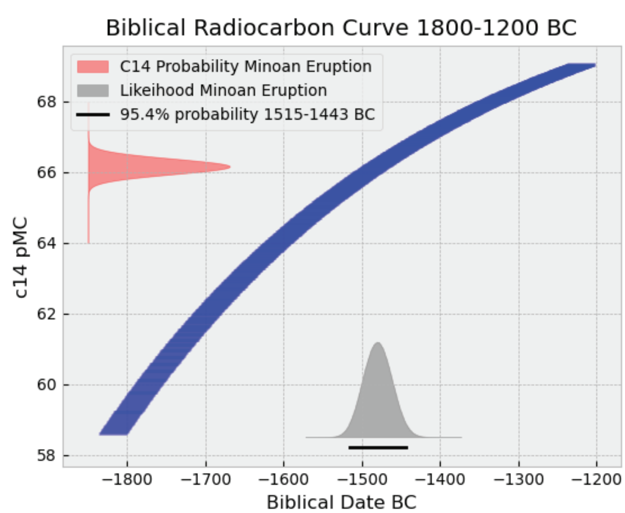

Fig. 3. Illustrating the calculation of the likelihood distribution from the mean C14 value using the biblical radiocarbon curve. The portion of the biblical radiocarbon curve from 1800 to 1200 BC is in blue. The horizontal axis values are negative to represent dates BC. The width of this blue curve represents the 18-year Flood date uncertainty. A normal distribution representing the weighted mean of the 52 c14 values is in red against the vertical axis. The product of the weighted mean distribution versus the blue calibration curve is the likelihood distribution represented by the grey peak. The underlying black line represents 95.4% of the likelihood distribution.

Did the Minoan Eruption Contribute to the Plagues?

Of the 10 plagues with which God judged Egypt two seem to be possible candidates for events associated with the Minoan Eruption: the plague of hail and fire (seventh plague) and the plague of darkness (ninth plague). The plague of hail and fire is described in Exodus 9:22–26.

> Now the Lord said to Moses, "Reach out with your hand toward the sky, so that hail may fall on all the land of Egypt, on *every* person and animal, and on every plant of the field, throughout the land of Egypt." So Moses reached out with his staff toward the sky, and the Lord sent thunder and hail, and fire ran *down* to the earth. And the Lord rained hail on the land of Egypt. So there was hail, and fire flashing intermittently in the midst of the hail, *which was* very heavy, such as had not occurred in all the land of Egypt since it became a nation. The hail struck everything that was in the field through all the land of Egypt, from people to animals; the hail also struck every plant of the field and shattered every tree of the field. Only in the land of Goshen, where the sons of Israel *were*, was there no hail. (Exodus 9:22–26, NASB)

First described by Pliny the Younger in his account of the AD 79 Vesuvius eruption, volcanic lightning occurs with most eruptions. As the ash plume ascends, the particles accumulate static electricity, causing lightning bolts to flash between areas of positive and negative charge in the plume. For example, in the recent eruption of Mount Ruang in Indonesia, nearly 4,000 lightning strikes were observed. The most intense lightning storm ever recorded produced 2,600 lightning strikes per minute during the peak phase of the eruption of Hunga Tonga-Hunga Ha'apai in January 2022 (Kuta 2024). As the greatest Plinian eruption in history, the Minoan Eruption could have produced the fire of the seventh plague described above. Hail is also associated with volcanic eruptions, especially those that explode with large amounts of water vapor, as the sea-filled caldera of the Minoan Eruption was sure to have done. The hail would be dirty with ash and, perhaps, also mixed with rocks. Such an event would make a grievous hail indeed, enough to shatter trees and kill cattle (Van Eaton et al. 2015). But the timing of the eruption and the fact that the land of Goshen where Israel lived was spared from the hail demonstrated to Pharaoh that the God of Israel had caused this plague and protected His own people from it. Since lightning and hail are well-recognized volcanic phenomena, it seems reasonable to assign this plague to the influence of the Minoan Eruption if it occurred at the time of the Exodus. Associating the ninth plague with the eruption will not prove to be quite so easy.

The plague of darkness is described in Exodus 10:21–23.

