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THE RELATIONSHIP BETWEEN SOLAR AND VOLCANIC ACTIVITY AND THE CHRONOLOGY OF ARCHAEOLOGICAL CULTURES OF EURASIA IN THE 4TH–1ST MILLENNIA BC

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Abstract: A well-known problem of archaeological chronology is that radiocarbon chronology differs from historical chronology. Historical chronology of the Bronze Age corresponds to dendrochronology and radiocarbon chronology in case of using Bayesian statistics of AMS dates. Therefore, it is desirable to link the chronology of Northern Eurasia on the basis of typological analysis with the chronology of those regions where it is possible to use historical sources and dendrochronology. However, due to remoteness, it is difficult to find many reliable typological analogies. Therefore, it is necessary to rely on cultures that were formed as a result of migrations caused by abrupt global climatic changes, which can be dated by dendrochronology. First of all, we are talking about major volcanic processes. Such events are most clearly manifested in tree rings, which allows us to obtain their accurate dates. The use of this approach made it possible to propose benchmarks for constructing the chronology of Eurasia for the 3rd–2nd millennia BC, which make it possible to suggest a system with younger and shorter intervals than that based on radiocarbon analysis.

Keywords: *Eurasia, Bronze Age, dendrochronology, historical chronology, volcanic eruptions, migration.*

INTRODUCTION

There is a difference between radiocarbon dates and dates obtained from written sources and tree rings. At the same time, old LSC dates give wider and more ancient intervals compared to AMS dates. Due to the shortage of high-resolution AMS dates in many regions, LSC dates are often used together with them when summing up the intervals of existence of a culture, which is a gross error. There are many problems within the method: the reservoir effect and the old tree effect, the presence of a plateau in the calibration curve, soil or geology features, etc. All this turns into a difficult problem. We often forget that the radiocarbon method is being improved, and new calibration curves appear that make the dates younger. However, we use dates from old publications that were calibrated before.

The transition to accelerating technologies (AMS) made the dates more recent, bringing them somewhat closer to historical ones. Nevertheless, the intervals remain wide if we stop using dates with a deviation of ±1σ, whose probability is 68.2%, and start using dates with a deviation of ±2σ and a probability of 95.4%. However, in this instance the intervals of cultures are extremely wide, they merge, which will not allow us to discuss the processes of cultural genesis. Taking into account individual dates is completely risky in this case. If we have a partial overlap of two intervals calculated with a probability of 68.2%, we may assume that one of them was earlier or they were simultaneous. If we choose any of these solutions, we artificially cut off parts of the intervals, reducing the probability to 50%. Therefore, when answering an alternative question, we get a senseless result. However, even the summarized result of a large series of dates for some culture should be correctly assessed. For example, the interval 1950–1660 BC does not mean that the culture was formed around 1950 BC and ceased to exist around 1660 BC. It means that it existed within this interval. If we use intervals calculated with a probability of 95.4%, historical dates will fall within them if there are no problems with the calibration curve. This means that the problem is not in the correctness of the method, but in the correctness of our interpretation of its results. Moreover, the procedure for summing probabilities is not aimed at identifying calendar dates, but at comparing two intervals and determining the homogeneity of the dates. Thus, this is relative chronology, not absolute one.

An important step in solving the problem is the use of Bayesian statistics in the analysis of AMS dates. The principle of the method is obvious: if we have two successive intervals, the boundary between them should be somewhere in the middle of their overlap zone. However, the method assumes the analysis of only those events whose sequence is reliably established. It is desirable to use AMS series of dates of short-lived plants. The mathematical apparatus used is complex, but with the introduction of this function into calibration programs, the method has become widely used. Unfortunately, it is often used in cases where the sequence of events is not reliably established, but only assumed, often the median values of the dates are used as a sequence, as well as dates of different quality together. All this is a violation of the principles of the method. As a result, a dubious product is created with a seemingly sophisticated scientific procedure.

The identity of historical dates for the Eastern Mediterranean and China, and their coincidence with dendrodates, indicate the adequacy of these methods[1]. Therefore, ideally, we should build a chronology on their basis. However, this also requires caution. There are three chronologies of Mesopotamia: Short, Middle and Long, due to gaps in the king lists. Recent projects on the dendrochronology of Anatolia and the comparison of these data with the eponym lists from Kültepe have shown the validity of the Middle Chronology, but there are variations within it too, and there is no continuous dendrochronological scale for Anatolia, and the dendrochronology is built on the Bayesian statistics of AMS tree-ring analyses, so an error of about 10 years is allowed[2]. These discrepancies are insignificant, compared to radiocarbon chronology, but when trying to typologically link our materials to the chronology of regions with historical chronology or dendrochronology, we encounter again problems of wide probability intervals, since the duration of existence of a certain type can vary. Therefore, it is necessary to look for other ways to get exact dates.

ORBITAL AND SOLAR CYCLES

A peculiarity of cultural genesis in Eurasia is its cyclical nature, when archaeological periods changed in close time. The changes of the EBA – MBA – LBA – Final Bronze Age in Northern Eurasia correspond to the changes of the Copper Age – EBA – MBA – LBA[3] in Europe, and one can find correspondences in other regions. Within these periods, changes also sometimes occurred that have corresponding parallels. This often corresponds to cyclical changes in climate. It is assumed that climate cycles were caused by the coincidence of orbital changes leading to fluctuations in solar radiation[4]. The largest are the Milankovitch cycles with a quasi-periodicity of about 26,000, 41,000 and 93,000 years, which explain the phases of glaciations. The Bond cycles have a shorter periodicity. They describe climate fluctuations in the North Atlantic, occurring with a periodicity of about 1470±500 years. This study was based on the analysis of marine sediments, which made it possible to identify events with peaks at approximately 11,100; 10,300; 9400; 8100; 5900; 4200; 2800, and 1400 cal. BP[5]. For the period under discussion, paleoclimatologists identify the so-called events of 5.2, 4.2, and 3.2 cal. BP, i.e. approximately 3200, 2200, and 1200 BC[6]. Thus, only the event of 4200 BP coincides with the Bond cycles. In this original study, however, it was emphasized that the nature and mechanism of these cycles are unclear, since they do not coincide with the known orbital and solar cycles. However, these climate changes were subsequently associated with orbital changes[7]. Nevertheless, the latter are smooth in nature and could not lead to abrupt climate changes.

In addition, there were other climate fluctuations, which were more numerous than these events, and as a result we do not see this periodicity in the paleoclimatological data. Therefore, the sun is responsible for many of these events. It is assumed that despite the absence of a solar cycle with a periodicity of about 1470, this cycle was associated with the sun, which is explained by the superimposition of two shorter solar cycles[8]. In this case, we are also not dealing with

[1] GRIGORIEV 2023a.

[2] BARJAMOVIC/HERTEL/LARSEN 2012, 29, 34, Fig. 11; MANNING *et alii* 2016, 6, 7, 16, 17, 20, 21.

[3] Abbreviations used in the article: EBA – Early Bronze Age, MBA – Middle Bronze Age, LBA – Late Bronze Age.

[4] WANNER *et alii* 2008.

[5] BOND *et alii* 1997 – In fact, the quasi-periodicity of 1470±500 years, which is sometimes used to discuss the Holocene events, is not accurate. In this study, a periodicity of 1536±563 years was proposed for the Pleistocene and about 1374±502 years for the Holocene, while a study of Greenland ice (GISP2) indicates a 1450-year cycle for the Holocene. Therefore, an average interval of 1470±532 was proposed for the Holocene (BOND *et alii* 1997, 1263).

