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137 ancient human genomes from across the Eurasian steppes

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Supplementary Materials

137 ancient human genomes from across the Eurasian steppe

Contents:

Section 1: Archaeological background for Iron Age to Medieval steppe cultures

By Kristian Kristiansen, Peter de Barros Damgaard, Lotte Hedeager, and Nikolay Kradin

The steppe belt of Eurasia has undergone intense population dynamics with influences from Europe, Western Asia, South Asia and East Asia. We here describe the chronological succession of these different archaeological cultures and languages particularly focused on the periods that succeed the Bronze Age.

Transition to Iron Age in the steppe

First we shall provide a brief background to the transition from Late Bronze Age to Early Iron Age societies. By the end of the Bronze Age, the descendants of western Srubnaya groups and eastern Andronovo groups had become increasingly sedentary, although still retaining a herding economy based on cattle husbandry[40,41]. The final Bronze Age experienced a significant and widespread increase in aridity, beginning around 1200 BCE[42,43]. It meant an extension of seasonal herding movements, and some groups leaving the drier parts of the steppe. Also, the introduction of iron technology demanded large quantities of timber for charcoal, which meant that the forest steppe gained in importance for iron production. However, around 850/800 BCE a rapid cooling event followed by a more humid climate once again made the steppe more productive and allowed new pastoral groups to enter, which provided a boost for the emergence of Scythian culture[44].

In south Siberia there is described a continuous cultural sequence from Andronovo-related to Karasuk and Saka-related cultural groups[45,46]. In Mongolia, the transition from Late Bronze Age to Iron Age culture included the Khirigsuur (West) and Slab Burial culture (East). In the Ordos, this was the Ordos Bronze culture (Taohongbala – Maoqinggou), while, in Inner Mongolia, these were of Xijiadian culture and, later on, Jinggouzi culture[47]. The mentioned cultures were approximately synchronous to the archaeological periods on the Central Plain of China from the Shang dynasty till the Warring States period[48].

The expansion of Iranian speaking mounted nomads (850BCE – 300 BCE). Cimmerians, Scythians, Sakas and related groups.

The Scythians were true mounted archers who dominated the Eurasian steppe throughout the Iron Age. They held a military competitive advantage over their neighbors, the emerging civilizations in Iran to the south, China to the east, the European hinterlands to the west, the forest steppe cultures, and the hunter gathering groups in the northern steppe tundra[41]. The first time these powerful and feared 'barbarians' appeared in written sources is when described by Herodotus and others, and it is for this reason that we put tribal or ethnic names on them. However, the exact nature and origins of the Scythian organization is controversial.

The "Scythian" affiliation is an attribution given to various nomadic entities with shared traditions, which were characterized in contemporary and later written sources (Achaemenid, Greek, and Chinese sources). Now they are known to present-day archaeology through their burials and associated material culture, in particular through petroglyphs such as the Deer Stone[49–51] found in association to kurgan

burials and elaborate ritual structures in Mongolia, Altai and the Tian Shan, as well as metallurgic widespread across both the western and the central steppe. Their timber chamber tombs are found from east central Europe to south Siberia. In Tuva, we find ostentatious chiefly or princely burials in Arzan 1 and Arzan 2, from 800-600 BCE, which show close affinities to a chiefly network/confederation in the eastern steppe[52], but also strong affinities to the timber chamber burials in Kelermes in Caucasus and the Hallstatt C chamber burials in Central Europe[53], in essence representing a network that connected all corners of Eurasia.

Scythians and their confederations created a 'barbarian' periphery to the civilizations, which by now were depending on them for providing essential trading goods, from silk to horses. This lead to the emergence of a new economic sector that supported the formation of large-scale political confederations designed to maintain this prosperous trade. Likewise, the steppe nomads had become dependent on the urban civilizations for luxury goods and grain to supplement their diet. The steppe nomads' economy remained dependent on stock breeding, and although there were variations throughout the vast Eurasian steppe belt, the combination of pastoralism, warfare and trade remained the foundation for the steppe economy well into modern times.

Based on both archaeology and anthropology four main groups of Scythians can be defined: i) the Altaian Scythians, mainly represented by the Tagar and Pazyryk groups[54] and by some considered to represent the main Scythian centre[55], ii) the central steppe Scythians forming the 'Tasmola culture'[56], iii) the Tian Shan mountain Scythians, referred to as the Scytho-Saka cultures[57], and iv) the western Scythians in the Danube region in Eastern Europe[58] thereby encircling most of the present-day Kazakh steppe. However, the primordial genetic and/or cultural origins of the Scythians remains contested. Three conflicting hypotheses prevail, summarized as a western origin, an eastern origin and a multipe origins model.

Some scholars suggest that the Scythian culture with its characteristic figurative animal art of deer and lion likely arose in the Black Sea/Caucasus area, and quickly spread over the western and central steppe territory, from the Hungarian plains to the Altai, the Tian Shan and back to the Caspian Sea[5–7]. Some have considered these population movements as conquest migrations[6,59] while others propose a more prolonged period of steppe interaction and transformation starting in the Late Bronze Age[60]. It seems plausible that the early animal motifs, such as lion heads, emerged from early interactions between Cimmerians and Urartu culture in Iran[6]. Recent series of C14 datings have also revealed that the early Scythian/Saka culture in the east started already in the 9th century thus preceding the western Scythians[56]. These dates are comparable to the Cimmerian horizon, and under this western model, the Cimmerians would thus have been forerunners of Scythian culture and expanded west and eastwards taking over the steppe territory through militant dominance.

However, this hypothesis is in stark contrast to both genetic and cultural evidence of Late Bronze Age herders, associated to the Andronovo horizon, interacting and admixing with local hunter-gatherer groups populating the steppe[2,9,11,61] and disseminating art and culture forming large nomadic confederations. The archaeological chronology of the central steppe suggests a major population turnover associated with the onset of the Scythian period, where the increasing aridity at the end of the Bronze Age from 1200- 800 BCE led to a gradual exodus of many groups thus depleting the central steppe from human occupation[62]. The rapid increase in precipitation from 800 BCE (van Geel 2004) improved grazing productivity over large stretches of the central steppe, attracting nomads from the Khakassian and Minusinsk Basins. These were descendants of Late Bronze Age herders who admixed with southern Siberian and descendants of forest-steppe hunter-gatherer groups. These migrations into the central steppe also moved into Tuva, where early Scythian royal tombs were found[44,63]. The Inner

Asian model therefore considers Southern Siberia as the origin of a Scythian population and culture, coupled to a westward migration.

In an attempt to reconcile these models and explain evidence for local distinctions between Scytho-Saka cultures others have formulated a multiple origins model[12,13]. These suggestions consider that both the western steppe and the central and eastern steppes had distinct population histories, but that these groups united under the same steppe confederation while borrowing cultural elements from each other. This suggestion is in accordance with existing genetic evidence[11] and completely re-frames the conception of a "Saka population". In this view Scythian tradition ought to be considered as a cultural horizon that does not reflect population genetic history, but rather a political and military organization that was highly advantageous and could not be defeated by the surrounding civilizations. This dominance lasted throughout the Iron Age until the time of Common Era. The genome-wide data presented herein is in agreement with multiple genetic origins and cultural associations to Scythian tradition, therefore re-theorizes the conception of the Scythians as an ethnic designation.

By the time of the unification of China (221 BCE), there is mentioning of the Yuezhi people who lived in the steppe on the north-west boundaries of the Central Plain. They are frequently identified with the Pazyryk archaeological culture and the Eastern Scythians, such as Sacae, Tochari, and Massagetae (Strabo, Geography, 11.8.1.). The Pazyryk polity was a powerful confederation with large armies. They traded with the Central Plain states, controlled the trading routes to Central Asia and conquered the other Iranian nation Wusun to the West and Xiongnu to the East. Finally, the Xiongnu leader Maodun defeated them in middle second century BCE. They were not only defeated, but large groups appear to have been forced to move off to Transoxiana. There, they were subject to gradual Hellenization and played an important role in the Kishan empire formation. Thus historical and archaeological evidence point to eastward movements of eastern steppe nomad as key for explaining the demise of the Scythian confederation.

Sauromatians and Sarmatians (500 BCE- 400 CE)

The Sauromathians originated in the cultural and economic transformations that changed the semi-nomadic late Bronze Age cultures into mounted nomads between the Don river and the southern Urals during the sixth to fifth centuries BCE. Sarmatians continued this development through incorporation of new groups and cultural traits, and thus finally formed a western branch of the Scythian confederation during the second half of the Iron Age, which persisted into the first centuries CE, now under Sarmatian leadership. Their power ended with the invading Huns during the fourth century CE, and the remaining Sarmatians formed a hybrid culture, called the Hun-Sarmatian, or Gunno-Sarmatian culture that lasted a few centuries. Their language was Scythian, a north eastern Iranian dialect. During the apex of their power they represented a formidable military force, and according to legend they descended from Scythian men and Amazon women, the latter being fighting women, who had been expelled from the Cappadocian area, in present-day Turkey. According to these legends recorded as historical events by Herodotus (4.110-117), the women were forced into the Black Sea from where they sailed unto the present-day Azov Sea, hence reaching Scythian territory.

Thus, from the sixth century BCE to the fourth century CE, Sauromathians and later Sarmatians gradually came to occupy the territory from the Danube River to the Southern Urals and the Aral Sea. Three stages can be identified: Early Sarmatian or Prokhorovo culture (400-200 BCE), Middle Sarmatian (150 BCE - 150 CE) and Late Sarmatian (150 – 400 AD) (Davis-Kimball, Bashilov, and Yablonsky 1995, chapters 6-12). The Sarmatians were mounted nomads as the Scythians, and during the third century BCE, they expanded westwards and conquered the Northern Black Sea region. They

had frequent commercial contacts with the ancient colony towns on the northern coast of the Black Sea, Greeks and later Romans, and carried out raids or extorted tribute. On their eastern border, they had contact with the Caucasus and Central Asia. This territory, between the Azov and Caspian Seas, is frequently called the Asian Sarmatia.

