Zeitschrift: Asiatische Studien : Zeitschrift der Schweizerischen Asiengesellschaft = Études asiatiques : revue de la Société Suisse-Asie

Herausgeber: Schweizerische Asiengesellschaft

Band: 76 (2022)

Heft: 4

Artikel: The climate downturns in China caused by volcanic eruptions in 535-40 CE and by Thera (Santorini) at the founding of the Shang dynasty (1562 BCE)

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DOI: https://doi.org/10.5169/seals-1046525

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The climate downturns in China caused by volcanic eruptions in 535–40 CE and by Thera (Santorini) at the founding of the Shang dynasty (1562 BCE)

https://doi.org/10.1515/asia-2022-0042
Received December 7, 2022; accepted February 5, 2023; published online April 25, 2023

Abstract: It is well known that ancient Chinese written records are an invaluable source of historical information on astronomy, technology, economy, and climate, dating back in some cases to the second millennium BCE. Numerous studies have established that the climatic consequences of the ejection of volcanic aerosols into the atmosphere can have a major impact on the climate worldwide. Here, the Chinese evidence of such a severe climatic anomaly during the decade of the 530s is first reviewed. A preponderance of the evidence from ice cores and tree rings worldwide points to more than one large volcanic eruption during the 530s, although which volcano was responsible has not yet been conclusively established. Even more severe than 1815, the "year without a summer," due to the eruption of Tambora, in 536–537 summer frosts and snowfall occurred in China causing multi-year drought, crop failures, and catastrophic famine. Study of pre-imperial Chinese texts gives reason to believe that in mid-second millennium BCE a massive loading of the atmosphere with volcanic aerosols from the eruption of Thera (Santorini) may have been the cause of dramatic climatic downturn in the sixteenth century BCE. Dating of the events based on verifiable records of astronomical phenomena suggests that the long-remembered ancient calamity could have been caused by the eruption of Thera in the eastern Mediterranean. This benchmark date can be helpful in establishing a secure chronology of eastern Mediterranean kingdoms in the period.

Keywords: chronology; climate anomalies; Early China; Thera; volcanic eruptions; years without summer

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1 Introduction

A devastating multi-year drought occurred in medieval China. As is well known, this climatic downturn in the 530s is associated with the so-called "dry fog" reported to have blanketed the Mediterranean basin and Europe, obscuring the light of the sun for many months and resulting in the collapse of agriculture across the world. A decade with multiple years of unseasonable cold in summer then culminated in the Justinian plague of 541–543 that caused catastrophic mortality among populations from the Byzantine Empire to Scandinavia. The literature on the cause of the devastation is extensive and a consensus has settled on volcanic eruption(s) in the northern hemisphere as the cause, with some suggestion of a possible cosmogenic contribution as well.[1] The consequences were evidently on a par with the massive 1257 eruption of Samalas in Lombok, Indonesia.[2] By now, the climatic consequences of the injection of volcanic aerosols into the atmosphere are well established.[3]

Chinese historical records eloquently attest to the devastation in north China caused by successive years of cold and drought. The accounts reproduced here begin in 535, the year of a schism in the Northern Wei 北魏 (386–535) that resulted in the short-lived Eastern (535–550) and Western Wei (535–557) dynasties. Included are contemporaneous records from the neighboring Southern Liang Dynasty 南梁朝 (502–559). These events, and the consequences of a massive eruption in 43 BCE of Okmok volcano in Alaska can serve as proxies for the Thera eruption in the mid-16th century BCE.[4]

2 Methods and materials

We begin with a review of the historical, documentary, chronological and geophysical evidence bearing on the epic multi-year drought that occurred in China in the 530s. The following passages are taken from the year-by-year annals of the reigns of emperors and from the "Treatise on Foodstuffs and Commodities," which preserves records of tax receipts, grain and silk production, the price of rice, administrative policies, economic disruptions, etc.

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1 Abbott, et al., 2013; Arjava, 2005; Büntgen, et al., 2016, 2022; Druitt, 2019; Gibbons, 2018; Gräslund/Price, 2012; Gunn, 2000; Gao et al., 2008; Houston, 2000; Larsen, 2008; Newfield, 2018; Nooren, Keys, et al., 2017; Pearson, et al., 2020; Rigby, et al., 2004; Samuli, et al., 2018; Sigl, 2015; Stothers, 1984; Stothers/Rampino, 1983; Zhang, et al., 2010.

2 Guillet, et al., 2017.

3 Pearson, et al. 2022; Iles, et al. 2013; Zhang, et al., 2010; Zhuo, et al. 2014; Gao, et al. 2008.

4 Pearson, et al., 2022; McConnell, et al., 2020.

[535 CE]

– *In the Tianping reign period, 2nd year, the 3rd month, on day xinwei* [14 May 535]. *On account of the drought an edict was issued ordering that within the capital district and the several provinces of commanderies and prefectures should gather up and bury the skeletons of the dead."*
二年三月 … 辛未以旱故，詔京邑及諸州、郡、縣、收瘞骸骨。
History of the Wei Dynasty, fasc. 1, "Annals of Emperor Xiaojing" (*Weishu* 1: 299); History of the Northern Dynasties, fasc. 5, "Annals of Emperor Xiaojing" (*Beishi* 5: 185)