[6] The article uses date systems based on calibrated radiocarbon dates, as well as on historical chronology and dendrochronology. In order to distinguish them, the index "cal." is applied to radiocarbon dates, for example, "1500 cal. BC". This index is not applied to the so-called "2200 event etc.", although its dating is based primarily on radiocarbon analysis, but other methods are also used. Ultimately, we are not talking about specific dates, but about conventional names of periods with significant climatic changes.

[7] WANNER *et alii* 2008.

[8] BRAUN *et alii* 2005, 208.

a fact, but with an explanatory hypothesis. Nevertheless, many of the events that will be discuss below coincide precisely with the periodicity of solar changes, but its study has many problems.

To study solar activity in the past, one use data on astronomical observations of sunspots, and for more ancient times, cosmogenic isotopes ^{14}C and ^{10}Be in ice cores and tree rings. The dates of the latter are based not on dendrochronology, but on calibrated AMS dates of tree ring[9]. However, we are dealing with a precisely established sequence, and these dates are close to the real ones, although not identical to them.

The main cycle in solar activity is the 11-year Schwabe Cycle, but it can vary within 9–14 years. Due to the peculiarities of isotope transport and interaction with the ocean, it is difficult to diagnose it using isotopes[10]. The largest proven cycle is the Hallstatt cycle with a quasi-periodicity of about 2400 (in reality 2000–2500) years, although there is a Suess and de Vries Cycle of 205–210 years, and an Eddy Cycle of 600–700 or 1000–1200 years is being discussed, but the first two are the most pronounced. There is also the Gleissberg Cycle, which consists of different cycles with a duration of 90–100 or 50–60 years[11]. These cycles do not demonstrate strict periodicity, and the process is rather chaotic[12].

The influence of solar activity on climate is not a solved problem, but its effect is insignificant[13]. It is believed that the average temperature and wind speed determine the exchange of CO_2 between the ocean and the atmosphere, and this manifests itself in 2400-year cycles[14]. However, it is already a secondary effect. Instrumental measurements show that the influence of 11-year cycles on temperature increase is small. It was studied for the period 1959–2004, and on average for the planet it was 0.2°K, but about 0.7°K near the edges of seasonal sea ice at high latitudes and about 0.3°K in Europe. Greater heating is observed in continental areas and less near the oceans; no changes have been noted in the tropics[15]. Changes in ultraviolet radiation have also been noted and are assumed to influence atmospheric circulation and annual climate variability, producing stratospheric ozone and providing heating of the middle layer of the atmosphere[16].

Heterogeneity of changes is observed in Northern Europe and in the southern regions. This is explained by the fact that as temperatures in the North Atlantic decrease, the regime of air mass transport to the east changes, which leads to a weakening of the Asian monsoon. As a result, a slightly colder climate contributes to a decrease in evaporation and leads to more humid conditions in Europe, while in Asia and North Africa an increase in temperature and aridization is observed[17]. However, these changes were gradual, and humanity is adaptive, so they could not cause simultaneous large-scale migrations that would provoke a change of cultures over vast areas. During the so-called "2200 BC event," temperatures in the North Atlantic decreased within 1–2°C, which is insufficient for large-scale cultural transformation to begin[18]. Finally, while changes occur at high and low latitudes, changes at temperate latitudes are minor[19]. This is especially true for Europe with its mild climate.

However, cyclic solar changes created a general background that reduced the ability to adapt to abrupt changes. In some areas, unbearable conditions were created, such as droughts, which could have been a trigger for migration. But we are not discussing here the various causes of migrations and cultural transformations. Our task is to identify common chronological benchmarks for different regions. Therefore, we are interested only in global changes that provoked migrations throughout Eurasia.

THE INFLUENCE OF VOLCANISM ON CLIMATE

Only abrupt climate events triggered by volcanic activity could have caused global changes. The year 1816, the "Year Without a Summer" in North America and Europe, which followed the eruption of Tambora in 1815, is well known. The eruption of the Huaynaputina volcano in Peru on February 19, 1600 caused the Russian famine of 1601–1603 and the ensuing Time of Troubles, changing the history of the country. A correlation has been observed between volcanic activity and a decrease in temperature in Greenland, which was clearly noticeable during the Little Ice Age (14th–19th centuries AD)[20]. A negative correlation has also been found between solar activity and volcanism in recent times.

There is a consensus that volcanic activity is higher during periods of prolonged solar minimum and lower during periods of prolonged maximum. However, only cycles of 200–215, 100–105, and 80–90 years are reliably associated with volcanic activity. Determining this relationship for longer cycles is difficult due to the lack of direct data. 11-year solar cycles either do not show such a relationship, or it is very weak[21], although some studies have found a relationship with volcanism for them as well[22]. This is quite natural, since the nature of the process during short cycles is similar to the processes of long cycles. Some researchers believe that the relationship here is not so much with the number of eruptions and earthquakes, but with their energy release: with an increase in solar activity, the number of small eruptions and earthquakes increases, but the number of large ones decreases, and *vice versa*. At the same time, the strongest earthquakes and eruptions occur at the borders of 100-year cycles[23]. The reason for this relationship is unclear, probably it can be explained by the interaction of cosmic energy particles with the magnetosphere and ionosphere of the Earth and derivative processes[24].

Naturally, this also affects the climate, since the process

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[9] HATHAWAY 2015, 28; USOSKIN *et alii* 2016, 1, 4; USOSKIN 2017, 3, 24.
[10] HATHAWAY 2015, 37, 72; USOSKIN 2017, 18, 23, 37, 38, 41–43.
[11] HATHAWAY 2015, 56, 57; USOSKIN *et alii* 2016, 6, 19, 20; USOSKIN 2017. P. 66.
[12] USOSKIN 2017, 64, 77.
[13] HATHAWAY 2015, 7; USOSKIN 2017, 65.
[14] VASILIEV/DERGACHEV 2002, 117.
[15] CAMP/TUNG 2007, 1, 3.
[16] HAIGH *et alii* 2010; INESON *et alii* 2011.
[17] WEISS *et alii* 1993.
[18] DE MENOCAL 2001, 670.
[19] KOBASHI *et alii* 2013, 2299, 2304.
[20] KOBASHI *et alii* 2013, 2306, 2309.
[21] STŘEŠTIK 2003. P. 393; HERDIWIJAYA/ARIF/NURZAMAN 2014, 105; CASATI 2014; HAGEN/AZEVEDO 2023, 9.
[22] MAZZARELLA/PALUMBO 1989; KOMITOV *et alii* 2022.
[23] BELOV/SHESTOPALOV/KHARIN 2009.
[24] HERDIWIJAYA/ARIF/NURZAMAN 2014, 107.

of decreasing solar activity itself leads to a decrease in temperature, and volcanic gases and dust create a screen in the atmosphere that prevents the penetration of solar rays. This effect usually lasts for about 1–3 years or longer in the presence of a series of eruptions, and it is difficult to determine what share of the temperature decrease is due to the sun and what share is due to volcanism[25].

For the period 1445–2005 AD, dendrochronology of the Kola Peninsula revealed solar cycles of 11, 20–25, and ~100 years, and volcanic eruptions coincided with solar minima. At the same time, cooling begins earlier than major eruptions and lasts longer. For example, significant reduction of tree growth and cooling from 1780 to 1830 AD coincides with the Dalton Minimum of solar activity and the eruption of Tambora in 1815[26].