Ancient authors compared Sarmatian women with the fighting Amazons. "They do not lay aside their virginity until they have killed three of their enemies, and they do not marry before they have performed the traditional sacred rites." (Hippocrates, *De Aere* XVII). In the first century BCE, the Sarmatians and Parthians introduced heavy cavalry (cataphract). The body of the cavalier was protected by scale armour, the head by a spiked helmet. Weapons were sword and lance. Organized in ordered lines they represented a menacing force[64].

With their powerful cavalry, the Sarmatians now approached the frontiers of Rome, in alliance with Germanic tribes, and began a series of wars against the Empire. They constituted a great threat and on several occasions, Rome had to conclude peace treaties with the nomads. After 50 CE the Sarmatians established a large confederation – by some termed a super-complex chiefdom or early state[65]. It represented the apex of their power, which now encompassed a territory stretching from the Vistula to the Volga. Soon after their power was broken first by the invading Goths, and during the fourth century CE by the invasion of the Huns. Some groups allied with the Goths migrated to the Roman frontiers, and were merged in the empire[66], while others mixed with the settled population of Eastern Europe. Finally, a branch of Sarmatians moved into the northern Caucasus where they are thought to be the ancestors of the people of the Iranian speaking Alan culture and todays Ossets of the Caucasus Mountains[67].

The early formation and expansion of Turkic speaking mounted nomads. Xiongnu, Donghu, Huns and related groups (700 BCE- 500 CE)

The formation and expansion of nomadism in Eastern Asia coincided with the last pre-imperial stages of the Chinese Empire: Spring and Autumn (770 – 476 BCE), and Warring States (475 – 221 BCE). The Chinese chronicles report of the nomads Hu (胡) in the pre-Han periods. It is a collective name for the north pastoral peoples, consisting of many individual small polities and ethnic groups. They would soon after unify the eastern steppe under a new political and military leadership by the Xiongnu in the last part of the third century BCE[47,68]. To the North-East of the Central Plain, the Donghu (or Tung Hu) were located, corresponding to the archaeological culture of slab burials (or Slab Grave Culture 1000-400 BCE). The sites of this culture are located in East Mongolia and in the East Baikal area[69]. Ancient Chinese historians recognized that the Donghu language was proto-Mongolic. Donghu formed a large polity, similar in power to the Xiongnu. The Donghu, however, were defeated by the Xiongnu leader Maodun at the turn of the third to second centuries BCE. Thereafter, the nomadic empire of Xiongnu was established[24]. It was the largest nomadic polity in Eastern Asia for more than two hundred years. Unique elite burials of the Xiongnu were discovered in Mongolia and Transbaikalia with elegant golden and silver goods, embroidered carpet, remarkable foreign gifts[70–76].

The ethnic and archaeological origin of the Xiongnu is contested. Some researchers see the beginnings of the Xiongnu archaeological culture in migrating groups from the so-called Slab Burial Culture[77,78], others in the Ordoss Culture[17,79,80], while a third group connect the Xiongnu with the Scythian sites from Siberia[81,82]. According to Mongolian anthropologists results from comparative craniofacial analysis suggest that they arose through a mixing of western and eastern groups, a process of admixture that began in the Mongolian territory as early as the Neolithic age and lasted until the Mongolian invasions.

There is also a rather close relation between ancient DNA of the Xiongnu and modern Mongols[83,84]. Some scientists propose the Xiongnu came to the Mongolian territory from the West rather than from the East due to the presence of a Y-chromosomal haplogroup characteristic for Indo-European speakers[18]. Other researchers are prone to connect their origin with the indigenous people of the Mongolian steppes[85].

Linguistic reconstructions based on Xiongnu vocabulary recorded in Chinese sources suggest that in the early centuries of the first millennium CE, an archaic Turkic language existed in the territory between Ordos and Sayano-Altai[15]. However, it should be remembered that the Xiongnu were a poly-ethnic and a poly-lingual nomadic empire. According to written sources the Xiongnu aristocracy included also Chinese counselors and military commanders (most famous among them is warlord Li Ling). Ethnic tolerance has been suggested based genetic data[18], and the genome-wide data presented herein clearly distinguishes between two different clusters of Xiongnu nomads, an East Asian and an admixed group with west Eurasian steppe nomad ancestry. If, according to data of physical anthropology, the Xiongnu of the Central and West Mongolia are close to the cultures of the Turkic circle, then the Xiongnu of East Mongolia bear many similarities to the Xiongnu of the East Baikal area and Xianbei[86].

In 48 CE the Empire was divided into a northern and southern confederation. The southern confederation accepted the Chinese protectorate, and they were gradually assimilated by the Chinese. In 91 CE the northern confederation was defeated. After that a group of Xiongnu nomads departed to Central Asia, and some went further to Europe and became known under the name of Huns[20,87]. Data presented herein shows that the Hun period nomads were Scythians admixed with East Asians indicating assimilation into the local population. Previously, the similarity among iron cauldrons for feasting from eastern to western Eurasia has been taken as evidence of migration[88,89]. However, the classic dilemma had remained: what moved – people or artefacts[90]? While there are many supporters of the Xiongnu migration to the West among archaeologists, Sergey Botalov recently presented the idea of a stepwise migration of the Xiongnu first to the Ural and then to Europe[91]. In Kazakhstan, Alexandr Podushkin discovered the Arysskaya culture in which he identified a phase with Xiongnu influence[92]. We also find Hunnic burials in the Caucasus[93]. Likewise, it is possible to trace the custom of cranial deformation over a wider region[94], just as Hunnic material culture has been systematically mapped[95]. Their historical rise and fall was exposed in a classic study[96].

A process of stepwise Hunnic migrations and local incorporation into the Hunnic polity therefore seems a likely scenario, thus blurring direct archaeological similarities between Xiongnu and Huns. This view is in agreement with the ancient DNA evidence presented herein.

Early Mongols (100-550 CE)

After the collapse of the Northern Xiongnu, nomads of the eastern steppe accepted the ruling of the Xianbei, and this became the beginning of the hegemony of the ancient Mongols 100-555 CE. Xianbei gradually occupied the whole territory from Inner Mongolia to Central Asia. The greater part of the ethnically Xianbei chiefdoms and tribes was concentrated in the central and eastern areas of the imperial confederation[97]. At this time, the invention of the stirrup became an important stage in cavalry development. The stirrup allowed the use of the long sword and enhanced the use of archery at full tilt. The prosperity of Xianbei evolved during the ruling of T'an-shih-huai in 156-180 CE. With his death, the confederation was divided into several parts. In the late 2nd century AD, more than 50 ethnic tribes coming from Donghu were located in the territory of the Xianbei confederation, many of which are

mentioned in written sources.

Apart from Xianbei and Wuhuan, the Murong, Tuoba, Tuyuhun, Yuwen, Yuchi, Kumo Xi (Tatabi), Rouran, Shiwei, and Khitan are also known as early Mongols. After the collapse of the Han dynasty, the time was ripe for the Sixteen Kingdoms (304 - 439 CE) in the history of China. In this period, many small kingdoms were established but they were quickly destroyed. Many kingdoms were then founded by nomads who migrated to the territories of Northern China and were gradually assimilated by the settled population (Taskin 1989–2012). The greatest state was established by Tuoba (T'o-pa, Tabgach). Tuoba were one of the largest segments of Xianbei, stretching over the mountain slopes of the Khingan. In the early 4th century CE, they founded a confederation and, then, migrated south of the Gobi and created the Northern Wei dynasty (386–535). It was a large state which occupied a considerable part of Northern China with settled populations. The ruling dynasty became estranged from the nomadic mode of life but remembered its origin[98].

In the North, in the Mongolian steppe, the Rouran Khaganate was created 402 CE. These were also Mongolian-speaking people. The Rouran Khaganate occupied a vast territory from the Ili river to the boundaries of Koguryo[99]. After the crushing defeat of the Rouran Khaganate in 552 CE, the remainder of the population migrated to Pannonia where they became known as Avars. They introduced the stirrup and cavalry to Europe[100]. The blacksmiths of the Rourans in turn overtook domination of the central steppe: the Turks[99].

The later expansion of Turkic-speaking nomads (500 – 1200 CE)

The origin and spread of Turkic-speaking peoples remain debated[22,25], not least the relation between the eastern Xiongnu and the western Huns. The Turkic written languages are attested only from the early 8th century CE onwards with the Orkhon inscriptions of Mongolia[38,101]. However already during the second and third century CE the steppe gradually went from being populated by Iranian-speaking groups to become increasingly Turkic speaking and inhabited by steppe nomads associated with the Xiongnu tradition[20].

The first written Turkic sources and reported Turk polities, the Göktürk Khaganate of the 6-8th centuries CE[22,25,102], covered the same area that was previously Scythian, then Hunnic, territory. After the collapse of the Rouran Khaganate the Eurasian steppes came under Turk domination. The period saw the development of heavy cavalry with heavy spears. They conquered territory in a westward direction and reached the Black Sea. In the west it extended to the Volga river and the Caspian see, in the east to the Manchuria forests, in the north to Lake Baikal and the upper reaches of the Amur, and in the south to the great Gobi desert. Nomads controlled the Silk road and trade communication between the T'ang empire in China, Muslim caliphates, and the Byzantine Empire. In 603, the Khaganate was divided into an Eastern (603 - 630) and Western (603 - 704) part. In the Mongolian steppes Turkic-speaking peoples later created the Second Göktürk Khaganate (682 - 745) and the Uighur Khaganate (744 - 840). In Central Asia Turkic-speaking peoples formed the Kimak Khaganate (750 – 1035), Oghuz Khaganate (750 – 1055), Karluk Khaganate (766 – 940), and Kara-Khanid Khanate (940 – 1212).