– *In the 5th month* [July], *there was severe drought. At city and palace gates, as well as official residences, temples, administrative offices, and lane entrances, it was mandated that the people should be watered, and not simply princes and dignitaries, to continue indefinitely, stopping only when it rains.*
五月，大旱. 勒城門、殿門及省、府、寺、署、坊門澆人，不簡王公，無限日，得雨乃止。
History of the Wei Dynasty, fasc. 12, "Annals of Emperor Xiaojing" (*Weishu* 12: 299); *History of the Northern Dynasties*, fasc. 5, "Annals of Emperor Xiaojing" (*Beishi* 5: 185)

– *In the beginning of the Tianping reign period* [of Emperor Xiaojing of Eastern Wei, 535–6], *in order to provide displaced people with a new start, and because production had not yet been established, an imperial edict went out ordering that 1.3 million bushels* [piculs] *of millet should be distributed in relief.*
孝靜天平初以遷民草創，資產未立，詔出粟一百三十萬石以賑之。
History of the Wei Dynasty, fasc. 110, "Monograph on Foodstuffs and Commodities" (*Weishu* 110: 2861)

– *In winter, in the 11th month* [13 Nov–11 Dec 53], *yellow dust rained down like snow.*
冬十月，雨黃塵如雪。
History of the Southern Liang Dynasty, fasc. 7, "Annals of Emperor Wu", (*Liangshu* 7: 211)

[536]

– *In the 2nd year* [of the Datong reign period of Emperor Wu], *11th month* [Dec 536], *yellow dust fell like snow,* [so thickly that it could be] *scooped up by the handful.*
[二年]十一月，雨黃塵如雪，攬之盈掬。
History of the Southern Liang Dynasty, fasc. 7, "Annals of Emperor Wu", (*Liangshu* 7: 212)

– *In the summer of the 3rd year* [May–Jul 536], *once again relief provisions were provided for forty days. By autumn that year* [Aug–Oct], *the nine provinces Bing, Si, Fen, Jian, Jin, Tai, Shen, Dong yong, and Nan Fen* [i.e., all across N & NW China] *suffered frost and drought. The people were starving and dispersed."*

三年夏，又賑遷民稟各四十日。其年秋，並、肆、汾、建、晉、泰、陝、東雍、南汾九州霜旱，民飢流散。
History of the Wei Dynasty, fasc. 110, "Monograph on Foodstuffs and Commodities" (*Weishu* 110: 2861)

– *In this year, there was severe famine in Guanzhong* [Shaanxi Province in the NW]. *People ate each other's* [corpses], *and seven or eight out of ten died.*
大統二年, 是歲關中大飢，人相食，死者十七八。
History of the Northern Dynasties, fasc. 5, "Annals of Emperor Wen of Western Wei" (*Beishi* 5: 176)

– *In the 8th month* [3 Sep–3 Oct 536] *frost fell in the four provinces Bing, Si, Fen, and Jian and there was severe famine.*
八月並、肆、汾、建四州隕霜，大飢。
History of the Wei Dynasty, fasc. 12, "Annals of Emperor Xiaojing" (*Weishu* 12: 300)

– [*In the 3rd year* [of Emperor Xiaojing of Wei] *winter, the 11th month. On day wushen* [11 Dec 536], *an imperial edict ordered emissaries to be dispatched on a circuit of inspection of the famine refugees north of the Yellow River* [Hebei].
三年冬十一月戊申, 詔遣使巡檢河北流移飢人。
History of the Wei Dynasty, fasc. 12, "Annals of Emperor Xiaojing" (*Weishu* 12: 300)

[537]
– *This year there was famine in Province Yu* [Henan]*; rewards were issued for opening the granaries to help with relief. Many were provided complete relief.*
是歲豫州飢, 慶之開倉濟賑, 多所全濟.
History of the Liang Dynasty, fasc. 32, "Biography of Chen Qingzhi" (*Liangshu* 32: 464).

– *In the 3rd year of the Datong reign period of Emperor Wu of Liang, the first month of spring, on day renyin* [1 Feb], *it rained yellow ash from a cloudless sky".*
大同三年正月壬寅, 天無雲, 雨灰黃色。
History of the Liang Dynasty, fasc. 7, "Annals of Emperor Wu, Pt. 2," (*Liangshu* 7: 81)

– *In the 6th month* [26 Jun–24 Jul], *at Qushan in Qing Province* [Shandong] *frost fell. In autumn, in the 7th month* [25 Jul–23 Aug], *it snowed in Province Qing, damaging the crops.*
六月，青州朐山境隕霜。秋七月是月，青州雪，害苗稼。
History of the Liang Dynasty, fasc. 7, "Annals of Emperor Wu, Pt. 2" (*Liangshu* 7: 81)

[538]

– *In the spring of the 4th year, an imperial edict went out ordering that all granaries in the* [affected] *locations should be opened to provide relief and to show solicitous concern for the people, but extremely many died.*
四年春，詔所在開倉賑恤之，而死者甚眾。
History of the Wei Dynasty, fasc. 110, "Treatise on Foodstuffs and Commodities" (*Weishu* 110: 2861–2862)

– *In the 4th year, 8th month, on day jiachen* [28 Sep 538], *an imperial edict ordered that … since famine was ongoing in these Twelve Provinces, Southern Yan, and the rest, rents and debts in arrears are to be exceptionally excused, and the year's Three Levies are not to be collected.*
四年春正月庚辰 … 八月甲辰，詔「南兗、北徐、西徐、東徐、青、冀、南北青、武、仁、潼、睢等十二州，既經饑饉，曲赦逋租宿責，勿收今年三調。
History of the Liang Dynasty, fasc. 3, "Annals of Emperor Wu, Pt. 3" (*Liangshu* 3: 82)

[540]

– *In the 2nd year* [of the Xinghe reign period] *3rd month, on account of the drought, sentences of death are already commuted to imprisonment.*
東魏興和二年 … 三月，以旱故，宥死罪已下囚。
History of the Wei Dynasty, fasc. 12, "Annals of Emperor Xiaojing", (*Weishu* 12: 185)

3 Discussion

There can be no doubt of the severity of the calamity in northern China which paralleled the consequences in Europe. For example, in Scandinavia it is estimated that half the sedentary population starved.[5] In Shaanxi in northwest China contemporary sources say that seven out of ten died or fled the province.