> Then the Lord said to Moses, "Reach out with your hand toward the sky, so that there may be darkness over the land of Egypt, even a darkness which may be felt." So Moses reached out with his hand toward the sky, and there was thick darkness in all the land of Egypt for three days. They did not see one another, nor did anyone rise from his place for three days, but all the sons of Israel had light in their dwellings. (Exodus 10:21–23, NASB)

Since the plague of locusts occurred between the plague of hail and fire and the plague of darkness, some may object to an attempt to apply the Minoan Eruption to both plagues 7 and 9. However, geologists have found evidence that the Minoan Eruption proceeded in phases (Friedrich and Heinemeier 2009), which could have been days or weeks apart. We are not told exactly how much time separated the seventh from the ninth plagues, during which the plague of locusts devoured all the green plants of Egypt. Maybe it was several weeks. But the time between the several phases of the Minoan Eruption is also unknown, allowing us to speculate on the eruption having contributed to both plagues 7 and 9. Another question arises from the description in Exodus 10 that the darkness was profound, so that "they did not see one another" for three days. How much darkness (and how long-lasting) would the greatest Plinian eruption in human history produce? The darkness caused by most eruptions seems to be a local phenomenon associated with copious ash falling on towns within a few miles of the eruption. But when Mt. Saint Helens erupted May 18, 1980, on that same day, 400 km (250 mi) away, Spokane was plunged into darkness. Since the Egyptian Delta is about 640 km (400 mi) from Santorini, the plume from the Minoan Eruption may well have plunged Egypt into darkness. But two aspects of the plague of darkness seem to be out of line with the idea that the Minoan Eruption was the cause. First, the darkness lasted three days. That seems to be an unusual duration of darkness for a volcanic eruption to produce. But if there is any eruption large enough to produce three days of darkness, the Minoan Eruption might qualify since it was the greatest eruption in human history. The plume from the Plinian phase is thought to have extended into the upper stratosphere. Furthermore, the tephra fallout from the eruption is oriented in a southeastern direction, suggesting that the plume could have overspread Egypt, perhaps sparing some parts of the Nile Delta, such as Avaris, where the children of Israel lived. Second, the darkness was said to be so dark that they could not see each other. While some may think this is an exaggeration of rhetorical effect, that degree of darkness has clear supernatural implications. Could the light from lamps and hearths also have been blocked by the power of God so that they literally could not see each other's faces? This may have been so, in which case there was no exaggeration. Such profound darkness seems to go beyond what might be expected from volcanic dust and smoke blocking the sunlight. The supernatural darkness may have been a neurological affliction of the optic nerve or a cortical blindness such as afflicted the Sodomites of Genesis 19:10–11. The supernatural character of this judgment is further seen in the fact that while Egypt was plunged into dense darkness, "all the children of Israel had light in their dwellings (Exodus 10:23b)."

These considerations of how the Minoan Eruption could have contributed to the plagues by which God judged Egypt and humbled Pharaoh should not be construed as an attempt to explain away miracles as purely natural events. God controls all parts of his creation and uses them as he sees fit. And timing is important when it comes to miracles. For example, the walls of Jericho may have been brought down by an earthquake. But to have that earthquake happen after the seventh lap around the city on the seventh day and with the blowing of the horns and the shouting of the people requires a miracle. If God used the Minoan Eruption to cause plagues in Egypt in the process of redeeming Israel, let no one say it was not miraculous.

Discussion

When the radiocarbon samples associated with the Minoan Eruption are recalibrated to a biblical timescale, the estimated date for that eruption is moved to the mid-fifteenth century BC. The 95% confidence range of possible dates includes 1446 BC, the date of the Exodus according to many biblical chronologists. If the Minoan Eruption occurred at the time of the Exodus, then it may have contributed to some of the miraculous plagues with which God afflicted Egypt in the course of redeeming Israel from slavery to Pharaoh. Being the largest eruption in human history, how could it not have contributed? Plagues 7 and 9 are both suggestive of volcanic phenomena, furthering speculations of this nature.

This study involves several crucial assumptions that could be wrong, casting some doubt on the conclusion that the Minoan Eruption occurred in 1446 BC. These assumptions can be put into one of three groups. First, we will consider assumptions concerning the reliability of the collected radiocarbon samples being associated with the Minoan Eruption. Next, we will consider the method used in this paper to average the radiocarbon values to get the C14 value indicative of the eruption date. Then, we will consider the assumptions of the biblical radiocarbon calibration curve.