The main driver of eruptions and seismic activity are processes in the mantle. They may be partly related to solar activity, but may also be provoked by other reasons. When different factors overlap, the probability of strong eruptions may increase. Even small eruptions can lower the temperature in temperate latitudes by 1°C for two years[27]. The consequences of large eruptions were more significant, but relatively short-lived. It is assumed that as volcanic aerosols settled, the climatic situation was restored. However, in two cases we see otherwise. At the settlement of Tell Leilan, ca. 2200 cal. BC, a change in climate towards aridization is observed in the layer deposited above the volcanic tephra layer, and the new climatic situation persisted for hundreds of years[28]. The same happened in the layers of marine sediments lying above the layer with Santorini tephra, and this climatic situation persisted for a long time, not only in the Eastern Mediterranean, but also in China. Therefore, large eruptions contributed to the deepening of cyclic processes and their sharp intensification, but the facts presented, at first glance, indicate that they themselves could create a long-term trend. However, in reality, we are dealing with two parallel processes associated with one cause.

CLIMATE CHANGE AND CHRONOLOGY

Changes in solar activity triggered migrations and could serve as a basis for constructing chronology. However, they were gradual and not strong enough to cause migrations. Since climate is influenced by many other factors, solar activity is far from being the main one; droughts or frosts could trigger local migrations. However, if we see sharp climate and cultural changes in different regions at the same time, this most likely indicates powerful volcanic activity and can serve as a tool in constructing chronology. For the last three millennia BC, tree ring studies in the southwestern United States have revealed a greater number of years with minimal growth or frost signals in the early 3rd millennium BC, in the 22nd–19th centuries BC, in the 17th–16th centuries BC, and in the 12th century BC. These periods correspond to known climate events, and two of them correspond to eruptions associated with climate change. However, this is not an indisputable sign, since the degree and nature of volcanic impact depends not only on its intensity, but also on the season of the eruption, the chemical composition of the erupted materials and the area where these trees grew. At the same time, local events, such as droughts, have a greater impact on tree growth[29]. There is, however, the possibility of chemical analyses of tree rings, which indicate volcanic activity[30]. Nevertheless, volcanic signals may also be the result of local eruptions, so everything needs to be supported by alternative data. The fundamental thing in our case is the nature of the eruption, since even during a large eruption, its products can only reach the troposphere and settle on the ground within a few months. In case of Plinian eruptions they reach the stratosphere and remain there for 2–3 years, making synchronous migrations inevitable in some regions.

There are problems to connect these events with climate change. Unfortunately, short and sharp changes are difficult to detect. Most of this data is obtained from sediments of water reservoirs or from buried soils. These climate events are dated by the radiocarbon method and have a low resolution. When studying sediments, this method dates individual samples, which are often far from some climate event. Detailed dating of the section is done on the basis of modeling. This does not allow us to obtain data that can be used for chronology. The historical chronology of the Near East appears only from the late 4th – early 3rd millennium BC, but only in the second half of the 3rd millennium BC it becomes relatively accurate, and gradually its accuracy increases. Dating of Greenland ice with volcanic signals detected in it is also not entirely reliable, and when comparing them with dendrochronological data, the probability of coincidence decreases: for the last millennium, the coincidence is 86%, but for the 2nd millennium BC it is 46%, and for the 3rd millennium BC only 31%[31]. Only for the 17th–16th centuries BC was it possible to achieve exact matches[32]. The only accurate method is dendrochronology, since it allows us to reconstruct climatic changes, but they may reflect local events.

As a result, when trying to identify major volcanic events that caused cultural transformations in different parts of Eurasia, we have relatively accurate chronological data only for Europe. Weak possibilities for checking these data with the historical chronology of the Near East appear around 3000 BC, but gradually its accuracy increases. Nevertheless, generalization of the available data allows us to obtain benchmarks to which other processes can be tied, reconstructed on the basis of archaeological sources.

There are also difficulties in connecting these events with migrations revealed archaeologically, since it is extremely rare that we can see traces of volcanic tephra in archaeological layers (although it is not excluded if special analyses are made), and it is extremely rare that we can obtain an exact date for a site. In some cases, the solution to the problem is facilitated by the correspondence between the sequence of climatic and archaeological events. In this case, we can connect them hypothetically, but the task of checking with parallel sources remains.

25 STŘEŠTIK 2003, 393, 395.
26 KASATKINA *et alii* 2018, 67, 68, 71–73, 75.
27 SCUDERI 1990, 67.
28 WEISS *et alii* 1993.
29 SALZER/HUGHES 2006, 57–62, Tabl. 2.
30 PEARSON *et alii* 2005; PEARSON *et alii* 2020.
31 SALZER/HUGHES 2006, 63–65.
32 PEARSON *et alii* 2022.

Recently, I have published several works on individual periods within the mid–4th – mid–2nd millennia BC, in which one can become acquainted in more detail with the justification for certain dates[33]. This article is aimed at generalizing the obtained data into a single system. The proposed chronological benchmarks are based on the historical chronology, dendrochronology, and Bayesian statistics of AMS dates. It should be borne in mind that we are talking specifically about chronological benchmarks that can be used to construct chronology, but not about the chronology in general.

CULTURAL PROCESSES AND CHRONOLOGY OF THE 4TH – 3RD MILLENNIA BC

The creation of an accurate chronology for the end of the Eneolithic – beginning of the EBA is the most difficult task. In the 4th millennium BC, a megalithic tradition spread to the east from Europe, which is clearly expressed in Novosvobodnaya in the North Caucasus, Usatovo in the northwestern Black Sea region and in the Urals. The formation of Novosvobodnaya around the first half of the 36th century cal. BC was accompanied by not only European but also Uruk impulses from the Near East[34]. This allows us to assume that global climatic problems took place, and it is possible to find some chronological marker for this event. At this time, a sharp aridization of the climate began in Africa and the Near East, while in Europe, on the contrary, a climate drift is observed towards more humid and cold conditions[35]. However, apparently, the European and Near Eastern impulses in the North Caucasus were at different times, and the latter were close in time to the European impulses that led to the appearance of megalithic features in Usatovo around the 35th century cal. BC[36]. These events coincide with the solar minimum in 3620 BC, followed by an increase with a peak ca. 3560/3550 BC and a sharp decline to a minimum in 3495 BC. The latter period is characterized by an increase in stratospheric aerosols, indicating volcanism (fig. 1)[37]. Two ice-drilling projects in Greenland have revealed peaks of volcanic activity in 3530 and 3516 BC[38]. Due to the problems of ice dating, this may be a single event that occurred at the beginning of the sharp decline in solar activity to the minimum in 3495 BC. It is promising for the Novosvobodnaya and Usatovo chronologies, but verification with other data is needed.