Given this representative catastrophe, our principal task here is to determine the dates of events in China during the sixteenth century BCE when an equally severe if not worse multi-year drought occurred.[6] Some years ago I reconstructed the founding dates of the Shang (ca. 1555–1046 BCE) and Zhou (1046–256 BCE) dynasties, based largely on secure benchmarks identified in a Zhou annalistic history, the *Bamboo Annals* and in other historical works such as the *Lost Books of Zhou* 逸周書.[7] The absolute dating of singular historical events in those sources during the late

5 Holmberg, et al. 2018–2019: 14.
6 Pang 1991.
7 Ban 2008; Loewe 1993; Pankenier 1992a, 1992b, 1981–82.

second millennium BCE was accomplished based on certain benchmark dates embedded in the relative chronology. Those benchmarks are recorded observations of rare astronomical phenomena whose dates could be scientifically verified using modern methods. The original text of the *Bamboo Annals*, written with brush and ink on bamboo slips, was recovered in 281 CE from a Warring States period (5th c. to 221 BCE) elite tomb that had been looted by grave robbers. Classical scholars at the court of the Jin 晉 dynasty (266–420) who were involved in reconstructing the disordered bundles of bamboo slips on which the chronicle was written were not capable of retrospectively calculating the precise dates of astronomical phenomena a millennium earlier, nor could any would-be interpolator during the later imperial period have understood the ancient events' precise chronological relationships. For over two-thousand years, attempts have been made to precisely date the Shang and Zhou dynasties and the reigns of their kings prior to 841 BCE, the earliest Zhou period date established with confidence in late antiquity.

Most important among the astronomical records were eye-witness accounts of impressive conjunctions of the five naked-eye planets and a total lunar eclipse. Dating these astronomical events effectively bracketed the late-Shang dynasty (mid-16th c.–1046 BCE) and the founding of the Zhou dynasty (1046), spanning the period from the heroic Shang founder, Cheng Tang 成湯, through the last "dissolute Shang tyrant," Di Xin 帝辛 (1086–1046 BCE). The chronological relationships among the verifiable astronomical observations prove that the *Bamboo Annals*, long thought to comprise a mix of legend and history, was undoubtedly based in part on actual chronicles and transmitted genealogies from the late second and early first millennium BCE. Assiduous preoccupation with the cult of the royal ancestors throughout the Shang and Zhou dynasties and the perennial court office of Scribe-Astrologer fostered such preservation and transmission. Indeed, the inscription on the famous *Li gui* 利簋 that records the Zhou conquest of the Shang in 1046 BCE is explicitly ascribed to "Scribe of the Right Li."

Until recently, the early historical events recorded in the *Annals* had largely been dismissed as unreliable. While it is true that the received text of the *Annals* is defective in parts, having been restored in the third century CE from the disordered bundles of broken and damaged slips, nevertheless, the text has been proven to accurately preserve such vital historical evidence as the king list of the Shang dynasty, confirmed by 20th century archaeological discoveries, and the verifiable astronomical observations. Many of the text's defects are the result of misplaced slips, misreading of the archaic graphs, or "reconstructions" of the early chronology by the scholarly restorers based on third century received wisdom.

One such obvious interpolation is the enumerating of years using the ancient sexagenary cycle of day-dates. The paired sets of ten and twelve terms first made their appearance when oracular divinations were recorded during the Shang on turtle shells and bovine scapulae in the thirteenth century BCE and were used

without interruption to enumerate the days from then on. However, the use of the cycle to also label the years only began in the early imperial period. It probably served the third century scholars as a convenient framework when reconstructing the relative chronology of the *Bamboo Annals* chronicle.

In the case of the dating of the Zhou conquest of the Shang, the astronomical benchmarks made it possible to undo distortions that had worked their way into the *Annals'* relative chronology, both during the Warring States period (ca. 479–221 BCE) before interment in the tomb and again during the third century reconstruction.

The touchstone astronomical events most relevant here are:

i. the Sun marching through a cluster of all five naked-eye planets in late 1576 BCE so that the planets were successively overtaken by the sun, making some switch horizons and times of observation from east to west, dawn to dusk, and vice versa. This phenomenon is recorded as occurring during the reign of the last king of the Xia "dynasty" which preceded the Shang. That a prosperous, well-organized, centuries-old, urban polity preceded the Shang is archaeologically well-established. In the absence of written records, exactly what sort of polity it was remains unclear.[8] The planetary phenomenon is described as *wu xing cuo xing* 五星錯行 "the five planets criss-crossed" and the date indicated by the *Bamboo Annals* is only four years earlier than the verified date of the phenomenon, raising the level of confidence in the chronicle.

ii. a total eclipse of the Moon on March 12–13, 1065 BCE actually recorded in *Yi Zhou shu* 逸周書.[9]

iii. a second, much more spectacular massing of the five visible planets in late May 1059 BCE, at which time all five could be circumscribed by a circle only 7° in diameter (roughly the size of a fist held at arm's length). On May 27 the longitudes of the planets, in Shang time denoted the Supernal Lord's "Five Minister Regulators," were: Mercury 79°, Venus 82°, Mars 76°, Jupiter 78°, Saturn 83°, a singularly impressive sight. The conquest of Shang and the founding of Zhou followed this "Mandate from Heaven" by thirteen years, in 1046 BCE, one Jupiter cycle later when that planet had returned to the same location in the heavens as in 1059, the space allotted to the Zhou in the Spring and Autumn period (722–479 BCE) "field-allocation" *fenye* 分野 astrology. Based on these historical precedents, conjunctions of all five planets became established as the requisite sign from the Supernal Lord that a legitimate dynastic change had occurred or was in the offing.[10]

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8 Li 2013; Liu/Xu 2007, Huber 1988.

