Dendrochronology and the date of the Thera volcanic eruption

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Abstract. The main disciplines that contribute to our understanding of the chronology of the ancient Near East are history, archaeology, and various scientific dating techniques including dendrochronology, radiocarbon dating, and ice-core analysis. Beginning in the 1980s, a major rift began to develop between the historical-archaeological chronology and that based on dendrochronology-calibrated radiocarbon dating. The current disparity between these alternate timelines is probably best seen in two, seemingly irresolvable, debates: 1) the absolute date of the Thera (modern Santorini) volcanic eruption, which is a crucial event in establishing a relative chronology between the historically-dated Near East and the archaeologically-dated Aegean region and, by extension, the wider European continent; and 2) the 'Conventional' versus 'Low' Chronology dates assigned to Palestinian Iron Age I, a period in Near Eastern history often referred to as the 'Dark Ages'. I argue that both these disputes arise from incorrectly assembled dendrochronology master sequences, and which underlie the international radiocarbon calibration (IntCal) curve used to convert primary radiocarbon dates (BP) into secondary, calibrated, historical dates (cal. BC). The proposed correction to the IntCal curve will require a radically different set of correlations between volcanic signals in Greenland ice-cores (GISP2, GRIP and Dye-3), on the one hand, and, on the other, tree-ring growth anomalies (from various regions of the northern hemisphere) that are also seen as resulting from the atmospheric effects of large volcanic eruptions. Moreover, it will be argued that all scientific research since 2006 that has disassociated the massive GISP2 volcanic signal at 1623 BC from the similar sized signals in the GRIP core at 1636 BC and in the Dye-3 core at 1644/41 BC is built upon a wrong analysis. This hypothesized 'alternative chronology' will provide near precise dates for four of the largest volcanic eruptions of the Holocene period, namely, Thera, Aniakchak II, Hekla 3 and Hekla 4, and it will bring much greater chronological clarity to the so-called Hallstatt Plateau.

1 Introduction

By necessity the history of the Bronze Age and Early Iron Age Near East is founded upon the twin pillars of Egyptian and Assyro-Babylonian chronology. The latter prevails east of the Euphrates River and is the framework upon which the additional histories of the Great Kingdoms of Hanigalbat and Elam are constructed. The former measures historical time to the west of the Euphrates, most notably for the Great Kingdoms of Hatti and Mitanni, the Syro-Palestinian principalities, and the Aegean region. The first attested absolute date in the history of Near Eastern civilization is the solar eclipse of June 15, 763 BC, which was registered in the year of the Assyrian *limmu* official Bur-Sagale (Hunger, 2008). Prior to that date, historians must rely upon discrete chronologies constructed from king-lists and other administrative documents from various kingdoms. This textual information was assembled along with archaeological evidence over the past two centuries to create a widely accepted historical-archaeological chronology for the Ancient Near East. The latter ‘conventional’ chronology began to be disputed in the 1980s following the introduction of the Accelerator Mass Spectrometry (AMS) technique in radiocarbon dating, and the additional use of short-lived organic samples for greater accuracy and precision. Currently, calibrated radiocarbon dating is found to be significantly older than historical-archaeological dating during various phases of the Bronze Age and Early Iron Age periods (Zerbst and van der Veen, 2015). The conventional chronology is afflicted by three significant uncertainties. First, based on ‘The Venus Tablet of Ammisaduqa’, the First Dynasty of Babylon is provided with a ‘High’, ‘Middle’ and ‘Low’ date-range, and which would see Year 1 of the penultimate king Ammisaduqa dated to 1702, 1646, and 1582 BC respectively. The High chronology has fallen out of favour in recent years, only to be replaced by an ‘Ultra-Low’ chronology of 1550 BC (Pruzsinszky, 2009; Gasche et al., 1998). Second, New Kingdom Egyptian chronology suffers from a similar High, Middle, and Low debate in which the accession year of the 18th Dynasty Pharaoh Tuthmose III varies between 1504 (Memphite calendar), 1490 (Elephantine calendar), and 1479 (Theban calendar) BC (Åström, 1987–1989; Bietak, 2002). And third, the New Kingdom is separated from the first securely attested absolute date in Egyptian history (664 BC) by the complex and chronologically indeterminate Third Intermediate Period.

It was argued by Furlong (2007) that Egyptian New Kingdom (Memphite) dates should be lowered by 200 years to match historical actuality. This Alternative Chronology (AC) was achieved in two stages: first, the overlapping of precisely 85 years in Assyrian chronology from between the reigns of the Conventional Chronology (CC) 11th century king Shalmaneser II (1031–1021 CC) and the securely dated Ashur-dan II (934–912 BC); and second, the downward displacement of Egyptian dates relative to Late Bronze and Early Iron Age Assyrian chronology by a further 115 years. This means that the accession of Tuthmose III will equate to 1304 AC. Year 1 of Ammisaduqa was also therein dated to 1419 AC, meaning that Year 1 of the dynasty’s founder, Hammurabi I, will become 1565 AC (Furlong, 2010: 94 and n. 16). For clarity, the letters ‘BC’ will be used below to signify scientifically derived dates, and ‘CC’ to signify ‘conventional’, historically derived, dates (BC/BCE).

The date of the Thera volcanic eruption has been a point of serious scholarly disagreement for the past five decades. At a time before dendrochronology-adjusted radiocarbon calibration, uncalibrated BP dates associated with this event were too low to be compatible with historical-archaeological evidence, and since that adjustment they have been considered by many historians and archaeologists as too high. Currently, the discrepancy amounts to anywhere between a few decades to as high as 100 years or even more during the mid-second millennium CC (Bietak, 2024; Manning, 2024a). The dating discrepancy in the Palestinian Early Iron Age (EIA) I–II debate is somewhat less. However, the repercussions for the political history of Old Testament Israel are no less significant as it would transform the EIA IIA monumental buildings at Megiddo VA–IVB, Hazor X–IX and Gezer VIII from being constructions of the United Monarchy under Solomon (as seemingly referred to in 1 Kgs 9:15) to being constructions of the time of King Omri of Israel (Finkelstein, 2020; Shochet and Gilboa, 2018, esp. p 383; Mazar, 2011; Steiner and Killebrew, 2014). And such a dating adjustment would necessarily reverberate throughout the wider Syro-Palestinian region. These two chronological disputes involve plateaus in the IntCal curve, and where calibrated dates exceed primary ^{14}C BP dates by approximately the same amounts as the calculated differences between the alternate ‘high’ and ‘low’ chronological viewpoints.

The 1990s saw a period of general consensus amongst researchers in dendrochronology, radiocarbon dating, and ice-core analysis regarding the date of the Thera eruption. Three very large SO_4^{2-} ion aerosol signals in three different Greenland ice-cores were, within acceptable error margins, all compatible with the date-range of the Thera eruption according to calibrated radiocarbon evidence (Pearson et al., 1983; Pearson and Stuiver, 1986). These three sulfate signals – GISP2 (1623 ± BC), GRIP (1636 ± 7 BC) and Dye-3 (1644/41 ± 5 BC) (Zielinski et al., 1994; Hammer et al., 1987; Clausen et al., 1997) – were then associated with three significant dendrochronology signals: 1) in the bristlecone pine sequence from the south-west USA (1627 BC frost-ring – LaMarche and Hirschboeck, 1984); 2) in the Irish oak sequence (1628 BC tree-ring width minima – Baillie and Munro, 1988); and 3) in the 1,503-year Anatolian floating chronology based on trees growing within the tephra fall-out zone of the Thera eruption (tree-ring 854 growth spurt – Kuniholm et al., 1996). Barring minor differences, this level of chronological agreement suggested a ‘global-wide’ environmental signal for the Thera eruption (Baillie, 1995).

However, by the early 2000s, this consensus began to crumble. First to go was tree-ring 854 from the dendro-isolated Porsuk tree-ring series, and which was moved back in time to 1650 +4/–7 BC due to adjustments to the radiocarbon dating of the Anatolian floating chronology, thereby placing it outside the probable radiocarbon date-range for the Thera eruption (Manning et al., 2001: 2535). Subsequently, the latter event was again persuasively argued to be the most plausible cause of the tree-ring 854 anomaly (Pearson et al., 2009: 1207). But any possible association was later definitively excluded when the date of tree-ring 854 was again moved about 20 years earlier to ~1681–1673 BC (Manning et al., 2016: 8/27). Then followed any claimed connection between the Thera eruption and either the GISP2 1623 ± BC or the Dye-3 1644 ± BC acid signals. Comparison between the chemical composition of tephra discovered in the GISP2 1623 ± BC lamination and Theran material indicated that they had quite different volcanic origins (Zielinski and Germani, 1998a). Conversely, S. W. Manning argued that the chemical composition of the GISP2 signal was quite consistent with its derivation from the Thera eruption, and he continued to suggest that all three signals (1628/7 BC tree-ring signals, and the Dye 3 and GISP2 sulfate spikes) were most likely associated with the Thera eruption (Manning, 1998: 1041, 1999: 280–281; see Zielinski and Germani, 1998b, in response to Manning, 1998). Another research team discovered tephra in the GRIP ice core (located 30 km east of the GISP2 site in central Greenland), but now dated to 1645 ± 4 BC, and which they argued originated in the Thera eruption (Hammer et al., 2003). Subsequently, other researchers argued that the tephra found in the relevant Dye-3 ice-core lamination was not from the Thera eruption but rather from the Aniakchak II eruption in Alaska (Wiener, 2003; Pearce et al., 2007). And this view was supported by later research which found that the GRIP 1636/1645 ± BC signal (presumably corresponding to the Dye-3 1644 ± BC signal) also probably came from the Aniakchak eruption (Coulter et al., 2012: 9). Previously, the GISP2 1623 ± BC signal had been removed from the equation altogether when its date was lowered by about 27 years in the new composite ‘Greenland Ice Core Chronology 2005’ (GICC05), which was created using all the available ice-cores (except GISP2), and then replaced by the preceding GISP2 acid signal at 1669 ± BC to then become 1642 ± 5 BC. This adjusted date, compared with the other two signals in Dye-3 (1644 ± BC) and GRIP (1636/1645 ± BC), permitted the continued assertion of a (new) triple ice-core 'Theran' signal (Vinther et al., 2006: 9/11, and Table 5). Lastly, one of the strongest advocates for the 1628/1627 BC Thera 'global-wide' environmental signal admitted that the associated dendro evidence more likely relates to the Aniakchak II eruption (Baillie, in McAneney and Baillie, 2019: 108). Two clear conclusions can be drawn from this debate. First, that it is difficult to make an affirmative identification between tephra appearing in an ice-core and the volcanic source of that material. And second, that the Thera eruption currently has no convincing association with any sampled volcanic signal in the Greenland ice-cores. The case for the 'Aniakchak' association is much stronger, but still not certain. The current intense, and seemingly irresolvable, dispute over the date of the Thera eruption has now mostly been left to those who rely on radiocarbon evidence from Thera-related deposits (e.g. Manning, 2024a), and those who argue on the basis of historical-archaeological evidence (e.g. Bietak, 2024).

Numerous recent scientific articles, despite quite different and sometimes contradictory findings, all argue (either explicitly or implicitly) that calibrated radiocarbon and ice-core evidence is in broad agreement throughout the Holocene period, and which, if correct, would provide strong support for the 'scientific' 'high' chronology case (see Sect. 2.3.4). Conversely, it is argued below: that the dendrochronology master sequence(s) underlying the international radiocarbon calibration curve are incorrectly assembled; that uncalibrated radiocarbon dates provide a more <u>accurate</u> measure of historical time than does calibrated dates; and that, as such, the currently accepted synchronisms between tree-ring growth anomalies and ice-core acid signals during the historical period preceding the Hallstatt Plateau (c. 750–450 cal. BC = 2520–2420 BP) are profoundly wrong. An alternative arrangement of dendro versus ice-core signals will be provided that more accurately reflects historical reality, and which would deliver an almost precise answer as to where the original errors were made in constructing the embryonic dendrochronologies that subsequently became the foundation of the IntCal curve. Moreover, it will be shown how this alternative chronology, based solely on dendrochronology and ice-core evidence, can provide a solution to the 'Thera' and 'Palestinian Iron Age I–II' chronological disputes, and how it can deliver greater chronological clarity to the archaeologically confusing LBA–EIA and Hallstatt plateaus in the IntCal curve.