The date of the appearance of the Ural megaliths is not entirely clear, but it is more likely that they formed in the last quarter of the 4th millennium cal. BC, at the same time when sites of the Zhivotylovka-Volchansk type appeared in the Eastern European steppe. This period corresponds to the "3200 event". In Egypt, it led to the formation of the Old Kingdom, in Mesopotamia to the "urban revolution" of the Uruk-Warka culture, and then to the transition to the Early Dynastic Period[39]. The climate crisis also took place in Iran[40]. However, in Europe, some deterioration was noted only in Western Ireland[41], Northern Sweden[42] and in the Austrian Alps around 3200 cal. BC[43]. Therefore, it is impossible to assert that some global catastrophe occurred that led to the appearance of the megaliths in the Urals. Nevertheless, a general explanatory model for the "3200 event" may be the following. After the solar maximum in 3170 BC, there was a sharp decrease in solar activity. This coincides with noticeable peaks of volcanic aerosols in the stratosphere, and between 3160 and 3092 BC a long period of volcanic activity is observed (fig. 1)[44]. This activization of volcanism coincides exactly with the beginning of a noticeable decrease in solar activity. Therefore, this time interval explains the "3200 event" and the cultural transformations of this period. However, since its duration is 68 years, it is impossible to obtain an exact date for any archaeological phenomenon of this period. This was certainly accompanied by a blockage of the Asian monsoon, so the events in the Near East could have been caused, first of all, by this, although they should be dated to the same time span. Nevertheless, obtaining exact dates in this way is also unrealistic.

More promising are the dendrodates of the 3rd millennium BC for Europe. At this time, aridization continued in the Near East, as well as cooling and humidification in Europe[45]. This coincides with a sharp transition from solar activity fluctuations with two maxima in ca. 3170 and 2955 BC to a solar minimum centered ca. 2855 BC and a decrease in solar activity in the 26th century BC[46]. Against the background of general cooling and humidification in Europe, 2850 and 2564 BC were the coldest in this millennium, with the first event associated with volcanic processes[47]. It corresponds to a series of years of tree growth cessation in North America, but analogs to the cooling of 2564 BC are not noted there[48]. Both dates are close to sharp peaks in stratospheric aerosols (fig. 1)[49], which allows us to assume global events, but the first peak is rather weak. Therefore, it is quite possible that the frosts of 2850 BC were caused by a solar minimum. At the same time, there is a noticeable peak of volcanic aerosols in 2910 BC, as well as frost signals in tree rings of different regions between 2910 and 2900 BC[50]. They coincide with a sharp decline in solar activity between the maximum in 2955 BC and the minimum in 2855 BC. The events of 2910 and 2850 BC are close to the beginning of the interval of the earliest dendrodates of the Corded Ware culture (CWC) from Eschenund and Erlenproben – 2844–2737 BC[51]. Therefore, this time span can be associated with the westward movement of the Yamnaya tribes, the displacement of the descendants

[33] GRIGORIEV 2023a; GRIGORIEV 2023b; GRIGORIEV 2024a; GRIGORIEV 2024b; GRIGORIEV 2024c.
[34] REZEPKIN 2012, 76–78, 85, 95–97, 101, 104; REZEPKIN 2022, 47.
[35] CLARKE *et alii* 2016; AMIRKHIZ/ISLAM 2020; DRESLEROVÁ 2012, 48, 50–52.
[36] DERGACHEV 2022, 97, 103–105, 108, 122, 134, 149.
[37] SIGL 2022, Fig. 9.
[38] BALDIA 2013, 181, 220–222, Fig. 16.7.
[39] CLARKE *et alii* 2016, 97, 101, 104, 106, 108, 110, 111, 114, 117.
[40] AMIRKHIZ/ISLAM 2020.
[41] CASELDINE *et alii* 2005.
[42] VORREN *et alii* 2011, 19.
[43] ILYASHUK *et alii* 2011, 185, 188.
[44] SIGL 2022, 3173, 3183, Tab. 3, Fig. 9.
[45] MOIR *et alii* 2010, 935, 937, 938, 939; KULLMAN 2013, 555, 559, 562.
[46] USOSKIN 2017, 54, Fig. 20.
[47] HELAMA *et alii* 2013, 1, 4.
[48] SALZER/HUGHES 2006, Tabl. 2.
[49] SIGL 2022, Fig. 9.
[50] SIGL 2022, Tabl. 4; GRIGORIEV 2024a, Fig. 2.
[51] WŁODARCZAK 2012, 133.

