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Absolute chronology for the transition to the North Eurasian Late Bronze Age and European Middle Bronze Age

Keywords: Middle Bronze Age / Late Bronze Age transition, historical chronology, dendrochronology, radiocarbon, steppe Eurasia

Түйін сөздер: орта қола дәуірінен соңғы қола дәуіріне көшу, тарихи хронология, дендрохронология, радиокөміртек, далалық Еуразия

Ключевые слова: переход от среднего бронзового века к позднему бронзовому веку, историческая хронология, дендрохронология, радиоуглерод, степная Евразия

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The use of historical dates, dendrochronology, and Bayesian statistics to determine archaeological chronology yields comparable results and shorter and more recent intervals compared to radiocarbon analysis. The disadvantage of the latter is the wide confidence intervals, which make it impossible to understand the processes, since the intervals of any two interrelated cultures tend to overlap. However, in steppe Eurasia, the use of dendrochronology and historical chronology is rarely possible. The solution to the problem is to link to the absolute chronology of cultures formed as a result of migration from areas where there is such an opportunity. The main cultural transformations of this period were associated with migrations caused by three major volcanic eruptions, which led to abrupt climate changes for a short time in 1654, 1628 and 1560 BC. These dates may correspond to some cultural transformations during the transition from the Middle to the Late Bronze Age, which makes it possible to obtain shorter intervals for the beginning of some cultures and build a more dynamic scheme of cultural changes of this period.

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Солтүстік Еуразияның кейінгі қола дәуіріне және Еуропаның орта қола дәуіріне өтудің абсолюттік хронологиясы

Археологиялық хронологияны анықтау үшін тарихи даталарды, дендрохронологияны және байес статистикасын пайдалану радиокөміртекті талдаумен салыстырғанда ұқсас нәтижелер мен қысқа әрі жаңа интервалдарды көрсете алады. Өзара байланысты кез келген екі мәдениет интервалының тұтасып кететін тенденциясы бар болғандықтан, соңғысының кемшілігі – ықтимал интервалының ауқымды болуы, соның салдарынан процестерді түсіну қиындық тудырады. Алайда далалық Еуразияға дендохронология мен тарихи хронология сирек қолданылады.

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Абсолютная хронология перехода к позднему бронзовому веку Северной Евразии и среднему бронзовому веку Европы

Использование исторических дат, дендрохронологии и байесовской статистики для определения археологической хронологии демонстрирует сопоставимые результаты и более короткие и молодые интервалы по сравнению с радиоуглеродным анализом. Недостатком последнего являются широкие доверительные интервалы, делающие невозможным понимание процессов, так как интервалы любых двух взаимосвязанных культур имеют тенденцию сливаться. Однако в степной Евразии использование дендохронологии и исторической хронологии редко

Бұл мәселе миграция мүмкіндігі бар аудандардан көшу нәтижесінде қалыптасқан мәдениеттердің абсолюттік хронологиясын байланыстыру арқылы шешіледі. Осы кезеңдегі негізгі мәдени трансформациялар б.д.д. 1654, 1628 және 1560 жж. климатты қысқа уақытқа күрт өзгертіп жіберген ірі жанартаулардың үш рет атқылауынан туындаған миграциямен байланысты болды. Бұл даталар ортадан кейінгі қола дәуіріне көшу кезіндегі кейбір мәдени трансформацияларға сәйкес келуі мүмкін. Сол арқылы кейбір мәдениеттердің басталуының қысқа интервалдарын алып, сол кезеңнің мәдени өзгерістерінің барынша динамикалық сызбасын құруға болады.

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возможно. Решение проблемы заключается в привязке к абсолютной хронологии культур, сформировавшихся в результате миграции из районов, где есть такая возможность. Основные культурные трансформации этого периода были связаны с миграциями, вызванными тремя крупными извержениями вулканов, приведшими к резким изменениям климата на короткое время в 1654, 1628 и 1560 гг. до н.э. Эти даты могут соответствовать некоторым культурным трансформациям при переходе от среднего к позднему бронзовому веку, что позволяет получить более короткие интервалы для начала некоторых культур и выстроить более динамичную схему культурных изменений этого периода.

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Introduction

During the Bronze Age, significant cultural transformations occurred over large areas almost simultaneously, and new archaeological periods or sub-periods commenced as a result. One of these was the EBA/MBA[1] transition in Central and Western Europe and the MBA/LBA transition in the Eurasian steppes, which occurred at the end of the first half of the 2nd millennium BC. However, it is difficult to synchronize these phenomena in different regions, since the radiocarbon chronology has wide confidence intervals, which does not allow us to study processes that lasted for relatively short periods of time. With the introduction of the AMS method and new calibration curves, we see a drift towards the historical dates based on written sources, but the problem is not yet solved. As a result, the confidence intervals of calibrated radiocarbon dates have become shorter, but they remain too wide to compare two different sites. Besides, scholars usually prefer to use intervals calculated with a probability of 68.2% [Мимоход 2023], because with a probability of 95.4% the intervals are so wide that they do not allow us to discuss the chronology of sites and cultures. It does not follow from this that the radiocarbon method is incorrect, since if it is used correctly, with a probability of 95.4%, some part of the interval corresponds to historical dates. However, it is necessary to abandon the use of dates with a probability of 68.2%. Only the correct use of Bayesian modelling of AMS dates makes it possible to get intervals close to historical chronology (for example [Liu et al. 2021]). Unfortunately, it is very difficult to use Bayesian statistics in steppe Eurasia, since well-stratified multi-layer sites are rare there. With some exceptions [Panyushkina et al. 2008], works based on Bayesian statistics in our region contradicts the principles of the method: analysis of series of dates with a narrow confidence interval from layers, whose sequence is established reliably. In some cases, materials are used which are separated by many kilometers. In addition, the sequencing is based on median date values [Chechushkov, Epimakhov 2023]. In other cases, a hypothetical sequence of ceramic types is taken as the sequence [Schreiber et al. 2023]. That is, something that had to be proven or confirmed. The second problem is the use of the AMS (accelerator mass spectrometry) and LSC (liquid scintillation spectroscopy) dates together in statistical analyses and their direct comparison [Мимоход 2023].

[1] Abbreviations used in the text: EBA – Early Bronze Age, MBA – Middle Bronze Age, LBA – Late Bronze Age, LH – Late Helladic, LM – Late Minoan.

Comparison of the Chinese and Eastern Mediterranean chronologies and dendrochronology demonstrates that these unrelated chronological systems correspond to one another. As a result, it was shown that such an important chronological benchmark as the Santorini eruption can be dated to 1560 BC. Contrary to this, radiocarbon dates of this event were within the second half of the 17th century cal. BC[2] [Grigoriev 2023]. Therefore, it seems that the results of historical chronology and dendrochronology are more accurate. Precise reconstructions of chronological timeframes are complicated by a number of issues: the lack of written sources in the region, and the impossibility of using dendrochronology in this area. Typological correlations with other regions, where the chronology has been reconstructed based on historical sources and dendrochronology, could be another solution. However, the main problem derives from the fact that cultural types and even cultures could have different durations in different areas. The solution to this problem may be in the locating of the first appearance of some type or culture in a new area as a result of migration, which originated in the regions with a reliably elaborated chronology. Such cases can be used as chronological benchmarks. Analysis of broader frameworks and wider areas within a relative chronological timescale with a number of radiocarbon dates served as benchmarks could allow us to date a number of archaeological cultures that lack absolute dates. For this, we must distinguish earlier and later processes, and link some of them to the absolute chronology. The purpose of this article is to link the chronology of the MBA/LBA transition to historical chronology and dendrochronology.

Migrations and volcanoes

Ancient migrations are usually explained by climate change. However, the climate changes were very smooth, and mankind is very adaptive. However, abrupt climate change caused by volcanic activity could trigger migrations. It is well known that large eruptions are able to cause the onset of volcanic winters. Nevertheless, it is impossible to use each of the large eruptions for our chronological studies. For example, during the so called "catastrophic 2200 BC event" we see cultural transformation in many areas, but climatic changes in Europe were insignificant. It was triggered by a major eruption in Eastern Anatolia or Transcaucasia ca. 2175–2150 BC, that destabilized cultural systems in the Near East and caused migrations to Europe and the formation of the European EBA in 2150–2135 BC, but transformation in Northern Italy and Britain occurred later (respectively ca. 2077 and 2025 BC). It is explained by the fact that the consequences of the eruption were significant, but for a limited region [Grigoriev 2023**a**]. It has been demonstrated that it is possible to create a well-balanced chronological system based on historical chronology, dendrochronology and Bayesian statistics of the AMS dates, but it is impossible to synchronize processes in remote areas, because there was no sharp sudden crisis. For this, larger eruptions are needed, whose consequences were global.