2 Tree-ring, radiocarbon, and ice-core dating

2.1 The current situation

Calibrated radiocarbon dating currently presents the principal objection to any radical revision of Ancient Near Eastern chronology. B. Becker examined the dendro-sequences of the two principal timbers used in constructing the early dendro master sequence underlying the IntCal curve, namely, the bristlecone pine of the south-west USA and the European oak. Based on the German oak absolute tree-ring chronology (2800–800 BC), he found that: "the first deviation of the [uncalibrated] ^{14}C ages from the appropriate dendro-dates becomes evident from 1000 to 1400 BC (. . .). Between 1550 and 1750 BC, the ^{14}C ages are too young by ca 100-150 years, increasing more or less steadily at 2200 BC to ca 250 years;" and that the long-term trends of these two timber sequences were very similar for the period 700 to 2800 BC (Becker, 1983: 200). Subsequently, the German 'long' dendrochronology sequence was broken at 500 BC and the older section moved back in time by 71 years

(Baillie, 1995: 39), which would thereby increase this dendro-radiocarbon offset at c. 1550–1750 BC to about 170-220 years, and at 2200 BC to about 320 years. There is a further one–to–one (1:1) relationship between calibrated and uncalibrated radiocarbon dates over the period between 5000 and 9000 BP (Fairbanks et al., 2005: 1785, Fig. 2). So, why should there have been little if any deviation in this long-term dendro-radiocarbon trend over these two relatively long periods, but a quite dramatic deviation of up to 350 years and more during the second millennium BC? In other words, where is the independent evidence – i.e., not based on the dendrochronology record – that solar activity, or the strength of the earth's magnetic field, did not remain more or less constant over the last (let us say) 7,000 years, and ignoring both short-term variations known to occur over periods of some few years or decades, and also moderate dating offsets between different environmental regions.

A long-standing, and seemingly irresolvable, debate surrounds the absolute (and indeed relative) historical date of the cataclysmic volcanic eruption on the island of Thera (modern Santorini). Many historians and archaeologists have argued for a mid–late 16th century CC date (e.g., Warren, 2006: 319). However, the use of various scientific techniques over the past four decades or so, particularly high precision radiocarbon dating, has indicated a date within the late 17th or early 16th century BC (Kutscher et al., 2012: 408). Undoubtedly the single most important piece of evidence in favour of this 'high' chronology is the Thera olive branch which possesses 72 'tree-rings', though apparently excluding the bark layer. This branch was attached to a tree that seemingly died due to the Thera eruption. Because it potentially provides a more or less precise series of radiocarbon dates from its formation to the death of the tree, this branch can be used to establish the sample's best fit to the IntCal curve. Moreover, its dating is supported by numerous other organic samples from different Thera-related contexts (Manning 2024a, esp. pp. 154–57; 2024b; cf. Bietak, 2021: 286). Similarly, one of the strongest archaeological arguments in support of the historical dating is that out of 400 samples of Thera pumice found in securely identified strata, not a single example occurs in a context before the 18th Dynasty, and with one assessment maintaining that the pumice found at sites in Egypt and the Levant appears only in post-Ahmose contexts, and possibly not any earlier than the reign of Tuthmose I (Wiener, 2003: 370–371; Foster and Bichler, 2003). Thera pumice does not appear at the major Egyptian site of Avaris/Tell el-Daba before the Tuthmosid period (General Phase C2); and which, if calibrated radiocarbon dating is correct, would then mean that this high-quality material had remained unused for an estimated minimum period of about 100 years. As with the Thera olive branch, this Egyptian and Levantine pumice evidence is also supported by a wide variety of other archaeological evidence favouring a 'low'/'lower' date for the Thera eruption (Bietak, 2021, esp. p. 289). So, if both these cases for archaeo-historical and scientific dating possess such strong supporting evidence – hence the irresolvable nature of the debate – then, how may one interpret the current impasse between the 'high' and 'low' chronology advocates?

2.2 Dating the 'Aniakchak II' and 'Thera' volcanic eruptions according to radiocarbon and ice-core evidence

2.2.1 Aniakchak II and the 'solar eclipse' in the Mari Eponym Canon

The earliest significant evidence purportedly related to the absolute date of the Thera eruption was provided by the identification of volcanic aerosols in various Greenland ice-cores. The first relevant aerosol signal was found in the Dye-3 ice-core (122 ppb of $H_2SO_4^{2-}$) and dated to 1645 ± 20 BC, later modified to 1641 ± 4 BC. Subsequently, signals were discovered in the GISP2 ice-core (145 ppb) and dated to 1623 ± BC and in the GRIP ice-core (139 ppb) and dated to 1636 ± BC (Clausen et al., 1997: 26,715 Table 3; Hammer et al., 2003; Wiener, 2003: 373 with n. 49; Zielinski and Germani, 1998a). Meanwhile, dendrochronologists had noticed a link between volcanic eruptions during the last two millennia and annual tree-ring width minima, and with frost damage in the high-altitude bristlecone pines of Pacific North America being another correlate (LaMarche and Hirschboeck, 1984; Baillie and Munro, 1988; Baillie, 2010). Also, in some 6,500 years of Anatolian dendro chronologies so far collected, an unprecedented growth spurt occurred in relative tree-ring 854 of the 1,503-year Anatolian floating chronology. Since the initial calibrated radiocarbon age of this tree-ring was close to that of the two 'exceptional' tree-ring signals in the North American and Irish dendrochronology master sequences at 1627 and 1628 BC respectively, and since one might expect trees growing in Anatolia to have been positively affected by the Thera eruption (in terms of cooler and wetter conditions in a semi-arid environment, or through a type of 'fertilization effect'), it was argued that tree-ring 854 should be added to this now proposed 1628/7 BC 'world-wide' Thera signal (Kuniholm et al., 1996; Pearson et al., 2009: 1213). That these three respective aerosol signals from the Dye-3, GISP2 and GRIP ice-cores are so exceptional in magnitude when compared to those within a century either side, that the matching years of high-acidity duration are so similar and, within error margins, that they are of essentially the same date, would indicate that they all originate from the same volcanic eruption. Moreover, there are triple sequences of Greenland acid signals in the preceding four centuries that essentially share the same offset arrangements: in addition to the massive signals at "2034" (GISP2), "2045" (GRIP), and "2053" (Dye-3), there are two more that can be synchronized with GISP2 "1948" and "1919". Other factors being equal, this would argue against the GISP2 "1623" ± BC signal having been disassociated from the formerly correlated GRIP and Dye-3 signals (see Table 1 below: numbers within quotation marks signify currently accepted absolute years BC; those without signify either AC dates or else firmly established absolute dates from the late first millennium BC onwards).

While dendrochronology can provide a precise year-by-year calendar, it suffers from the potential problem that the dendro master sequence is constructed from numerous local/site and regional tree-ring sequences through the process of cross-matching, and which is therefore potentially open to producing errors. On the other hand, ice-cores provide a continuous sequence of ice layers, but where there is some moderate uncertainty in the absolute date of each layer because the annual laminations covering a number of years may melt to form a single layer, or else the annual snow fall in a particular location may have been too little to register as a separate lamination. Conversely, two significant and separate snow falls in a single year could have been interpreted as two annual laminations, particularly if the investigation primarily relied on Electrical Conductivity Measurement (ECM) data (Meese et al., 1997: 26,412–14). Notwithstanding, it is possible to accurately correlate sections of cores from different sites by comparing their sequences of volcanic aerosols. For example, the signals at ice-core dates "584.35" BC (GISP2) and "583" BC (GRIP) are preceded in each case by a significant ammonium signal, thereby seemingly making this a firm synchronism between the two cores. And the volcanic event deemed responsible for these two aerosol signals has been associated with the North American bristlecone pine frost-ring appearing at 570 BC (McAneney and

Baillie, 2019: 103). If correct, this would then require a reduction of 14.35 and 13 years in the respective ice-core sequences at "584.35" and "583" BC to match this historically accurate 570 BC dendro date.

Resolving the dispute between scientific versus archaeo-historical chronology may be aided by examining a reference to a celestial phenomenon during the eponym of *limmu* Puzur-Ishtar in the Mari Eponym Canon (MEC Tablet A 23), and which equates to the year following the birth of Shamshi-Adad I of Assyria. According to this document, Shamshi-Adad was born in the Revised Eponym List (REL) Year 126 and died in REL 197 (Barjamovic et al., 2012: 94; Sallaberger and Schrakamp, 2015: 7). Since Shamshi-Adad was recognized as king for 57 years, although he ruled Assyria for only 33 years (Whiting, 1990: 170), and he died in Year 17 of Hammurabi I (Reade, 2001: 9 note 30), (i.e. 1549 AC, above), Shamshi-Adad would have inherited his father's crown in REL 141 (1605 AC – see Sect. 1) aged 15 years. The omina text consists of one line: "'[in Puzureshtar: da]rkening of the sun'" (Pruzsinszky, 2009: 75). The relative chronology of this solar phenomenon, *vis-à-vis* the regnal dates of Shamshi-Adad, is firmly established and with very little room for movement (Barjamovic et al., 2012, Appendix 1). Meanwhile, there is no appropriate solar eclipse to be found within 15 years either side of REL 127 (= 1619 AC/BC) (see Kudlek and Mickler, 1971). The crucial detail surrounding the (customary) interpretation of this solar event as an eclipse is the meaning of the term "'the darkening of the sun' ([n]*a'dur Šamaš*)", since, during the Old Babylonian Period, eclipses were usually designated by the terms "*antallûm*" or "*namtallûm*" (Sallaberger and Schrakamp, 2015: 8 and n. 30; Barjamovic et al., 2012, esp. p. 27). So, if not a solar eclipse, then what might this (obviously remarkable) celestial phenomenon have represented?

Let us test the hypothesis that "the darkening of the sun" witnessed during *limmu* Puzur-Ishtar (1619 AC) referred to the atmospheric effects of the volcanic eruption that gave rise to the GISP2 ice-core signal dated to "1623" ± BC; hence the use of the term '([n]*a'dur Šamaš*)' rather than either of the two Old Babylonian terms conventionally used for an eclipse. This would mean that the approximate "1623" ± BC date of this ice lamination should be reduced on historical grounds by four years to 1619 AC. Having inaccurately calculated an additional 14 annual ice laminations in the approximately 2,600-year period back to 570 BC, glaciologists would then have failed to detect 10 laminations in the GISP2 sequence during the approximate 1,000 years further back to 1619 AC, at an average rate of just one lamination per century. Those who carried out a multi-observer manual count of the GISP2 ice-core stated that it had an estimated error margin of 1 % at 3289 BP, and 2 % at 8021 BP (Meese et al., 1997: 26,415 Table 2; Alley et al., 1997). The GISP2 ice-core signals between 570 BC and 1619 AC can now be allocated the appropriate and approximate dating adjustment of plus one year per century.

Whilst Late Bronze Age Chinese chronology would appear to be equally open to debate (see the 'Xia-Shang-Zhou Chronology Project') as is Near Eastern chronology, it is nonetheless interesting to note that, according to the Chinese Bamboo Annals, there were "epigrammatic style odd atmospheric phenomena and summer frosts" at the start of the Shang Dynasty c. 1620 BC (Foster et al., 1966: 9 n. 43). Meanwhile, two teams of researchers have argued that the Dye-3/GRIP signals of "1645–1641" ± BC originated in the Aniakchak II volcanic eruption (Pearce et al., 2007; Coulter et al., 2012: 9). And the location of this Alaskan volcano (57° N) should mean that the eruption's solar-obscuring effects would have been conducive to producing a severe, volcanic-induced, summer cooling event in the Shang Kingdom of north-central China.