9 Li 1981; Pankenier 1981–82. Liu 1979; Newton 1977.

10 Pankenier 2013, 2019.

3.1 Climate forcing by volcanic eruptions and their role in dating

For many years, hopes for the establishment of a secure chronology for the kingdoms of the eastern Mediterranean have been pinned on securely fixing the date of the Thera eruption that nearly obliterated the Greek island of Santorini and the Minoans.[11] In revisiting earlier studies which favored a 1627 dating, more recent analysis has found that no volcanic horizons in the seventeenth century can be attributed to Thera, which now seems to have erupted in mid-sixteenth century, based on the tree-ring and ice-core evidence.[12] These findings lend support to the sixteenth century so-called "young chronology" for the Middle East suggested by the archaeological evidence.[13] Estimates of the huge volume of erupted magma from Thera range from 48 to 86 km^3 DRE. One estimate of Thera's eruption assigns a Volcanic Explosivity Index of 7–7.3, making it one of the most voluminous eruptions in the past 10,000 years.[14] Recent estimates suggest that the volume of Thera's sulfur aerosols injected into the atmosphere lay mid-way between that of Tambora (1815) and Krakatau (1883).[15]

Negative radiative forcing of the climate is mainly caused by the injection of sulfur into the stratosphere; however, recent studies indicate that volcanic halogens also play an important role in depleting stratospheric ozone.[16] In the case of Thera, the amount of sulfur spewed into the atmosphere was not record-high, but significant stratospheric ozone losses could have played an important role.[17]

Large eruptions are known to produce global or hemispheric cooling for two to three years, with maximum cooling occurring about one year after an eruption. The cooling typically follows the Sun's declination in being displaced toward the northern or southern hemispheres, depending on the location of the volcano. Maximum summer cooling in the northern hemisphere occurs around 40° N.[18] "Analysis of the observed cooling patterns following major eruptions of the past 140 years […] suggests that the first two winters following the Minoan eruption would have been marked by a slight [winter] warming in high-latitude parts of North America and Eurasia, and an enhanced cooling of high-latitude continental areas for two or three summers."[19]

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11 Pearson, et al. 2018, 2022; Druitt, et al. 2019.
12 McAneney/Baillie 2019; Pearson, et al. 2018, 2020.
13 McAneney/Baillie 2019.
14 Druitt, et al. 2019; Johnston, et al. 2014.
15 Pearson 2022: 6.
16 Cadoux, et al. 2015; Robock 1996, 2000; Pyle 1997.
17 Druitt, et al. 2019; Cadoux, et al., 2015.
18 Robock 2000; Cadoux, et al. 2015.
19 Sigl, et al. 2015; Büntgen, et al. 2016; Gao, et al. 2008.

Recently, it was shown that a massive eruption of Okmok volcano in Alaska in 43 BCE was responsible for a dramatic multi-year climatic downturn documented from Europe to China that affected northern hemisphere mid-latitudes.[20] Two millennia earlier, the Shang dynasty capital was located on the Yellow River at 35° N in the North China plain, some 7,500 km due east of Santorini (36.4° N). While significant ashfall from the Thera eruption ought not to have reached that far, the consequences for the continental climate in north China would have been very significant.

3.2 Historical climatic disruptions in China

Dry farming in the North China Plain was always precarious due to the high variability of rainfall, often exceeding 70%. By the time the southeast monsoon reaches north China most of its moisture has already precipitated out. During the late Shang, divinations by the king's diviners inscribed on a multitude of "oracle bones" (turtle plastrons and bovine scapulae) regularly seek affirmation from the supra-visible powers that rain would be forthcoming and that there would be a harvest. These entreaties attest to a strong preoccupation by Chinese Bronze Age ruling elites with the weather and grain production. Studies have shown that cooler temperatures "may be the driving force in causing high frequencies of meteorological, agricultural disasters and then man-made disasters (wars) in ancient China".[21] Such may also have been the case during the transition from Xia to Shang in mid-sixteenth century BCE.

What is the likelihood that Thera was responsible for a severe disruption of the climate in China? The possibility of a connection between Thera and the beginning of the Shang dynasty came to mind because of one of the most storied events in ancient Chinese history, a severe multi-year drought that marred the ascendancy of the Shang founder, Cheng Tang. Numerous accounts in fifth to second century BCE works celebrate Cheng Tang's benevolence and virtuous self-sacrifice in offering himself as a victim to the Supernal Lord, entreating the high god to end the drought which ultimately lasted five to seven years.