Investigations of tree-rings show that small eruptions can reduce temperatures in the mid-latitude in the order of 1°C for up to two years [Scuderi 1990: 67], which is not significant for human communities. A more catastrophic situation took place in 1258 AD: after the eruption of an unknown volcano, a cold summer was observed for two years all over the world [Oppenheimer 2003: 417, 422]. The great Santorini eruption on the island of Thera led to the spread of volcanic ash over a significant distance. It caused heavy rains and subsidence of the ash on the ground, which led to the soil degradation. The modelling shows that most of the ash from this eruption spread to the north-east, and that resulted in the devastation of many settlements in the North-Eastern Aegean. The main blow fell in Western and partly Central Anatolia, where the ash layer exceeded 10 cm in some places. It was a large problem for agriculture. In the Levant and Eastern Anatolia, the consequences were here less significant, and Greece was not affected at all [Athanassas et al. 2017]. But the eruption caused problems in many areas. Summer frosts in China led to the weakening of the Xia Dynasty in China and provoked its replacement by the Shang Dynasty ca. 1558 BC, which supports the ideas that this event took place in 1560 BC [Grigoriev 2023]. Volcanic stratospheric aerosols of this major eruption should have caused the effect of a volcanic winter for a relatively short

[2] In the text, the radiocarbon dates and historical dates/dendrochronology are distinguished (for example, 2000 cal. BC and 2000 BC).

time, resulting in the global cooling in the Northern Hemisphere. Decreased calcium content in tree-rings in Anatolia which began in 1560 BC and lasted until 1557 BC, explained by the volcanic activity and Santorini eruption, demonstrate significant climatic problems for three years. This date is confirmed by the ice-core and tree-ring records [Pearson et al. 2020: 8413; Manning 2022]. In steppe Eurasia with its pastoral economy, consequences of this event should have been more catastrophic than in the agricultural areas. It could have triggered migrations, which it may be possible to use for synchronization of remote areas. The most reliable dates for this period of climate change are provided by dendrochronology. Studies of tree rings in the southwestern USA revealed many years with minimal tree growth and frost signals in the 17th-16th centuries BC. But the influence of volcanoes on climate depends on many factors (location, season, Sulphur content, etc.). In addition to volcanic aerosols, the growth of tree-rings is influenced by altitude and local climatic conditions and events, such as droughts. Moreover, the effect of the latter is stronger than the volcanic impact [Salzer, Hughes 2006]. Therefore, we cannot associate any changes in tree rings with volcanoes. Volcanic activity is well recorded in ice cores in Greenland and Antarctica, but formerly their chronology was unreliable, and it was difficult to match signals in ice cores and tree rings. But the problem has been solved recently. Studies of ice cores from Greenland and Antarctica and tree rings reveal three powerful volcanic eruptions of that time, that caused short but sharp climate crises: 1654 BC (Aniakchak II); 1628 BC (unknown volcano); and 1560 (Santorini). In terms of Sulfur emission, the first two events were the largest in the Holocene [Pearson et al. 2022: 1]. The Santorini eruption was more powerful, but it was characterized by lower Sulfur emissions [Manning 2022: 32]. Three major eruptions within a relatively short period allows us to explore how they may have influenced cultural change in Eurasia. To do this, it is necessary to describe the sequence of cultural changes that could be associated with migrations and to investigate if there is indeed any correlation with the timing of volcanic eruptions. Furthermore, verification through the use of dendrochronology could offer further support for such a connection.

Cultural genesis and periodization in Northern Eurasia at the LBA beginning

Sintashta and Seima-Turbino chronology

I have already discussed the formation of the LBA cultures to the east of the Urals [Grigoriev 2021]. In general, as a result of migration from the Near East, the Sintashta culture formed in the steppe of the Southern Transurals (fig. 1, *1*). This migration also absorbed a part of the Eastern European population (Abashevo, Poltavka, Catacomb cultures). Almost simultaneously, to the east in the steppes of Kazakhstan, the Petrovka culture formed, and in the forest-steppe zone, the early Alakul culture appeared (fig. 1, *2, 3*). Previously, the Sintashta culture was dated (LSC, 68.2% of probability) to ca. 2200–1650 cal. BC [Черных 2007: 86], but with the increase in the number of AMS dates its interval has become more recent and shorter – 1960–1770 cal. BC (68.2% of probability) [Епимахов 2020]. The old LSC dates of the early Alakul sites in the forest-steppe of the Transurals fall in the interval 2300–1950 cal. BC [Молодин и др. 2014]. Recent analysis of 34 AMS dates for the Transurals has allowed scholars to conclude that Alakul sites located in the forest-steppe were somewhat more recent than those in the steppe. Furthermore, Petrovka sites belonged to the same interval. The beginning of the Alakul culture in the steppe has been dated to 1966–1777 cal. BC, and their end to 1736–1606 cal. BC. Their beginning in the forest-steppe is dated to 1813–1650 cal. BC, and the end to 1621–1511 cal. BC (2 σ, 95.4%) [Епимахов 2023: 176, 179, 182], but the number of analyses is too small. Besides, the beginning of the Alakul sites in the steppe falls within the late part of the Sintashta interval, and this culture was located in the same area. Therefore, it is a very useful start of the research, but it is still very difficult to rely on its results.

In historical chronology, we get later and shorter intervals. Previously, the beginning of the Sintashta culture was synchronized with the beginnings of Babino culture in Ukraine and other post-Catacomb cultures, and by such a way with the beginning of Central European sub-phase Br A1c (this phase can also be designated as the final part of the Br A1 phase) [Grigoriev 2019]. In South-eastern Europe, it corresponds to the beginning of the MBA, and in Southern Bulgaria the Anatolian and Aegean parallels to this material

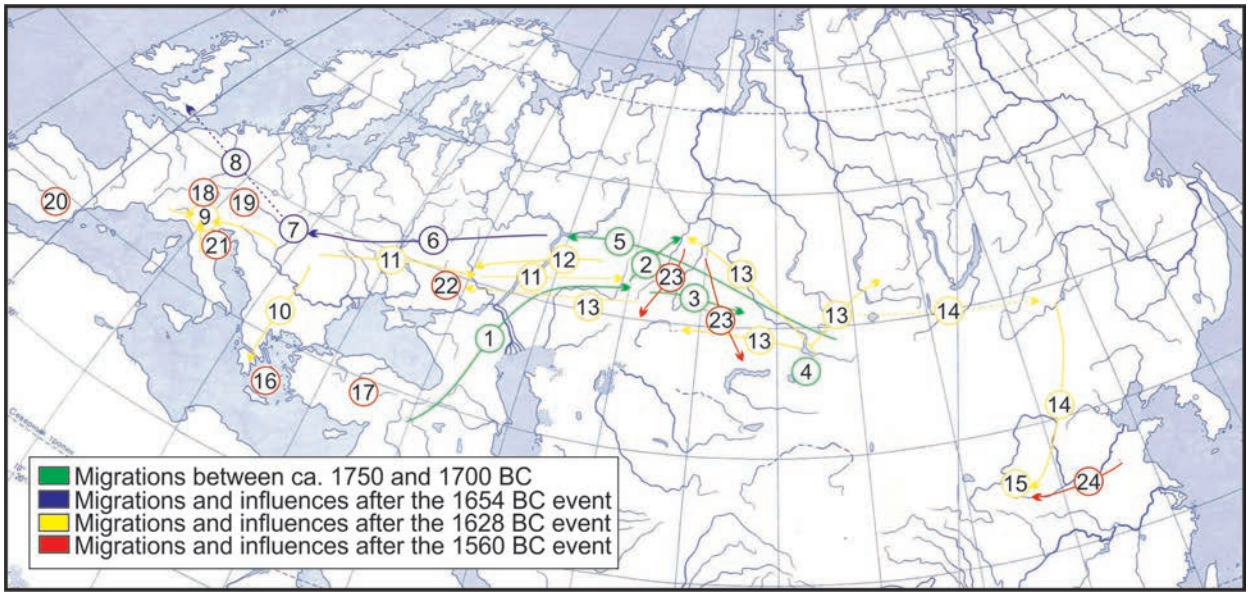


Fig. 1. Cultural influences between the mid-18th century BC and mid-16th century BC: 1 – Sintashta migration, 2 – Alakul culture formation, 3 – Petrovka culture formation, 4 – early Fyodorovka culture, 5 – Seima-Turbino migration to the Urals and Volga-Kama region, 6 – Seima-Turbino migration to Central 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)

1-сур. Б.д.д. XVIII ғ. ортасы — XVI ғ. ортасындағы мәдени импульстер: 1 — синташта миграциясы, 2 – алакөл мәдениетінің қалыптасуы, 3 — петров мәдениетінің қалыптасуы, 4 — ерте федоров мәдениеті, 5 — Урал мен Волга-Камьеге сейминск-турбинск миграциясы, 6 — Орталық Еуропаға сейминск-турбинск миграциясы, 7 — A2a/A2b ауысуы, 8 — Ортаеуропалық импульстар және Уэссекс II қалыптасуы, 9 — Террамар мәдениетінің қалыптасуы, 10 — Грециядағы карпат мәдениетінің ықпалы, 11 — Дон мен Уралға карпат мәдениетінің ықпалы, 12 — Синташта мен Уралдағы абаш мәдениетінің Донға ықпалы, 13 — федоров миграциясы, 14 — Қытайдағы сейминск-турбинск миграциясы, 15 — Эрлитоу III, 16 — Санторин жанартауының атқылауы, 17 — Хетт патшалығындағы дағдарыс, 18 — Швейцариядағы РБВ/СБВ ауысуы, 19 — Орталық Еуропадағы Br A/Br B ауысуы, 20 —Испаниядағы Эль-Аргар мәдениетінің күйреуі, 21 — Италияда СБВ 2-нің басталуы, 22 — Шығыс Еуропадағы қима мәдениеті, 23 – алакөл мәдениетін ұстанушылардың далаға қоныс аударуы, 24 — Шан династиясының басталуы (Эрлитоу IV)