	1	2	3	4	5	6	7	8
FROST RINGS	NORTH AMERICA **HI5** Dates	FINNISH LAPLAND **FIN** Dates	N.W. SIBERIA **YAM** Dates	IRELAND '**Belfast Oak**' Dates	GREENLAND **GISP2** Ice Core Dates	GREENLAND **GRIP** Ice Core Dates	GREENLAND **Dye-3** Ice Core Dates	VOLCANO Historical Dates (AC)
YEARS "BC"				[3970 calBC = 5151 BP ≡]	"3201" (175 ppb)			
	"2911" (–601)				"2310" (80 ppb)			~2310
"2906"	"2905"				"2304" (47 ppb)			
								Hekla 4?, Iceland
	"2495" (–461)				"2034" (42 ppb) → 2034 (0)	"2045 (132 ppb) → 2034 (–11)	"2053" (173 ppb) → 2034 (–19)	2034
					"1948" (38 ppb) → 1947 (–1)	"1964" (58 ppb) → 1947 (–17)	"1968" (42 ppb) → 1947 (–21)	
					"1919" (35 ppb) → 1918 (–1)	"1938" (47 ppb) → 1918 (–20)	"1939" (24 ppb) → 1918 (–21)	
					"1864" (39 ppb) → 1862 (–2)		"1886" (110 ppb) → 1862 (–24)	
	"1996" (–304) 1692	"1997/96" (–304) 1693/92	"1997" (–304) 1693		"1695" (213 ppb) → 1693 (–2)			1693
					"1669" (87 ppb)			
								Aniakchak II, Alaska
	"1921" (–304) 1617		**"1921" (–304) 1617**		**"1623" (145 ppb) → 1619 (–4)**	**"1636" (139 ppb) → 1619 (–17)**	**"1641" (186 ppb) → 1619 (–22)**	**1619**
	"1857" (–304) 1553		"1858" (–304) 1554			"1566" (39 ppb) → 1554 (–12)	"1569" (62 ppb) → 1554 (–15)	1554
					"1459" (104 ppb) → 1453 (–6)		"1463" (110 ppb) → 1453 (–10)	1453
				Long Chronology	"1454" (164 ppb) → 1448 (–6)		"1457" (98 ppb) → 1448 (–9)	1448
						"1425" (141 ppb) → 1419 (–6)	"1428" (41 ppb) → 1419 (–9)	
	"1693"	"1695"						
"1653"					"1337" (27 ppb) → 1330 (–7)			**Thera/Santorini**
"1627"	**(–304) 1323**	**"1627" (–304) 1323**		**"1628" (–305) 1323**	**"1327" (46 ppb) → 1320 (–7)**			**1323**/[1320]
	"1626" (–304) 1322		**"1626" (–304) 1322**					
	Dendro Break	*Dendro Break*	*Dendro Break*	*Dendro Break*				
	"1386" (–202) 1184	"1388" (–204) 1184	"1387" (–203) 1184		"1192" (110 ppb) → 1184 (–8)	"1182" (43 ppb) → 1184 (+2)	"1183" (30 ppb) → 1184 (+1)	1184
	Dendro Break	*Dendro Break*	*Dendro Break*	*Dendro Break*				
								Hekla 3?, Iceland
	"1147" (–72) 1075		"1147" (–72) 1075	"1159" (–84) 1075	"1084" (129 ppb) → 1075 (–9)	"1073" (88 ppb) → 1075 (+2)	"1074" (135 ppb) → 1075 (+1)	[1075]/1076
"1138"	(–72) 1066					"1063" (40 ppb) → 1066 (+3)	"1064" (12 ppb) → 1066 (+2)	[1066]/1067
		"965/64" (–71) 894	"966" (–72) 894			"888" (73 ppb) → 894 (+6)		[894]/895
				["949" (–84) 864 (End)]	"864" (43 ppb) → 852 (–11)			
				["947" ***GB2*** (Start)]				
	"826" (–72) 754					"757" (77 ppb) → 754 (–3)		[754]/755
			"824" (–72) 752			"755" (77 ppb) → 752 (–3)		[752]/753
YEARS								
BC	*Dendro Break*	*Dendro Break*	*Dendro Break*	*Dendro Break*				
570		(≡ Hallstatt Plateau)			**"584.35" (132 ppb) → 570 (–14)**	**"583" (? ppb) → 570 (–13)**		
		"607" (–72) 535	"607" (–72) 535					
				"465" → 500				
		484	482					
476		476						
				"285" → 320				
244	245			*Dendro Break*		244 (186 ppb) → 245 (+1)		
				["229" ***GB2*** (End)]				
					54 (291 ppb)			
				[13 BC ***AD Sequence*** (Start)]				

Table 1: Alternative arrangement of dendrochronology dates versus ice-core sulfate aerosol signals.

2.2.2 Dating the Thera volcanic eruption

The traditional historical date for the Thera eruption would place it within the second half of the 16th century CC, and which equates to the second half of the 14th century AC. There are only two ‘climate-forcing’ $H_2SO_4^{2-}$ aerosol signals (≥ 25 ppb) in the GISP2 ice-core for the entire 14th century BC, at “1337” (27 ppb) and “1327” (46 ppb), and the latter value is the largest recorded in 250 years (“1192 to 1442” BC). Also, since the three main extrusive phases of the Thera eruption are believed to have happened without a (significant) break in time (Pichler and Friedrich, 1980: 20), this would mean that the “1337” and “1327” signals were caused by aerosol deposits from two different volcanoes. The Thera volcanic eruption was one of the largest recorded during historical times: it has a Volcanic Explosivity Index (VEI) of ~6.9, and various other volcanic eruptions from the northern hemisphere with a VEI of 6 have produced $H2SO_4^{2}$- values of slightly less than 50 ppb. Also, whilst not directly related to the amount of atmospheric loading, sulfate values are our best proxy for this figure in the absence of identifying the particular volcanic source of the emissions (Zielinski et al., 1994: 949–50, Tables 1 and 2). Accepting that the GISP2 and GRIP ice-core chronologies must be lowered by 14 and 13 years respectively at 570 BC (above), and based upon the above-argued, absolute, historical date for the GISP2 “1623” ‘Aniakchak II’ eruption of 1619 AC, one may now propose that the Thera eruption produced the “1327” acid signal. And applying the dating adjustment of plus one year per century, the latter date will provisionally become 1320 AC (= –7 years in Table 1, col. 5). This reconfigured chronology also satisfactorily deals with the absence of any significant $H_2SO_4^{2-}$ volcanic signal in any of the Greenland ice-cores between c. “1566” and “1459” BC, that is, the period covering the conventional archaeo-historical chronology span for the Thera eruption. The latter anomaly was quite naturally used by advocates of calibrated radiocarbon dating to argue that the massive Thera eruption is unlikely to have occurred during that period (Manning, 1999).

A sequence of acidity peaks in the GRIP and GISP2 cores show only a ± 10-year discrepancy back into the late second millennium BC, but prior to this date the two timescales are seen to deviate too much from each other to permit safe comparison (Clausen et al., 1997: 26,713 and Table 3). Meanwhile, the GRIP and Dye-3 cores appear to be closely synchronized back to “1636” ± 7 BC and “1641” ± 4 BC respectively. And these two ice-cores appear to be almost precisely synchronized across the period “1425/1428”, “1182/1183”, “1073/1074” and “1063/1064” BC respectively, thereby strongly indicating an accurate annual lamination count in both the GRIP and Dye-3 cores between the two end-dates. Based on the presently proposed accuracy of GISP2, by the time of the ‘Aniakchak II’ “1623” date (= –4 years), the GRIP ice-core date of “1636” would have been inaccurately counted 17 (13 + 4) years too early, and the Dye-3 core date of “1641” counted 22 (18 + 4) years too early. This error margin is within the 5 % to 10 % allowable when relying solely on ECM annual layer counting (see below). Also, based on the above-proposed dating adjustment, the very large GISP2 ice-core signals at “1459” (104 ppb) and “1454” (164 ppb) would become 1453 and 1448 AC respectively, and their similarly-sized proposed correlates in the Dye-3 core of “1463” (110 ppb) and “1457” (98 ppb) would need to be lowered by 10 and 9 years respectively to achieve the same dates (see Zielinski et al., 1994: 950 Table 2; Clausen et al., 1997: 26,714 Table 3).

One of the currently puzzling aspects of the dendro-radiocarbon versus archaeo-historical dating of the Thera eruption is that these two chronological systems are almost identical for the mid–14th century CC (i.e., the Amarna and Late Helladic IIIA2 periods), but deviate by around 100 years during the period from about 1700 to 1500 BC (Manning, 2014, Part 2: 13–18). And, despite efforts on both sides of the debate to reach a compromise solution, the science-based system and the archaeo-historical system are currently seen as incompatible (e.g., Manning, 2024b: 363; Bietak, 2024). So, what, if anything, changed between these two periods? One answer can be clearly seen on the relevant section of the IntCal curve (Manning, 2014, Part 2: 127, Fig. RE29). Without resorting to detailed measurements from the primary data, one can nonetheless see that the period between 3000 BP/1260 cal. BC and 3200 BP/1450 cal. BC involves a disparity of just '–10 years' of calibrated chronology compared to uncalibrated chronology, and this section of essentially a 1:1 ratio between BP and cal. BC dates completely overlaps the mid–14th century CC. The preceding 200 BP years back to 3400 BP/1725 cal. BC involves a disparity of +75 years, and this section almost completely overlaps the problematic radiocarbon period between 1700 and 1500 cal. BC. By removing these radiocarbon offsets through creating an overlap between adjacent sections of the dendrochronology master sequence(s), this would essentially eliminate the difference between the 'high' and 'low' dates for the Thera eruption.

The above calculation equates to a provisional lowering in absolute dates of the Irish oak dendro-sequence by 308 years from "1628" BC to 1320 AC. The latter approximate date for the Thera eruption now overlaps the reign of Tuthmose I (Memphite 1520–1517 CC = 1320–1317 AC), and which thereby matches the above-cited 'Tuthmosid' pumice evidence from Tell el-Daba (General Phase C2), and also from the wider eastern Mediterranean region. Additionally, a number of the most recently living samples taken from various pre-Thera eruption deposits are found to cluster around c. 3310 ± 35 BP (= 1360 ± 35 BC) (Pearson et al., 2018: 3); a *terminus ante quem* range of uncalibrated dates which just fails to overlap the presently argued 1320 AC date for the eruption. Moreover, one of the most securely identified archaeological contexts from this period of Egyptian history is undoubtedly the tomb of Tutankhamun, which remained untouched for over 3,000 years until opened in a systematic archaeological excavation in 1922 by Howard Carter. A set of six (or seven) organic samples from the funerary context of this Pharaoh has produced a coherent weighted average of 3117 ± 12 BP (Manning et al., 2020: 6). And this date-range (1167 ± 12 BC) overlaps the reign of Tutankhamun according to the Alternative Chronology (1161–1152 AC).

2.2.3 How reliable is the dendrochronology underlying the IntCal curve?

So, how might such an error have been introduced into the various master dendrochronology sequences? Dendrochronology cross-matching involves three levels of comparing tree-ring patterns/fingerprints: primary replication from an individual site/location; secondary replication between independent site chronologies; and tertiary replication between master chronologies assembled by independent teams of dendrochronologists (Baillie, 1995: 28). Secondary replication is potentially particularly problematic, since it involves comparing tree-ring patterns which may have arisen from quite different environmental conditions. The Irish oak master dendrochronology initially possessed gaps/depletions in the sequence, including those around 100 BC and 900 BC, and which could only be bridged using English and Scottish oak chronologies. Although this situation is still not completely rectified, a series of recently found archaeological timbers from Ireland has permitted an extension of the 'Belfast Long Chronology' (c. 1000–4000 BC) to now completely cover the previous gap in the 10th century BC. However, the younger end of this (now) extended 'Long Chronology' failed to show a correlation with the older section of the 719-year 'Garry Bog 2' sequence, and which has an end-date of 229 BC. The reason for this failed correlation is thought to be the different growing conditions of the GB2 bog-grown oaks versus the dry-land-grown archaeological timbers used for the 'Long Chronology' (Baillie, 1995: 28; Brown and Baillie, 2012). So, in light of this environmental explanation, what are we now to make of the original secondary replication that crossed the gap between the 'Long Chronology' and GB2 dendro sequences by using oak chronologies from significantly different environments in England and Scotland?

The Irish and German master chronologies also cannot be described as truly independent. That two such chronologies can be cross-matched demonstrates that the tree-ring patterns in both regions are related in very similar ways to a common northwestern-European climate; this cross-regional comparability is, after all, an integral part of dendrochronology. Therefore, if an error had been made in say the 'Belfast Long Chronology' by incorrectly cross-matching two local dendro chronologies, then, it should not appear overly improbable that similar tree-ring patterns in contemporary German local chronologies could potentially have led to the exact same error being made in the German master chronology. Furthermore, both the Northern Irish and German teams used the same North American bristlecone pine calibration curve to suggest the approximate dates for their own floating site chronologies prior to establishing their precise position within each respective long chronology (Baillie, 1995: 35, 39). While this use of radiocarbon dating should only have served as an aid in placing the floating sectional chronologies in their true relative order, it may also have created certain subtle expectations as to absolute dates as well. Therefore, as a result, both the Northern Irish and German teams may have been looking in the same approximate time-period for potential dendro cross-matches via primary and secondary replication (see Furlong, 2007: 263).