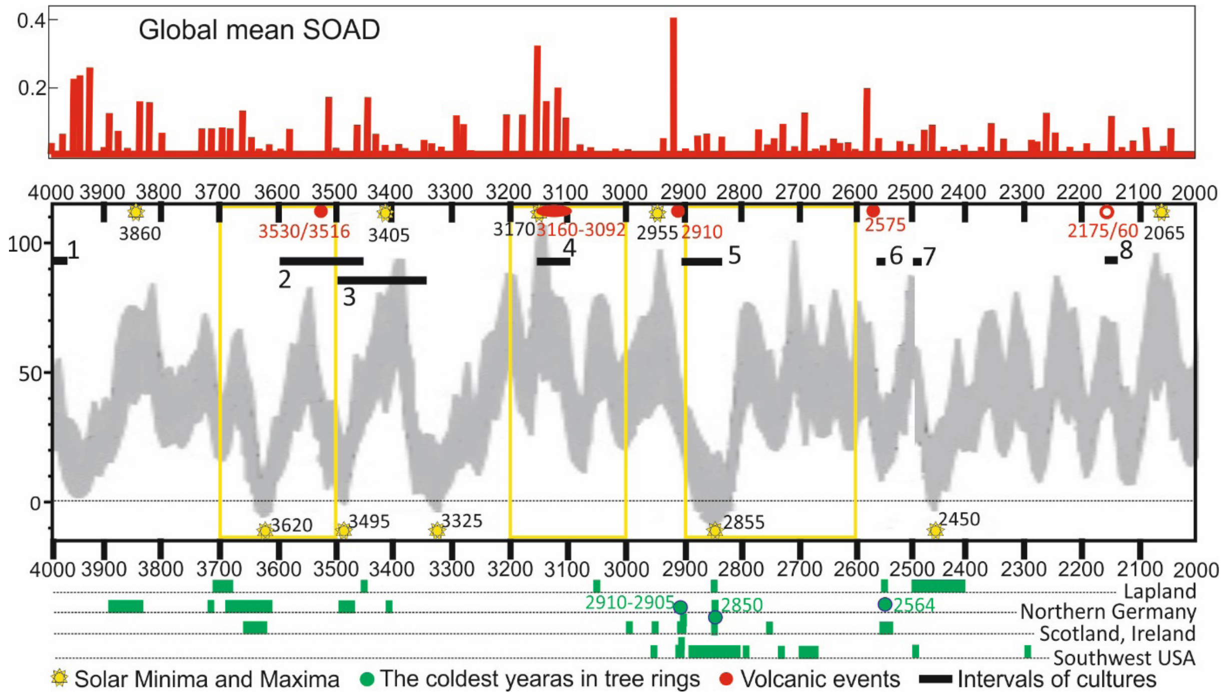

Fig. 1. Solar activity with Solar Maxima and Minima in the 4th – 3rd millennia BC (after USOSKIN 2017); periods of climate crises with low resolution (palynology, speleological data, etc. – yellow frames); major volcanic eruptions: 3530/3516 BC (BALDIA 2013), 3160–3092, 2910, 2575 BC (SIGL *et alii* 2022), 2175/60 (WEISS *et alii* 1993). Global annual mean stratospheric aerosol optical depth (SAOD) (SIGL *et alii* 2022, fig. 9). The coldest years and frost signals in tree-rings: Lapland – 3712–3683, 3453, 3053, 2850, 2564, 2500–2401 BC (HELAMA *et alii* 2002, 2013); Northern Germany – 3895–3838, 3720, 3691–3614, 3496–3473, 2850 BC; III – Scotland, Ireland – 3660–3620, 3000–2990, 2960–2950, 2905, 2910–2900, 2850, 2750, 2569, 2642 BC (MOIR *et alii* 2010; MOIR 2012), the southwest USA – 2951*, 2911*, 2906*, 2905*, 2885, 2879, 2872, 2862, 2853, 2841*, 2821, 2800, 2794, 2732*, 2731*, 2699, 2685, 2677, 2670, 2495*, 2294* BC (SALZER/HUGHES 2006): * – frost signals and possible connection with eruptions). Dates and probable intervals of some cultures: 1 – radiocarbon date of the beginning of the Maikop culture in the North Caucasus; 2 – interval of the early Novosvobodnaya culture in the North Caucasus (36th century cal. BC); 3 – formation of the Usatovo culture in the Northwestern Black Sea region, the beginning of the 3rd phase of the Novosvobodnaya culture and repeated Uruk influences in the North Caucasus (35th century cal. BC); 4 – final Chalcolithic in the steppe of Eastern Europe, Zhivotilovka-Volchansk group, megaliths in the Urals (32nd century BC, more probable interval is 3160–3092 BC); 5 – Yamnaya migration to Central Europe and the formation of Corded Ware culture (2910/2850–2844 BC); 6 – formation of the Fatyanovo culture (2564 BC); 7 – formation of the early Donets Catacomb and Okunev cultures (the early 25th century BC); 8 – collapse of the Akkadian Empire and the Egyptian Old Kingdom.

of the first Eneolithic migrants from the Carpathian Basin, and the formation of the CWC[52].

The sharp cooling in 2564 BC corresponds to the dendrodates of the end of the middle phase of the CWC, 2625–2568 BC[53]. There are typological grounds for linking the formation of the Fatyanovo culture of the Upper Volga with this phase[54], but most likely, with its end. Therefore, the transformation that led to the formation of the third CWC phase and the Fatyanovo migration was associated with the climatic event of 2564 BC. The peak of volcanic aerosols is close to this (fig. 1), but its date is unreliable. Data from other regions have low resolution. However, the above dates are promising for constructing a global chronology.

Around the middle of the 3rd millennium BC, a wave of transformations swept across Eurasia. The Bell Beaker culture began to spread from Iberia to Europe, and cultures with catacomb burial rites spread from Eastern Iran: the Early Donets culture in Eastern Europe, the Zaman Baba culture in Central Asia, and the early Uybat phase of the Okunev culture in Southern Siberia. This first phase of the period also includes the migration of Western European tribes to Inner Asia, which resulted in the appearance of megalithic monuments of the Chemurchek culture there[55]. Somewhat later, the Donets culture and catacomb burials in Jericho of the EB IV period appeared[56]. At the same time, the Lefkandi I/Kastri culture was formed in Greece as a result of migration from Anatolia[57]. Further influences from the Balkans stimulated the gradual formation of the A0 phase cultures in the Danube basin.

However, only the sites of Lefkandi I in Greece and EB IV in the Levant can be associated with the historical chronology within the 24th/23rd centuries BC[58]. The first phase of this process coincides with the decrease in solar activity after ca. 2500 BC to a minimum ca. 2450 BC and with a volcanic signal in tree rings of the southwestern United States in 2495 BC (fig. 1). The second phase coincides with some falls in solar activity in the 23rd–22nd centuries BC after the rise, but global volcanic processes have not been noted for this time span[59]. Therefore, 2495 BC can serve as a benchmark for some processes (but verification by alternative sources is

52 GRIGORIEV 2022a.
53 WŁODARCZAK 2012, 131, 133.
54 GRIGORIEV 2022a, 62, 63.
55 KOVALEV 2022, 767, 768, 775–778, 781, 782, 786, 789.
56 GRIGORIEV 2002, 168, 187–192, 381–384; BRATCHENKO 2001; LAZARETOV 2019, 16, 17, 20, 24, 38.
57 GRIGORIEV 2022b.
58 GRIGORIEV 2022b, 9.
59 SALZER/HUGHES 2006, Tabl. 2; USOSKIN 2017, 54, Fig. 20; SIGL 2022, Fig. 9.

required), and the events of the second phase are problematic to date. In addition, some migrations of the mid–3rd millennium BC could have been triggered by local processes that took place against the background of general aridization in the Near and Middle East, which also affected the Eurasian steppe. They were caused by a general noticeable decrease in solar activity, but for Europe, I am not aware of any sharp climatic changes at this time.

Thus, for the period of the 4th–3rd millennia BC, only for the CWC formation, Fatyanovo and, possibly, some early catacomb cultures, relatively precise dates can be proposed, but they should also be verified by parallel sources. In subsequent periods, the amount of data increases.

CHRONOLOGY OF THE "2200 EVENT" AND OF THE EARLY 2ND MILLENNIUM BC

The so-called "2200 event" is considered to be the trigger that led to the formation of the European EBA cultures, the collapse of the Akkadian Empire, the Old Kingdom of Egypt, the Harappan civilization, and the replacement of the Chinese Neolithic cultures by the Xia dynasty. This "event" is understood as major climatic changes that led to the weakening of the Asian monsoon and the beginning of a dry period, but they were preceded by a large eruption that caused tephra deposits even in Syria[60]. It is a popular topic, but in reality, these processes were smooth. Most of the data describing this "event" are of low resolution and do not allow us to judge either its date or its nature. In terms of long-term cycles, it was a period of strong fluctuations in solar activity (fig. 1)[61]. At the same time, it was in the period of the 22nd–20th centuries BC, a series of years with a sharp decrease in tree growth or tree rings with frost signals are recorded in the southwestern United States during the 22nd–20th centuries BC, and some of them coincide with volcanic signals (2148, 2036, 2035, 1996, 1962, 1921, 1909, 1908, and 1907 BC)[62]. The period 1909–1907 BC is especially interesting, since it may reflect a major volcanic event when volcanic aerosols remained in the stratosphere for a long time. This coincides with a period of noticeable decrease in solar activity after the maximum in 2065 BC (figs. 1, 2). For the 20th–19th centuries BC, an increase in stratospheric aerosol deposits is recorded. In contrast, for the 22nd century BC the situation with aerosol deposits does not go beyond the usual limits[63] (figs. 1, 2).

In general, the situation in the 22nd century BC cannot be explained in terms of some strong "2200 BC event". After a major eruption in Eastern Anatolia or Transcaucasia in the second quarter of the 22nd century BC, a crisis began in the Near East with the fall of Akkad (2154 BC) and the Old Kingdom of Egypt (ca. 2160 BC). In different areas, there are years when tree growth ceased, but we do not see an exact coincidence to discuss a global one-time catastrophe. Around 2150 cal. BC, drought ended life in Troy IV and impulses began to flow into Europe, leading to the formation of the EBA (A1a) cultures in the Danube region in the interval of 2150–2135 cal. BC. Only later did the Polada culture in Italy (from 2077 BC) and the EBA 1 in Britain (from 2050 BC) emerge. However, no climatic crisis has been noted in the Danube region, and it was rather the spread of the EBA traditions[64]. It is certain that aridization was associated with this in the southern regions, but there are no strict dates for this time span that can be used as chronological benchmarks for Eurasia. Many of the climatic events included in the "2200 crisis" are either definitely dated to the 20th–19th centuries BC, or may be dated to this time span, since these are radiocarbon dates of sediments made with very low resolution.