Рис. 1. Культурные импульсы сер. XVIII – сер. XVI в. до н.э.: 1 – синташтинская миграция, 2 – формирование алакульской культуры, 3 – формирование петровской культуры, 4 – раннефедоровская культура, 5 – сейминско-турбинская миграция на Урал и в Волго-Камье, 6 – сейминско-турбинская миграция в Центральную Европу, 7 – переход A2a/A2b, 8 – центральноевропейские импульсы и формирование Уэссекса II, 9 – формирование культуры Террамар, 10 – карпатские влияния в Греции, 11 – карпатские влияния на Дону и Урале, 12 – влияния Синташты и Уральского Абашева на Дону, 13 – федоровские миграции, 14 – сейминско-турбинская миграция в Китай, 15 – Эрлитоу III, 16 – извержение Санторина, 17 – кризис в Хеттском царстве, 18 – переход РБВ/СБВ в Швейцарии, 19 – переход Br A/Br B в Центральной Европе, 20 – крах культуры Эль-Аргар в Испании, 21 – начало СБВ 2 в Италии, 22 – срубная культура в Восточной Европе, 23 – миграция носителей алакульской культуры в степь, 24 – начало династии Шан (Эрлитоу IV)

are dated to the 18th century BC [Leshtakov 2009: 61]. But taking into account that all Central European analogies are applicable only to the Babino and Abashevo cultures, there is no basis for the complete synchronization of Sintashta with them. The beginning of Sintashta should be dated within the sub-phase Br A2a. In the Middle chronology of the Near East 1740 BC was suggested. Besides, chariots came to the Urals from the Near East, and as before 1750 BC (within the "middle" chronology) the Near Eastern chariots had wheels with four spokes and after that with eight or nine, the Sintashta's wheels can be dated to later than the middle of the 18th century BC [Grigoriev 2002: 137; 2023**b**]. We have contradictions here, since the Bayesian statistics of AMS dates suggest the interval 1865–1545 cal. BC for the Br A2 phase, but there are two dendrodates for the complexes of phase Br A2a (1942 and 1840 BC) from the Únětice culture burials in Leubingen and Helmsdorf. This was explained by the fact that the Br A2 traditions originated initially in the Únětice area. In addition, the earliest Carpatho-Mycenaean style ornaments at Kültepe Ib in Anatolia are reliably dated by dendrochronology and historical chronology since 1852–1843 BC, and the appearance of these ornaments in the Carpathians occurred at the very beginning of the Carpathian MBA [Grigoriev 2021**a**]. In this case, the chronology is based on rare finds, and it is necessary to increase the number of dating parallels between the Sintashta and Anatolian materials.

In the Altai and Sayan regions at the time close to the beginning of the Sintashta culture, the Seima-Turbino (ST) tradition appeared, and soon after that the tribes of this tradition started their migrations to Western Siberia, Volga-Kama regions, and later to Central Europe, where this tradition appeared by the beginning of sub-phase Br A2b (fig. 1, *5, 6*). In China, the ST bronze artifacts appeared since the layer Erlitou III, immediately before the beginning of Shang Dynasty, which is associated with the Erligang culture (Erlitou IV) [Grigoriev 2023] (fig. 1, *14, 15*). The previous layers and the Erlitou culture are associated with the earlier Xia Dynasty [Chang 1980: 263, 269, 287, 344, 345]. Therefore, the ST artifacts in China belong to the pre-Shang period. Seima-Turbino sites are dated to the 22nd–20th centuries cal. BC [Marchenko et al. 2017: 10–12], but it is too early as it precedes the Sintashta interval.

It is impossible to date the beginning of these bronze artifacts within the historical and dendrochronological timeframes, but their appearance within the 18th century BC is probable. Their penetration into Europe and the beginning of sub-phase Br A2b took place about the mid-17th century BC (it was based on Swiss dendrochronology), and the following interaction of the bearers of this tradition with Mycenaean Greece in the LH I period (Borodino hoard) took place ca. 1630/1610 BC [Grigoriev 2018]. This westward penetration coincides with, and may have been stimulated by, the eruption of Aniakchak II in 1654 BC. It corresponds to the dendrochronology of this penetration, and allows us to assume that the beginning of phase Br A2b can be dated to this time (fig. 1, *7*). But in Northern Eurasia, the ST artifacts existed earlier and later, so this date adds nothing to their general chronology.

There was no abrupt cultural change in Britain in this period. The Wessex I culture (EBA 2) was replaced ca. 1750/1650 cal. BC (old radiocarbon chronology) by the Wessex II culture (fig. 1, *8*). It was characterized by the appearance of the Camerton-Snowshill daggers and bronze artifacts of the Arreton type. Analogies in Switzerland (Arbon-Bleiche 2) have dendrodates 1630–1508 BC [Gerloff 2007: 141]. The appearance of socketed spearheads in Wessex II allowed these processes to be partly synchronized with the coming of the Seima-Turbino tradition to Central Europe. Correspondently, in the dendrochronology, Wessex II can be also dated to the second half of the 17th century BC [Grigoriev 2018: 40]. Thus, it can be seen as a continuation of the process triggered by the Aniakchak II eruption, but these were later changes, secondary to those in Central Europe.

The beginning of Shang Dynasty in 1558 BC was synchronized with the Santorini eruption, as well as the occurrence of the ST artifacts in the Erlitou III phase. However, as mentioned above, the beginning of the Shang era is associated with the Erlitou IV layer. These layers have been provided with a large series of AMS dates, to which a wiggle-matched procedure has been applied allowing the intervals to be reduced. As a result, the Erlitou III layer is dated to 1610–1555 cal. BC, and the Erlitou IV layer to 1560–1520 cal. BC [Zhang et al. 2008: 200]. This corresponds to the historical chronology of the early Shang, and suggests that the dating of layer III is also correct. Therefore, we can date the coming of the ST tradition to China to the late 17th century BC, and it is not impossible that the eruption of 1628 BC could have caused

movements in Siberia, which resulted in the coming of the ST-people into China. Thus, the consequences of this eruption were felt throughout Eurasia.

After the Seima-Turbino penetration to Europe, but within the same sub-phase Br A2b, we see a reverse influence from Central Europe; Carpathian ornaments and specific morphological features of cheek-pieces appeared in the Don-Volga Abashevo culture (called sometimes "early Pokrovsk"). This influence reached the Urals and Kazakhstan at the very late stage of Sintashta culture, where there is a cheek-piece with this ornamentation (Kamenniy Ambar-5, 8/2). This influence has been dated to within the second half of the 17th century BC (fig. 1, *11*) [Grigoriev 2021a: 159, 163, 164, 170]. Later in Eastern Europe, influences of the Don-Volga Abashevo culture resulted in the formation of early Srubnaya Pokrovsk sites in the Volga region. At the same time, in the Eastern European steppes, ornaments appeared that had analogies in Mycenae [Беседин 1999; Grigoriev 2021**a**: 173–176]. By this time, the Sintashta culture did not exist in its previous form. In its fortified settlements in the eastern areas of the Tobol tributaries, Petrovka ware appeared. This does not make an impression of a complete replacement of the population, since Petrovka dwellings on the settlements of Ustye and Alandskoe correspond exactly to the borders of the previous Sintashta dwellings, and the architecture was inherited from that of the Sintashta [Виноградов 2013; Зданович и др. 2007: 104, 105, 108]. But in the western part of the area of the Ural tributaries, early Srubnaya ware appeared, and, on the Kuysak fortified settlement it is found on the floors of the dwelling, and the ware with early Srubnaya features was present at the last stage of the Arkaim settlement [Малютина, Зданович 1995: 103, 104; Зданович и др. 2020: 145, 283, 284]. The only Petrovka burial of the area is mound 22 of the Bolshekaraganskiy cemetery near the Arkaim settlement. In mound 20 of the cemetery, we found early Srubnaya ceramics and evidence of corresponding burial rite [Боталов и др. 1996]. The latter indicates influence from the west. Therefore, this stage can be synchronized with the early Srubnaya stage in the Volga region. It can be considered as a late phase of Sintashta culture, when the inflow of the Petrovka and early Srubnaya people started to change the ceramic complex, but rather as a post-Sintashta phase.

In general, the LH I period in Greece was synchronous to the Central European phase Br A2c. This synchronization is quite reliable, as it is confirmed by numerous parallels caused by the interaction of the Carpathians and Greece, which is reflected in the Hajdúsámson-Apa hoards with metal objects decorated with Carpatho-Mycenaean ornaments, and this horizon was synchronous to the early Srubnaya culture. It is possible that a part of Br A2b was also synchronous with the beginning of LH I. Since the very beginning of LH I, Carpatho-Mycenaean ornaments and signs of the use of chariots occurred in the Mycenaean Shaft Graves of Circle A. The bearers of these traditions came to Greece from the Carpathians and they were included in the Mycenaean elite (fig. 1, *10*). It is indicative that in the Carpathians, the objects decorated with this style are present in the settlements and in Greece only in the prestigious context. No other Carpathian traditions appeared in Greece. In the Don area, we see an identical situation: Carpathian influences are limited to cheek-pieces and corresponding ornaments, which suggests the coming of small elite groups, but not a mass migration (fig. 1, *11*). In addition, the formation of the Abashevo culture in the Don area was influenced by the coming of Abashevo-Sintashta people from the Urals (fig. 1, *12*), which suggests some instability there too [see in details Grigoriev 2021a: 170–173, 176, 179–181; Grigoriev 2022: 30, 31]. Earlier, this phase Br A2c in Central Europe was defined as late Br A2, Br A2/B or Br A3, and it was dated on the basis of dendrochronology to the 17th – early 16th centuries BC [Gerloff 2007: 137], i.e. its beginning corresponds to the 1628 BC event. On the basis of Egyptian parallels, the LH I beginning is dated to ca. 1630/1610 BC [Wiener 2020: 279], which also corresponds exactly to this eruption.