2.3 Dendrochronology versus ice-core evidence

2.3.1 Methodology

Having now established the foundational hypothesis of the present argument, namely, that the Thera eruption occurred in the late 14th century AC (= late 16th century CC), and not in the late 17th century cal. BC, then, the repercussions of this correlation must be accepted as they radiate forwards and backwards in time. The dendrochronology sequence currently dated to the 17th century BC must be lowered by some 300 years, and this reduction must be satisfactorily accommodated within the following period prior to the end of the Hallstatt Plateau where a secure dendrochronology is indisputable. This adjustment will require a totally new series of correlations between significant dendro signals, on the one hand, and significant ice-core signals, on the other. It will primarily employ dendro signals from multiple regions, as opposed to a single region, and also multiple ice-core signals, the latter being amongst the largest acidity values recorded during the relevant period (Table 1). Using Occam's razor, the following discussion will rely upon a few basic criteria. First, all dendrochronology sequences must be closely correlated, since otherwise the derived calibrated radiocarbon dates would be in conflict, and therefore have become a cause of concern for relevant experts. Second, all the separate master dendrochronology sequences must have been incorrectly cross-matched in order that the Thera eruption could have occurred in the 14th century AC/BC rather than the 17th/16th century cal. BC. And third, one should reduce the number of potential incorrect cross-matches to a minimum. Considering that this hypothesis involves a paradigm shift from the currently understood chronology, a test of its viability will be whether the reader considers that the following findings show a greater degree of coherence than would be expected if the two reordered timelines (dendrochronology versus ice-core) were simply random independent series.

2.3.2 A new series of dendro versus ice-core correlations

M. W. Salzer and M. K. Hughes (2007) compared bristlecone pine rings and volcanic eruptions over the past 5,000 years using tree-ring sequences from five separate locations in the Pacific region of North America, the resulting master sequence being identified as HI5. Additional evidence was included from two high-latitude regions: 1) the 7,000-year chronology from Lapland in northern Finland (FIN); and 2) the 4,000-year Yamal Peninsula chronology from north-west Siberia (YAM) (see Table 1, cols. 1–3). This study accepts tree-ring minima correspondences between two or more regions within an accuracy of ± 2 years, and correspondences with ice-core volcanic signals are accepted within 10 [± 10] years of the tree-ring minima. The ± 2 years figure is to allow for seasonality or lag effects between the volcanic eruption and tree growth response (ibid., 64–65 and Table 6). However, I would stress that the dendro master chronology is deemed to be precise to the actual historical year, for otherwise one would have to accept an incorrect cross-match correlation and therefore a break of indeterminate length across two adjacent sections of the dendrochronology sequence.

The Salzer-Hughes study demonstrated a series of dendro versus ice-core correspondences in 86 % of cases over the last millennium, but this figure falls to 66 % in the first millennium AD, to 56 % in the first millennium BC, to 46 % in the second millennium BC, and to just 31 % in the third millennium BC. The explanation given for this diminishing correspondence is, in part, because earlier periods have fewer available ice-core records, and because ice-core dates are said to become increasingly uncertain the older the ice lamination (Salzer and Hughes, 2007: 62–63 and Table 3). However, the latter cause would appear to be invalid in the present case because if one has correlated a given ice-core lamination with an absolute dendro year, as provided by a correctly constructed dendrochronology (e.g., the proposed ‘Thera’/‘Aniakchak’ dendro-volcanic synchronism), then, the chronological uncertainty factor should be reset to zero. Also, while the two statistical tests done to support their findings used exact matches between dendro (HI5) and ice-core (GISP2) dates over the whole period back to “3000” BC, only 3 of the 16 matches that were found belonged to the chronologically contentious period pre-570 BC (see above). And, based on the figures provided in this study, it would seem marginal at best if these latter three results should be deemed significant ($p<0.01$) on their own merit (ibid., 61–62 and Table 2). Meanwhile, apart from statistically acceptable random variation, another reason for the diminishing degree of correspondence during the three millennia preceding 1 BC could be that the two timescales have become significantly disconnected and are therefore no longer even approximately synchronized.

The “1623” GISP2 ‘Aniakchak II’ acid signal (145 ppb) is preceded by two further major signals within the preceding 72 years at “1669” (78 ppb) and “1695” (213 ppb). Apart from the “1454” signal (164 ppb), the “1623” and “1695” signals are the largest values between 54 BC (291 ppb) and “3201” BC (175 ppb) (Zielinski et al., 1994: 950 Table 2). The “1695” eruption, producing the largest signal in over 3,000 years, might therefore be seen as amongst the most likely of volcanic events to have produced an easily identified dendro signal across the northern hemisphere. The dendro date provided for the GISP2 “1623” ice-core signal in the HI5-FIN-YAM study is “1626” (HI5 and YAM), and for the “1695” signal is “1693” (HI5) and “1695” (FIN). Subsequently a frost-ring dated to 1627 BC was recovered in subfossil pinewood from Finnish Lapland (Helama et al., 2019), and which thereby corresponds to the HI5 frost-ring at “1627” BC. The “1695” and “1627” growth anomalies in the FIN sequence are separated by 68 years, whereas the corresponding GISP2 ice-core signals are separated by 72 years. Meanwhile, if these twin “1627” frost-rings represent the Thera eruption, and which was provisionally dated to 1320 AC (above), then, the actual dendro signals for the GISP2 “1623” and “1695” eruptions would have occurred, in relative dendrochronology dates, about three centuries earlier. I now propose that the earliest of these ice-core signals be associated with the triple dendro correspondence at “1996” (HI5), “1997/1996” (FIN) and “1997” (YAM), and that the later ice-core signal be associated with the twin correspondence at “1921” (HI5 and YAM). The “1997” and “1921” signals in the YAM sequence are separated by 76 years. The two scenarios are therefore equivalent in terms of correlation accuracy, differing only in that the former has four more ice-core years than dendro years and the latter has four less ice-core years than dendro years.

Regarding the ‘Aniakchak II’ eruption, now hypothetically dated to 1619 AC (above), and allowing that the corresponding growth anomalies in the HI5 and YAM dendro sequences occurred a maximum of two years later than the eruption, then, the “1921” date would have to be lowered by 304 years to 1617 AC. And if the HI5 and FIN sequences are accurately constructed between “1997/1996” and “1627”, then, in order to synchronize the “1695” GISP2 ice-core signal with the 1693 (“1997” minus 304 years) AC dendro date, one must assume that two ice laminations are missing between “1695” and “1623”; a perfectly acceptable figure with a GISP2 ± 2-year error margin per century prior to 3289 BP. This would further mean that the massive 1693 AC volcanic signal identified in the GISP2 sequence would have been recognized in the YAM and FIN dendro sequences in the same year as the eruption, and this signal would have continued into the following year in the FIN sequence, at which time it would have first appeared in the HI5 sequence (1692 AC). Since the “1627” frost-ring signals in the HI5 and FIN sequences must now also be lowered by 304 years, that is, to 1323 AC, this will mean that the Thera eruption cannot have occurred later than this date. And if it is further accepted that the Thera signal was registered in the HI5 and FIN sequences in the year of the eruption, then, its actual date must be raised three years earlier than provisionally calculated based on the above-proposed GISP2 ice-core offsets (i.e., at 1320 AC).

The next major multiple ice-core signal after the date of the Thera eruption is that appearing in GISP2 at “1192” (110 ppb), in GRIP at “1182” (43 ppb), and in Dye-3 at “1183” (30 ppb). Based on the above-proposed primacy of GISP2, all three signals have been correlated and dated to 1184 AC (“1192” minus 8 years) in Table 1. The only multiple-region signals during the entire dendro “15th” and “14th” centuries are the triple signal at “1388” (FIN), “1387” (YAM) and “1386/1385” (HI5). These dates fall in the very middle of the Egyptian 18th Dynasty based on the 'conventional' archaeo-historical chronology, and when calibrated radiocarbon and historical dates are known to be consistent (above). But these Egyptian (Memphite) dates must be lowered by precisely 200 years according to the Alternative Chronology to match historical actuality, and so that these dendro dates must be lowered by about the same amount. The 1184 AC triple ice-core signal can therefore be associated with the HI5 (–202), FIN (–204) and YAM (–203) signals. This finding would require that there was an incorrect cross-match correlation within each of these three dendro sequences between "1626" BC, which requires a three-century lowering of dendro dates, and "1388–1386" BC, which requires a lowering of only two centuries. This proposed one-century overlap would then eliminate the Thera 'high' versus 'low' dating anomaly.

The next major multiple ice-core signal occurs in GISP2 at "1084" (129 ppb), in GRIP at "1073" (88 ppb), and in Dye-3 at "1074" (135 ppb); signals which may now be correlated and dated to GISP2, offset-adjusted (–9 years), 1075 AC. The only identified multiple-region dendro signals for the entire "12th" and "11th" centuries are at "1147" in both the HI5 and YAM sequences. If these ice-core and dendro signals are also correlated, then, the "1147" dendro date would need to be lowered by 72 years to match historical actuality. And, since dendro dates from all chronology sequences must broadly keep in unison with each other, the 'exceptional' "1159" signal in the Irish oak dendrochronology sequence (Baillie and Munro, 1988; Kuniholm et al., 1996: 781) might also be included in this correlation. This relationship is supported by the presence of a frost-ring in the bristlecone pine sequence at "1138", nine years after the "1147" signal (Salzer and Hughes, 2007, Table 2), and which matches the double 10-year separation between GRIP signals at "1073" and "1063" (40 ppb), and Dye-3 signals at "1074" and "1064" (12 ppb) respectively (Clausen et al., 1997, Table 3). The twin dendro signal at "965/64" (FIN) and "966" (YAM), when reduced by the same 72 years, would equate to a potential volcanic eruption in 894 AC. Whilst not recording a multiple signal in the currently available ice-cores, this tree-ring growth minima may confidently be associated with the major acid signal (73 ppb) at "888" in the GRIP sequence, the only one recorded in over three centuries between "1063" and "757" BC, and which endured for 2 years. A later twin dendro synchronism has been proposed for the years "826" (HI5) and "824" (YAM). However, rather than a single eruption causing these two dendro signals, the latter can now be seen to represent distinct volcanic eruptions occurring two years apart. Reducing the latter dates by 72 years to 754 and 752 AC respectively, these dendro signals will correlate with the two largest of only three significant acid signals in the GRIP core between "888" and "569", that is, those at "757" (77 ppb) and "755" (77 ppb). This offset of –3 years is almost precisely what one would predict for GRIP acid signals placed about mid-way between the +6 years offset at "888" and the –13 years offset at "583" (see Table 1).

Three further dendro versus ice-core correlations can now be proposed. A twin signal at "1857" (HI5) and "1858" (YAM) BC, when reduced by 304 years, become 1553 and 1554 AC respectively. These two signals should be correlated with the "1566" (39 ppb) and "1569" (62 ppb) acid spikes in the GRIP and Dye-3 cores respectively. These are the only signals registered for the entire 16th century BC in either core. With offsets of –12 and –15 years respectively, these can be seen to fit neatly within the offset trend between Dye-3 "1641" (–22 years) and "1463" (–10 years). The other two proposed correlations are far more informative in that they would provide the potential to recalibrate the IntCal curve for the third millennium BC to its correct historical setting. First, there are only three volcanic signals (≥ 25 ppb) in the GISP2 sequence during the 24th century BC, the two largest being at "2304" (47 ppb) and "2310" (80 ppb) (Zielinski et al., 1994, Table 2). Equivalent to 4254 and 4260 BP, both these dates appear along an extremely steep (and therefore very precise) part of the IntCal curve between the two major plateaus situated either side. Both these BP dates equate almost precisely to 2900 cal. BC. And since the latter date is essentially equivalent to the same date on the dendro master sequence used to calibrate the IntCal curve, then, one would expect to find matching tree-ring minima signals in one or more of the recognized master sequences covering this period. Featuring just four significant width-minima signals for the entire 30th century BC, the HI5 sequence has just such an appropriate pairing set six years apart at "2905" and "2911", and with a frost-ring at "2906" (Salzer and Hughes, 2007, Table 2). Second, the three largest signals in the GISP2, GRIP and Dye-3 ice-cores from the 21st century BC are at "2034" (42 ppb), "2045" (132 ppb), and "2053" (173 ppb) respectively (Zielinski et al., 1994, Table 2; Clausen et al., 1997, Table 3). Based on the offset trend in the GISP2 ice-core (above), a date of about 2034 AC may be proposed for all three signals. The latter date equates to 3980 BP, which intersects the IntCal curve twice at about 2550 and about 2480 cal. BC. And there is only one significant ring-width minima signal in the HI5 dendro sequence during the entire 24th through 26th centuries, that at "2495" BC. This latter date would now correspond to the later of the two intersection points, differing by only 15 years.