The situation in China is indicative, since the beginning of the Xia dynasty is associated with the "2200 event", but its actual dates are more recent. The crisis in China began during the reign of Yao, the penultimate of the "Five Emperors". The crisis started with the Great Drought, which was followed by the Great Flood. Yao's successor Shun called upon Yu to fight the flood, who successfully coped with this task and became the founder of the Xia dynasty. Recently, the remains of a dam of seismic origin were discovered in the upper reaches of the Yellow River, which had blocked the river for almost a year in the interval of 1976–1882 cal. BC (95% probability) with a median value of 1922±28 cal. BC, and after the breakthrough, the water flooded huge areas. Before Yu's accession, sources describe phenomena characteristic of a volcanic winter: "blood rained from the sky, there was ice in the summer, the earth cracked and a spring gushed out, a green dragon was born in a temple, the sun rose at night, the sun did not come out during the day". This was associated with the eruption of 1909 BC[65]. In any case, it is much later than the hypothetical "2200 event".

There is no reason to assume a connection between the "2200 event" and the formation of the Babino and Abashevo cultures in Eastern Europe[66], since chrono-typologically they correspond not to the European phase A1a, but to the phase A1c (or, according to the two-fold periodization, to the late part of A1b). At this time, another Anatolian impulse is observed, which brought chariots and ornaments of the Carpatho-Mycenaean style to the Balkans. This occurred during the early phase of the Monteoru and Costișa cultures in Romania[67], and soon this tradition penetrated into the Carpathian Basin (Wittenberg and further MBA cultures of Hungary, such as Otomani-Füzesabony). Thus, this corresponds to the final part of the EBA in Hungary and the beginning of the MBA. These migrations caused an outflow of people from the Carpathian Basin, including to Eastern Europe and Northern Italy, where the Danubian influences strengthened during the EBA IB period. According to the Italian dendrochronology, this period is dated to 1985–1916 BC. However, in the Kültpepe Ib layer in Anatolia, linked to historical sources and dendrochronology, objects decorated in this style are dated from 1852–1843 BC. The use of Bayesian statistics to a large series of AMS dates for closed complexes allowed dating the next A2 phase to the interval 1865–1545 cal. BC. There are two dendrodates of the A2a phase (1942 and 1840 BC) from the Unetice burials in

60 WEISS *et alii* 1993.
61 USOSKIN 2017, Fig. 20.
62 SALZER/HUGHES 2006, Tabl. 2.
63 SIGL 2022, Fig. 9.
64 see GRIGORIEV, 2023b for more detail.
65 Bamboo Annals 1.4.2, GRIGORIEV 2024c.
66 MIMOKHOD 2018.
67 GRIGORIEV 2019; 2021.

Leubingen and Helmsdorf. These discrepancies are explained by the fact that the A2 stereotypes began to form earlier in the Unetice area, and it is difficult to rely on the dates from Kültepe, as well as on any date based on a single type of artifacts. As a result, a wide interval within the mid–20th – mid–19th centuries BC can be proposed for the Babino and Abashevo formation[68]. This coincides with a decrease in solar activity after 2065 BC, which caused aridization in many regions, and with peaks of volcanic aerosols in the early 2nd millennium BC. Nevertheless, it is not yet possible to propose a specific date associated with a specific event of this time span. Thus, the ideas about the connection of the Babino and Abashevo formation and the beginning of the Xia with the "2200 event" are based on the use of radiocarbon dates. However, many other episodes of this "event" are based on them too. Therefore, in this case, we are not talking about denying this connection in general, but about changing the date and denying the fact of this "event", which includes processes from the 22nd to the 19th centuries BC, which had different causes and mechanisms.

CHRONOLOGICAL MARKERS FOR THE 17TH–11TH CENTURIES BC

The situation in the 17th–16th centuries BC (let me remind that we are discussing historical dates, not radiocarbon intervals here) looks the most promising from the point of view of constructing a global chronology. At that time, the Sintashta culture existed in the Transurals. It was formed later than the Abashevo and Babino cultures, but within the A2a phase, since by the beginning of the A2b phase (ca. the mid–17th century BC), the Seima-Turbino tradition, which was synchronous to the Sintashta culture, penetrated into the Carpathian Basin. This is not contradicted by the date of the Sintashta beginning ca. 1742/1740 BC[69]. This date cannot be used as an anchor for constructing a general chronology, since the Sintashta migration was apparently stimulated by political reasons. However, after this we have a series of reliable chronological markers due to the fact that eruptions that occurred during this period are well dated both by ice cores and by dendrochronology: 1654 (unknown volcano), 1628 (Aniakchak II) and 1560 BC (Santorini). The Santorini eruption was the most powerful in the Holocene, but the first two were distinguished by the largest sulfur emissions, which should have provoked long-term problems and migrations[70]. This is clearly manifested in the peaks of stratospheric aerosols during this period (fig. 2)[71]. In terms of the relationship with solar activity, the first two are close to the beginning of the decline from a small peak, and the third is close to the peak before the start of a sharp decline[72]. The subsequent downward trend explains the signs of aridization in the sediments above the Santorini eruption layer. This aridization was therefore not related to the eruption itself.

As a result, it became possible to link many cultural transformations in Eurasia to these volcanic events (fig. 3)[73]. The eruption of 1654 BC coincides with the penetration of the Seima-Turbino tradition into Central Europe and the transition between the A2a/A2b phases. The eruption of 1628 BC provoked the beginning of Wessex II whose analogies in Swiss are dated to 1630-1508 BC, impulses from the Carpatho-Danube basin to Northern Italy (the formation of the Terramare culture), to Greece (the beginning of the