This is duplicated by the chronology of Northern Italy. Radiocarbon analyses and dendrodates indicate the beginning of the Terramare culture (and the Italian MBA) in the 17th century BC. It formed under influences from the east (*palaitta* sites – post-Polada), south (from the Apennines), and west (Pollera-Mercurago type), which indicates large-scale migrations in the region (fig. 1, *9*). There were also some limited influences from the Danube, resulting in the appearance of cheek-pieces. The early phase of the culture has been synchronized with the Bodman-Schachen IC layer in Switzerland, dated dendrochronologically to 1611–1591 BC, whereas the earlier layers in Bodman-Schachen IB have dates

within 1644–1640 BC, and in Meilen-Schellen within 1647–1641 BC. This early phase is synchronized with Br A2c in Europe and LH I in Greece [Vanzetti 2013: 277, 278]. Thus, the migrations in Italy that caused the formation of Terramare culture took place between 1640 and 1610 BC.

All these migrations suggest the impact of this major eruption in 1628 BC that caused the outflow of some of the Carpathian groups to Greece, Northern Italy and the Don basin as well as the westward movement of some of the Sintashta-Abashevo people. Accordingly, we have a series of dates from independent sources, and we may date from that time the late phases of the Sintashta and Petrovka cultures. After this time, we may date the last Sintashta phase, when the early Srubnaya and Petrovka ware appeared in its fortified settlements. As a result, we have a quite reliable interval for the culture. The fact is that the dwellings in its settlements had only been rebuilt twice, in some cases three times. In Northern Italy, dwellings of the Terramare culture had the same sizes and were attached to each other like Sintashta dwellings. Dendrochronology shows that they were rebuilt every 35 years [Vanzetti 2013: 271]. The timber-earth pole dwellings could not exist 100 years without needing to be rebuilt. Therefore, the Sintashta interval can vary within 115–150 years. Besides, the number of burials in the Sintashta cemeteries is too small to suggest the existence of these large settlements for several hundred years. But the upper Sintashta date is problematic. It was based on the idea of two movements in Eastern Europe that brought the ornamentation of the Carpatho-Mycenean style: the first within sub-phase Br A2b with the cheek-pieces and ornaments from the Carpathians, and the second in the early Srubnaya period with the Mycenaean ornaments. The first movement is reflected in one of the Sintashta burials, but there are no traces of the second [Grigoriev 2021a]. We do not know if this second movement started at the very beginning of LH I, but the Pokrovsk Srubnaya culture cannot be dated before 1600 BC.

Fyodorovka chronology

In the Irtysh region adjacent to the Altai (Eastern Kazakhstan), bearers of the early Fyodorovka (Andronovo) culture arrived (fig. 1, *4*). This happened soon after the Sintashta culture formation, since the early Fyodorovka complexes contain ceramics with the Petrovka features [Grigoriev 2021]. This probably triggered the westward movement of a part of the Seima-Turbino groups. From this area, a part of the Fyodorovka population spread to the west through the Kazakhstan steppes, but their main westward migration occurred later through the forest-steppe, initially to the Lower Tobol area, and from there to the Transurals (fig. 1, *13*). This happened at the end of Sintashta culture. As a result, a part of the Alakul population in the forest-steppe of the Transurals was assimilated, and Cherkaskul culture started to form there. Another part of Alakul people moved to the steppes of the Transurals and Kazakhstan, assimilating the related Petrovka tradition, and the remains of Sintashta one. As a result, the whole steppe zone between the Ural and Irtysh rivers was occupied by the Alakul culture in its developed phase. The second direction of the Fyodorovka migration was towards the east, where these tribes later reached the Minusa depression in the Yenisei basin (fig. 1, *13*). These Fyodorovka migrations put an end to the Seima-Turbino tradition.

Fyodorovka culture can be dated to: 2000–1700 cal. BC in the Altai, 20th – early 16th centuries cal. BC in the Lower Tobol region, 1980–1510 cal. BC in the Transurals, 1800–1500 cal. BC in the Baraba steppe, and 1900–1500 cal. BC in the Minusa depression on the Middle Yenisei [Молодин и др. 2014; Зах и др. 2013: 18; Илюшина 2015: 46]. From these dates we may conclude that Fyodorovka culture formed contemporaneously with Sintashta. Very soon it spread westward, and later eastward. But these are mainly LSC dates and they are incomparable with the AMS dates of Sintashta. Based on typology, only some Fyodorovka complexes in Eastern Kazakhstan may be related to the early Sintashta phase. In the Sintashta period, the forest-steppe of the Transurals and Lower Tobol was inhabited by people of the Alakul culture. Eleven AMS dates from the Fyodorovka complexes in the Transurals form the interval 1742–1451 cal. BC [Епимахов 2023: 182], which mark the appearance of the Fyodorovka groups in the Transurals in the late Sintashta period. The cultural overlap of Fyodorovka and Alakul complexes in the Lisakovsky cemetery forms an interval between 1780 and 1660 cal. BC (AMS and floating tree-ring chronology). A date 1719±50 cal. BC is obtained from the Alakul-Fyodorovka burial of this cemetery [Panyushkina et al. 2008; Усманова, Панюшкина, 2011: 378]. In all other regions, the early beginning of Fyodorovka

culture ca. 20th century cal. BC is based on old analyses of bad quality. On the Middle Yenisei, the culture is dated by the AMS method within the 17th–15th centuries cal. BC, and it appeared there later than in the west [Поляков 2019]. Correspondingly, in the south of Western Siberia, the Altai and south-eastern Kazakhstan, the dates within the 19th–18th centuries cal. BC are probable. In Xinjiang, at the settlement of Adunqiaolu, Fyodorovka materials are dated (AMS) to the 19th century cal. BC [Jia et al. 2017]. The Kulsay Fyodorovka group in the Trans-Ili Alatau in southern Kazakhstan is dated from the 19th to the 15th centuries cal. BC [Гасс, Горячев 2016: 113-114]. Thus, the use of AMS dates from the Fyodorovka sites in the east actually shows the interval of the early Sintashta culture. Therefore, the existence of Seima-Turbino tradition between the Altai and the Irtysh River was very short.

A clay vase from the settlement of Pavlovka in Northern Kazakhstan makes it possible to synchronize the Fyodorovka culture with the early Kelleli phase of the Namazga VI culture in Turkmenistan. This culture is a part of BMAC (Bactro-Margianan archaeological complex) [Grigoriev 2002: 248], whose early phase was dated to ca. 2200–2100 cal. BC, but based on the Near Eastern analogies V.I. Sarianidi proposed the interval 1750–1500 BC [Kohl 1992: 186–192; Сарианиди 1990: 74]. Thus, this coincides both with the old radiocarbon dates for Sintashta and with its dates based on the Near Eastern chronology. In North-Eastern Iran, the layer Hissar IIIC belongs to BMAC. The modern AMS dates for Hissar III do not go beyond the 18th century cal. BC [Gürsan-Salzmann 2016]. Therefore, the layer Hissar IIIC, synchronous to the early BMAC, can be dated within the 19th–18th centuries cal. BC. This corresponds also to the AMS dates for the appearance of Fyodorovka culture in the Altai and Kazakhstan. Therefore, in the historical chronology, the probable interval is the second half of the 18th century BC. The further movement of some Fyodorovka groups to Eastern Europe took place in the early Srubnaya period [Grigoriev 2002: 259], i.e. the first half of the 16th century BC. This confirms that these people came to the Urals in the previous period. No later than the late 17th century BC, the Fyodorovka people came to the Middle Yenisei. Since Andronovo metalworking replaced the culture Seima-Turbino in Siberia, and the latter appeared in China in the late 17th century BC, we may assume the following scenario: the eruption of 1628 BC triggered the movement of some Fyodorovka groups to the east, where they forced out the Seima-Turbino people. This probably also stimulated the Fyodorovka migration to the Urals (at least to the Lower Tobol region), that happened in the late part of the Sintashta period. But this hypothesis must be confirmed by alternative sources. For some time in the forest-steppe Transurals, we see the coexistence of the local Alakul population with the small alien Fyodorovka groups.

Santorini and cultural changes in Europe and steppe Eurasia

The next important trigger for cultural transformations in Eurasia was the eruption of Santorini that occurred at the end of LM IA in 1560 BC. At the Palaikastro settlement, materials of this period were found under the tsunami layer, and under the eruption layer of the Akrotiti settlement on Thera, imported Mycenaean LH I pottery was found, imitating the LM IA pottery (fig. 1, *16*) [Marthari 1993; Bruins et al. 2009: 397]. Therefore, it is generally accepted that within the Aegean chronology this event took place in the final part of LM IA, and in the LH I period of mainland Greece. The latter period can be partly synchronized with the Br A2c phase of Central Europe, and at the end of this phase significant changes occurred throughout Europe.

At the EBA/MBA transition (or Br A/Br B) everywhere in Europe (fig. 1, *19*), we see a cultural break accompanied by drastic socio-economical changes. Based on a series of AMS dates, the phase Br B was dated to ca. 1550–1450 cal. BC [Müller, Lohrke 2009: 8]. The Bayesian modelling of AMS dates from complexes of Central Europe, which reliably belong to a particular Reinecke's phase, allows similar probable intervals to be obtained: Br A2 – within 1865–1545 cal. BC, the transition to the phase Br B – within 1615–1530 cal. BC, and in the Swiss dendrochronology the end of EBA is dated ca. 1550 BC (fig. 1, *18*) [Brunner et al. 2020: 1, 14]. Thus, the transition to the European MBA corresponds to the date of the Santorini eruption.