Implications

Present-day Turkic-speaking populations consist of more than 20 diverse ethnicities inhabiting geographically distinct areas, from Northwest China to Siberia, Central Asia, the Caucasus, European Russia, Anatolia and Afghanistan. Clearly, the language distribution in the steppes and surrounding

areas today, when compared to the Iron Age, is the result of a gradual population replacement and admixture with incoming groups. Notably, the Turkic language group dates back to the end of the Iron Age around the beginning of the Common Era in Mongolia[38,101], rendering an understanding of the demographic processes that accompany it key to understanding how an entire new language group was formed, and how the languages were disseminated. Tracing the origins and modes of dispersal of Turkic languages – as they gradually replaced Iranian languages - motivated this genomic study in order to come to grips with the complex interplay between cultural, linguistic and genetic change.

Section 2: Linguistic background of the population history of the Eurasian Steppe

By Michaël Peyrot

1. Early Indo-Europeans on the steppe: Tocharians and Indo-Iranians

The Indo-European language family is spread over Eurasia and comprises such branches and languages as Greek, Latin, Germanic, Celtic, Sanskrit etc. The branches relevant for the Eurasian steppe are Indo-Aryan (= Indian) and Iranian, which together form the Indo-Iranian branch, and the extinct Tocharian branch. All Indo-European languages derive from a postulated protolanguage termed Proto-Indo-European. This language must have been spoken ca 4500–3500 BCE in the steppe of Eastern Europe[21]. The Tocharian languages were spoken in the Tarim Basin in present-day Northwest China, as shown by manuscripts from ca 500–1000 CE. The Indo-Aryan branch consists of Sanskrit and several languages of the Indian subcontinent, including Hindi. The Iranian branch is spread today from Kurdish in the west, through a.o. Persian and Pashto, to minority languages in western China, but was in the 2nd and 1st millennia BCE widespread also on the Eurasian steppe. Since despite their location Tocharian and Indo-Iranian show no closer relationship within Indo-European, the early Tocharians may have moved east before the Indo-Iranians. They are probably to be identified with the Afanasievo Culture of South Siberia (ca 2900 – 2500 BCE) and have possibly entered the Tarim Basin ca 2000 BCE[103].

The Indo-Iranian branch is an extension of the Indo-European Yamnaya Culture (ca 3000–2400 BCE) towards the east. The rise of the Indo-Iranian language, of which no direct records exist, must be connected with the Abashevo / Sintashta Culture (ca 2100 – 1800 BCE) in the southern Urals and the subsequent rise and spread of Andronovo-related Culture (1700 – 1500 BCE). The most important linguistic evidence of the Indo-Iranian phase is formed by borrowings into Finno-Ugric languages[104–106]. Kuz'mina (2001) identifies the Finno-Ugrians with the Andronoid cultures in the pre-taiga zone east of the Urals[107]. Since some of the oldest words borrowed into Finno-Ugric are only found in Indo-Aryan, Indo-Aryan and Iranian apparently had already begun to diverge by the time of these contacts, and when both groups moved east, the Iranians followed the Indo-Aryans[108]. Being pushed by the expanding Iranians, the Indo-Aryans then moved south, one group surfacing in equestrian terminology of the Anatolian Mitanni kingdom, and the main group entering the Indian subcontinent from the northwest.

2. Andronovo Culture: Early Steppe Iranian

Initially, the Andronovo Culture may have encompassed speakers of Iranian as well as Indo-Aryan, but its large expansion over the Eurasian steppe is most probably to be interpreted as the spread of Iranians. Unfortunately, there is no direct linguistic evidence to prove to what extent the steppe was indeed Iranian speaking in the 2nd millennium BCE. An important piece of indirect evidence is formed by an archaic stratum of Iranian loanwords in Tocharian[34,109]. Since Tocharian was spoken beyond the eastern end of the steppe, this suggests that speakers of Iranian spread at least that far. In the west of the Tarim Basin the Iranian languages Khotanese and Tumshuqese were spoken. However, the Tocharian B word *etswe* 'mule', borrowed from Iranian **atswa-* 'horse', cannot derive from these languages, since Khotanese has *aśśa-* 'horse' with *śś* instead of *tsw*. The archaic Iranian stratum in Tocharian is therefore rather to be connected with the presence of Andronovo people to the north and possibly to the east of the Tarim Basin from the middle of the 2nd millennium BCE onwards[110].

3. Scythians

For the western and central steppe linguistic evidence is severely limited too. The only variety surviving today is Ossetic, spoken in the northwestern Caucasus in two main dialects: Iron and Digoron. Ossetic is a direct descendant of Alanic, which is attested a.o. through names, a short text in the Theogonia of Tzetzes, marginal notes in a Greek liturgical manuscripts, and the so-called Yassic wordlist[111]. Alanic is in turn closely related to Sarmatian, which is, however, known only through personal names in Greek inscriptions and literary sources[112]. The poor attestation of Sarmatian and Alanic makes an exact dialect assignment difficult. An overview of the defining features of Sarmatian, Alanic and Ossetic is given by Bielmeier[112]. Obviously, these increased as the languages evolved further. As far as can be established with the available evidence, Alanic seems to be descended from Sarmatian directly.

One of the features of Ossetic and Alanic is *p- > f-, a feature that is shared with a steppe dialect tentatively identified as "Scythian" by Lubotsky[113]. In this "Scythian" steppe dialect this change goes back to at least the 8th century BCE. However, in Sarmatian both *p-* and *f-* are found: *p-* in the west of the Sarmatian area, and *f-* in the east. Thus, Lubotsky suggests that *p- > f- was characteristic of East Scythian dialects[113].

Another defining trait of Ossetic and Sarmatian / Alanic is the change *ti, *θi (*θy) > či (in Ossetic reflected as *c*). Interestingly, this change is also found in the archaic stratum of Iranian loanwords in Tocharian; cf. Tocharian B *waipecce* 'possession' from Iranian *hwaipaθya-. This may be taken as an argument that the Iranian steppe dialect represented by the archaic stratum in Tocharian is related to the dialect ancestral to Ossetic and Sarmatian / Alanic. Whether the archaic stratum also had the feature *p- > f- cannot be established because Tocharian has no *f* and any *f* would probably be represented with *p*.

The archaic stratum in Tocharian seems to show yet another trait: a special treatment of the group *rd as in Tocharian B *speltke* 'zeal' from Iranian *spardaka-. Perhaps *rd had developed to *ḍ, which was represented by *lt*[34,109]. A similar change is possibly seen in Turkic *balto* 'axe'[39] from Iranian *paratu*[34], though the same word is borrowed into Tocharian B as *peret*. Probably, *paratu is a specifically Scythian variant of original *paratsu < *paraću*[114]. In the Eastern Iranian language Khotanese from the Tarim Basin, analogous changes are found: *rt develops into *ḍ (cf. Khotanese *paḍa-* 'axe') and *rd into *l*[115].

Another Iranian language that is relevant is Sogdian. Throughout the 1st millennium CE Sogdian, originally from Sogdiana (today partly in Uzbekistan and partly in Tajikistan), was an important language on the eastern steppe and in Northwest China. Present-day Yaghnobi is closely related to it, and a Sogdian-Yaghnobi protolanguage can be posited datable to the 1st millennium BC. Sogdian shares a number of characteristics with the other "East Iranian" languages (to which the Iranian languages of the steppe belong), such as *ft, *xt > vt, γt*[116], but Sogdian and Yaghnobi do not show the supposedly Scythian change *p- > f-. The change *ti > či is not found in Sogdian in the same way as in Sarmatian / Alanic either. It seems impossible to decide on linguistic grounds when the Sogdians settled in Sogdiana. Therefore it remains uncertain whether there was a non-Scythian pre-Sogdian variety among the "Scythian" steppe dialects in the early 1st millennium BCE.

4. Wusun

Unfortunately, the language of the Wusun is entirely unknown. The main options appear to be Iranian or Tocharian[21]. Sims-Williams detects an otherwise unattested Iranian language, different from Bactrian, in the names of the Kushan kings[114]. He points out that this language has left its traces in Tocharian as well and tentatively identifies it as Scythian; however, it cannot be decided with the

available evidence whether this is the same dialect as the Scythian identified by Lubotsky[113]. Since the Wusun lived between Bactria and the Tocharian city-states in the Tarim Basin, their language might have been that of the Kushan kings. However, the Yuezhi (Rouzhi) are more likely to have been speakers of this Kushan language, since they are known to have migrated from Gansu to Bactria and are usually thought to have founded Kushan rule. Yet this by no means excludes that the Wusun also spoke an Iranian language and this indeed seems the most likely[110]: Andronovo influence in the area is assured. In any case, there are no indications that the language of the Wusun was Tocharian; for instance, no traces of influence from Tocharian are found in Bactrian or in Sogdian. In addition, the Wusun and Yuezhi are known to have been nomads, and in this period the population of the Tocharian city-states was sedentary[117]. According to the Han Shu[118], the Wusun and Yuezhi lived close to each other, which also fits them both having been Iranian. One may further speculate that the name of the Wusun, Old Chinese *ʔɑsun[119], Late Han Chinese *ʔɑsuən[120] is somehow related to the Scythian tribe names *Asii* and *Asiani*, who were among the invaders of Bactria[121].

5. Early contacts with East Asians

The obvious linguistic interpretation of the East Asian groups that admixed with the steppe people in the Xiongnu and Hun periods is that they were early Turks. The Turkic languages are attested only from the early 8th century CE onwards with the Orkhon inscriptions of Mongolia. However, to account for the difference of the language of the Orkhon inscriptions with that of the Bulgharic (or Oghuric) branch of which Chuvash survives until today, the divergence of the Turkic languages is generally estimated to have begun around the beginning of the Common Era. Since Mongolic languages contain loanwords from an early, prehistoric form of Turkic, Proto-Turkic is mostly located in present-day Mongolia, to the west of pre-Mongolian[38,101]. It is generally held that the Xiongnu were a federation of several tribes according to[122] including Yeniseian, which, nevertheless, most probably contained a Turkic component [123]. In any case, the divergence of the Turkic language family is geographically and chronologically nicely parallel to the rise of the Xiongnu.