3.3 Severe drought at the beginning of the Shang dynasty (mid-sixteenth century BCE)

We saw above how devastating the drought and cold were 2,000 years later in the 530s. North China was catastrophically affected at the same time as the

20 Pearson, et al. 2022; McConnell, et al. 2020.

21 Hinsch 1998, Zhang et al. 2010; Keys 1999.

Mediterranean basin, Europe, and Central America. Similarly, the long-remembered drought at the beginning of Shang was also accompanied by a "yellow fog," crop failures, and abnormally cold temperatures. Numerous fourth century BCE sources recount how in Cheng Tang's time "the Sun and Moon appeared irregularly, cold and heat arrived confusedly. The five grains withered and died" 「遝至乎夏王桀，天有酷命，日月不時，寒暑雜至，五穀焦死」.[22] The anomalies were long remembered because they would ordinarily have been interpreted as baleful omens from the supra-visible powers and as such should have posed a major impediment to the perceived legitimacy of Shang founder Cheng Tang's ascendancy. By itself this speaks in favor of the event's historicity. Such an inauspicious event necessitated a rationalization of the disaster in later hagiography, so that the catastrophe was ultimately transformed in cultural memory into a token of the surpassing virtue of the dynastic founder who was uniquely able to bring an end to the suffering. Ordinarily, a calamity of such magnitude would be blamed on misrule by a ruler in process of being deposed.

Here, for example, are relevant excerpts from the philosopher Mozi (ca. 470–ca. 391 BCE), first from a discussion of "Universal Love" (Pt. 2):

> … *in the "Oath of Tang" Tang said: "Unworthy,* [am I], *Lü, having presumed to sacrifice a first-born male animal to Heaven above, saying: Now there is a great drought from Heaven. It happens right in my … time. I do not know how I have offended* [Heaven] *above or* [the spirits] *below. Good deeds, I dare not conceal; guilt, I dare not excuse – this much is clearly in the mind of the Supernal Lord. If there is wrongdoing in the world, hold me responsible for it; if I myself am the guilty one, let not* [*the consequences*] *be visited upon the world." This is to say that, although Tang was so elevated in dignity as to be emperor, and so wealthy as to possess the whole world, he did not shrink from sacrificing himself in supplication to the Supernal Lord and the spirits.*
> 湯曰：『惟予小子履，敢用玄牡，告於上天后曰：「今天大旱，即當朕身履，未知得罪于上下，有善不敢蔽，有罪不敢赦，簡在帝心。萬方有罪，即當朕身，朕身有罪，無及萬方。」即此言湯貴為天子，富有天下，然且不憚以身為犧牲，以祠說于上帝鬼神。』。
> (*Mozi* 4.3: 29)

From *Mozi*'s chapter "Seven Afflictions":

> *The* Book of Yin(-Shang) *says, 'Drought was visited on Tang for five years.' This is the most extreme of calamities and yet the people did not freeze or starve. Why? The reason lies in* [prior] *meticulous attention to production and frugal consumption.*
> 《殷書》曰：「『湯五年旱。』此其離凶餓甚矣。然而民不凍餓者，何也？其生財密，其用之節也。」 (*Mozi* 1.5: 6)

And from the *Mozi's* chapter "Against Aggressive Warfare":

22 *Fei gong xia*《非攻下》(*Mozi* 5.3: 34); cf. Sun 1934: 97.

> *When it came to King Jie of Xia, Heaven issued a severe command. The Sun and Moon appeared irregularly, and cold and heat arrived confusedly. The five grains withered and died.*
> 至乎夏王桀，天有酷命，日月不時，寒暑雜至，五穀焦死。(*Mozi* 5.3: 34)

From a 7th century CE sub-commentary on the 3rd–4th century BCE *Shangshu da zhuan* 尚書大傳 (*Great Commentary on the Venerable Writings*) there is:

> *After Tang attacked Jie there were seven years of severe drought. The Scribe-Diviner said: "*[You] *should offer yourself in sacrificial prayer." Thereupon, Tang cut his hair, broke off his nails, and offered himself as a sacrificial victim. He prayed in supplication at the Mulberry Grove altar to the soil, and the rains came in abundance for several thousand li around* [one *li* equals 0.5 km].
> 湯伐桀之後，大旱七年。史卜曰：「當以人為禱。湯乃剪髮斷爪，自以為牲，而禱於桑林之社，而雨大至，方數千里。」[23]

From an early Han dynasty (206 BCE–220 CE) apocryphal commentary on the Zhou classic *Shangshu* "Venerable Writings," *Shangshu zhonghou* 尚書中候:

> King Jie of Xia lacked virtue and the earth emitted a yellow fog.
> 夏桀無道, 地吐黃霧. (*Chōshū isho shusei* II: 81)

Windblown loess dust storms from the NW are a common occurrence in north China, hardly worth mentioning, so this event should refer to a particularly severe instance or some other atmospheric anomaly.

Finally, from the *Book of Master Huainan* (*Huainanzi* 淮南子; mid-2nd century BCE), "Managing Technical Arts":

> *In the time of Tang there was a drought lasting seven years. He offered himself up in supplication at the edge of the* [sacred] *mulberry grove, whereupon the clouds from the Four Seas gathered, and rain arrived from a thousand li* [0.5 km] *around.*
> 湯之時，七年旱，以身禱于桑林之際，而四海之雲湊，千里之雨至。(*Huainanzi* 9: 69)

3.4 Second millennium BCE chronology

One crucial aspect of the circumstances surrounding the 1576 planetary omen was that it actually occurred in the astral space known as Great Fire (*da huo* 大火), traditionally allocated to the Shang for astrological purposes. That space was