In the Carpathian basin, the culture of tell-settlements of the previous period ceased to exist. But it was not an instant process: some of the settlements had been abandoned, others continued to be used. It

was a time of mild temperatures, and the transition to an arid phase occurred later. Therefore, all changes are explained by the changes in the communication system and by other socio-economic reasons [Fischl et al. 2013: 362, 366; Metzner-Nebelsick 2013: 343]. In Northern Italy, the Terramare culture continued to exist. But its brightest development started in the MBA 2 (fig. 1, *21*), with the radiocarbon dates between 1580 and 1480/1460 cal. BC [Vanzetti 2013: 278, 279]. In Spain, a gradual collapse of the El Argar culture took place (fig. 1, *20*), which began ca. 1550 cal. BC on the basis of Bayesian statistics for AMS dates of short-lived plants. The collapse was triggered by some migration that led to the abandonment of half of the settlements and the reduction of others [Lull et al. 2013: 285–290; Hernández et al. 2013: 308, 309].

The crisis in the Hittite Kingdom started ca. 1560 BC (fig. 1, *17*) (Middle Chronology of the Near East). The last Hittite king, who pursued the traditional active expansionist policy, was Hantili I, and he ruled from 1590 to 1560 BC. Significant changes took place in 1558 BC in China. As a result of summer frosts, the Xia Dynasty collapsed and was replaced by the Shang Dynasty. According to written sources and archaeological evidence, the founders of this Dynasty came from the east (eastern Henan, western Shandong and north-western Anhui) (fig. 1, *24*)[3] [Chang 1980: 345–347; Li 2018: 232]. It is an area with a mild climate, and it was less affected by this cooling.

Something similar took place in central Eurasia, where this abrupt climate change was more severe in the steppe areas inhabited by the Petrovka people from the Tobol basin to the Irtysh, the post-Sintashta people in the Ural basin in the Transurals and early Srubnaya tribes in Eastern Europe. The third related group is presented by the early Alakul culture in the forest-steppe of the Ural-Tobol area. At this time, the mass of the Alakul population migrated south, occupying vast spaces of the steppe in the Urals and in Kazakhstan (fig. 1, *23*), and Cherkaskul culture was formed in their former place in the forest-steppe under the influence of the Fyodorovka tribes. It should be noted that biological resources in the forest-steppe are incomparably richer than those in the steppe. For this reason, already in the Sintashta period, a significant Alakul demographic residue had formed there, which later allowed the Alakul culture to became a dominant factor in the Transurals and Kazakhstan. Summer frosts of a volcanic nature could lead to degradation of steppe pastures and the weakening of the Petrovka and post-Sintashta communities, making impossible the concentration of people around the large fortified centers. This contributed to the Alakul expansion, although some of its episodes had taken place earlier. In Eastern Europe at this time there was a consolidation of various early Srubnaya groups into a unified Srubnaya culture of its classic stage (fig. 1, *22*). Probably, this climate catastrophe somehow influenced this process, but its mechanisms are not entirely clear.

Chronological benchmarks for the end of MBA – the beginning of LBA in Northern Eurasia (1654, 1628 and 1560 BC)

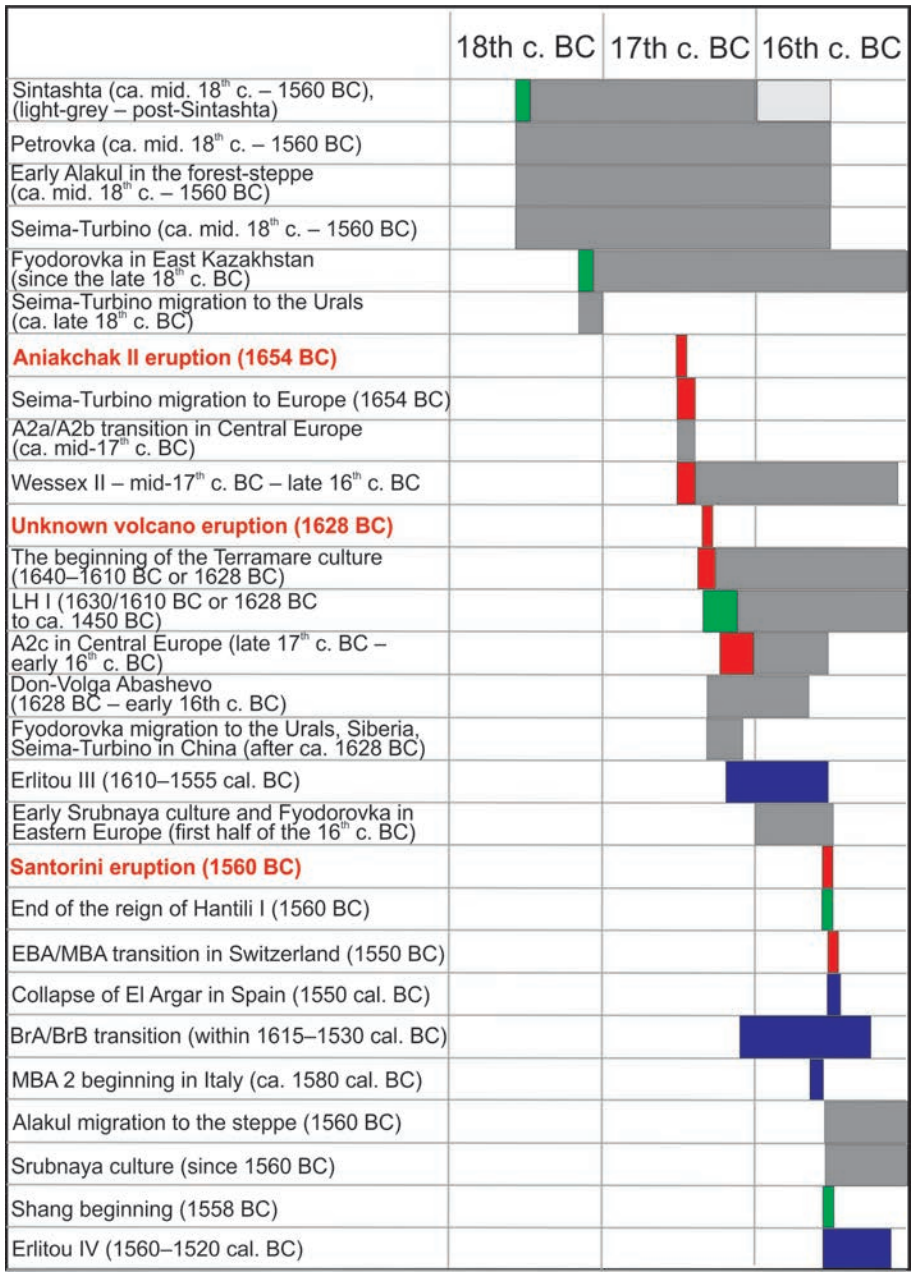
The dates discussed above are linked to historical chronology, dendrochronology and Bayesian statistics. They are summarized in table 1. In contrast to the radiocarbon chronology, they form much shorter intervals, that allow the logic of historical processes to be understood. The major cultural transformations of the period under consideration were associated with volcanic events that took place in 1654, 1628 and 1560 BC. It is indicative that this scheme corresponds to the relative chronology. The chronology of many cultural processes is duplicated by alternative data. In particular, the event of 1654 BC coincides with the dendrochronology of the appearance of Seima-Turbino culture in Europe, the chronology of the transition

[3] It is possible that the beginning of the previous semi-legendary Xia Dynasty was also associated with volcanic events. According to legend, the beginning of the dynasty coincided with such an event as the Great Flood of Yu, the founder of the dynasty. In the refined chronology the start of the dynasty can be dated to 1914 BC [Nivison 1999: 12]. Chinese colleagues discovered traces of this flood, which was associated with powerful seismic activity. A series of AMS dates has placed this event in the interval 1976–1882 cal. BC (95% probability), and they suggested a date of ca. 1920 BC [Wu et al. 2016: 580–582], and it is close to the chronology of Nivison. Interestingly, in the southwestern United States, dendrochronology showed frosts in 1921, 1909, 1908 and 1907 BC, which were associated with some volcanic events [Salzer, Hughes 2006: 57–62, table 2]. If this connection is confirmed, we will be able to look for other cultural transformation in the Northern Hemisphere connected with this events.

Table 1 – Chronological benchmarks of cultures and migrations in the 18th–16th centuries BC within the historical chronology (green), dendro- and ice-core-chronologies (red) and Bayesian modelling of AMS dates (blue). Reconstructed intervals are grey (references in the text)

1-кесте — Тарихи хронология (жасыл), дендро- және гляциохронология (қызыл), AMS даталарын байестік модельдеу (көк) аясындағы б.д.д. XVIII—XVI ғғ. мәдениеттер мен миграциялардың хронологиялық реперлері. Реконструкцияланған интервалдар сұр түспен көрсетілген (сілтемелер мәтіннің ішінде)

Таблица 1 – Хронологические реперы культур и миграций в XVIII–XVI вв. до н.э. в рамках исторической хронологии (зелёные), дендро- и гляциохронологии (красные) и байесовского моделирования AMS дат (синие). Реконструированные интервалы выделены серым цветом (ссылки в тексте)



to the European phase A2b and the beginning of Wessex II. Especially indicative is the chronology of the 1628 BC event, which is confirmed by the dendrochronology of Central Europe for the latest part of the Br A2c period and the Terramare culture, the historical chronology of LH I and AMS dating of the Erlitou III layer. This allows us to date the late Sintashta phase, the beginning of the Abashevo culture in the Don basin (early Pokrovsk), and the penetration of the ST artifacts into China. Since the latter could have been stimulated by the Fyodorovka movement to the south of Middle Siberia, we may assume that this movement is dated to the same time, which quite consistent with its AMS dates. The 1560 BC event is also reflected in a number of independent sources, but its connection with the wide distribution of the Alakul and Srubnaya cultures is a hypothesis that requires additional chronological data from alternative sources. Other complexes of steppe Eurasia need the same, and this is a rather difficult task. But there is a general chronological frame for this. Based on the relative chronology of these complexes we are at least able to estimate their approximate date within the framework of absolute chronology. Certainly, it is necessary to take into account that some local abrupt climatic changes could also lead to local cultural transformations, so the chronological verification by alternative sources is required. But the general logic of the events of this period is quite clear.