Even indirect evidence of early Turkic from around the beginning of the Common Era is scarce. There are possible Turkic place names in Northwest China from that time[124]. Further, Turkic borrowings of the Bulgharic type into Proto-Samoyedic show that early Turkic had begun spreading west before the Samoyedic branch of the Uralic language family diverged[101]. The break-up of Proto-Samoyedic is commonly dated around the beginning of the Common Era[125].

Since linguistic stages preceding Proto-Turkic are entirely unknown, it is even more difficult to go further back into time. Contacts of earlier stages of Turkic, technically "pre-Proto-Turkic", with Iranian are likely a priori, and for East Asian groups in the area no suitable linguistic alternative to Turkic is known. Yet it is theoretically perfectly possible that one or more languages of East Asian groups have disappeared without a trace. Possible Iranian borrowings into Turkic are e.g. *padaka- 'foot' and *hamdāna- 'put together', i.e. "wrought metal" (Ossetic *ændon* 'steel', Cheung 2002: 161), which would correspond to Proto-Turkic *hadak 'foot'[126] and *alton 'gold'. Such borrowings are not widely accepted and they must remain speculative. Even if they are correctly identified, these words need not have been borrowed into early pre-Proto-Turkic. Although the change *p > *h in 'foot' points to a certain antiquity, it is possible that *p had already changed into *f in the Iranian source dialect[113], or that *h was simply substituted for either *p or *f because both sounds were lacking in Proto-Turkic. Thus, *hadak could be an older loanword, but this is difficult to prove.

Less controversial, but still far from generally accepted, are loanwords from Tocharian into Turkic[101,127]. Often cited is Proto-Turkic *höküŕ 'ox, bull' (Common Turkic *öküz*, Chuvash *văkăr*, borrowed as Hungarian *ökör*, Mongolian *üker*, *hüker*), which probably derives from a form related to Tocharian B *okso* 'ox, bull'. Also Proto-Turkic *yäŕ 'bronze' (Common Turkic *yäz*, borrowed as Mongolian *jer*) may derive from Proto-Tocharian *ẃəsa* (Tocharian B *yasa* 'gold'). (Here *ŕ* represents

the correspondence Bulgharic *r* ~ Common Turkic *z*, which were probably in origin positional allophones[128]) As far as their shape is concerned, these words do not prove borrowing long before the beginning of the Common Era. However, it is unlikely that these words were borrowed in the Xiongnu period, because at that time the Tocharian speaking city-states can hardly have been influential enough and it is difficult to see how borrowings could have reached the whole of Turkic. Alternative scenarios include the following: 1) the contacts took place before the Tocharians entered the Tarim Basin; 2) the words were borrowed from another branch of Tocharian that did not move south into the Tarim Basin and became extinct later, technically "Para-Tocharian". In the case of the first scenario, an additional option is that the Tocharians entered the Tarim Basin not ca 2000 BCE, but later. All these scenarios require contacts well before the beginning of the Common Era and they might be connected with the East Asian groups that admixed with the Iranians of the steppe.

6. Turkic and Mongolic

Early contacts between Turkic and Mongolic are the subject of a long debate. The moot point is whether Turkic and Mongolic are in the end also genealogically related, as claimed in the Altaic Hypothesis. This problem is not directly relevant for the migrations on the steppe, since both opponents and proponents of the Altaic Hypothesis acknowledge longlasting prehistorical contacts between Turkic and Mongolic, termed pre-Proto-Turkic and pre-Proto-Mongolic. Influence of pre-Proto-Turkic on pre-Proto-Mongolic is evidenced by a substantial body of loanwords from Turkic into Mongolic that show a stage of Turkic that is considerably older than the earliest form of Turkic reconstructable on the basis of the Turkic languages alone: Proto-Turkic[38,101]. Two important semantic fields for this layer of borrowings are animal husbandry and metal working[101]. In many cases, criteria to determine the direction of borrowing are lacking, but borrowings from Mongolic into Turkic are for some lexical matches assured[101,129]. These can tentatively be dated to the Xianbei period.

After the breakup of Common Turkic and the spread of Mongolic, the individual Turkic languages have been influenced by Mongolic[101]. The strongest influence is found in Northeast Turkic, especially in Yakut (Sakha and Dolgan) and Tuva, languages of Siberia that have no bearing on the steppe. The influence becomes gradually weaker in a rough east-west order: Kirghiz; Kazakh and Karakalpak; Western Kipchak, Uzbek and Uyghur; Turkmen; Azeri and Eastern Anatolian dialects; Standard Republican Turkish[130–132]. Schönig further notes that at least in two languages with a relative low proportion of Mongolic elements, these are probably the result of borrowing through the intermediary of another Turkic language: Chuvash and Khalaj through Western Kipchak and Azeri, respectively. Stronger structural influence from Mongolic on Turkic is found mainly in Yakut. Reverse influence from Turkic on Mongolic is rare and restricted to Oirat, Kalmuck and Buryat. Traces of Tungusic influence are found relatively far to the west, but north of the steppe, in Uralic languages of Siberia, and are of a comparatively late date[133].

7. Language diffusion

Language diffusion is not an autonomous process. Languages do not spread because they would be better in any sense, or because they are easier to learn. Rather, languages spread because their speakers are culturally, technologically, economically or militarily advanced, which makes their language prestigious. Naturally, language spread is a mixture of the spread of people and the adoption of the newly introduced language by local populations[134]. Nichols argues that the Eurasian steppe is a closed spread zone, which is characterised by repeated spreads of a new language over the complete territory, causing extinction of the preceding languages[35,135]. In this case, the main language spreads are that of the Iranian branch of Indo-European from the west, probably preceded by Tocharian, followed by Turkic and then Mongolic from the east. Indo-Aryan, with which Iranian forms the Indo-Iranian

branch, never spread over the entire steppe, but was probably pushed south off the steppe by Iranian. In the case of Turkic, a first wave, so-called Bulgharic Turkic, started in the Hunnic period, instigated by the preceding spread of the Xiongnu. A second wave was the spread of Common Turkic in the 6th–7th centuries. Mongolic did not spread in the same way as Turkic. Nichols attributes this to the large number of Turkic speakers on the steppe, and the fact that "Turkic rather than Mongolian had traditionally served as the inter-ethnic language in mixed Mongol-Turkic situations"[136]. When it is spread, a language is often impacted by the substrate of local languages and may lose marked features that are not shared by these local languages. In the case of Indo-European, this has resulted in a sharp typological contrast between the reconstructed protolanguage and the daughter languages. For instance, the so-called laryngeals $*h_1$, $*h_2$ and $*h_3$ are lost almost everywhere. For Turkic, it has been argued that its relative simplicity and regularity are the result of such a simplification[137]. This is a good possibility, which can, however, not be proved as long as it is not known how complex and irregular the language had been before. There is no evidence that Turkic could spread in the first place thanks to its simplicity and regularity (pace Johanson l.c.).

Section 3: Ancient Data Generation and Analysis

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3. 1 Sample selection

Approximately 200 relevant skeletons were first screened for their human DNA content and contamination proportions. Sample substrates were either tooth cementum, sampled as in[138], or petrous bone sampled as in[139,140]. All pre-PCR sample processing was undertaken in the dedicated clean-laboratory facilities of the Centre for GeoGenetics, Natural History Museum, University of Copenhagen according to the following steps:

1) Samples were pre-digested for 30 minutes at 50°C with a proteinase K and EDTA buffer, modified from[138] by excluding the N-lauryl sarcosyl, because surfactants have no effect on digestion of bone or tooth[141]. Samples were finally digested in 4.9 mL EDTA and 100 μL recombinant Proteinase K, for either 24 hours or 48 hours in an incubator at 50°C.

2) DNA was extracted using a binding buffer optimized at binding ultra-short DNA fragments to silica particles. The buffer was used in combination with a silica-in-solution approach which has previously been shown to outperform spin-column purification[2]. The buffer consist of 500 mL Qiagen buffer PB with 9 mL sodium acetate (5M), and 2.5 mL sodium chloride (5M).

3) Next-generation sequencing libraries were then built according to a modified NEBNext DNA Sample Prep Master Mix Set 2 (E6070) incorporating P5 and P7 adaptors as previously described[2]. All libraries were amplified with Kapa U+ which has been shown to be an optimal enzyme for amplifying ancient human DNA due its low GC-bias[142]. Libraries were amplified in a two-round amplification set-up as in[2] with a total of 18 to 22 PCR cycles.

For the screening phase, approximately 10-15 million sequences were generated for each sample. A total of 155 individuals qualified for full genome sequencing based on three criteria of which only the third was an absolute disqualifier whenever applied: 1) by containing more than 20 % human DNA, or 2) being of particular relevance to the research questions, and 3) not displaying more than 5% contamination on the upper CI of contamination estimated with the contamMix programme[143]. Through these criteria, sample size was reduced to 145 DNA extracts averaging 40% human DNA content. These resulted in 145 genomes sequenced to an overall average coverage of ~1X, and the authentication step was then extended using the approaches incorporated in Schmutzi[144] resulting in 137 genomes passing contamination criterion – see "DNA authentication" below for outline.

3.2 Processing of read data

All libraries were sequenced single-read to 80 bp, on an Illumina HiSeq 2500 at the Danish National High-Throughput Sequencing Centre. The sequences were basecalled using the Illumina software CASAVA CASAVA-1.8.2 and de-multiplexed using a full match of the 6 nucleotide index incorporated during library amplification. The reads were trimmed using AdapterRemoval-2.1.3[145] for adapter sequences and leading/trailing stretches of Ns. Additionally bases with quality of 2 or less were removed by trimming from the 3'. Reads of at least 30 bp were mapped to GRCh37 using bwa-0.7.10[146] with the seed disabled. Alignments were processed using samtools-1.3.1[147] removing reads with a

mapping quality lower than 30 and merged to libraries. Hereafter duplicates were removed using picard-1.127 MarkDuplicates (https://broadinstitute.github.io/picard/), libraries merged to sample level and realigned using GATK-3.3.0[148] with Mills and 1000G gold standard indels. Finally, realigned bams had the md-tag updated and extended BAQs calculated using samtools calmd. Read depth and coverage were determined using pysam (http://code.google.com/p/pysam/) and BEDtools[149]. Statistics of the read data processing is shown in Supplementary Data Table 1.