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23 Quoted in Kong Yinda's 孔穎達 seventh century *Zheng yi* commentary to the fourth century BCE narrative history *Zuozhuan* (左傳正義), under Lord Xiang 襄公 10th year. Tang's self-sacrifice had evidently become necessary when prior animal sacrifices had no effect (*Chunqiu* 31: 6a [539]).

marked by the "Great Fire Star," orange-red Antares (α Scorpii), whose seasonal appearances were celebrated with sacrifices in the earliest Shang oracular inscriptions. Despite a hiatus of nearly two millennia, this precedent-setting planetary "criss-crossing" *cuoxing* 錯行 phenomenon resurfaced as a portent of dynastic transition from the Later Han 漢 to Cao-Wei 曹魏 in the third century of the common era.[24]

This is not the place to rehearse the details of the reconstruction of the early Chinese chronology set forth in a series of prior publications. Crucial benchmarks in that reconstruction most notably included the dating of the Zhou conquest of Shang to 1046 BCE (1050 in the *Bamboo Annals*), which was subsequently confirmed by the Chinese Academy of Social Sciences Xia-Shang-Zhou Chronology Project.[25] Here, I plan only to briefly reconsider the date of the beginning of the Shang dynasty. This effort was prompted by the recent publication of new rigorous studies concerning the dating of the cataclysmic eruption of Thera suggesting that it occurred in mid-sixteenth century.

Turning to the *Bamboo Annals* chronology for the sixteenth century BCE, here is what the chronicle has to say about the early years of Cheng Tang's reign:

> *In his* [Cheng Tang's] *18th year … the king ascended the throne and took up residence at Bo. He first roofed over the Xia altar to the* [spirit of the] *soil.*[26]
> 十八年癸亥，王即位，居亳。始屋夏社。
>
> *In his 19th year, there was a great drought. Di and Qiang* [neighboring ethnic-minority] *people came to be hosted.*
> 十九年，大旱。氐、羌來賓。
>
> *In his 20th year, there was a great drought. The* [deposed] *Xia king died at Tingshan: music, song, and dance* [i.e., obsequies] *were forbidden.*
> 二十年，大旱。夏桀卒于亭山。禁弦歌舞。
>
> *In his 21st year, there was a great drought. Bronze coins were cast.*
> 二十一年，大旱。鑄金幣。
>
> *In his 22nd year, there was a great drought.*
> 二十二年，大旱。
>
> *In his 23rd year, there was a great drought.*
> 二十三年，大旱。

24 Pankenier 2019.

25 Chen 2014; Xia Shang Zhou duandai gongcheng zhuanjiazu 2000.

26 To cut off further communication between the Xia and the Supernal Lord above.

> *In his 24th year, there was a great drought. The King prayed at the* [sacred] *mulberry grove and it rained* [ending the drought].
> 二十四年，大旱。王鑄于桑林，雨。(*Zhushu jinian*, 12)

The *Bamboo Annals* agrees with the later traditions regarding the multi-year drought immediately after Cheng Tang became king. The question is, what was the date? Here are two excerpts from the parallel *Bamboo Annals* account of the last two decades of the Xia king Jie 夏桀, beginning with his tenth year:

> *In his 10th year, the five planets moved criss-cross. During the night the stars fell like rain. The earth quaked. The Yi and Luo Rivers dried up.*
> 十年，五星錯行，夜中星隕如雨。地震。伊、洛竭。(*Zhushu jinian*, 11)

This is followed by several years of aggressive campaigning by Xia. Then, Xia Jie's final years record several victorious campaigns led by Cheng Tang against lesser kingdoms allied with the Xia. Finally, in king Xia Jie's last year we read:

> [*In his 31st year*], *from Er Shang attacked the Xia capital and overcame Kunwu. It thundered and rained heavily as they battled at Mingtiao. The Xia army was utterly defeated and Jie fled to Sansha. The Shang host attacked Sansha. Jie was captured at Cheng and exiled to Nanchao.*
> 三十一年，商自陑征夏邑。克昆吾。大雷雨，戰于鳴條。夏師敗績，桀出奔三朡，商師征三朡。戰于郕，獲桀于焦門，放之于南巢。(*Zhushu jinian*, 11)

Setting aside the historical details, the focus here will be on the parallel chronologies. It is apparent that if Cheng Tang founded the Shang dynasty in his "eighteenth" year, then his years 1–17 must have overlapped with the final seventeen years of Xia Jie's reign. Now, according to the *Annals*, the criss-crossing of planets and meteor shower supposedly occurred at a date corresponding to 1580, which I previously revised to 1576 BCE based on the span of 517 years between 1576 and 1059, the date of the spectacular 1059 conjunction of the five planets in the Zhou astrological space (the Vermilion Bird, *zhu niao* 朱鳥—Cancer-Hydra-Corvus),[27] and the persistent four-year backdating in the *Annals* chronology (BA 1580 > actual 1576, 1063 > 1059, 1050 > 1046). The span of 517 years is key because 516.33 years has been shown to be a resonance period for the sidereal locations of Jupiter, Saturn, and Mars to potentially coincide.[28] Later history records conjunctions of the five planets as playing a political role in legitimizing dynasties when the circumstances were right at this and other intervals, for example, in 205 BCE, 234, 750, 967, 1524, 2040.[29] The naked-eye

27 All references to constellations are to their sidereal locations.
28 Needham/Wang 1959: 408.
29 Pankenier 2013.

visibility of such a conjunction depends on Mercury's and Venus's locations vis à vis the Sun at the opportune moment, from which Venus and Mercury can never stray more than 46° and 30° respectively. The approach of the slow-moving outer planets to each other as well as their subsequent dispersal take some time, so that noticing a twenty-year conjunction of the slowest-moving Jupiter and Saturn will give advance notice of a possible impending gathering of more. If the "speeding" Sun advancing at the rate of 1°/day happens to march through an on-going grouping, the planets can "criss-cross"; that is, switch horizons from west to east and dusk appearance to pre-dawn.