The burned plant samples from the ruined city of Akrotiri date to the event because they are on the Island of Thera and buried in volcanic ash from the eruption. These samples pose no concerns about their proximity to the eruption date. Tsunami debris samples are of more concern because the eastern Mediterranean is geologically unstable and prone to earthquakes that could produce tsunamis (Burton et al. 1984). The Santorini caldera collapse associated with the Minoan Eruption is thought to be the cause of a major tsunami, but other events, earlier or later eruptions or earthquakes, could have caused the tsunami debris fields on the coast of Crete and Turkey. If these tsunamis were many years removed from the Minoan Eruption, then the C14 ages associated with these debris fields would not correspond to the Minoan Eruption date. A similar concern must be raised for the carbons taken from below pumice deposits. Pumice was valued and collected by ancient peoples for use in construction and other industries. So, just because pumice is found somewhere doesn't prove that it was borne over the sea and floated in after a recent eruption. Archaeologists try to distinguish between these possibilities. Regarding the seeds collected from the abandonment layer of the Tell el Dab'a site, these were in the stratigraphic layer below a layer with pumice from the Minoan Eruption. How much time elapsed between the abandonment and the arrival of the pumice is uncertain and may amount to enough time to render the C14 age of the seeds remote from the eruption date. These uncertainties fall in the realm of archeological science. The publications referenced above discuss the issues to their satisfaction, giving them the confidence to propose the C14 ages of their collected samples as indicative of the Minoan Eruption.

In eight of the nine sites from which radiocarbon samples were obtained, a range of C14 ages was reported between about 3440 to 3230 BP. At each site, the later dates, with higher C14 values, were thought to be closest to the eruption date. Thus, some form of weighted mean would be required to get the most likely radiocarbon date from the range unless one took the youngest and used it as the value. Several options for weighting the samples were considered: a linear increase in prior expectation, a cut-off of values below 66 pMC, and an exponential weighting function. The exponential function was finally selected as the weighting method. The exponential of eq. 2 was chosen because it gave a curve that almost ignored the oldest samples without completely devaluing the later ones until it weighted the youngest. This method was also used in the analysis of Manning et al. (2014) and Höflmayer (2012), who used exponential functions to weight their similar prior assumptions about the radiocarbon values. Of course, different parameters for the exponential function could be used to make the weighting curve more or less steep, with the steeper exponential increasing the contribution of the youngest radiocarbon ages to the result. Alternative weighting methods would alter the likelihood distribution for the eruption date, but given all the uncertainties of radiocarbon dating, it would not alter the conclusion of this paper. Now, we will proceed to consider the assumptions that will undoubtedly provoke great consternation from secular radiocarbon scientists and questions from creationists interested in radiocarbon dating.

The biblical radiocarbon calibration curve is based on several key assumptions and, therefore, is bound to cause some skepticism. Most radiocarbon scientists will be appalled at the idea that coal is from plants that died in the Flood just 4,500 years ago. Likewise, they will reject the idea that the atmospheric C14 level then was less than 1% of today's level or that the C14 decay rate could have been higher in the past. Convincing them to accept the biblical radiocarbon calibration curve is a lost cause from the start. But even creationists and those who accept the reality of the global Flood are bound to have some skepticism regarding the many assumptions of biblical radiocarbon calibration. The major sources of uncertainty attending the construction of the curve are the "known carbon" anchor points: the date of the Flood of Noah, and the date of the Joseph famine of Genesis 41. The published biblical radiocarbon curve used a 215-year uncertainty on the date of the Flood (Jordan 2024). This degree of uncertainty seemed to be unwieldy for this attempt to date the Minoan Eruption since the range of possible dates would be too large. A solution to this excessive uncertainty was found in the paper by Thomas (2017), where a careful analysis of the Genesis genealogies led to the conclusion that the Flood was between 2518 and 2532 BC. The published calibration curve of eq. 3 was based on a Flood date of 2500 BC, so a new and much smaller uncertainty of ±18 years was applied to the biblical radiocarbon curve before it was used to compute the likelihood of the Minoan Eruption from the radiocarbon values. The date of the Joseph famine is also controversial, as some adopt the "long sojourn" model of Israelite stay in Egypt (430 years), and others adopt the "short sojourn" with a stay of 215 years. The published biblical radiocarbon curve assumes the long sojourn and places Jacob's entry into Egypt with the Children of Israel in 1875 BC. This date was correlated to the "Neolithic Decline," a well-recognized population collapse in Europe for which radiocarbon-aged human remains are available. If either of these assumed dates is wrong, the date of the Joseph famine or the date of the Neolithic Decline, the curve would be thrown off, and the calculated likelihood distribution for dating the Minoan Eruption might not include the time of Exodus. The same would apply to any error in the dating of the Flood, although that error would be less severe because the Flood was 1,000 years before the Exodus.