The historical processes in steppe Eurasia were based on the Sintashta, Petrovka and early Alakul cultures, which formed soon after the mid-18th century BC. Perhaps, the Seima-Turbino culture appeared at the same time. But then in the area between the Altai mountains and the Irtysh river, the Fyodorovka people appeared, who provoked the westward Seima-Turbino migration. Accordingly, the existence of the ST complexes in the region was very short. However, exact dates of the beginning of these cultures need to be clarified, because their appearance was not associated with global natural disasters.

In 1654 BC, the Aniakchak II eruption occurred, and it triggered the Seima-Turbino migration to Central Europe and essential transformations in Europe (transition to Br A2b and Wessex II). A global eruption in 1628 BC provoked a series of new changes. Carpatho-Danubian influences are visible in the features of the Mycenaean Shaft Graves of Circle A, the early Terramare and Don-Volga Abashevo cultures. All these processes were based on local cultural components, so we can synchronize with this time the Sintashta-Abashevo migration from the Urals to the Don basin, and the beginning of the late Sintashta phase. Judging from the series of AMS dates from Erlitou III, Fyodorovka people forced out the bearers of the Seima-Turbino tradition to China also at that time. The appearance of the Fyodorovka culture in the Transurals in the final part of the Sintashta period corresponds to this scenario too. Therefore, we may suggest that this event of 1628 BC triggered the Fyodorovka migrations from Eastern Kazakhstan.

The formation of the classic Pokrovsk sites started later, at about the end of the Sintashta period. It can be dated to ca. 1600 BC, but a detailed comparison of the Pokrovsk and Balkano-Carpathian complexes is necessary to clarify the date. The latest layers of the Sintashta fortified settlements belong to this time: they contain the early Srubnaya ware in the west of the Sintashta area and the Petrovka ware in the east. But it is necessary to understand that these cultural transformations were not instant throughout Eurasia, different cultures could coexist in neighboring areas, for example Abashevo and Pokrovsk ones, etc. I think this was rather the rule than the exception.

Finally, the eruption of Santorini in 1560 BC caused the transition to the MBA (Br B) in Europe, the beginning of MBA 2 in Italy, the collapse of El Argar in Spain, the succession of the Xia dynasty by the Shang dynasty in China, the cessation of the post-Sintashta and Petrovka cultures and the wide distribution of the Alakul culture in the steppe, probably, the formation of the Cherkaskul culture in the forest-steppe Transurals and the classic Srubnaya culture in Eastern Europe.

Conclusions

The chronological benchmarks for Northern Eurasia quite accurately correspond to the reconstructed historical processes. In this case, the most important fact is that these benchmarks have been obtained through the application of different methodologies (e.g., historical chronologies and dendrochronology in different regions). Together these combined methodologies display greater accuracy of the timing of cultural transformations in the steppes. It is important to note that using radiocarbon dates alone is not

sufficient for comparison. As a result of shorter intervals achieved via the use of these benchmarks, we get a more dynamic picture of cultural processes and understanding of possible links between individual processes. It does not follow from this that the radiocarbon dates are wrong. Even the old LSC dates are perfectly valid when used correctly. If we pretend to use the exact scientific method, we should use intervals calculated with a probability of 95.4%, not 68.2%. The intervals are too long in this case, and it is difficult to interpret them, but they include all dates based on dendrochronology, historical chronology and Bayesian statistics. Therefore, the problem is not in the methods themselves, but in the ways they are applied. There is no simple solution in the further building of the absolute chronology for steppe Eurasia. A lot of standard work with typology and stratigraphy is required, but we must take its results with caution, since we have to admit that types of objects of different phases could coexist. Typological comparisons with areas with historical chronology and dendrochronology are needed, as well as correct systematization of radiocarbon dates. By such a way, step by step, we will be able to create the absolute chronology for Eurasia, corresponding to the historical chronologies of the Near East and China and European dendrochronology.

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ЛИТЕРАТУРА

1 *Беседин В.И.* «Микенский» орнаментальный стиль эпохи бронзы в Восточной Европе // Евразийская лесостепь в эпоху металла / Пряхин А.Д. (ред.). Воронеж: Воронежский ун-т, 1999. С. 45-59.

2 *Боталов С.Г., Григорьев С.А., Зданович Г.Б.* Погребальные комплексы эпохи бронзы Большекараганского могильника (публикация результатов археологических раскопок 1988 года) // Материалы по археологии и этнографии Южного Урала / Иванова Н.О. (ред.). Челябинск: Каменный пояс, 1996. С. 64-88.

3 *Виноградов Н.Б.* Древнее Устье: укрепленное поселение бронзового века в Южном Зауралье. Челябинск: Абрис, 2013. 484 с.

4 *Гасс А., Горячев А.А.* К вопросу о типологии и хронологии могильников эпохи бронзы в высокогорной зоне Заилийского Алатау // Вестник Новосибирского гос. ун-та. Сер.: История, филология. 2016. Т. 15, № 5: Археология и этнография. С. 85-123.

5 *Григорьев С.А.* Хронология сейминско-турбинских бронз на основании ближневосточных и китайских источников и датировки извержения Санторина // Археология Евразийских степей. 2022. № 6. С. 186-200.

6 *Епимахов А.В.* Радиоуглеродные аргументы абашевского происхождения синташтинских традиций бронзового века // Уральский исторический вестник. 2020. № 4 (69). С. 51-60.

7 *Епимахов А.В.* Хронология алакульской культуры (новые материалы к дискуссии) // Краткие сообщения Института археологии. 2023. Вып. 270. С. 171-186.

8 *Зах В.А., Рябогина Н.Е., Илюшина В.В., Иванов С.Н., Мурзина Е.И.* Федоровский поселок Курья 1 в системе Андреевских озер // Вестник археологии, антропологии и этнографии. 2013. № 1 (20). С. 10-23.

9 *Зданович Г.Б., Малютина Т.С., Зданович Д.Г.* Материалы к исследованию ранних этапов синташтинской культуры (укрепленное поселение Аландское) // Проблемы археологии: Урал и Западная Сибирь / Вохменцев М.П. (ред.). Курган: Курганский гос. ун-т, 2007. С. 103-108.

10 *Зданович Г.Б., Малютина Т.С., Зданович Д.Г.* Аркаим. Археология укреплённых поселений. Кн. 1. Челябинск: Челябинский гос. ун-т, 2020. 450 с.

11 *Илюшина В.В.* Керамика федоровской культуры поселения Щетково 2 в Нижнем Притоболье (результаты технико-технологического анализа) // Вестник археологии, антропологии и этнографии. 2015. № 4 (31). С. 38-47.

12 *Малютина Т.С., Зданович Г.Б.* Куйсак – укрепленное поселение протогородской цивилизации Южного Зауралья // Россия и Восток: проблемы взаимодействия / Зданович Г.Б., Иванова Н.О., Таиров А.Д. (ред.). Челябинск: Челябинский гос. ун-т, 1995. Ч. V, кн. 1. С. 100-106.

13 *Мимоход Р.А.* 14С данные посткатакомбных памятников Поволжья и Волго-Уралья в контексте региональной радиоуглеродной хронологии // Поволжская археология. 2023. № 1 (43). С. 27-39.

14 *Молодин В.И., Епимахов А.В., Марченко Ж.В.* Радиоуглеродная хронология культур эпохи бронзы Урала и юга Западной Сибири: принципы и подходы, достижения и проблемы // Вестник Новосибирского гос. ун-та. Сер.: История, филология. 2014. Т. 13. Вып. 3: Археология и этнография. С. 136-167.