3.3 Damage assessment and authentication

Several damage parameters were estimated from the data in order to characterize the fragmentation and damage of the ancient human DNA. First, the fragmentation was computed by fitting an exponential model to the decaying part of the sequence length distribution according to the decay model outlined in[150]. Next, position specific mismatches were estimated using mapDamage2.0[151], as well as damage parameters of the Bayesian model implemented in this programme, of which we report the δs parameter, the probability of deamination within single stranded overhangs characteristic for ancient DNA, in Supplementary Data Table 8.

Next, contamination of the samples was estimated with two approaches. First, mapping affinities of sequences that mapped to the mitochondrial genomes using the standard mapping approaches described above were compared to their own reference and to a global dataset of potential contaminant sources, using the contamMix approach[143]. For further authentication, all trimmed reads were aligned to a reference excluding the autosomal chromosomes – the rCRS only, using SHRiMP version 2.2.3. The resulting aligned DNA fragments were used as input by schmutzi, a Bayesian algorithm aiming at co-estimating levels of present-day human contamination, while also inferring the mitochondrial sequence of the endogenous material. Contamination estimates were repeated by disabling the prediction of the contaminant mitogenome (without the option --notusepredC). The endogenous consensus was called with a quality cutoff of 30 on the PHRED scale on the predicted base thus ensuring a probability of error of less than 1/1000. Haplogrep2.0 [nar.oxfordjournals.org/content/early/2016/04/15/nar.gkw233.full] was then used on those mitochondrial sequences to assign haplogroups. Samples with > 10X coverage showing contamination levels > 10 % in the CI from either the contamMix or the schmutzi contamination estimate obtained without predicting the contaminant, were removed from the study.

For downstream analyses on the mitogenomes, three other criteria were used to filter out low quality mitochondrial sequences namely: 1) average coverage of more than 25X, 2) stable haplogroup assignment when stricter quality cutoffs was used for the prediction endogenous mitochondrial genome and 3) mitochondrial sequences for which we had more than 1% undefined sites were removed from downstream mitogenome analyses.

Finally, X-chromosome based contamination estimates for the male individuals were performed as an additional confirmation that the data is not affected by contamimation. We used the two approaches implemented in angsd (http://www.popgen.dk/angsd/index.php/ANGSD) using HapMap variable sites exactly as undertaken in the original publication it was used in[152]. The first approach is based on total read count while the other approach is based on sampling random reads. Neither methods detected any considerable contamination in the samples.

3.4 Relatedness analyses

We estimated relatedness using a two-step approach. First, we computed all the outgroup-f3 statistics of the form f3(Individual X, Individual Y; Mbuti) using randomly selected alleles, and flagged all pairs of individuals with excess shared ancestry, by setting a background threshold of 0.3 for the outgroup f3-statistic. Then, we used ngsrelate[153] to estimate relatedness for all pairs of individuals in the dataset, using a background panel of 1200 Eurasian individuals at the Affymetrix positions from the Human Origins dataset[154] for background frequencies. We found an exact overlap between the flagged individuals in the first approach and the second approach, thereby defining a cut-off at first degree cousins (ie. relatedness coefficient of 0.0625). When relatives were identified, the individual with highest coverage was selected for downstream analyses. This resulted in a final selection of 132 unrelated individuals.

3.5 Datasets

By merging random alleles from the ancient samples with previously published data, we generated two datasets for the population genomic analyses. We excluded reads with a BAQ score <30 (from bam files that were previously filtered for reads with mapping quality under 30). One panel included variants at 1,233,553 genomic variable positions from the newly generated unrelated 132 samples, random alleles from previously published ancient genomes of relevance[2] and previously published variants including ancient and present-day populations[154]. The second dataset included 242,406 genomic positions, and was generated by merging random alleles from the newly generated genomes, relevant ancient genomes[2], and a dataset containing overlapping positions between previously published data[155] and new Central Asian and Siberian data generated in this project, see Supplementary Section 5.

3.6 Data Analyses

Principal Component Analyses were conducted using the PLINK1.9 software[156], i.e. including the ancient samples in the calculations of the components. Similarly, the model-based clustering was estimated including the ancient samples in the analyses, using the ADMIXTURE software[14], and defining K clusters from K=2 to K=20 and running 20 replicates for each run. The ADMIXTURE results are reported in Supplementary Section 5. The data was also converted to eigenstrat format and the D- and f-statistics were calculated using the admixtools package (https://github.com/DReichLab/AdmixTools).

In order to illustrate gene flow across time and geographical regions between two groups in question, all possible proxies were inserted in the D-statistics of the form D(Test, Mbuti; Group 1, Group 2), denoted according to the nomenclature in[157] indicating gene flow between Test and Group 1 when positive and between Test and Group 2 when negative. All D-statistics that significantly deviated from 0 for two tests were plotted in the Extended Figure 4 and 6. In addition, selected D-statistics were reported in the manuscript and can be found in Supplementary Section 3.7.

Population admixture models were constructed using qpAdm[1] with two different sets of outgroups designed to distinguish between ancestral components of major relevance to the questions addressed. The first set was used to discriminate between the Steppe_EMBA and the Steppe_MLBA clusters, and between Han and BHG_BA, respectively, as sources, in order to assess previous claims on Scythian origins[11]. The first two meta-populations are differentiated by the European Neolithic farmer ancestry in the latter, and the second two meta-populations are differentiated as one represents an East Asian

component widely distributed in Siberia, while the other represents a Mongolian/Han/South East Asian component that are discernable in ADMIXTURE analyses. This set comprised: Mbuti, Ust'Ishim, Clovis, Kostenki14 Switzerland_HG, Natufian and MA1 as outgroups. See Supplementary Figure 1 for pairwise plot of all possible values of f4("Source1", "Outgroup1"; "Outgroup2", "Outgroup3") versus f4("Source2", "Outgroup1"; "Outgroup2", "Outgroup3") for all possible combinations of sources.