2.3.3 The Aniakchak II, Hekla 3 and Hekla 4 Eruptions

The above findings can now add information on three of the largest volcanic eruptions to occur during the Holocene period, and which have added importance for historical studies. The calibrated radiocarbon age of ~3600 cal. BP/1650 cal. BC is currently assigned to the Aniakchak CFE II eruption in recent scientific literature. Having found tephra that matches the CFE II event in various strata that are dated to this approximate time in cal. BC years, the material is then deemed to have come from that particular, caldera-forming, eruption (Pearce et al., 2007; Blackford et al., 2014; Pearce et al., 2017: 303, 305; Monteath et al., 2017; Pearson et al., 2022). However, this is an unproven assumption. The Aniakchak volcano has erupted explosively at least 40 times in the last 10,000 years, and with most of the deposits from these events extending north and north-east from the volcano (Neal et al., 2001: 4); that is, at a rate of once every 250 years on average. One discovery of cryptotephra from the Aniakchak volcano comes from varved sediments in Rupert Lake in northern Alaska, and in Woody Bottom Pond (WBP) situated less than 1 km distant. These sites are located about 2,000 km north-northeast of Aniakchak. And "chemically identical" cryptotephra were found at four points in the sediment cores: RS126 (3670–3200 cal. BP) and RS151 (4070–3760 cal. BP) in the same core; RC127 (3650–3180 cal. BP) in a core located further towards the centre of Rupert Lake; and in WBP65 (4110–3740 cal. BP). Calibrated using a series of ^{14}C measurements from the different cores, RS126 and RC127 are associated with the '~3600 cal. BP' CFE II eruption, and RS151 is interpreted as an earlier eruption of Aniakchak. And, despite the almost identical ^{14}C ages of RS151 and WBP65, the latter signal is also considered to be associated with the ~3600 cal. BP event; the mid-point offset of some 500 cal. BP years is thought to be possibly due to contamination from a macrofossil found earlier in the WBP core (Monteath et al., 2017, esp. pp. 169, 171, 176).

The chemically identical tephra from these four deposits is presumably not unique to this tiny area of Alaska and may therefore be assumed to apply to all material ejected from (at least) these two temporally separated eruptions of the Aniakchak volcano, thereby making any distinction between their signals at other (geographically distant) sites very difficult, if not currently impossible, to achieve. Since the dendrochronology-calibrated dates of the RS151 (= 3915 ± 155 cal. BP/1965 ± cal. BC) and the WBP65 (3925 ± 185 cal. BP/1975 ± cal. BC) tephra samples are highly compatible with the double dendro signal (HI5 and YAM) at “1921” BC, and since the CFE II eruption was amongst the very largest during the entire Holocene (> 50 km^3), I propose that the “1921” BC dendro signal and the corresponding and massive triple ice-core signal appearing at 1619 AC in Table 1 should be associated with the RS151 and WBP65 varve deposits, and not with the RS126 and RC127 deposits.

The recovery of cryptotephra from a high-precision, varved lake, chronology at Diss Mere in East Anglia has been used to date the Hekla 4 eruption to 4435 ± 16 cal. BP (sample DISS16_T1047.6); a date which is seen to be compatible with other varve chronologies from Sweden and Germany (Walsh et al., 2023). This ‘DISS16’ varved chronology presents a major challenge to the integrity of the Alternative Chronology, since multiple radiocarbon dates are deemed to have been successfully correlated with the unbroken sequence of annually laminated sediments from Unit 2 (8.90–13.5 m), and whereas the present chronological hypothesis is that, between the end of the Hallstatt Plateau and the end of the 21th century BC, calibrated radiocarbon dates increased by an additional 465 years compared to historical actuality. The three relevant carbon samples are SUERC-73248 (3519 ± BP/3798 ± cal. BP), SUERC-73326 (3927 ± BP/4357 ± cal. BP) and SUERC-78894 (3863 ± BP/4273 ± cal. BP). I can see no alternative but to argue that an error was made in constructing the DISS16 composite (Unit 2) core segments. And the only conceivable place where this proposed error could have occurred would have been in cross-correlating sections A5 and B5. The chronologically assured reference dates for section A5 are the Glen Garry tephra at 2073 ± 39 cal. BP and the OMH-185 tephra at 2617 ± 29 cal. BP. The Glen Garry tephra is situated at 888.5 cm and the OMH-185 tephra at 921.5 cm, and with the A5–B5 transition not occurring until 972 cm (Martin-Puertas et al., 2021). SUERC-73248, from the mid-2nd millennium BC, has a BP versus cal. BP offset of 279 years versus my proposed 304 years. And, from around the end of the 3rd millennium BC, SUERC-73326 has an offset of 430 years, and SUERC-78894 has an offset of 410 years, versus my proposed 304–465 years during the interval between 1693 and 2034 AC/BC. This additional dendro overlap presumably occurred after 3863 ± BP (= 1913 ± BC) according to these dates. Of course, these BP versus cal. BP offsets are also exactly what one would expect if the IntCal curve had been correctly constructed. So, my hypothesis must depend entirely upon the strength of the argument that dendro and ice-core dates should be radically realigned.

A varved chronology from Lake Nautajärvi in central-southern Finland dates the Hekla 4 eruption to 4145 ± 41 varve yr BP (sample NAU_T255) and is 290 years later than the DISS16 date (4435 ± 16 cal. BP) for the same proposed event (Carter-Champion et al., 2025). And another recent date for Hekla 4 tephra from the NGRIP ice-core is 4325 ± 8 b1.95k/BP (Davies et al., 2024). But these alternate dates for the Hekla 4 eruption are hugely outside the combined error-margins of all three studies. The varved age estimate of the Hekla 5/Lairg A tephra from Nautajärvi (7001 ± 44 cal. BP) is about 176 ± years later than that identified from Diss Mere (7166–7187 cal. BP), and again with the age difference being of a similar degree outside the combined error margins of both studies (Carter-Champion et al., 2025; Walsh et al., 2021). The Nautajärvi varved sequence had no relevant terrestrial-derived ^{14}C samples, and so had to rely upon bulk aquatic vegetation in one Bayesian age model. However, the uncertainties associated with estimating a consistent local reservoir effect precluded the use of aquatic vegetation in constructing this and any future Nautajärvi age models (Carter-Champion et al., 2025). Consequently, one cannot use terrestrial-derived ^{14}C dates to compare the Diss Mere and Nautajärvi varved sequences.

Meanwhile, using 35 tephra-associated dates from humin and humic fractions in 15 peat profiles from Iceland and Scotland (28 and 7 dates respectively), the age of 3826 ± 12 BP [= 1876 ± BC] was assigned to the Hekla 4 eruption. And using nine dates in six peat profiles from Iceland, the age of 2879 ± 34 BP [= 929 ± BC] was assigned to the Hekla 3 eruption (Dugmore et al., 1995). The Hekla 3 and 4 eruptions are amongst the largest of the Holocene period, with estimated volumes of 11.2 km^3 and 13.3 km^3 respectively (Stevensen et al., 2015). Meanwhile, a study of blanket peat profiles from five sites in County Down, Northern Ireland, has shown that ^{14}C ages from different peat fractions are younger than absolutely dated contemporaneous cryptotephra ages by a median figure of 171 years, and that neither the bulk sediment, humic, nor humin fraction gave a better age match (Essell et al., 2025). Meanwhile, based on an annually varved floating sequence from Lake Belau, Northern Germany, and adjusted using <u>calibrated</u> ^{14}C dates, tephra identified as coming from the Hekla 3 eruption has been dated to 3095 (cal.) BP (Dörfler et al., 2012). This date (= 1145 cal. BC) almost precisely matches the double dendro/IntCal date of "1147" BC and also the above-correlated major triple ice-core signal at 1075 AC (Table 1). I therefore propose that the Hekla 3 eruption was responsible for these multiple dendro and ice-core signals. If correct, this would mean that the BP-age peat offset is 146 years (1075 minus 929), which is suitably similar to the County Down result. Based on this blanket peat offset using mostly Icelandic dates, one would predict that the actual age of the Hekla 4 eruption was closer to 2022 ± AC/BC (1876 plus 146 years). And this date provides a very good correlation with the triple ice-core signal dated to GISP2 "2034" BC, and which I associated with the "2495" BC growth minimum in the HI5 dendrochronology, thereby allowing all four signals to have been caused by the Hekla 4 eruption. Unfortunately, Davies et al. (2024) did not sample the interval ~3150-4250 b2k in the NGRIP ice-core, and so we do not know if any Hekla-type tephra was present during this period.

The DISS16 and NAU_T varved cores can be harmonised as follows. The Alternative Chronology would demand that the DISS16 composite sequence was inflated by about 300 years during the A5–B5 correlation transition. This would mean that the GISP2 date of "2034" BC for the Hekla 4 eruption can be correlated with the unidentified tephra signal DISS16_T1038.7 (2365 ± 16 cal. BC). Unfortunately, this material (22 shards/g) was not able to be geochemically analysed (Walsh et al., 2021 Table 2; Walsh et al., 2023 Fig. 1). Requiring that the latter date now be lowered by 331 (2365 minus 2034) years, this would further mean that the DISS16_T1047.6 date (2485 ± BC) would be similarly lowered to ~2154 BC. And if the latter tephra material and that from NAU_T255 (2195 ± 41 BC) were from the same Hekla eruption, as the respective geochemical analyses indicate, this would require that the latter date be lowered by 41 (2195 minus 2154) years, which is within its error margin. Currently lacking geochemical analysis, and with four tephra layers between the start of the targeted interval beginning c. 3900 BP and the NAU_T255 date of 4145 BP at an average separation of 61 years, the tephra layer (~35 shards/g) identified two places later than NAU_T255 would then be dated to c. 2032 ± BC (2154 BC minus ~122 years). The dates of DISS16_T1038.7

("2034" BC) and the Nautajärvi (~35 shards/g) varved layer (c. 2032 ± BC) would then be in close union, thereby supporting their joint synchronisation with the Hekla 4 eruption. This proposed 331-year inflation of the DISS16 composite sequence would be equivalent to the B5 core having been improperly moved back in time by ~14 cm based on the average varve thickness of 0.425 mm.

2.3.4 Resolving current anomalies

The Hallstatt Plateau in the IntCal radiocarbon curve is a period where calibrated radiocarbon measurements increase by an additional 200 years over uncalibrated dates (c. 750–450 cal. BC versus 2520–2420 BP). And note that the upper boundary of this ^{14}C offset period (c. 2520 BP = 570 BC) equates to the above-proposed earliest securely dated year in the HI5 sequence as provided by the 570 BC bristlecone pine frost-ring in the North American master dendrochronology. This would place any incorrect cross-match in the HI5/FIN/YAM dendro sequences shortly before this date, and with the older sections of these three sequences lowered by ~72 years to overlap the younger sections. This ~72-year overlap can now be seen to almost precisely equate to the extended period introduced into the German 'long' dendrochronology due to conflict with the 'Garry Bog 2' dates. The older section of the German sequence was broken at 500 BC and then moved back in time by 71 years to match the GB2 end-date of 229 BC (see above). However, the presently argued hypothesis demands that the former should have remained as it was, and that instead the Belfast GB2 sequence should have been broken around that time and with the earlier section moved forwards in time by 71 years in order to preserve the (new and presumably acceptable) dendro cross-matching evidence between the Irish sequence and the GB2-adjusted German 'long' dendrochronology.

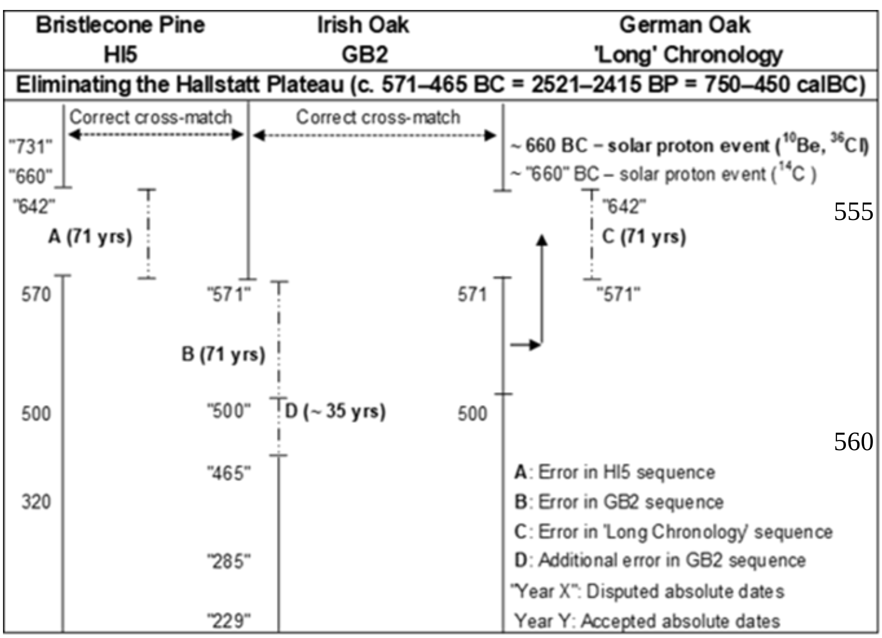

Figure 1: The source of the dendro-radiocarbon problem and the Hallstatt Plateau.