15 *Поляков А.В.* Радиоуглеродные даты памятников андроновской (фёдоровской) культуры на Среднем Енисее // Записки Института истории материальной культуры РАН. 2019. № 20. С. 163-173.
16 *Сариниди В.И.* Древности страны Маргуш. Ашхабад: Ылам, 1990. 316 с.
17 *Усманова Э.Р., Панюшкина И.П.* Андроновские памятники Лисаковской округи // Археология Казахстана в эпоху независимости: итоги, перспективы. В 3-х т. Т. 1. / Отв. ред. А.З. Бейсенов. Алматы: ИА КН МОН РК, 2011. С. 375-380.
18 *Черных Е.Н.* Каргалы. Т. V: феномен и парадоксы развития; Каргалы в системе металлургических провинций; Потаенная (сакральная) жизнь архаичных горняков и металлургов. М.: Языки славянской культуры, 2007. 200 с.
19 *Athanassas C.D., Modis K., Alçiçek M.C., Theodorakopoulou K.* Contouring the Cataclysm: A Geographical Analysis of the Effects of the Minoan Eruption of the Santorini Volcano // Environmental Archaeology. 2017. DOI: 10.1080/14614103.2017.1288885
20 *Bruins H.J., Van der Plicht J., MacGillivray J.A.* The Minoan Santorini eruption and tsunami deposits in Palaikastro (Crete): dating by geology, archaeology, ^{14}C, and Egyptian chronology // Radiocarbon. 2009. 51/2. Pp. 397-411.
21 *Brunner M., von Felten J., Hinz M., Hafner A.* Central European Early Bronze Age chronology revisited: A Bayesian examination of large-scale radiocarbon dating. Central European Early Bronze Age chronology revisited: A Bayesian examination of large-scale radiocarbon dating // PLoS ONE. 2020. 15 (12): e0243719.
22 *Chang K.C.* Shang Civilization. New Heaven: Yale University Press, 1980. 417 p.
23 *Fischl K.P., Kiss V., Kulcsár G., Szeverényi V.* Transformations in the Carpathian Basin around 1600 B.C. // Tagungen des Landesmuseums für Vorgeschichte Halle. 2013. Bd. 9. Pp. 355-371.
24 *Gerloff S.* Reinecke's ABC and the chronology of the British Bronze Age // Beyond Stonehenge essays on the Bronze Age in honour of Colin Burgess / Burgess Ch., Topping P., Lynch F. (eds.). London: Oxbow Books, 2007. Pp. 117-161.
25 *Grigoriev S.A.* Ancient Indo-Europeans. Chelyabinsk: Rifei, 2002. 444 p.
26 *Grigoriev S.A.* Eastern influences and the transition to new types of metalworking at the end of the Early Bronze Age in Central Europe // Musaica Archaeologica. 2018. 2. Pp. 33-49.
27 *Grigoriev S.A.* Central European impulses in Eastern Europe in the early second millennium BC // Slovenská Archeológia. 2019. 2. Pp. 225–239.
28 *Grigoriev S.A.* Andronovo Problem: Studies of Cultural Genesis in the Eurasian Bronze Age // Open Archaeology. 2021. 7. Pp. 3-36.
29 *Grigoriev S.A.* The evolution of antler and bone cheekpieces from the Balkan-Carpathian region to Central Kazakhstan: chronology of "chariot" cultures and Mycenaean Greece // Journal of ancient history and archaeology. 2021**a**. 8.2. Pp. 148-189.
30 *Grigoriev S.A.* Origins of the Greeks and Greek dialects // Journal of ancient history and archaeology. 2022. 1. Pp. 5–46.
31 *Grigoriev S.* Chronology of the Seima-Turbino bronzes, early Shang Dynasty and Santorini eruption // Prähistorische Zeitschrift. 2023. 98 (2). Pp. 569-588.
32 *Grigoriev S.A.* Absolute chronology of the Early Bronze Age in Central Europe, Middle Bronze Age in Eastern Europe, and the "2200 event" // Journal of ancient history and archaeology. 2023**a**. 10.1. P. 22-46.
33 *Grigoriev S.A.* Horse and Chariot: Critical Reflections on one Theory // Archaeologia Austriaca. 2023**b**. 107. Pp. 159-190.
34 *Gürsan-Salzmann A.* The New Chronology of the Bronze Age Settlement of Tepe Hissar, Iran. Philadelphia: University of Pennsylvania Press, 2016. 408 p.
35 *Hernández P.M.S., Maestre F.J.J., Padilla J.A.L.* The social and political situation between 1750 and 1500 cal. B.C. in the central Spanish Mediterranean: an archaeological overview // Tagungen des Landesmuseums für Vorgeschichte Halle. 2013. Bd. 9. Pp. 303-314.
36 *Jia P.W., Betts A., Cong D., Xiaobing J., Dupuy P.D.* Adunqiaolu: new evidence for the Andronovo in Xinjiang, China // Antiquity. 2017. 91 (357). Pp. 621-639.
37 *Kohl Ph.L.* Central Asia (Western Turkestan): Neolithic to the Early Iron Age // *Chronologies in Old World Archaeology* / Ehrich R.W. (ed.). Chicago, London: University of Chicago Press, 1992. Pp. 179-195.
38 *Leshtakov K.* The second millennium BC in the Northern Aegean and the adjacent Balkan lands: main dynamics of cultural interaction. The Second Millennium BC in the Northern Aegean and the Adjacent Balkan Lands: Main Dynamics of Cultural Interaction // Greeks and Thracians: Acts of the International Symposium "Greeks

and Thracians along the Coast and in the Hinterland of Thrace during the Years before and after the Great Colonization" / Bonias Z., Perreault J. (eds.). Thasos, 2009. Pp. 53-82.
39 *Li Min* Social memory and state formation in Early China. Cambridge: University press, 2018. 582 p.
40 *Lull V., Micó R., Herrada C.R., Risch R.* Political collapse and social change at the end of El Argar // Tagungen des Landesmuseums für Vorgeschichte Halle. 2013. Bd. 9. Pp. 283-302.
41 *Manning S.W.* Second Intermediate Period date for the Thera (Santorini) eruption and historical implications // PLoS ONE. 2022. 17 (9): e0274835.
42 *Marchenko Z.V., Svyatko S.V., Molodin V.I., Grishin A.E., Rykun M.P.* Radiocarbon chronology of complexes with Seima-Turbino type objects (Bronze Age) in Southwestern Siberia // Radiocarbon. 2017. 59. Pp. 1-17.
43 *Marthari M.* The ceramic evidence for contacts between Thera and the Greek Mainland // Wace and Blegen: Pottery as Evidence for Trade in the Aegean Bronze Age / Zerner C. *et al.* (eds.). Amsterdam: Brill, 1993. Pp. 249-256.
44 *Metzner-Nebelsick C.* Gedanken zur Frage des kulturellen Wandels in der Zeit um 1600 v. chr. in Nordwest-Rumänien und Nordost-Ungarn // Tagungen des Landesmuseums für Vorgeschichte Halle. 2013. Bd. 9. Pp. 327-354.
45 *Müller J., Lohrke B.* Neue absolutchronologische Daten für die süddeutsche Hügelgräberbronzezeit // Germania. 2009. 87. Pp. 1-14.
46 *Oppenheimer C.* Ice core and palaeoclimatic evidence for the timing and nature of the great mid-13th century volcanic eruption // International Journal of Climatology. 2003. 23. Pp. 417-426.
47 *Panyushkina I.P., Mills B.J., Usmanova E.R., Cheng L.* Calendar Age of Lisakovsky Timbers Attributed to Andronovo Community of Bronze Age in Eurasia // Radiocarbon. 2008. 50 (3). Pp. 459-469. doi:10.1017/S0033822200053558
48 *Pearson Ch., Salzer M., Wacker L., Brewer P., Sookdeo A., Kuniholm P.* Securing timelines in the ancient Mediterranean using multiproxy annual tree-ring data // Proceedings of the National Academy of Sciences. 2020. 117 (15). Pp. 8410-8415.
49 *Pearson Ch., Sigl M., Burke A., Davies S., Kurbatov A., Severi M., Cole-Dai J., Innes H., Albert P.G., Helmick M.* Geochemical ice-core constraints on the timing and climatic impact of Aniakchak II (1628 BCE) and Thera (Minoan) volcanic eruptions // PNAS Nexus. 2022. 1 (2), pgac048, https://doi.org/10.1093/pnasnexus/pgac048
50 *Risch R., Meller H.* Change and Continuity in Europe and the Mediterranean around 1600 BC // Proceedings of the Prehistoric Society. 2015. 81. Pp. 239-264.
51 *Salzer M.W., Hughes M.K.* Bristlecone pine tree rings and volcanic eruptions over the last 5000 yr // Quaternary Research. 2006. 67 (1). Pp. 57–68.
52 *Schreiber F.A., Korochkova O.N., Novikov I.K., Usmanova E.R.* Radiocarbon Dating of Late Bronze Age Burials from the Great Urals (Steppe Trans-Urals and Northern Kazakhstan) and Bayesian Modeling // Journal of Field Archaeology. 2023. 48/3. Pp. 1-17.
53 *Scuderi L.A.* Tree-Ring Evidence for Climatically Effective Volcanic Eruptions // Quaternary Research. 1990. 34. Pp. 67-85.
54 *Vanzetti A.* 1600? The rise of the Terramara system (northern Italy) // Tagungen des Landesmuseums für Vorgeschichte Halle. 2013. Bd. 9. Pp. 267-282.
55 *Wiener M.H.* Helladic Greece from the Middle Bronze Age to c. 1350 BCE // From Past to Present. Studies in Memory of Manfred O. Korfmann / Blum S.W.E., Efe T., Kienlin T.L., Pernicka E. (eds.). Bonn: Habelt, 2020. Pp. 279-332.
56 *Zhang X., Qiu Sh., Cai L., Bo G., Wang J., Zhong J.* Establishing and Refining the Archaeological Chronologies of Xinzhai, Erlitou and Erligang Cultures // Chinese Archaeology. 2008. 8. Pp. 197-210.

REFERENCES

1 Besedin, V. I. 1999. In: Pryakhin, A. D. (ed.). *Evrazijskaya lesostep v epohu metalla (Eurasian forest-steppe in the metal age).* Voronezh: Voronezh University, 45-59 (in Russian).
2 Botalov, S. G., Grigoriev, S. A., Zdanovich, G. B. 1996. In: Ivanova, N. O. (ed.). *Materialy po arheologii i etnografii Yuzhnogo Urala (Materials on archaeology and ethnography of the Southern Urals).* Chelyabinsk: "Kamenniy Poyas" Publ., 64–88 (in Russian).