The second set was designed to characterize the three-five major ancestral components across Eurasia: we thereby described the increase in 'East Asian' ancestry (as proxied by BHG_BA) in the central steppe across time, and geographically in the present-day dataset. These comprised Mbuti, Ust'Ishim, Clovis, Kostenki14 and Switzerland HG. See Supplementary Figure 2 for pairwise plots of all possible values of f4("Source1", "Outgroup1"; "Outgroup2", "Outgroup3") versus f4("Source2", "Outgroup1"; "Outgroup2", "Outgroup3") for all possible combinations of sources. The qpAdm results for the present-day dataset is reported in Supplementary Section 5, and for the ancient dataset, it is summarized in Figure 4.
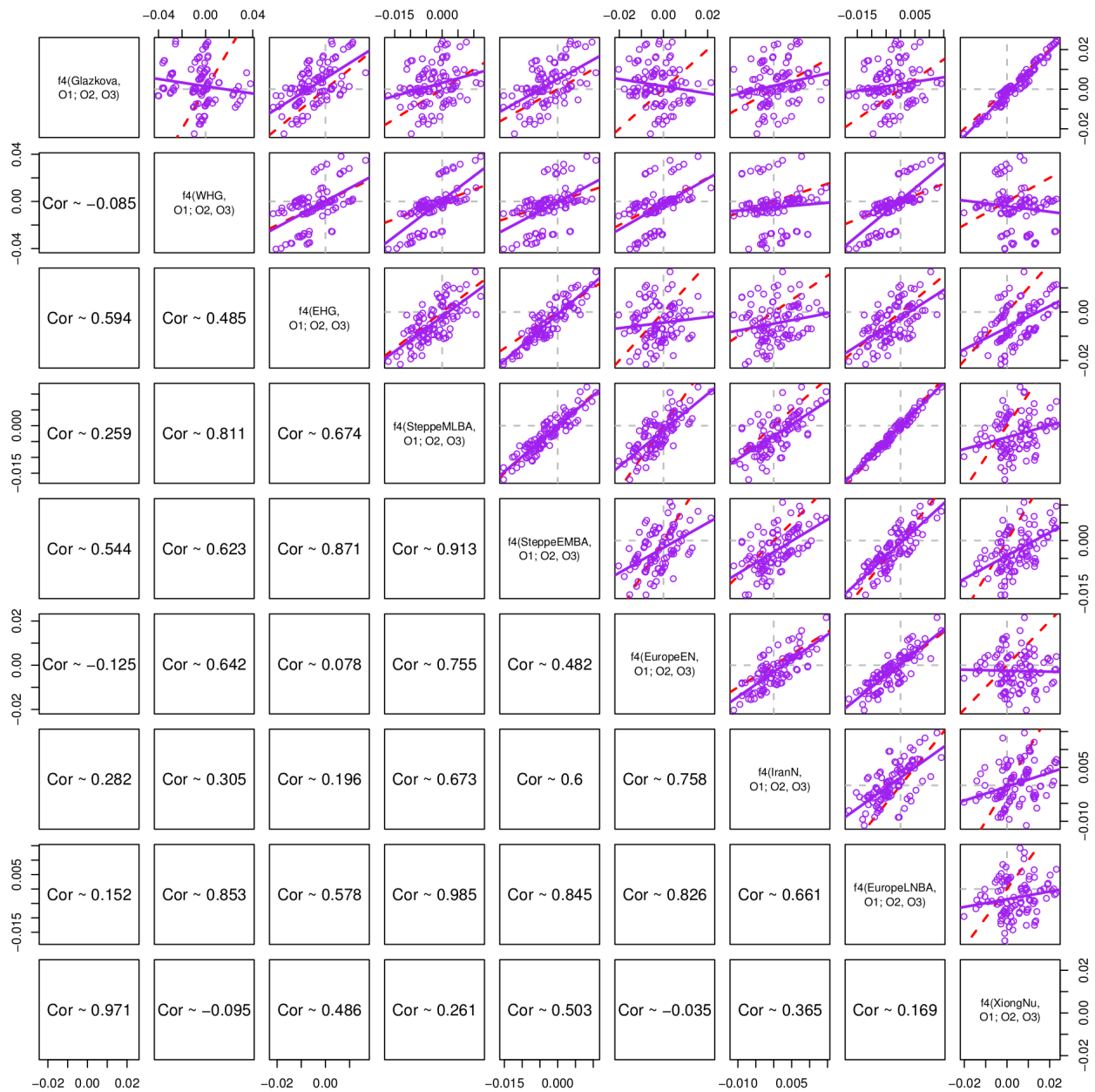
Supplementary Figure 1 - Pairwise f4-statistics of the form f4(Source, Outgroup1; Outgroup2, Outgroup3) for all possible combinations of outgroups, for all the sources considered in the qpAdm modelling using seven outgroups (Mbuti, Ust'Ishim, Clovis, Kostenki14 Switzerland_HG, Natufian and MA1). For reference, we show solid lines for a linear least squares regression, red dotted lines for x=y and gray dotted lines for f4=0 in both axes. Spearman correlation coefficients for each pairwise comparison are shown in the lower half of the matrix.
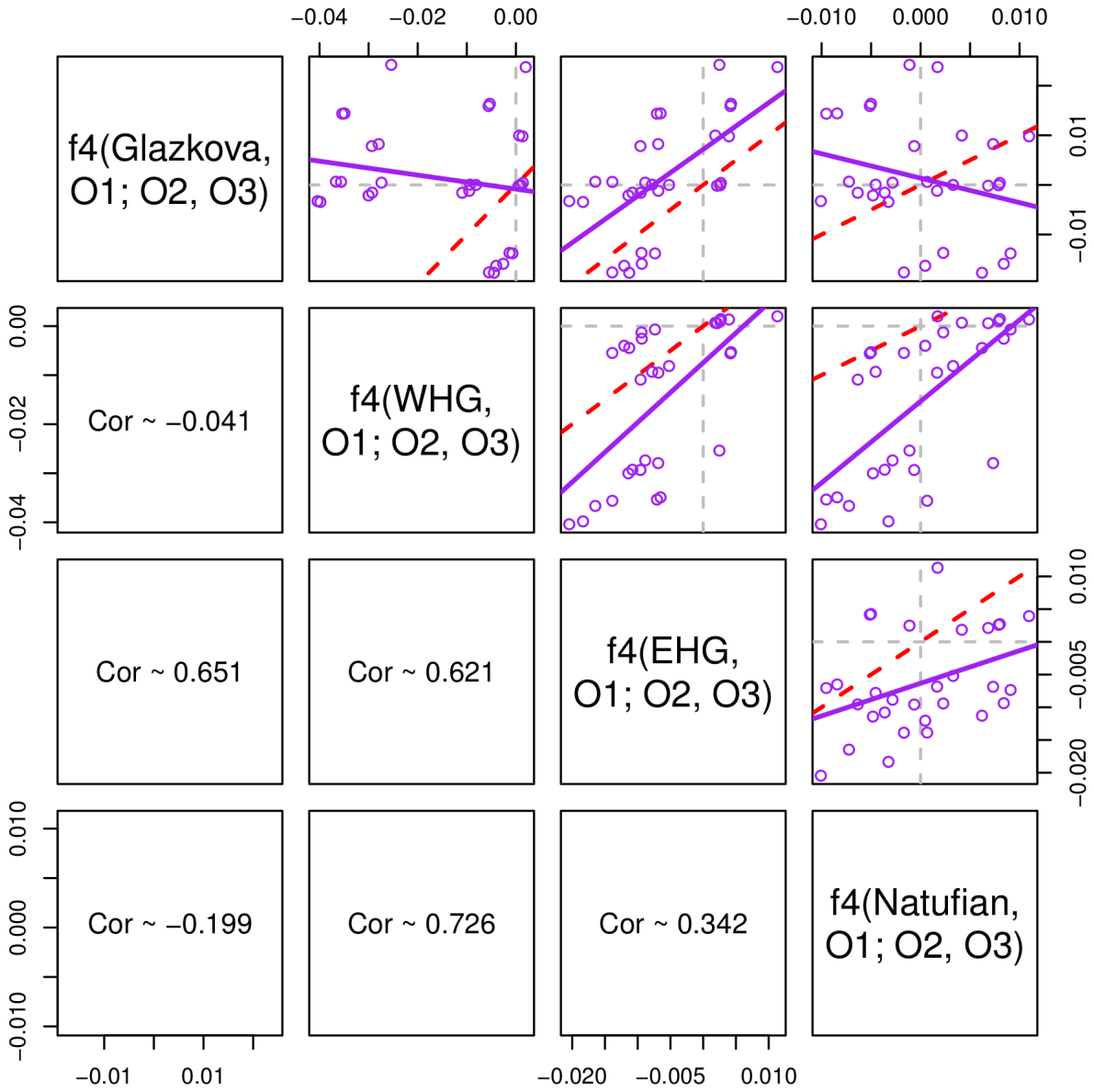
Supplementary Figure 2 – Pairwise f4-statistics of the form f4(Source, Outgroup1; Outgroup2, Outgroup3) for all possible combinations of outgroups, for all the sources considered in the qpAdm modelling using five outgroups (Mbuti, Ust'Ishim, Clovis, Kostenki14 and Switzerland HG). For reference, we show solid lines for a linear least squares regression, red dotted lines for x=y and gray dotted lines for f4=0 in both axes. Spearman correlation coefficients for each pairwise comparison are shown in the lower half of the matrix.

3.6 Sex-bias in admixture proportions

We determined sex-biased admixture rates for populations with sufficiently large numbers of individuals by contrasting admixture proportions estimated on the X chromosomes and the autosomes, using 49711 positions on the X chromosome and 1151161 autosomal positions[154], and considering a continual admixture model previously described[158].

We do not identify sex-biased admixture rates for the hunter-gatherer contributions in the Tagar and Tian Shan Sakas, while do we observe an increase in male hunter-gatherer and female Late Bronze Age herder ancestry of the Central Sakas forming the Tasmola culture. For the Tian Shan Sakas, we also find an increase in males contributing the Neolithic Iranian ancestry.

In the Tian Shan Huns, we do not identify an increase in East Asian ancestry on the X-chromosomes, while we find 10% increase in the autosomes, indicating a sex-biased admixture of westward moving East Asian male nomads. The results are summarized in Extended Figure 10.

3.6.1 Implications

With regards to the population dynamics following the Bronze Age, the Eurasian steppe history appears to be in strong contrast to human demographic changes in Europe where most of the European ancestral components were already established by this time[1,2]. In contrast, the steppe received continued gene flow from neighbouring groups. Intriguingly, bioarchaeological research of Scythians suggest that young males had a higher death rate than other sedentary Iron Age populations, despite good health conditions, leading to a decrease in population size due to extensive warfare[159]. Hence, engaging with newcomers might have helped steppe nomads maintain population sizes. Obviously, dominating the central steppe area including the Silk Road was a highly advantageous position and attracted warrior bands from the eastern steppe[22,26]. This is consistent, both with our findings of multi-ethnical cultural assemblages, but also the presence of sex-biased admixture rates attracting males to the central steppe.

3.7 Reported D-statistics

Test population	Outgroup	Ingroup 1	Ingroup 2	D-statistic	Z-score
Europe_EN	Mbuti	Hungarian Scythian	Andronovo	0.02	7.33
BHG_BA	Mbuti	Hungarian Scythian	Andronovo	⟳-0.01	-5.52
BHG_BA	Mbuti	Central Saka	Andronovo	0.06	20.01
BHG_BA	Mbuti	Tian Shan Saka	Andronovo	0.02	9.29
BHG_BA	Mbuti	Tagar	Andronovo	0.03	10.42
BHG_BA	Mbuti	Central Saka	Tagar	0.03	14.11
BHG_BA	Mbuti	Central Saka	Tian Shan Saka	0.03	15.18
Iran_N	Mbuti	Tian Shan Saka	Central Saka	0.01	5.33
EHG	Mbuti	Tagar	Hungarian Scythian	0.01	3.81
EHG	Mbuti	Tagar	Central Saka	0.01	5.31
EHG	Mbuti	Tagar	Tian Shan Saka	0.01	6.11
Europe_EN	Mbuti	Hungarian Scythian	Tian Shan Saka	0.04	24.44
Europe_EN	Mbuti	Hungarian Scythian	Tagar	0.03	18.63
Europe_EN	Mbuti	Hungarian Scythian	Central Saka	0.05	25.12
Xiongnu	Mbuti	Central Saka	Xiongnu_WE	-0.01	-1.51
Xiongnu	Mbuti	Tian Shan Saka	Wusun	0.01	5.54
Xiognu	Mbuti	Tian Shan Hun	Wusun	0.03	13.02
Xiongnu	Mbuti	Turk	Tian Shan Hun	0.02	7.51
Xiongnu	Mbuti	Kimak	Turk	0.01	1.15
Xiongnu	Mbuti	Karakhanid	Turk	0.01	3.08

Supplementary Table 3.7.1 – Selected D-statistics depict changes in ancestry across geography and time.

Section 4: Site descriptions and individual outgroup-f3 statistics

A large number of the sites and samples analyzed in this project have been described and published in Russian journals, while some have never previously been published. We provide an extensive catalogue of the human remains analysed. These include, for each specimen, an illustration of shared genetic drift with present-day Eurasian populations covering Europe, Central Asia and Siberia. 'Shared genetic drift' was measured using the outgroup-f3 statistic[157] – a higher value corresponds to more shared drift between the ancient sample and present-day populations, and as such, these maps provide a quick overview of whether a given ancient individual was predominantly of West Eurasian genetic ancestry or of East Eurasian genetic ancestry. Each map represents the outgroup-f3 statistic calculated for a single ancient individual against each of 44 present-day reference populations.

All skeletons are curated by the lead archaeologists, anthropologists and authorities, and in all circumstances, collaboration agreements were established in order to comply with formal and legal requirements in the countries of origins. In the country of the corresponding author, an application for ethical approval of the study by the National Committee for Science Ethics was placed. According to the committee law paragraph n. 14, the project was not considered notifiable, which serves as a legal approval for undertaking the project in the country of the corresponding author. Unused sample material will be returned to their respective collections upon termination of the project.