The manner whereby this 71-year error in the various dendrochronologies occurred may be imagined as follows (see Fig. 1). The first correlation error would have been made in the original bristlecone pine sequence shortly before 570 BC, and with an unwarranted 71 years (**A**) introduced into the derived HI5 dendro sequence. Presumably recognizing tree-ring growth-minima signals appearing in the Irish, FIN and YAM sequences arising from the same hemisphere-wide volcanic eruptions, and now relying on the inflated HI5 calibrated radiocarbon dating, all four dendrochronologies were synchronized and thereby inherited the

HI5 error (**B**). The German 'long' chronology would have avoided this mistake and been correctly constructed, probably having reliable dates as far back as the LBA–EIA radiocarbon plateau. Unfortunately, when the German dendrochronology was seen to be in conflict with this, now-argued, wrongly dated GB2 sequence, it was the latter which prevailed and so that the German chronology also had an unjustified 71 years introduced into its sequence (**C**). Meanwhile, an 'offset' of about –30 years exists between contemporaneous Irish and German ^{14}C dates between "2495" and 145 BC, with the Irish dates younger than the German. Similarly, a consistent offset of –41 ± 9.2 years exists between the Irish oak and North American bristlecone pine sequences for the period 500–320 BC (McCormac et al., 1995: 400, 401). However, very recent evidence has found a weighted average offset of only –6.4 ± 2 ^{14}C years between the latter two dendro sequences for the period 3615–3529 BP (1666–1580 BC) (Manning et al., 2020: 5). Since both these regions are heavily influenced by westerly oceanic weather patterns, one might have expected that they would have preserved a similar ^{14}C offset over historically long intervals of time; as does the Irish and German dendrochronologies. This significant offset difference between the two periods might therefore appear puzzling.

Let us now imagine, in addition to introducing an erroneous 71 years (**B**) into the GB2 sequence to establish a correct cross-match with the inflated HI5 sequence, that this tree-ring section included an additional period of, let us say, 35 years (**D**), and which had the effect of forcing the GB2 date of 500 BC lower by that amount to "465". When the latter period is removed, in addition to the inflated 71 years, then, the GB2 tree-rings between "465" and "285" will date to 500 and 320 BC, which would equate to an offset of just –5 ± 9.2 years for this adjusted dendro section against the HI5 sequence, and would thus agree with that found during the 17th–16th century BC. An additional chronological adjustment would need to be made between the end of the GB2 sequence in "229" BC and the beginning of the 'Belfast AD' sequence, which provides a precise chronology from the present back to 13 BC. This scenario would predict that the very large –41 ± 9 years offset does not extend beyond the end of the GB2 sequence. One may again note: the original gap in the Irish oak master dendrochronology around 100 BC that could only be bridged using secondary replication with the English and Scottish oak chronologies; and that this exercise was apparently unsuccessful as demonstrated by the fact that the younger end of the (now) extended 'Long Chronology' failed to show a correlation with the older section of the GB2 sequence (above). Furthermore, this proposed dendro overlap covers the period 465–571 BC (= 2415–2521 BP), and which would more or less equate to the uncalibrated dates of the Hallstatt Plateau (2420–2520 BP). The various regional dendrochronology master sequences would then have been correctly realigned at the upper end of the (BP dated) Hallstatt Plateau, only now including an unwarranted 71 years of additional time (Table 1, cols. 1–4). Of course, one would need to review the primary data from the Irish, German and North American dendrochronology sequences in order to better understand the particulars of this proposed chronology adjustment. Those with access to this data, and relevant expertise, may be able to provide a more elegant solution than that presently offered. Incidentally, an examination of annual resolution tree-ring samples from the first millennium BC has highlighted some "notable differences" around 900 and 425, and where, in contrast to the overall agreement with the previous decadal resolution, there is an observed absolute deviation of more than 25 ^{14}C years (Brehm et al., 2025: 3); dates which just happen to coincide with the Palestinian Iron Age I–II plateau and with the Hallstatt Plateau anomalies respectively.

One can now propose an explanation for that other long-standing ‘high’ versus ‘low’ chronology debate concerning the transition date of Palestinian Iron Age I to II. This dispute began in earnest when I. Finkelstein argued, contrary to the orthodox view, that Early Iron Age IIA strata previously assigned to King Solomon of the mid-10th century CC (such as Megiddo VA–IVB, Hazor X–IX and Gezer VIII) should be reassigned to the 9th century and dated to the Omride period (see Introduction). By lowering “10th” century CC dates by 71 years, the ‘low’ chronology proponents would then have been historically accurate in dating these monumental buildings to the time of King Omri of Israel; and, necessarily, relegating the United Monarchy to the Iron Age I period. Conversely, the ‘high’ chronology proponents would have been more precise in dating the same strata to the mid-10th century cal. BC. This dendrochronology overlap will correspond to the plateau in the IntCal curve during this period between 2900 BP/1100 cal. BC and 2740 BP/860 cal. BC, and which equates to about +80 years of calibrated chronology over uncalibrated chronology; that is, essentially the extent of the maximum disparity between the ‘high’ and ‘low’ Palestinian timelines. This dispute in dates, as with that concerning the Thera eruption, would then become simply the product of an incorrectly assembled dendro master chronology.

The final dendro overlap to be discussed is that between HI5 “1386/85” BC (–202/1 years) and “1147” BC (–72 years), and which correspond to dates of 1184 and 1075 AC respectively. This 130-year overlap (202 minus 72) matches another problematic plateau in the IntCal curve c. 1302–1051 cal. BC (at 2σ confidence) (Manning 2007b, esp. p. 57). About half of the latter period covers the much-disputed ‘Dark Ages’ of Near Eastern history, and which equates to Palestinian Iron Age I. According to the Conventional Chronology, this period lasted about two centuries (c. 1200–1000 CC), whereas according to the Alternative Chronology it lasted 125 years (c. 1000–875 AC) (see Furlong, 2007: 441–42). Thus, appropriately, this 75-year difference accounts for just over half of the proposed 130-year figure. The remaining 55 years would then constitute a continued dendrochronology overlap during the final years of the LBA. The division of this overall lowering of Egyptian New Kingdom (Memphite) chronology by two centuries into two phases of 71 and 130 years finds its historical complement in the two foundational criteria of the Alternative Chronology, namely: the overlapping of precisely 85 years in Iron Age Assyrian chronology from between the reigns of Shalmaneser II (1031–1021 CC) and Ashur-dan II (934–912 BC); and second, the downward displacement of Egyptian dates relative to LBA–EIA Assyrian chronology by a further 115 years (see Introduction).

3 Scientific arguments against chronological revision

A number of recent articles have argued (either explicitly or implicitly) that Greenland ice-core and radiocarbon dates are correctly synchronized, barring minor offset values, throughout the Holocene period. Since the argument just presented is that dendrochronology-dependent calibrated ^{14}C dates should be up to 300 years later than currently correlated ice-core acid signals by the mid-second millennium BC, this evidence must be addressed in the present discussion. As part of their effort to create the Greenland Ice Core Chronology 2005 (GICC05), Vinther et al. employed the Holocene parts of the Dye-3, Greenland Ice Core Project (GRIP), and North Greenland Ice Core Project (NGRIP) ice-cores. For the interval 1814–3845 b2k [before AD 2000], only the NGRIP ECM record had sufficient resolution for dating purposes. And with ECM annual layer counting typically associated with errors of 5–10 %, the underlying reference match of volcanic signals across the three ice-cores was only reconsidered if the discrepancy of a given matched section exceeded this error rate. The authors claimed to have established the date of the Thera eruption at 3641 b2k (= 1642 BC). By comparing all the available Greenland ice-cores, the maximum counting error in this new GICC05 timescale was established at ± 5 years. This date corresponds almost precisely with the Dye-3 date given for the 'Thera' volcanic signal at "1641" ± 4 BC [formerly "1644" ± BC], and is compatible with the originally provided date for the correlated acid signal in the GRIP core at "3635" ± 7 b2k (= "1636" ± 7 BC). However, the formerly associated "1623" (145 ppb) 'Thera' signal in the GISP2 core was abandoned in favour of the earlier "1669" (78 ppb) signal. Since this latter date is incompatible with the GICC05 date of "1642" ± 5 BC, even allowing for the maximum counting error of ± 21 years in GISP2 by this date, the discrepancy was credited to the quality of the latter ice-core (Vinther et al., 2006: 3, 10 and Table 6). Incidentally, if this proposed new correlation were to be correct, then, one would seemingly also have to disassociate the major GISP2 signals at "1459" and "1454" (separation 5 years) from their previously associated correlates in the Dye-3 core, that is, the major signals at "1463" and "1457" (separation 6 years). A lowering of anywhere near 21 years in these GISP2 dates would be incompatible with a similar-magnitude lowering in the Dye-3 and GRIP dates across the well synchronized periods of "1641–1428" and "1636–1425" respectively.

No doubt because of the GISP2 biyearly manual counting of SO_4^{2-} ion concentration across the entire ice-core back to 7000 BC (Zielinski et al., 1994), this chronology became a widely used standard until the creation of the GICC05 timescale in 2006. But, since that time, it has been almost completely disregarded in chronology-related research for the historical period preceding about 2500 BP. And yet the practice of multi-observer manual counting of ice-cores still remains the gold standard in checking electronic counting software, as seen in the new GICC21 timescale (Sinnl et al., 2022). The GISP2 chronology admittedly suffers from (now) established dating errors during the past two millennia due to understandable, but incorrect, correlations with known historical volcanic eruptions, such as Vesuvius in AD 79, and which would require a lowering of the GISP2 timeline at that date by about seven-nine years (Baillie and McAneney, 2015; Sinnl et al., 2022). And, as seen above, this error would have extended out to 14 years at 570 BC. However, the latter adjustment is perfectly acceptable within a ± 1-year counting error per century. Moreover, within its stated error-margins, the GISP2 sections earlier than the Thera eruption also agree with GICC05. Yet, somehow, between the Thera and Vesuvius reference horizons, the official GISP2 timescale includes 30 more years than observed in GICC05 (Vinther et al., 2006: 10/11). Conversely, as argued above, the GISP2 "1623" signal is just four years earlier than the historically argued date for the 'Aniakchak II' eruption of 1619 AC, and so that the preceding signal at "1669" would necessarily relate to a different volcanic event (Table 1, cols. 5–7).

The production of ^{14}C and ^{10}Be co-vary globally due to factors such as the modulating effect of solar and/or geomagnetic field strength and are therefore recognized as a powerful synchronization tool. F. Adolphi and R. Muscheler used this method to argue that the GICC05 date for the 'Thera' eruption of 3641 ± 5 b2k (here given as 3591 ± 5 BP) is incompatible with the radiocarbon-based date for the Thera/Santorini eruption of 3563 ± 14 BP [= 1613 ± 14 BC]. But, having identified a chronology offset between the GICC05 ice-core and radiocarbon timescales around this time of –20 ± 5 years, the authors were able to reconcile the two dates, and so to argue that, at least from a chronological perspective, one cannot rule out that the Dye-3 ice-core tephra associated with the ‘Thera’ eruption may be attributable to the Santorini eruption (Adolphi and Muscheler, 2016: 16, 26–27). This offset, if correct, would disprove the Alternative Chronology hypothesis, since the presently argued difference between ice-core and dendro-radiocarbon dates during the mid-second millennium BC should be some 300 years. Acknowledging the complex statistical processes used in this 2016 article, I may at least note the following details. First, having explicitly assumed that accurate tree-ring chronologies underlie IntCal13 throughout the Holocene, then, the authors found an underestimation of the absolute dating uncertainty of GICC05 for large parts of the Holocene, and that there appears to have been a systematic over-counting of GICC05 years versus dendro years; the latter finding is in accord with the Alternative Chronology. Second, ^{10}Be evidence cannot provide information on absolute ^{14}C ages, thereby requiring an analysis of relative differences (termed “^{10}Be-based Δ ^{14}C anomalies”) between the two timescales. Third, the latter analysis requires the use of complex Bayesian statistics together with wiggle-matching to correlate the ice-core record with the IntCal curve. And fourth, the more complex a hypothesis or analysis, the more likely it is to include mistakes.