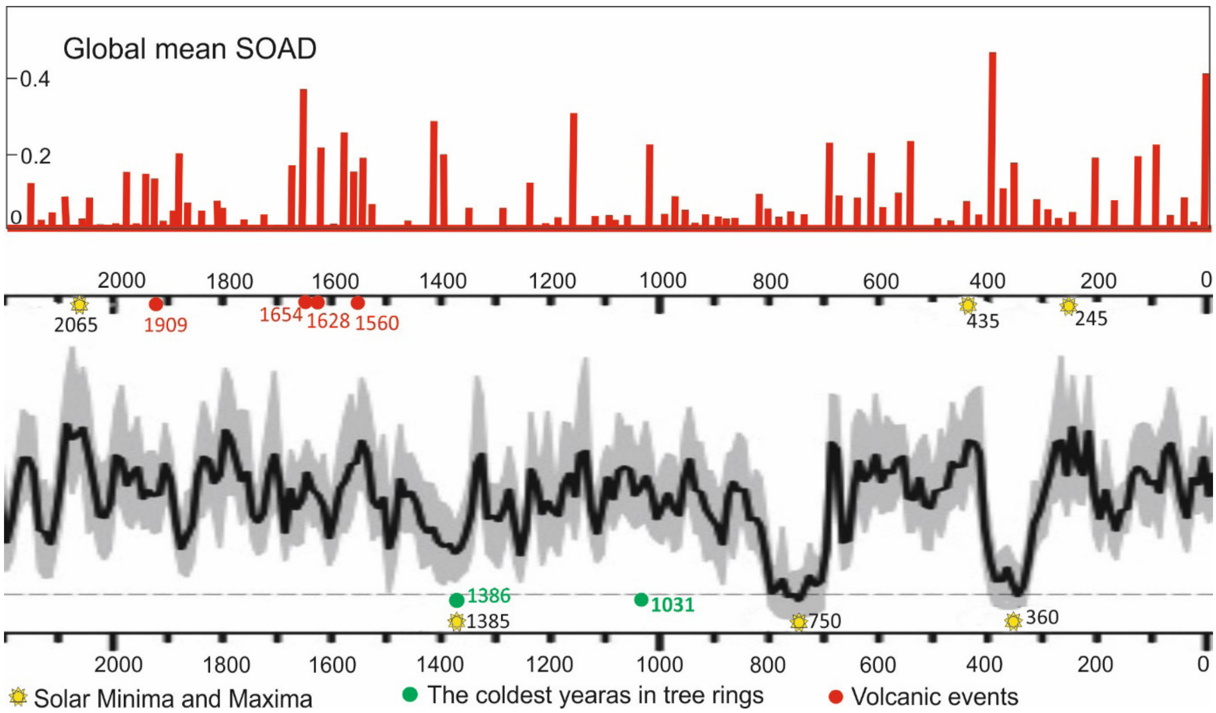

Fig. 2. Solar activity graph with Solar Maxima and Minima in the 2nd – 1st millennia BC (after USOSKIN 2017). Global annual mean stratospheric aerosol optical depth (SAOD) (SIGL *et alii* 2022, fig. 9).

[68] GRIGORIEV 2023b, 34, 35, 37.

[69] GRIGORIEV 2002, 137; GRIGORIEV 2018.

[70] PEARSON *et alii* 2022.

[71] SIGL 2022, fig. 9.

[72] USOSKIN 2017, fig. 20.

[73] for more detail, see GRIGORIEV 2024b.

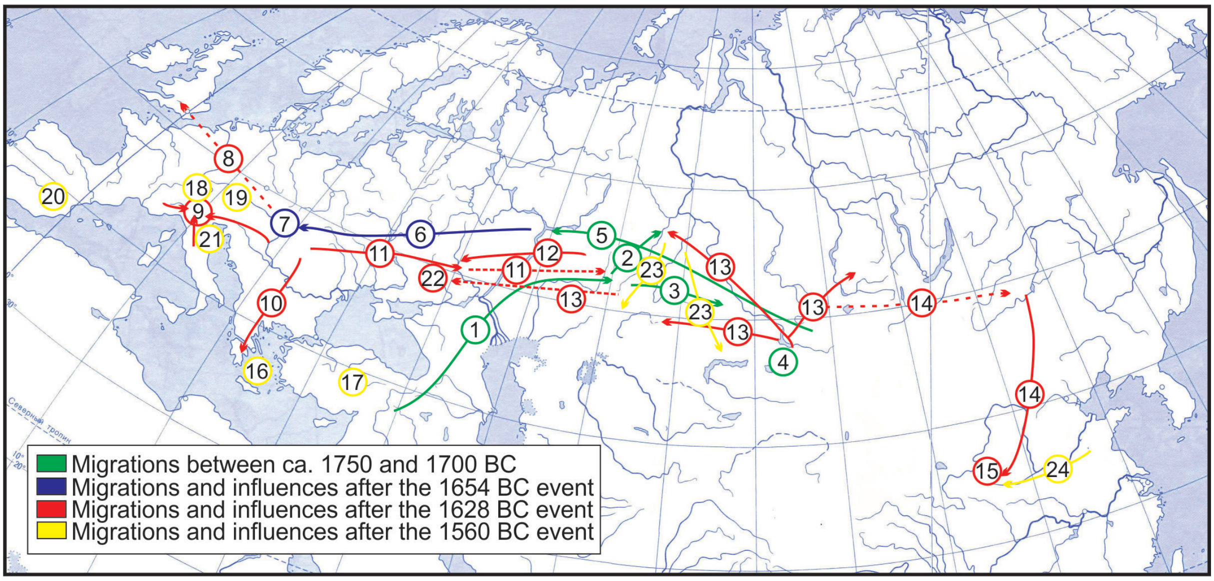

Fig. 3. Cultural influences between the mid–18th century BC and mid–16th century BC: 1 – Sintashta migration, 2 – Alakul culture formation, 3 – Petrovka culture formation, 4 – early Fyodorovka culture, 5 – Seima-Turbino migration to the Urals and Volga-Kama region, 6 – Seima-Turbino migration to Central Europe, 7 – A2a/A2b transition, 8 – Central European impulses and the Wessex II formation, 9 – Terramare culture formation, 10 – Carpathian influences in Greece, 11 – Carpathian influences in the Don area and the Urals, 12 – Sintashta and Ural Abashevo influences in the Don area, 13 – Fyodorovka migrations, 14 – Seima-Turbino migration to China, 15 – Erlitou III, 16 – Santorini eruption, 17 – crisis in the Hittite Kingdom, 18 – EBA/MBA transition in Switzerland, 19 – Br A/Br B transition in Central Europe, 20 – El Argar collapse in Spain, 21 – MBA 2 beginning in Italy, 22 – Srubnaya culture in Eastern Europe, 23 – Alakul migration to the steppe, 24 – beginning of the Shang Dynasty (Erlitou IV).

Late Helladic I period) and to the Don, where impulses from the Sintashta and Ural Abashevo were added. As a result, the Don-Volga Abashevo culture was formed on the Don. The Fyodorovka migration from the Irtysh region to the Urals and Siberia and the displacement of the Seima-Turbino groups from the latter region all the way to China, where the Seima-Turbino tradition appeared from the Erlitou III period in the late 17th – early 16th centuries BC, are also attributed to this time span. After 1620/1600 BC, judging by the Mycenaean parallels, the early Srubnaya Pokrovsk culture was formed as a result of the cultural integration of various components. In Central Europe, this period corresponds to the late part of the Reinecke A2 phase, whose dendrodates fall into the 17th – early 16th centuries BC[74].

However, the situation changed in 1560 BC after the Santorini eruption, whose effects on the climate were quite noticeable. In Anatolia, tree growth was interrupted for three years[75]. As a result, in 1560 BC the reign of Hantili I ended, and the Hittite Kingdom stops its expansionist policy, the El Argar culture collapsed in Spain, the transition from the EBA to the MBA occurred in Switzerland (1550 BC), and this date falls into the probable interval of 1615–1530 cal. BC for a similar transition in Southern Germany. The radiocarbon date of ca. 1580 cal. BC for the transition to the MBA 2 in Italy is also close to this. It is probably from this time that we can date the developed Srubnaya culture and the migration of the Alakul tribes from the forest-steppe to the steppe, where they assimilated the Petrovka and post-Sintashta traditions (fig. 3). The dates in Europe are duplicated by the chronology of China, where the Shang layer of Erlitou IV is dated to 1560–1520 cal. BC, and the beginning of the Shang dynasty in historical chronology is dated to 1558 BC. Moreover, the transition from the Xia to the Shang dynasty is marked by summer frosts[76]. This eruption was accompanied by long-term climatic changes, although the volcanic effect itself must have been short-term. It coincides with a period of prolonged decrease in solar activity, culminating by the solar minimum about 1385 BC, after which an increase began until the next decline at the end of the 2nd millennium BC (fig. 2)[77]. It can be assumed that this eruption also had some impact on the restructuring of the climate system. Besides, almost certainly a series of other cultural transformations in Eurasia can be linked to these three powerful events.

The solar minimum ca. 1385 BC corresponds to ring-width minima in the southwestern United States in 1386 and 1385 BC[78], as well as to the radiocarbon chronology of the formation of the Cordoned Ware cultures in Northern Eurasia in the early 14th century BC[79]. The Amarna archive contains evidence from this period, but without an exact date, that the country of Hatti "was frozen" (another translation is "paralyzed"), although this is usually explained by the Kaska invasion[80]. Nevertheless, additional verification is needed, since the dendrochronology of Fennoscandia does not provide data on a sharp crisis in these years.