The UST'-IDA I cemetery

By Andrzej Weber & Vladimir I. Bazaliiskii

The Ust'-Ida I (UID) cemetery is located on the bank of the Angara River at the mouth of its right tributary, the Ida, ~180 km north of Lake Baikal (53°11'20" N, 103°22'05" E). Like many other cemeteries in this area, UID was revealed by erosion of the Angara River's banks. A grave was first recorded by A.P. Okladnikov in the mid-1950s, and several more were spotted by local amateur naturalists in the mid-1980s[160]. Due to serious site disturbances, not much archaeological information is available on these graves. From 1987 to 1995, the cemetery was subjected to systematic archaeological excavations directed by V.I. Bazaliiskii (Irkutsk State University). This fieldwork produced 1 Early Neolithic Kitoi grave, 31 Late Neolithic Isakovo graves, and 19 Bronze Age Glazkovo graves. The UID graves were originally dug from red-brown loam, reaching depths of 0.60 to 1.20 m below the modern surface. Spatially, the graves were dispersed along a section of the river terrace, approximately 130 m long and 30 m wide, forming two distinct clusters, each of 20–25 graves. These two clusters are separated from each other by a gentle depression of ~20 m. The graves were either scattered or organized into rows of 3-6 graves side-by-side. The rows run in an E–W direction (i.e. perpendicular to the Angara River), whereas the grave pits themselves generally feature an N–S alignment (i.e. parallel to the river). Both grave clusters comprised Isakovo and Glazkovo graves in generally equal proportions. The single Kitoi grave was found at the southeastern periphery of the northern group. Isakovo and Glazkovo graves appear to be mixed in some rows.

Typological classification of the UID graves has relied on the following two main criteria: 1) heads of the Isakovo burials point southwards, whereas the Glazkovo interments point northwards; and 2) the Isakovo graves feature very few stones in the grave pits, whereas the Glazkovo graves are covered by paving slabs of local limestone. Additional distinctions include the presence of mitre-shaped clay pots in the Isakovo graves, as well as white nephrite and limestone discs and copper or bronze objects in the Glazkovo graves. Many of the other grave accoutrements—such as lithic arrowheads, bifacial points and rectangular inserts, or organic points, harpoons, and needle boxes—are culturally less distinctive. The classification of the single Kitoi grave is based on the presence of lithic fishhook shanks, which are idiosyncratic of this mortuary tradition. Finally, many of the Isakovo graves feature multiple interments placed side-by-side, whereas most of the Glazkovo graves are single inhumations.

Fourteen of the 19 UID European Bronze Age (EBA) graves, including all four skeletons analyzed in this study, were dated by the Baikal Archaeology Project in the 2000s using human bone samples[161]. However, it has recently been discovered that these dates are older than their true archaeological ages due to the Freshwater Reservoir Effect (FRE) present in Lake Baikal and the surrounding rivers, including the Angara River[162]. Dating of human bones paired with herbivore bones (which are not affected by the FRE) from the same graves permitted development of mathematical equations to correct the FRE errors[163,164]. However, to date the correction can only be applied to radiocarbon dates obtained from the Oxford Radiocarbon Accelerator Unit[165], so UID will have to be redated. Of the four UID EBA individuals analyzed here for DNA, only one (UID_1994.048) has an Oxford-derived date (OxA-28755, 3854±30 BP) that can be corrected for the FRE. However, based on the radiocarbon dates available for 91 EBA burials from the entire Cis-Biakal region, we feel confident that the EBA component of UID graves date to the period between 4597±76 cal. BP and 3726±34 cal. BP.

The skeletal remains from UID were also examined for their ancient DNA content, first by[166,167] and then by[168].
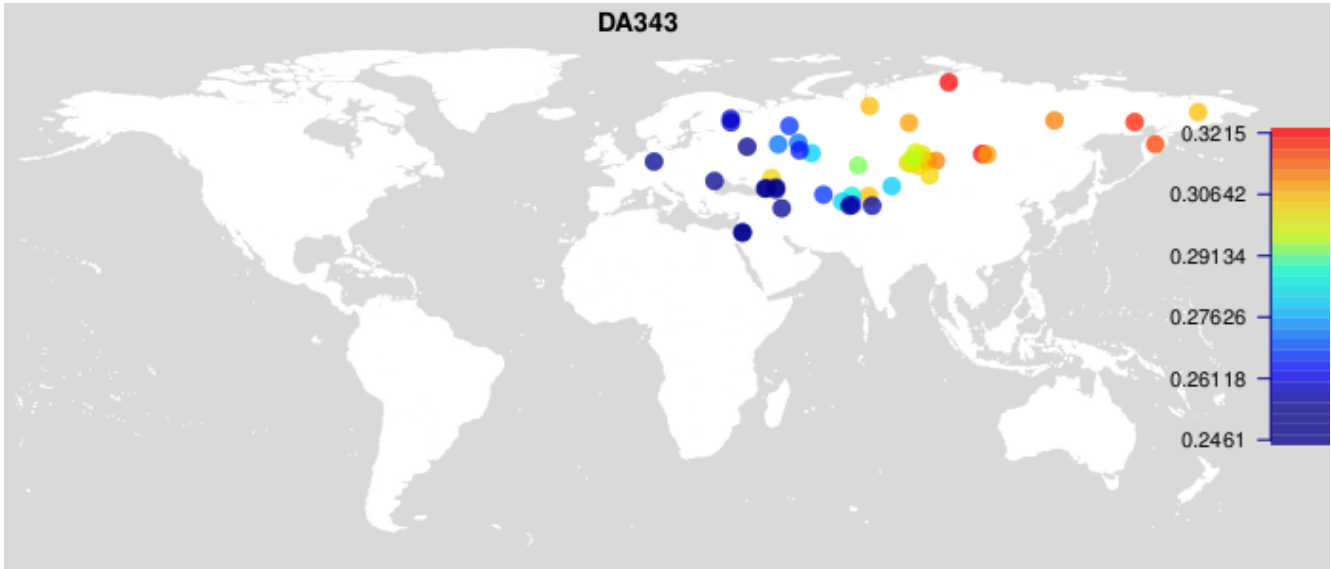
Supplementary Figure 3 - Outgroup-f3 statistics for sample DA343.