Sigl et al. (2016), based on research from the Western Antarctic Ice Sheet (WAIS), found that the synchronization between ^{10}Be records from the WAIS (WD2014) ice-core and ^{14}C data from IntCal13 was accurate to within ± 5 years back to 2345 BP. Since the preceding period back to 6009 BP was a zone of brittle ice, a complex statistical procedure (featuring various qualifications) was carried out to assess the correlation confidence of the pre-2.4 ka period by comparing stratigraphic links between the ice-core and tree-ring chronologies. This analysis provided a distribution of “best fit” results from all the procedure’s iterations, and with one of them having achieved “close agreement” at 6 ka (ibid.: 779). However, during the intervening period, there again was found to be a systematic over-counting of the GICC05 timescale versus the IntCal13 timescale, and as realized by comparing the respective ^{10}Be and ^{14}C records (ibid.: 774). One therefore has an essentially indisputable ^{10}Be ice-core and ^{14}C dendro correlation back to c. 2400 BP, but thereafter a systematic offset back to 6000 BP; that is, across the Bronze Age and Iron Age historical periods wherein lie the current ‘high’ versus ‘low’ chronological disputes. And the date at which this offset begins just happens to reach the lower end of the Hallstatt Plateau c. 2420 BP (above); that is, the first time in 2,500 years that one sees a break in the long-term 1:1 relationship between uncalibrated and calibrated radiocarbon dates.

Further evidence concerning cosmic-ray generated radionuclides (principally ^{14}C, ^{10}Be, and ^{36}Cl) in the Earth’s upper atmosphere is argued to support the more or less precise synchronization between the dendrochronology and ice-core timelines. For the most part, this research does not affect the present discussion, since the research data is taken exclusively from either the dendro record or from the ice-core record (Park, 2017; Miyake et al., 2021; Brehm et al., 2022). However, other research explicitly identifies a direct chronological correlation between the dendrochronology and ice-core records by comparing rapid increases of cosmogenic nuclides in tree-rings (^{14}C) and in ice-cores (^{10}Be, ^{36}Cl). Two frequently referenced events are those of AD 775 and AD 994, and which are seemingly now accepted as conclusively synchronized. A third event is that dated to around 2610 BP (~660 BC), and which is considered comparable in magnitude to that of the AD 775 event (O’Hare et al., 2019; Sakurai et al., 2020: 1). The first two events are of no direct relevance to the present discussion, since both post-date the Hallstatt Plateau. However, if the 660 BC correlation were to be correct, then, this would unequivocally destroy the integrity of the above-detailed chronological model, and where dendrochronology dates during this period are argued to be 71 years lower than their currently synchronized ice-core dates. So, is this hypothesized 660 BC dendro versus ice-core correlation correct? A number of details may support a negative answer.

First, ^{14}C dates alone do not provide an unequivocal detection of this event. Second, there is large uncertainty in estimating the peak amplitude in radionuclide production in the ^{14}C record. And third, while two ^{10}Be records from NGRIP indicate a rapid enhancement in radionuclide production around 2610 BP, and this is synchronized with a large concentration enhancement in the GRIP ^{36}Cl record, the ^{14}C data does not provide an unequivocal signal such as found for the AD 775 and AD 994 events (see O'Hare et al., 2019: 1, 3, 5 respectively). The extreme solar proton event of AD 775 witnessed the average date in ten (juniper) tree-rings sampled during the years AD 756 to 772, compared to the average date of the two tree-rings sampled during the years AD 775 to 777, change from 1329 BP to 1175 BP respectively, a difference of 154 uncalibrated years; and a similar calculation using oak trees resulted in a difference of 128 uncalibrated years (Scifo et al., 2019). The more or less accurate 660 BC ice-core date will equate to a presently hypothesized dendrochronology date of ~"731" (~660 + 71 years). Based on the AD 775 event, this should further mean that tree-rings dated to about "731" would appear a century or so younger in the first few years following this solar proton event, and there might have been a somewhat similar effect experienced by tree-rings dated to about dendro "660" BC. These dramatically lowered dates would cause them to overlap the, above-dated, Hallstatt Plateau ("642–465" = 571–465 BC); and only returning to the long-term average ^{14}C value over the following decades. It will have been this overlap resulting from the ~660 BC solar proton event that has caused the Hallstatt Plateau to be extended out to cover the radiocarbon period beginning c. 750 cal. BC. And, indeed, there are two such pronounced dips in the IntCal20 curve about "731" and "660" BC (Rose et al., 2022, Fig. 2); though, admittedly, their separation appears to be about 60 years rather than the presently argued 71 years.

The "possible" offset identified by Adolphi and Muscheler between the GICC05 and (IntCal13) radiocarbon timescales (though now reported as –19 ± 3 years) was used by Pearce et al. (2017) to lower the GICC05 date for the acid signal appearing in the GRIP core from 3591 ± 3 to 3572 ± 4 cal yr BP [= 1622 ± 4 BC], and thus to date the Aniakchak II ash layer. This new date ironically is essentially equal to the originally given GISP2 date of "1623" BC (145 ppb) acid signal, but which was later lowered by some 27 years in the GICC05 timescale when the 'Thera' eruption was associated with the preceding "1669" (87 ppb) acid signal (above). The main purpose of this article is to use the latter proposed ice-core date for the 'Aniakchak II' eruption to calculate the local marine radiocarbon reservoir age (ΔR) in the western Chukchi Sea (Pearce et al., 2017, esp. pp. 305, 312). This finding therefore categorically refutes Vinther et al. (2006)'s originally given maximum counting error of ± 5 years in the GICC05 timescale for this period. Moreover, one now has a disputed GICC05 date for the 'Thera'/'Aniakchak' eruption being combined with a possible IntCal13—GICC05 offset of –20 ± 5 years, and which ultimately relies on an accurate dendrochronology timescale, and all to argue that dendrochronology-derived calibrated radiocarbon dates for the Alaskan ice fields are compatible with those from the Greenland ice-cores. Is this not a circular argument?

Noting that there is a good correlation for the period from 430 BC to AD 1000 between intervals in frost-rings in bristlecone pines, and intervals in acid layers in ice-cores, McAneney and Baillie (2019) proposed to extend this finding back into the mid–second millennium BC. Having identified that the only two frost-rings known from the 17th century (at “1653” and “1627” BC) are separated by 26 years, they searched for contemporary ice-core signals separated by the same interval and thereby found that there are only two relevant compatible large acid spikes: at “1695.25” and “1668.85” in GISP2, and at “1667” and “1641” in the GRIP/GICC05 timescale. With Vinther et al. having correlated these two(?) twin signals to help create the GICC05 timescale, and Adolphi and Muscheler having proposed an offset of –20 ± 5 years to the IntCal13—GICC05 timescale (above), then, the respective GISP2 and GICC05 ice-core intervals of “1695–1669” and “1667–1641” could now be associated with the bristlecone pine “1653–1627” interval (McAneney and Baillie, 2019: 103). If correctly reasoned by these authors, this would essentially validate the single, global-wide, event associated with the ‘Thera’ (or rather ‘Aniakchak’) eruption, and therefore confirm the existing synchronization hypothesis between dendro/radiocarbon and ice-core chronologies throughout the late Holocene.

However, one may raise some objections to this line of reasoning. First, this calculation requires an error in the original GISP2 ice-core chronology for this period of 42 years, double that of the ± 21 years which Vinther et al. calculated as the absolute maximum permitted when based on the GISP2 estimated error of ± 1 % between an allegedly secure dendro synchronism with the Vesuvius eruption of AD 79 and the year 3339 b2k, and using a ± 2 % error rate further back to “1669” BC (2006: 8); though this purported Vesuvius synchronism is now widely seen as slightly wrong (Baillie, 2010: 206–209; Sinnl et al, 2022). Second, the original correlation exercise was done for the chronologically secure period 430 BC to AD 1000, only to now be extended to a chronologically contentious period where ice-core dates can seemingly move by anywhere up to 42 years should a new hypothesis require it. Moreover, Salzer and Hughes could only demonstrate 3 of 16 exact matches between the dendrochronology and ice-core timelines during the period c. 500–3000 BC, but where the total number of matches was used to establish significance across the past 5,000-year period (Sect. 2.3.2). And third, the twin 26-year ice-core separation is artificially constructed by correlating the “1669” (now “1667”) GISP2 signal with the “1644” (now “1641”) signal in the Dye-3 core, and then lowering the date of the GISP2 “1695” signal to postulate a GICC05 “1667” signal that does not appear in either of the original Dye-3 or GRIP cores (Clausen et al., 1997: 26,715, Table 3).

Pearson et al. (2022), using the findings of the articles just cited, claim to have precisely dated the Aniakchak eruption (termed V2) to the 1628 BC ice lamination; the particular ice-core is not specified, thereby suggesting that it refers to the simulated GICC05 timescale. This date is seen to be compatible with that for both the Aniakchak eruption of 3572 ± 4 years BP (1622/3 ± 4 BC) proposed by Pearce et al. (2007), and for the 1628/7 dendro signals in Irish oak and in bristlecone pine tree-rings. The 26-year gap hypothesis of McAneney and Baillie (2019) is then accepted as correctly correlating the GISP2 “1669/1670” signal with the bristlecone pine frost-ring at “1627”, and the GISP2 “1695” signal from an unknown volcano (termed V1) with the bristlecone pine frost-ring at “1653”. Adopting the error margins present in the Greenland ice-cores, and when applying ^{10}Be/^{14}C synchronization-matching, the date of the ‘Aniakchak’ eruption was found to be contemporary with an acid spike dated to 1629 BC in the independently layer-counted WD2014 chronology from Antarctica, and which is thereby seen as anchoring the ice-core chronology with the bristlecone pine frost-ring associations in 1653 and 1627 BC. And having established this precise date for the ‘Aniakchak’ eruption, the Thera/Santorini eruption is then associated with any one of a series of Greenland ice-core acid signals dated to 1611, 1561/1558/1555 and c. 1538 BC (Pearson et al., 2022: 1, 8). One major danger with this type of sequential argument is that it makes so many suppositions/qualifications, any one of which may be critical to a reliable outcome. Meanwhile, the interpretation of the evidence is constantly shifting with each new research finding.

An article by Pearson et al. (2018) seemed to have achieved some sort of consensus between the scientific and historical dating of the Thera eruption. Using annual radiocarbon dates across the problematic IntCal plateau (c. 1610–1540 cal. BC), as opposed to the previous decadal intervals, it is argued that the eruption could have occurred between 1570 and 1510 BC, thereby bringing it within the range of dates acceptable to many historians and archaeologists who favour the 'Low Chronology' (Pearson et al., 2018: 4; Bietak, 2021: 282). However, these findings were immediately challenged by S. W. Manning, who, using a statistical procedure that incorporated constraining 'Boundaries', continues to argue that relevant radiocarbon samples provide a date for the eruption in the period around and just before 1600 BC, that is, 1612–1592 BC (68.3 %) or 1617–1571 BC (95.4 %), and which would be incompatible with any historical date for the eruption in the late 16th century BC as favoured by some historians (Manning, 2024b: 357, 363). The debate is therefore still ongoing.

The reader should, of course, assess the respective merits of the dendro versus ice-core correspondences presented in Table 1 against those postulated by Salzer and Hughes (2007). One pertinent point of comparison is that the latter study seemingly allows too much of a relative error-margin between tree-ring width minima and corresponding ice-core acid signals with regard to the oft-cited GISP2 sequence. The glaciologists who carried out a visual count of the latter ice-core stated that it had an error margin of 1 % back to 3289 BP/1339 BC (above). Whilst presumably an average value, Salzer and Hughes deviate significantly from this figure without providing any reasons for doing so. For example, the YAM and GISP2 dates are synchronized respectively thus (page 65, Table 6): 1285 and 1284, 1147 and 1157, and 966 and 962 BC, thereby providing relative offsets of –1, +10, and –4 years, and all within a total period of just three centuries and an expected total error margin of ± 3 years.

The detailed chronological overlaps proposed in Table 1 are parallelled in a new paper that discusses some of the issues involved in radiocarbon dating, particularly the complex process of Bayesian statistics and the associated selection and removal of 'outlier' data from the analysis. The authors provide an excellent summary of the current situation regarding calibrated radiocarbon dating versus traditional (historical-archaeological) dating for the Ancient Near East, and they detail how: there is a discrepancy between these two timelines of between 150 and 300 years for the Old Kingdom and Early Bronze Age; how this is reduced to between 50 and 150 years for the Middle through Late Bronze Age; how this gap decreases to about half a century for the early Iron Age; and how it disappears altogether by the end of the Hallstatt Plateau c. 400 BC. One explanation suggested for this chronological mismatch is that the IntCal radiocarbon curve may possibly be constructed using an incorrectly assembled dendrochronology master sequence (Zerbst and van der Veen 2025, esp. pp. 390–94). To the best of my knowledge, the latter issue was first discussed in a detailed manner by Furlong (2007: 258-265).