3 Vinogradov, N. B. 2013. *Drevnee Ustie: ukreplennoe poselenie bronzovogo veka v Juzhnom Zauralie (Ancient Ustye: a fortified Bronze Age settlement in the Southern Transurals).* Chelyabinsk: "Abris" Publ. (in Russian).
4 Gass, A., Goryachev, A. A. 2016. In: *Vestnik Novosibirskogo universiteta. Seriya: Istoriya, filologiya (Bulletin of the Novosibirsk University. Series: History, Philology),* 15 (5): Archaeology and Ethnography, 85-123 (in Russian).
5 Grigoriev, S. A. 2022. In: *Arheologiya Evrazijskih stepej (Archaeology of the Eurasian steppes),* 6, 186–200. (in Russian).
6 Epimakhov, A. V. 2020. In: *Uralskiy istoricheskiy vestnik*, 4 (69), 51-60 (in Russian).
7 Epimakhov, A. V. 2023. In: *Kratkiye soobshcheniya Instituta arkheologii (Brief Communications of the Institute of Archaeology),* 270, 171-186 (in Russian).
8 Zakh, V. A., Ryabogina, N. E., Ilyushina, V. V., Ivanov, S. N., Murzina, E. I. 2013. In: *Vestnik arheologii, antropologii i etnografii (Bulletin of archaeology, anthropology and ethnography),* 1 (20), 10-23 (in Russian).
9 Zdanovich, G. B., Malyutina, T. S., Zdanovich, D. G. 2007. In: Vohmentsev, M. P. (ed.). *Problemy arheologii: Ural i Zapadnaya Sibir (Problems of archaeology: the Urals and Western Siberia).* Kurgan: Kurgan University, 103-108 (in Russian).
10 Zdanovich, G. B., Malyutina, T. S., Zdanovich, D. G. 2020. *Arkaim. Arheologiya ukreplyonnyh poseleniy. Kn. 1 (Archaeology of fortified settlements. Book 1).* Chelyabinsk: University press. (in Russian).
11 Ilyushina, V. V. 2015. In: *Vestnik arheologii, antropologii i etnografii (Bulletin of Archaeology, Anthropology and Ethnography),* 4 (31), 38-47 (in Russian).
12 Malyutina, T. S., Zdanovich, G. B. 1995. In: Zdanovich, G. B., Ivanova, N. O., Tairov, A. D. (eds.). *Rossiya i Vostok: problemy vzaimodejstviya (Russia and the East: problems of interaction).* Part 5, book 1. Chelyabinsk: Chelyabinsk University, 100-106 (in Russian).
13 Mimokhod, R. A. 2023. In: *Povolzhskaya archeologia (The Volga River region archaeology)*, 1 (43), 27-39 (in Russian).
14 Molodin, V. I., Epimakhov, A. V., Marchenko, Z. V. 2014. In: *Vestnik Novosibirskogo universiteta (Bulletin of the Novosibirsk University)*, 13 (3), 136-167 (in Russian).
15 Polyakov, A. V. 2019. In: *Zapiski Instituta istorii materialnoy kultury RAN (Notes of the Institute for the History of Material Culture of the RAS),* 20, 163-173 (in Russian).
16 Sarianidi, V. I. 1990. *Drevnosti strany Margush (Antiquities of the country of Margush).* Ashkhabad: "Ylam" Publ. (in Russian).
17 Usmanova, E. R., Panyushkina, I. P. 2011. In: Beisenov, A. Z. (ed.). *Arheologiya Kazahstana v epohhu nezavisimosti: itogi, perspektivy (Archaeology of Kazakhstan in the era of independence: results, prospects).* In 3 vol. Vol. 1. Almaty: Margulan Institute of Archaeology, 375-380 (in Russian).
18 Chernykh, E. N. 2007. *Kargaly: fenomen i paradoksy razvitiya; Kargaly v sisteme metallurgicheskih provintsiy (Kargaly: a phenomenon and paradoxes of development; Kargaly in the system of metallurgical provinces).* Moscow: "Jazyki slavyanskoy kultury" Publ. (in Russian).
19 Athanassas, C. D., Modis, K., Alçiçek, M. C., Theodorakopoulou, K. 2017. In: *Environmental Archaeology*, doi: 10.1080/14614103.2017.1288885 (in English).
20 Bruins, H. J., Van der Plicht, J., MacGillivray, J. A. 2009. In: *Radiocarbon*, 51/2, 397-411 (in English).
21 Brunner, M., von Felten, J., Hinz, M., Hafner, A. 2020. In: *PLoS ONE*, 15 (12), e0243719 (in English).
22 Chang, K. C. 1980. *Shang Civilization*. New Heaven: Yale University Press (in English).
23 Fischl, K. P., Kiss, V., Kulcsár, G., Szeverényi, V. 2013. In: *Tagungen des Landesmuseums für Vorgeschichte Halle*, 9, 355-371 (in English).
24 Gerloff, S. 2007. In: Burgess, Ch., Topping, P., Lynch, F. (eds.). *Beyond Stonehenge essays on the Bronze Age in honour of Colin Burgess*. London: Oxbow Books, 117-161 (in English).
25 Grigoriev, S. A. 2002. *Ancient Indo-Europeans*. Chelyabinsk: "Rifei" Publ. (in English).
26 Grigoriev, S. A. 2018. In: *Musaica Archaeologica*, 2, 33-49 (in English).
27 Grigoriev, S. A. 2019. In: *Slovenská Archeológia*, 2, 225–239 (in English).
28 Grigoriev, S. A. 2021. In: *Open Archaeology*, 7, 3-36 (in English).
29 Grigoriev, S. A. 2021**a**. In: *Journal of ancient history and archaeology*, 8.2, 148-189 (in English).
30 Grigoriev, S. A. 2022. In: *Journal of ancient history and archaeology*, 1, 5-46 (in English).
31 Grigoriev, S. 2023. In: *Prähistorische Zeitschrift,* 98 (2), 569-588 (in English).
32 Grigoriev, S. A. 2023**a**. In: *Journal of ancient history and archaeology*, 10.1, 22-46 (in English).

33 Grigoriev, S. A. 2023**b**. In: *Archaeologia Austriaca,* 107, 159-190 (in English).
34 Gürsan-Salzmann, A. 2016. *The New Chronology of the Bronze Age Settlement of Tepe Hissar, Iran*. Philadelphia: University of Pennsylvania Press (in English).
35 Hernández, P. M. S., Maestre, F. J. J., Padilla, J. A. L. 2013. In: *Tagungen des Landesmuseums für Vorgeschichte Halle*, 9, 303-314 (in English).
36 Jia, P. W., Betts, A., Cong, D., Xiaobing, J., Dupuy, P. D. 2017. In: *Antiquity,* 91 (357), 621-639 (in English).
37 Kohl, Ph. L. 1992. In: Ehrich, R. W. (ed.). *Chronologies in Old World Archaeology.* Chicago, London: University of Chicago Press, 179-195 (in English).
38 Leshtakov, K. 2009. In: Bonias, Z., Perreault, J. (eds.). *Greeks and Thracians: Acts of the International Symposium "Greeks and Thracians along the Coast and in the Hinterland of Thrace during the Years before and after the Great Colonization"*. Thasos, 53-82 (in English).
39 Li Min. 2018. *Social memory and state formation in Early China*. Cambridge: University press (in English).
40 Lull, V., Micó, R., Herrada, C. R., Risch, R. 2013. In: *Tagungen des Landesmuseums für Vorgeschichte Halle*, 9, 283-302 (in English).
41 Manning, S. W. 2022. In: *PLoS ONE*, 17 (9), e0274835 (in English).
42 Marchenko, Z. V., Svyatko, S. V., Molodin, V. I., Grishin, A. E., Rykun, M. P. 2017. In: *Radiocarbon*, 59, 1-17 (in English).
43 Marthari, M. 1993. In: Zerner, C. *et al.* (eds.). *Wace and Blegen: Pottery as Evidence for Trade in the Aegean Bronze Age*. Amsterdam: Brill, 249-256 (in English).
44 Metzner-Nebelsick, C. 2013. In: *Tagungen des Landesmuseums für Vorgeschichte Halle*, 9, 327-354 (in German).
45 Müller, J., Lohrke, B. 2009. In: *Germania*, 87, 1-14 (in German).
46 Oppenheimer, C. 2003. In: *International Journal of Climatology*, 23, 417-426 (in English).
47 Panyushkina, I. P., Mills, B. J., Usmanova, E. R., Cheng, L. 2008. In: *Radiocarbon,* 50 (3), 459-469 (in English).
48 Pearson, Ch., Salzer, M., Wacker, L., Brewer, P., Sookdeo, A., Kuniholm, P. 2020. In: *Proceedings of the National Academy of Sciences*, 117 (15), 8410-8415 (in English).
49 Pearson, Ch., Sigl, M., Burke, A., Davies, S., Kurbatov, A., Severi, M., Cole-Dai, J., Innes, H., Albert, P.G., Helmick, M. 2022. In: *PNAS Nexus*, 1(2), pgac048. DOI: 10.1093/pnasnexus/pgac048 (in English).
50 Risch, R., Meller, H. 2015. In: *Proceedings of the Prehistoric Society*, 81, 239-264 (in English).
51 Salzer, M. W., Hughes, M. K. 2006. In: *Quaternary Research*, 67(1), 57–68 (in English).
52 Schreiber, F. A., Korochkova, O. N., Novikov, I. K., Usmanova, E. R. 2023. In: *Journal of Field Archaeology,* 48/3, 1–17 (in English).
53 Scuderi, L. A. 1990. In: *Quaternary Research*, 34, 67-85 (in English).
54 Vanzetti, A. 2013. In: *Tagungen des Landesmuseums für Vorgeschichte Halle*, 9, 267-282 (in English).
55 Wiener, M. H. 2020. In: Blum, S. W. E., Efe, T., Kienlin, T. L., Pernicka, E. (eds.). *From Past to Present. Studies in Memory of Manfred O. Korfmann*. Bonn: Habelt, 279-332 (in English).
56 Zhang, X., Qiu, Sh., Cai, L., Bo, G., Wang, J., Zhong, J. 2008. In: *Chinese Archaeology*, 8, 197-210 (in English).

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