While focusing on the Zhou conquest of Shang, I initially took at face value the *Annals* account that the first year of Shang followed twenty-one years after the benchmark 1576 planetary event that occurred in Jie's "tenth" year. However, in separately recording Cheng Tang's early years, the *Bamboo Annals* in fact maintains that the first seventeen years of Tang's pre-dynastic rulership overlapped with the final years of Xia Jie's putative thirty-one-year reign. Because many bamboo slips were damaged and broken, multiple events that originally occurred in a single year were sometimes prone to misplacement and expediently assigned to "blank" year-slots in the reconstructed chronological framework. Such misplacement and resultant inflation of the relative chronology demonstrably occurred around the founding of Zhou.[30] Just as in the case of the Zhou conquest period half-a-millennium later, the third-century CE scholars reconstructing Xia Jie's reign in the *Annals* likely inflated it by some number of years.

If we now assume that the four-year backdating of the 1576 planetary portent to 1580 in the *Annals* relative chronology would necessarily have caused a corresponding inflation of Xia Jie's and Cheng Tang's reigns, and also that the 1576 planetary portent played a role in prompting Tang to begin the campaign to overthrow the Xia, just as it did for King Wen in 1059, this would mean that the span from astral portent to the defeat of Xia was only fourteen years and not eighteen. By counting down from 1576, Tang's fourteenth year becomes 1563, and 1562 would then be the first year of Shang.

Thus, the *Annals'* systematic four-year error previously shown to be present throughout the relative chronology of Zhou once again manifests itself. Xia Jie's reign has been inflated by four years, and the same applies to Tang's parallel reign was as well, giving him fourteen years of rule prior to the conquest of Xia rather than eighteen as the *Annals* would have it.

30 Pankenier 1992a, Shaughnessy 1986.

Bamboo Annals	Actual	Shang
Xia Jie	BCE	Cheng Tang
	1576	1576
1580 planets criss-cross	1576 five planets criss-cross in Shang astral space	Tang 1st year
↓	↓	1563
Tang 18th year	↓	Tang 14th year
Tang 19th year	↓	1562 Shang dynasty
drought begins	1561 Thera erupts	drought begins
	↓	↓
	↓	↓
	↓	↓
	↓	↓
	1558	1558
	2nd volcanic event	↓
	(location unknown)	↓
Tang 24th year		1557
drought ends		Tang 20th year, dies

4 Conclusion

Chinese historical records and traditional accounts about the early Shang dynasty in the sixteenth century BCE all stress the impact of a severe drought lasting several years. Injection into the atmosphere of volcanic aerosols and halogens resulting in negative climate forcing such as well-documented for the proxies 43 BCE and 536 CE could certainly have been the cause of the drought and sudden cold in north China. Reconstruction of the relative chronology of events in the *Bamboo Annals* chronicle based on secure benchmarks points to a likely correlation between the devastating climate anomaly and the 1561 BCE eruption of Thera in the eastern Mediterranean.[31]

Bringing to bear geophysical and astronomical evidence, the relative chronology of the *Bamboo Annals,* and long-remembered ancient Chinese traditions from the Three Dynasties *San Dai* 三代 era, we arrive at a date of about 1562–1555 for the multi-year drought that coincided with the founding of the Shang dynasty. This agrees well with the radiocarbon dating and ceramic typologies disclosed by Chinese archaeology, Erligang 二里崗 sites in particular, as well as with the ice core evidence and multiproxy annual tree-ring data. The fact that a second volcanic eruption in the northern hemisphere in 1558 following closely that of Thera could

31 Pearson, et al. 2022.

explain the significantly drawn-out climatic downturn in China.[32] It would be remarkable if such a coincidence were purely fortuitous. Future evidence of acid deposition and radiative cooling from the mid-sixteenth century BCE may ultimately settle conjectures definitively.

Appendix: Mencius' 孟子 statements on the early chronology

Mencius (390–305 BCE) was, of course, a dedicated follower of Confucius who lived a century later and came to be denoted the "Second Sage." In the eponymous text *Mengzi*, 孟子 he is quoted as having made several generalizations regarding the chronology of the Three Dynasties of the Chinese Bronze Age. In the past, these remarks have occasioned debate about their usefulness in pinning down the founding dates of Shang and Zhou in particular. Mencius' statements are as follows:

(1) "It is a rule that a true royal sovereign should arise in the course of five-hundred years, and that during that time there should be men illustrious in their generation." (*Mengzi*, 2B, 22).

(2) "From Yao and Shun down to T'ang there were 500 years and then some (*wu bai you yu* 五百有餘). As to Yu and Gao Yao [of the Xia], they saw those earliest sages and so knew their doctrines, while Tang heard their doctrines as transmitted and so knew them." (*Mengzi*, 7B, 84).

(3) "From Tang to King Wen [Zhou founder] there were 500 years and then some. As to Yi Yin and Lai Chu, they saw Tang and knew his doctrines, while King Wen heard them as transmitted and so knew them." (*Mengzi.* 7B, 84).

(4) "From King Wen to Confucius were 500 years and then some. As to Taigong Wang and San Yishang [of Zhou], they saw Wen and so knew his doctrines, while Confucius heard them as transmitted and so knew them." (*Mengzi.* 7B, 84).