4 A Question of paradigm change?

Paradigm changes are a fundamental and defining aspect of science. Thomas S. Kuhn, the scholar who has done most to develop this epistemology, maintains that when anomalies become sufficiently important, and remain resistant to solution, they take on a special function in that they can bring the prevailing paradigm/theory to a point of crisis (Kuhn, 1962: 62–65). The relevant community can then respond in a number of ways, one being the emergence of a period of revolutionary (or extraordinary) science in which there is an attempt to resolve the state of crisis through the development of new paradigms (Kuhn, 1962: 66–67). He argues that: "a scientific theory is declared invalid only if an alternate candidate is available to take its place... The decision to reject one paradigm is always simultaneously the decision to accept another, and the judgment leading to that decision involves the comparison of both paradigms with nature *and* with each other" (Kuhn, 1962: 77). He further maintains that it is the group, rather than the individual, which ultimately dictates the acceptance or rejection of a particular paradigm or theory (Kuhn, 1977: 320–21). Kuhn selects five criteria from the scientific method that he considers to be particularly important in comparing paradigms, namely, accuracy, consistency, breadth/expansiveness, simplicity and fruitfulness (Kuhn, 1977: 321–22).

Human perception of reality can never be anything more than a choice between competing probabilities. In the present instance, the question is whether or not dendrochronologists have made any errors in constructing the dendro master sequence(s) that is/are the basis for the various radiocarbon calibration curves (known as IntCal) and therefore for the reliability of all calibrated radiocarbon dates. And, of course, even a one-year cross-correlation error would destroy the integrity of any dendrochronology sequence. Moreover, the value of any chronology, no matter how accurate and precise it purports to be, can only rightfully be measured by its ability to provide a coherent understanding of historical and archaeological evidence. If the conventional historical-archaeology chronology and/or the calibrated radiocarbon chronology are more or less correct, and as maintained by most historians, archaeologists and relevant scientists, then, how should it be possible to propose a paradigmatically different chronology (as presented above), and one which correspondingly must be utterly wrong, and for the outcome not to be easily dismissed as fatuous nonsense? And this is not even to include the added task of using the very same body of historical, archaeological, and science-based dating evidence to create an alternative coherent chronological model.

The chronological hypothesis presented above, as most succinctly expressed in Table 1, exhibits all the criteria chosen by Kuhn. It provides not only historical accuracy, but also chronological precision. Note: 1) the near precise historical dates provided for both the 'Aniakchak II' and Thera eruptions; 2) the correlations between multiple dendro-signals from various regions and the largest acidity signals in the three Greenland ice-cores over some two millennia; and 3) the coherent relative offset pattern in those ice-core dates between the 21st and 6th centuries BC. Its consistency can best be measured by the fact that should any one of those correlations be shown to be in error by more than a few years, then, the whole chronological structure would begin to come apart and collapse. The breadth of material covered speaks for itself, and is but a small part of a much larger work to be published soon and titled *Alternative Timelines* II. Its simplicity is based on one foundational hypothesis, namely, that the Thera eruption occurred in the late 14th century AC/BC (= late 16th century CC), and not in the late 17th century cal. BC. From this premise flow the requirements: that current dendro-radiocarbon dates from the 17th century BC must be lowered by some 300 years during the period prior to the end of the Hallstatt Plateau; and that Conventional Chronology dates from the 16th century must be lowered by 200 years during the same period. Regarding fruitfulness, this hypothesis has provided potential answers to the 'Thera' and 'Palestinian Iron Age I–II' disputes and to the source of the Hallstatt Plateau. The Alternative Chronology also satisfies the two conditions required by Kuhn for paradigm change: first, the availability of an alternate paradigm to replace the existing one; and second, the fundamental nature of chronology (historical accuracy and numerical precision) should permit both competing paradigms to be tested against each other and against material reality. This essential scientific criterion of 'testability' can be achieved by dendrochronologists, glaciologists and geochronologists. The first group can definitively disprove the Alternative Chronology by demonstrating that the near-precise absolute dates provided for key sections of the various regional dendrochronologies will not permit successful cross-correlations across the intervening tree-ring gaps. The second group can effectively disprove it by finding volcanic evidence (aerosol sulfates or tephra) in the GISP2 "1327" ice lamination that is incompatible with the Thera eruption; even the GISP2 "1337" BC signal could not plausibly be associated with the Thera eruption according to Table 1. And the third group can definitively disprove it by demonstrating that the above-proposed Diss Mere cross-correlation adjustment between Sections A5 and B5 is not possible.

Compare this situation with that emerging from the current chronological paradigm. Since its inception, and apart from a few brief halcyon years of general unity, there has never been any consensus regarding the environmental signal of the 'Thera', or should it be 'Aniakchak', eruption. Each time one potential ice-core signal is ruled out as deriving from the Thera eruption, multiple others are ready to take its place, and such that its date has been pulled this way and that with dizzying regularity and is currently a black hole of conjecture. After so much intense Thera-related research over the past fifty or so years, there is increasingly less consensus as to the identification of the Thera volcanic signal in the Greenland ice-cores. Conversely, there is growing consensus that the mid-17th century Dye-3/GRIP signal does derive from an eruption of the Aniakchak volcano. Not only is there an irresolvable gap between historical-archaeological and scientific dating according to key scholars in the respective fields, but there is now a growing disunity as well within the scientific community over what constitutes acceptable radiocarbon dates. Scientific articles, building one upon another, rely on a whole series of qualified steps, any one of which may be critical to a reliable outcome. For example, if the relative offset pattern in ice-core dates shown in Table 1 is broadly correct, then, all research since 2006 which has disassociated the GISP2 volcanic signal at "1623" BC from the other massive signals in the GRIP core at "1636" BC and in the Dye-3 core at "1644/41" BC is fundamentally flawed. The conclusions arising from these articles also significantly change with each new research verdict. Conversely, any research that is based upon the true underlying chronological-historical and physical-scientific reality should create an ever-increasing level of coherence, and with each new research finding only providing greater accuracy and precision: one need only consider the iterative development of any well-founded scientific or engineering discipline.

There was once a time when the judicial system viewed the positive matches provided by forensic experts between two sets of fingerprints as infallible. However, while infrequent, the number of people convicted on the basis of false fingerprint matches is testament to the dangers inherent in this uncritical attitude. The cultural, procedural and technical factors that can influence forensic fingerprint matching have been well documented in recent years, as shown, for example, in the findings of the governmental-instituted Scottish Fingerprint Inquiry (http://www.theforensicinstitute.com). The high-profile Mayfield case is another example where various types of errors led three senior FBI experts to a wrongful identification between Brandon Mayfield and the 2004 Madrid bombing (see the U.S. Department of Justice 2006 publication: “A review of the FBI’s Handling of the Brandon Mayfield Case. Unclassified Executive Summary” at: https://oig.justice.gov). The computer program used in the initial fingerprint matching exercise was seen as a particular danger because if the true match is not present in the database, then, it will provide a number of closest possible non-matches (p. 7). The examiners’ claim of 100 % certainty in the fingerprint match was also not supported by the evidence upon review (pp. 8–9). With fingerprint-matching being the closest analogy there is to cross-correlating tree-ring patterns, can one be certain that such errors were not committed during the embryonic stages in constructing the dendrochronology master sequence underlying the ‘International Radiocarbon Calibration’ curve, and thereafter unwittingly perpetuated? There can be no objective knowledge other than that based in scientific, mathematical-statistical, and logical analysis; anything else is ultimately mere speculation without providing any opportunity for refutation. Chronological paradigm change, should it be warranted, must therefore ultimately be endorsed by science.

Conclusion

A choice may now be made between the conventional historical-archaeological and scientific dating paradigms for the pre-Hallstatt Plateau period, on the one hand, and the Alternative Chronology detailed above, on the other. Common sense is that innate capacity we all have to be able to compare, albeit not precisely, the probability equation between competing scenarios. I contend that the combined accuracy and precision of the dendrochronology versus ice-core timelines contained in Table 1 is extremely unlikely to have occurred by chance alone. Consider the following features: 1) the use of multiple-correlated signals in both the dendrochronology and ice-core sequences rather than individual signals; 2) the reliance, for the most part, on the largest ice-core acid signals recorded during the relevant period, and which serve as a proxy for the volcanic eruptions most likely to have caused tree-ring growth anomalies; 3) the compatibility between the HI5 “1997/96–1921” dendro gap and the GISP2 “1695–1623” ice-core gap; 4) the precision between the “2310–2304” GISP2 dates and the HI5 “2911–2905” dendro dates; 5) the similar precision between the “826” (HI5) and “824” (YAM) dendro dates and the “757” and “755” acid signals in the GRIP sequence; 6) the almost identical offsets between the massive ice-core acid signals at “1623”/“1636”/“1641” BC (+13 and +18 years) and those at “2034”/“2045”/“2053” BC (+11 and +19 years), a correlation which is supported by the general coherence of the offset trends for the three Greenland ice-cores over the two-millennia period between the 21st and 6th centuries BC; 7) that the necessarily approximate 72-year lowering required for Iron Age dates equates almost precisely to the correction (+71 years) that occurred when the independently constructed German ‘long’ chronology was seen to be in conflict with the Irish GB2 oak chronology, and which, incidentally, shows that there was at best only a 50 % success rate in constructing these two independent dendro master sequences during the embryonic phase of tree-ring dating; 8) that the dendrochronology overlaps emerging from Table 1 coincide extremely well with the periods of dispute between the ‘high’ versus ‘low’ advocates involved in the Thera volcanic eruption debate and in the Palestinian Iron Age I–II debate; 9) that similar, quantified, overlaps can be seen to affect the historically and archaeologically troublesome LBA–EIA and Hallstatt radiocarbon plateaus; 10) that the ^{14}C offsets between the Belfast Long Chronology and the German and North American chronologies of –30 years and –41 ± 9 years respectively can be harmonized within the overall radiocarbon evidence to explain the needless creation of the Hallstatt Plateau (2521–2409 BP); and 11) how the extreme solar proton event detected in Greenland ice-cores at ~2610 BP (= “731” BC) explains why the Hallstatt Plateau is extended out to cover the radiocarbon period beginning c. 750 cal. BC.

The Alternative Chronology would see the Thera eruption responsible for the quadruple dendro signals in the HI5, FIN, YAM and Irish oaks at “1628-1626” BC and for the almost precisely synchronized GISP2 “1327” BC acid signal, the largest recorded in this ice-core during some 250 years. Meanwhile, the Conventional Chronology is unable to propose with any confidence either a dendro or ice-core signal associated with this major volcanic event. The redating of tree-ring 854 to ~1681–1673 BC has also meant that it must be disassociated from the Thera eruption, and despite that it was recovered from Porsuk which is located within the estimated fall-out zone of Thera tephra (Sect. 1). In light of the presently argued problems with dendrochronology construction, I believe that any calibrated ^{14}C dating of the dendro-isolated Porsuk tree-ring series should be treated with suspicion until the dendro master sequence underlying the IntCal curve has been reassessed and, if necessary, corrected. The ‘common sense’ association between an unprecedented growth spurt in some 6,500 years of Anatolian dendro sequences so far collected, on the one hand, and, on the other, the Thera volcanic eruption, one of the largest during the Holocene period, and which deposited its ejected tephra reaching as far away as Porsuk, should not be dismissed prematurely.

Whilst it must always remain a possibility that the details contained in Table 1 could have occurred due to pure chance, the evidence provided above would seem more than sufficient to have the Alternative Chronology hypothesis tested by experts within the dendrochronology community and related fields. Moreover, near-precise absolute dates have been provided for key sections of the various dendrochronologies, thereby facilitating cross-correlation testing across the intervening tree-ring gaps. If the hypothesis presented in this work and elsewhere is correct, then, the arguments currently being made by scientists that maintain a close synchronization between the ice-core and radiocarbon timescales for the above-delineated period must be wrong. Conversely, if that synchronized chronology is broadly correct, then, by definition, the Alternative Chronology can be nothing more than delusional nonsense and should therefore be easily demonstrated as such by any experienced scientist within any of the relevant disciplines. There can, of course, be no doubt that science will eventually resolve both the ‘Thera’ and ‘Low versus Conventional’ Chronology debates, either by correcting its own errors or, should it prove essentially correct in the matter of Bronze Age–Iron Age chronology, by forcing all (evidence-based) opponents to accept its findings. However, such consensus has not been reached at present. And until it is achieved, all historians and archaeologists studying this period must continue to offer alternative hypotheses aimed at resolving the chronological, historical, and archaeological problems currently bedevilling this topic. If historians and archaeologists relinquish that obligation, then, scientists will be deprived of the opportunity to test alternative scenarios which may better agree with the constantly expanding body of evidence.

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