Finally, there are many events occurring in the 12th century BC with vivid and colorful descriptions of natural disasters, famines, and invasions in the Eastern Mediterranean. Many of these events have no precise dates. They occurred against the background of declining solar activity and a peak in stratospheric aerosols around the mid–12th century BC (fig. 2)[81]. However, there are no strict, consistent dates based

[74] GERLOFF 2007, 137: 141.
[75] PEARSON *et alii* 2020, 8413.
[76] GRIGORIEV 2023a.
[77] USOSKIN 2017, fig. 20.
[78] SALZER/HUGHES 2006, 62.
[79] MOLODIN/EPIMAKHOV/MARCHENKO 2014, 144.
[80] ALPARSLAN 2015, 136.
[81] USOSKIN 2017, Fig. 20; SIGL 2022, fig. 9.

Table 1. Chronological benchmarks for constructing the absolute chronology of Eurasia.

Chronological benchmarks (BC)	Historical events
2910/2850	Yamnaya migration to Central Europe, formation of the Corded Ware culture (CWC)
2564	Fatyanovo migration, transition to the third phase of the CWC
1909	The beginning of the Xia Dynasty in China
1742/1740	Sintashta migration to the Urals
1654	Penetration of the Seima-Turbino tradition into Central Europe, transition between the A2a/A2b phases in Europe
1628	Formation of the Terramare culture in Italy, Late Helladic I period in Greece, the Don-Volga Abashevo culture, beginning of Wessex II, the Fyodorovka migration to the Urals and Siberia. With some delay: the appearance of the Seima-Turbino groups in China and Erlitou III
ca. 1600	The beginning of the early Srubnaya Pokrovsk culture
1560	End of the reign of the Hittite king Hantili I, beginning of the Shang dynasty (1558 BC), collapse of El Argar in Spain, transition to MBA 2 in Italy, transition to MBA in Switzerland and Southern Germany, beginning of the Srubnaya culture and the classical phase of the Alakul culture, end of the Petrovka culture
1385	Beginning of the Final Bronze Age in Northern Eurasia
1031	Beginning of the Zhou dynasty in China (1027 BC), the Kamenny Log phase of the Karasuk culture and, possibly, the transition to the late complexes of the Final Bronze Age in the steppe Transurals (Bersuat)

on dendrochronology, historical chronology, or glaciochronology in this case. This period requires further research. It seems that we can find a date for some significant disaster around the mid–12th century BC, but other events of the so-called "Bronze Age catastrophe" were caused by deterioration of climatic conditions in some regions and socio-political processes.

The possibility of obtaining another chronological benchmark appears in the second half of the 11th century BC, when the Shang Dynasty was replaced by the Zhou Dynasty in China. This change is usually dated to 1050, 1046/1045 BC[82], 1059 BC[83] or 1027 BC[84]. A significant peak of volcanic aerosols in the stratosphere is noted for the 11th centuries BC; and for 1031 BC, frost signals have been recorded in tree rings in the southwestern United States[85], indicating a significant eruption. Perhaps its consequences weakened the Shang dynasty and led to its fall in 1027 BC. Chinese sources mentioned climatic problems under its last ruler: "During the time of Di-xin Shou, the sky was very gloomy", and other natural phenomena occurred, for example, the rising of two suns[86]. The latter is called the "parhelion effect", which occurs due to the refraction of light in ice crystals saturating the clouds. Therefore, the Shang crisis may indeed be associated with the volcanic event of 1031 BC. In this case, 1027 BC for the Zhou beginning is preferred[87].

In Southern Siberia, the Kamenny Log phase of the Karasuk culture can be dated from this time. In the same period, we see impulses of the Karasuk culture as far as the Western Urals. It is possible that cultural transformations associated with this event will be revealed in other regions of Eurasia.

The subsequent sharp reduction or disappearance of archaeological sites in the steppe Eurasia in the 10th–8th centuries BC is explained by a progressive decrease in solar activity to a prolonged solar minimum centered around 750 BC. It was followed by an equally sharp rise, coinciding with the spread of the early nomadic cultures of the Scythians and Sakas in the steppe. However, no significant volcanic events were recorded during this period, so chronological benchmarks for this time span cannot be identified in this way (fig. 2). However, later, after the solar maximum around 435 BC, an equally sharp drop in solar activity to a minimum around 360 BC is observed, and it is accompanied by noticeable peaks of stratospheric volcanic aerosols. Chronologically, this coincides with the spread of the early Sarmatian culture in the steppe. Therefore, identifying chronological benchmarks for this period is possible.

CONCLUSIONS

Climate changes in the 3rd–1st millennia BC led to changes in human living conditions. Most of them were caused by fluctuations in solar activity. The duration and intensity of these cycles vary, but solar activity has too little effect on the climate to cause abrupt socio-economic and cultural changes. Nevertheless, it can reduce the adaptive capacity of human communities to abrupt changes caused by other reasons. There may be many such reasons, but they only affect local events. For chronology, events of a global nature are important. These were often major volcanic eruptions that abruptly changed the climate on the planet and led to migrations. Recording such events and linking them to dendrochronology, historical chronology and Bayesian statistics of AMS dates allows us to obtain benchmarks for creating an absolute chronology of Eurasia, with shorter and more recent intervals. The most important thing in this case is that, relying on unrelated data, it is possible to obtain a balanced, consistent system that reflects well the processes of cultural genesis in Eurasia (Table 1). This means that historical chronology, dendrochronology and Bayesian statistics of AMS dates correspond to each other, and the ordinary use of radiocarbon analysis gives earlier and wider intervals.

82 SHAUGHNESSY 1999, 23; BAGLEY 2018, 61.
83 PANKENIER 1981/1982, 24.
84 VASILIEV 1995, 219, 223.
85 SIGL 2022, Fig. 9; SALZER/HUGHES 2006, Tab. 2.
86 Bamboo Annals 3.30.4; VASILIEV 1995, 207.
87 GRIGORIEV 2024c.

Further work in this direction will probably be fruitful, although one should not expect rapid progress. It is also necessary to understand that this volcanic impact manifested itself differently in different regions. In the Yellow River basin, the crisis was strongly felt, and the change of all early dynasties, with the coming to power of the Xia, Shang and Zhou, was each time associated with volcanic events. This effect was also very strong in the steppe Eurasia. In Europe, it was clearly felt in the Carpathian Basin. In other areas, the consequences could be less noticeable due to a milder climate. Therefore, in this way we can obtain only individual chronological benchmarks. They will not solve all the problems of archaeological chronology.

To understand these processes, a reliable chronology of solar and volcanic activity is extremely important, which requires a lot of labor-intensive and systematic typological and stratigraphic studies, as well as synchronization of dendrochronologies in different regions with glaciochronology. Recently, a hope for a faster solution to the synchronization problem has appeared, since it is possible to use the Miyake effect (Maczkowski et al. 2024). The only accurate method is dendrochronology, which also allows us to identify sharp climatic fluctuations. Therefore, when fluctuations in solar and volcanic activity are linked to it, we will receive not only an excellent tool for studying the problems of the sun, seismic processes and climate, but also for explaining the problems of cultural genesis in antiquity and for constructing a reliable chronology.

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