(5) "From Confucius down to our own day there have been 100 years and then some." (*Mengzi*, 7B, 84).

(6) "From the beginning of the Zhou dynasty until now there have been 700 years and then some. Numerically speaking, the time [for the appearance of a true sovereign] is past." (*Mengzi*, 2B, 22).

The debate about the chronological usefulness of the statements hinges of course on the imprecise expression "and then some" that Mencius repeatedly used. Ordinarily,

32 See Bagley 1999; Pearson, et al. 2022: 5, 6. Ordinarily, volcanic injections of aerosols into the atmosphere cause serious climatic perturbances for two to three years after the event.

you yu 有餘, which I translate here as "and then some" is generally understood to mean "slightly more than." In the past, because of the uncertainty about the dating of the Zhou conquest of Shang ranging from 1122 to 1027 BCE, a reliable assessment of the veracity of Mencius' statements remained elusive. Consequently, the estimates of the numerical value of *you yu* ranged between a handful of years to more than fifty.[33]

John Knoblock cites Joseph Needham and others who have argued in favor of the conventional understanding of *you yu* as "a little more than." But an influential analysis by Chen Mengjia 陳夢家 settled on the inflated value of "not less than fifty."[34] Until recently, these figures had to be considered speculative because of the uncertainty about the date of the Zhou conquest of Shang, now securely dated to 1046 BCE. With the addition of a more secure date for the founding of the Shang dynasty in 1562, it is now possible to assess the validity of Mencius' assertions more reliably. Testing each of the chronological statements in turn remains slightly imprecise, since when Mencius refers to the sages of the past, we still don't know whether he means dates of birth, death, or active years. But as we shall see, this proves not to be a significant problem.

In statement (6), Mencius claims that just over seven hundred years had elapsed from the beginning of Zhou to his own day. If this statement had been made in about 311 BCE on his second visit to Qi, as has been argued, then from the founding of Zhou in 1046 this makes 735 years. But in 311 BCE Mencius would have been 79 years old, which makes it seem improbable that he was still making such journeys. If, on the other hand, the statement were attributed to Mencius' active years, say between fifty and sixty, "seven hundred and then some" would suggest a span of about 710 years.

In statement (5), Mencius says that Confucius lived more than one hundred years before "our own day." If one assumes that the statement is authentic and made in middle-age about 40–50, and if one further assumes that Mencius is referring to the date of Confucius' death in 479, "one hundred and then some" would suggest about 139 years.

In statement (4), Mencius says from King Wen (1099–1050 BCE) to Confucius (551–479 BCE) was just over 500 years. Assuming that he is referring to the span from King Wen's death ca. 1050 BCE, shortly after the Mandate planetary portent, to Confucius' birth, "and then some" would mean about seven years (1050 – 551 = 499). If he was referring to King Wen's declaration of his receipt of the Mandate, the figure would be 507 years.

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33 Knoblock 1964.

34 Chen 1956.

In statement (3), Mencius asserts that from Cheng Tang to King Wen once again the period of the appearance of a sage ruler was just over 500 years. Given the dating of the founding of Shang to 1562 BCE (and 1557 for Tang's death), "and then some" would mean seven years if referring to the two ruler's death dates (1050 for King Wen), or about sixteen years if he is referring to the founding of the two dynasties (1562–1046 = 516).

In statement (2), Mencius says that from Yao and Shun who ruled before the Xia dynasty down to Cheng Tang was again just over 500 years. Here, the very remote dates of Yao and Shun from whom rulership devolved on Yu are very uncertain, and it is not even known whether the pair are truly historical figures. Nevertheless, 1562 + 500 = 2062. If the founding of Xia is tentatively set at about 1953 BCE, the date of the extraordinary planetary conjunction and Yu's receipt of the Mandate of Heaven, then the result would be 1953 – 1562 = 392 years. Allowing for the reigns of Yao and Shun prior to that, this would suggest a total of some 109 years for the two rulers, rather high for two reigns in the twentieth-first century BCE. However, a date of 1562 + 500 = 2062 BCE is consistent with the archaeological dating of the severe climatic late-Neolithic downturn followed by the flood disaster, leading to the subsequent gradual recovery and establishment of Erlitou during the following century or so.

Excluding statements two and five as the most uncertain, the controversies surrounding the Xia "dynasty's" founding, and whether Erlitou was the Xia "dynastic" capital, we are left with results for "and then some" of one to three decades at most, which is not unreasonable.

Bernhard Karlgren noted that Mencius "was exceedingly well versed in the lore of the early Chou" and "no Chou-time writer has dwelt so often and so enthusiastically upon the early history of the Royal House as he," so that Mencius' grasp of the chronology ought to have been reliable.[35] Mencius' assertion that a sage ruler must appear every 500 years strongly suggests that he was familiar with the historical record since his dating of the span from Shang to Zhou and Zhou to Confucius are on the mark. Considering that Mencius is talking about historical events more than a millennium before his own lifetime this is impressive. In the end, our conclusion is that Mencius' statements are well informed and agree with the dating of the Shang founding to 1562 and Zhou to 1046. The expression *you yu* "and a little more" ought reasonably to refer to not more than about three decades, consistent with the conventional understanding of the term.

35 Karlgren (1945). Quoted by Knoblock 1964: 264. Furthermore, Joseph Needham argued that Mencius was likely aware of the resonance periods of planetary conjunctions, i.e., 516.33 years for JU-SA-MA, at which time the potential for a cluster of all five to occur is good.

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