The several assumptions discussed above must cast some doubt on the assertion that the absolute date of the Minoan Eruption has been found. Without a definitive historical record of the eruption, it is impossible to eliminate all uncertainty. This idea is lost to the minds of some secular radiocarbon scientists, who seem to project a confidence inconsistent with the uncertainty of their methods. Wishing to avoid such overconfidence, one should conclude that the Minoan Eruption may have occurred at the time of the Exodus and may have contributed to some of the phenomena associated with the plagues with which God judged Egypt.

A word must be said about how the biblical date for the Minoan Eruption casts new light on the controversy between secular radiocarbon dates and archeological dates for this event. After some resistance, the archeologists who date the eruption to the late fifteenth or early sixteenth century BC have been, grudgingly perhaps, trying to accept the more "scientific" dates of secular radiocarbon calibrations that place the eruption 100 years earlier. However, the secular radiocarbon date disagrees with careful stratigraphy and archeological correlations across the eastern Mediterranean region. Well then, the archeologists should smile upon the biblical radiocarbon date for the Minoan Eruption since it serves to vindicate their archeological science. But for some reason, the radiocarbon ages from major universities, no matter how uncertain and tarnished with assumptions, seem to win the debate easily when opposed by the soft science of archeology. The bias included in the secular radiocarbon method is rarely discussed in detail by radiocarbon scientists, so strong is their nearly universal commitment to millions of years of earth history and uniformitarian geology. It falls upon traditional archeologists such as Bietak (2003) to list the problems of secular radiocarbon dating when these "scientific" dates are inconsistent with the methods of stratigraphy and ceramic seriation. But for those who believe the Genesis record of history, the presence of C14 in coal demands that the IntCal20 radiocarbon curve be reinterpreted for dates older than 1000 BC. Because Genesis gives an accurate record of the Flood with chrono-genealogies dating it about 4,500 years ago, we should be confident that a biblical radiocarbon scale can be made based on the certainty that "the world at that time was destroyed, being flooded with water." (2 Peter 3:6, NASB).

Conclusions

The greatest volcanic eruption in human history is the Minoan Eruption of the Middle Bronze Age, which destroyed the city of Akrotiri on the island Thera, modern Santorini. With no written historical record of this event, dating the Minoan Eruption has proven to be elusive as the evidence from archeology places the eruption in the late sixteenth to early fifteenth century BC while secular radiocarbon dating places the eruption from 100 to 150 years earlier. But secular radiocarbon dating based on the IntCal20 radiocarbon calibration curve is known to lose accuracy for dates older than 1000 BC due to a fundamental assumption involved with the construction of the dendrochronology that underlies the curve. A biblical radiocarbon calibration curve has been devised that can give more accurate radiocarbon dates for carbons between 4,500 and 3,000 years before the present, that is, from the Noah Flood to 1000 BC. This recalibration curve is based on the carbon-14 content of coal and human remains from the Neolithic Decline, which is correlated to the Joseph Famine of Genesis 41.

In this paper, 52 radiocarbon ages of samples associated with the Minoan Eruption are collected from the literature and analyzed using the biblical radiocarbon curve. The recalibration places the likelihood of the date of the Minoan Eruption in the mid-fifteenth century BC, close to the date of the Exodus (1450–1446). This allows speculation that the eruption may have contributed to the plague of hail and fire (seventh) and the plague of darkness (ninth), which God used to humble Pharaoh and judge Egypt in the process of redeeming his people, Israel, from slavery. The lack of a historical account of the Minoan Eruption and the assumptions that attend radiometric dating must lend some uncertainty to the date of the event and its correspondence to the date of the Exodus. Nonetheless, this interpretation of the radiocarbon data suggests that the Minoan Eruption and the Exodus were concurrent. If so, just as God may have used an earthquake in the destruction of Jericho or a meteor airburst to destroy Sodom, God may have used the greatest volcanic eruption in human history to plague Egypt during the Exodus. The Lord created all things and can use whatever means he chooses to accomplish his will. Even the winds and the waves obey his voice and we are justified in thinking the Minoan Eruption may have contributed to the Exodus if the two events were contemporaneous.

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