DA343 – Region: Baikal
Period: Early Bronze Age
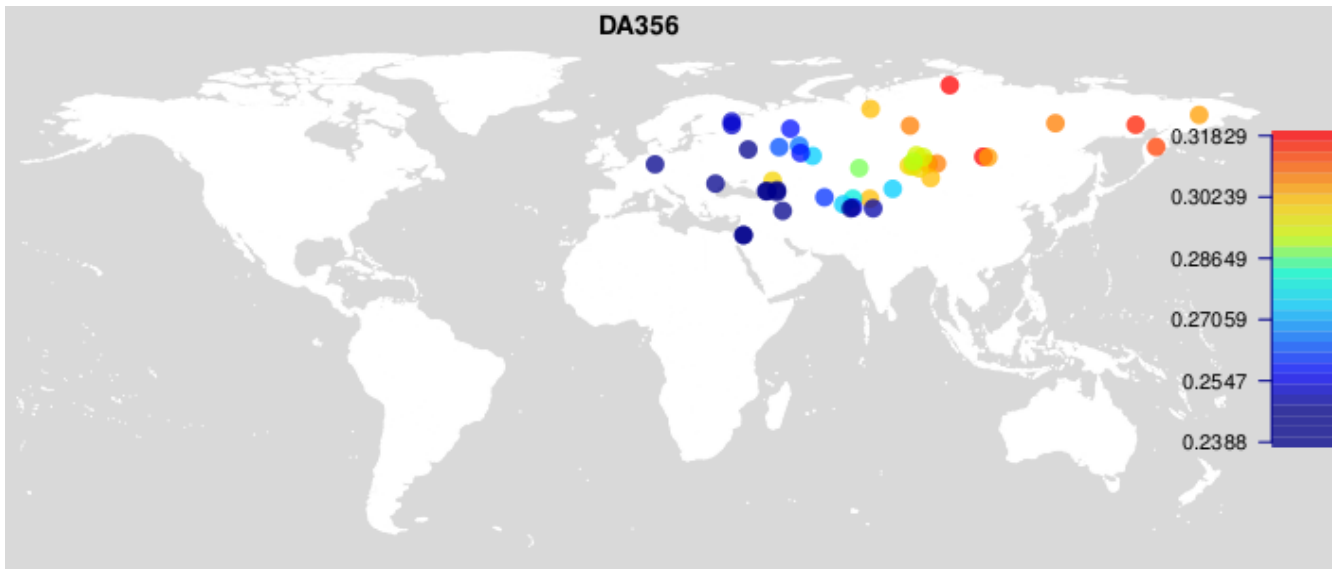**Population label: Glazkovo**
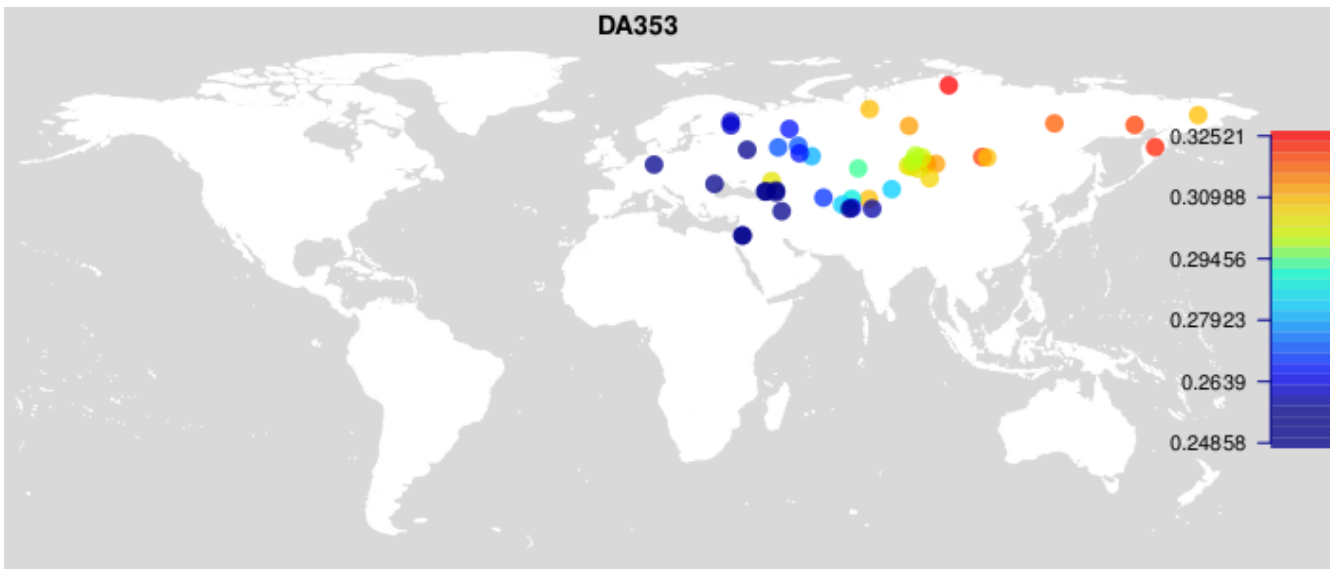
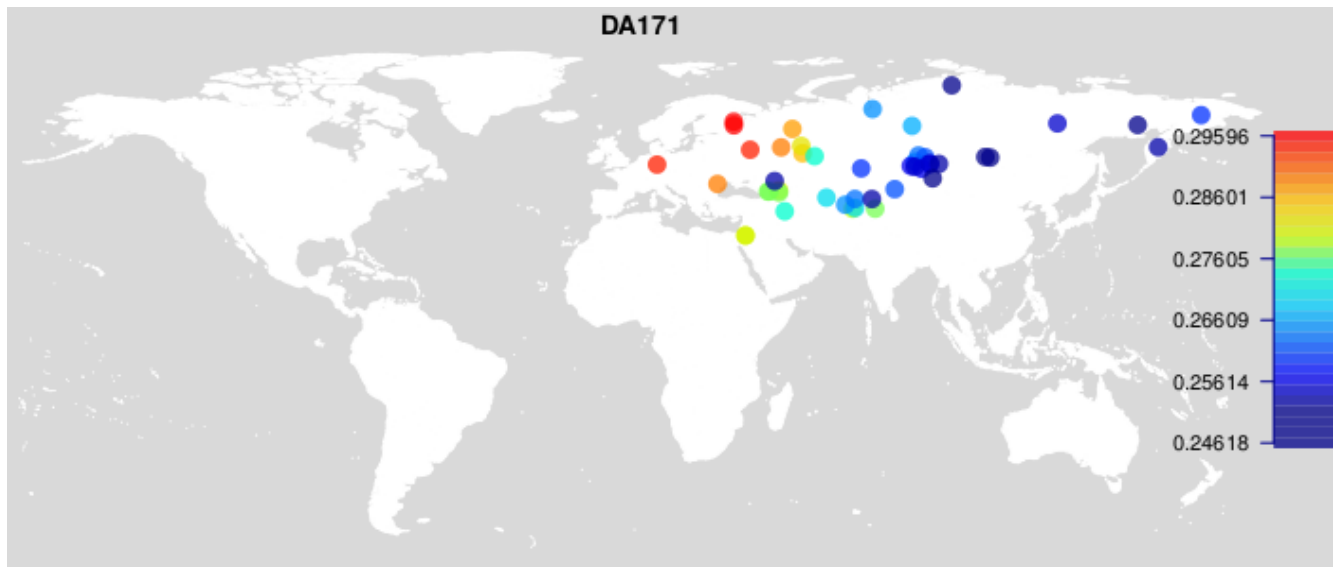**Supplementary Figure 4 - Outgroup-f3 statistics for sample DA353.**

DA353 – Region: Baikal
Period: Early Bronze Age
Population label: Glazkovo
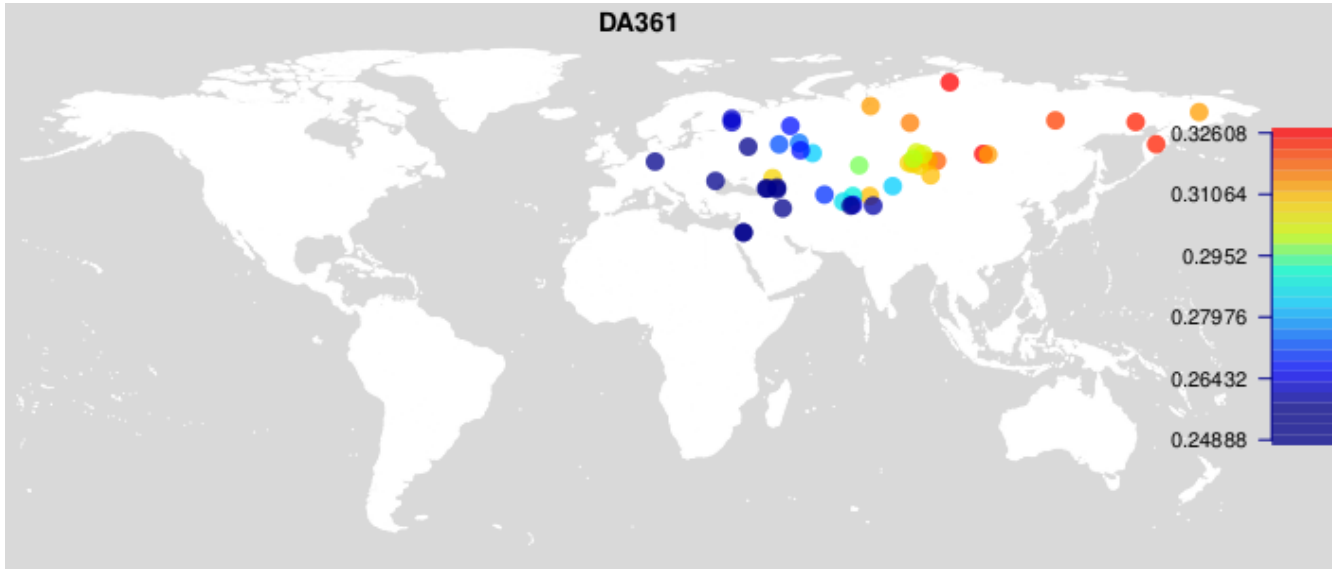
Supplementary Figure 5 - Outgroup-f3 statistics for sample DA361.

DA361 – Region: Baikal
Period: Early Bronze Age
Population label: Glazkovo

Supplementary Figure 6 - Outgroup-f3 statistics for sample DA356.

DA356 – Region: Baikal
Period: Early Bronze Age
Population label: Glazkovo

The Lithuanian sample

By Inge Merkyte

Based on archaeological study of human migration, the movement and re-settling of different peoples has not significantly affected the Balts. Only the southernmost populations (in present day Poland) were dragged into the European dynamics. Thus, the degree of change occurring due to migrations versus contacts can be measured in the Balts and serve as a case study for understanding population dynamics in other regions. Also, these earlier archaeological reconstructions might be challenged by DNA studies.

It should be noted that different Baltic groups have subscribed to divergent burial traditions during the same period and that could change rather abruptly. For example, during the 1st millennium CE, the same region could undergo several shifts from inhumations to cremations. The study sample is from a period and region of inhumations.

Supplementary Figure 7 - Outgroup-f3 statistics for sample DA171.

DA171 – Region: Baltic
Period: Migration Period IV-Vth Century CE
Population label: NLithuania

Alans, Sarmatians and Saltovo-Mayaki

By Gennady Afanasiev

The Alans played an important role in the lengthy process of Iranianization of the tribes in the central North Caucasus and, ultimately, they gave rise to present-day North Caucasian populations. Here, we investigate the gene pool of ancient Alans from the North Caucasus and Middle Don basin, as well as the possible genetic origin of Lower Don basin Sarmatians. The sample consists of 11 individuals from the Sarmatian culture (1st century CE), 13 individuals from the Alanic culture (4-14th centuries CE) and 6 individuals from the Saltovo-Mayatsk culture (8-10th centuries CE).

This study is based on the anthropological finds from tumulus burials of the Chebotarev V, Chebotarev IV, Nesvetay II, Nesvetay IV, and Kamyshevatsky X cemeteries (excavations of R. Mimohod and P. Uspensky, anthropological examination made by T. Shvedchikova), catacomb burials of the Beslan cemetery (excavations of F. Dzutsev, anthropological examination made by S. Frizen), burials of the Levo-Podkumsky-1 cemetery (excavations of D. Korobov, anthropological examination made by S. Frizen and N. Berezina), catacomb burials of the Arkhon and Dagom cemetery (excavations of E. Shestopalova, anthropological examination made by S. Frizen and I. Reshetova), catacomb burials of the Zmeyskiy cemetery (excavations of M. Bakushev, anthropological examination made by S. Frizen), and catacomb burials of the Podgorovsky and Dmitrovsky cemetery (excavations of A. Sarapulkin, anthropological examination made by I. Reshetova).
These cemeteries are located in the forest-steppe zone of the Middle Don basin, in the steppe zone of the Lower Don basin and in the foothills of the North Caucasus. The chronologies of these cemeteries were determined by the nature of the recovered artifacts. Archaeological dating indicates 1st century CE for samples from the Chebotarev V, Nesvetay II, Kamyshevatsky X, Nesvetay IV and Chebotarev IV cemeteries, 2–4th century CE for samples from the Beslan cemetery, 3–4th century AD for the Levo-Podkumsky-1 cemetery, 6-8th century CE for samples from the Arkhon cemetery, 7-8th century AD for samples from the Dagom cemetery, 8–9th century CE for samples from the Podgorovsky and Dmitrovsky cemetery, and 10-14th century CE for samples from the Zmeyskiy cemetery.
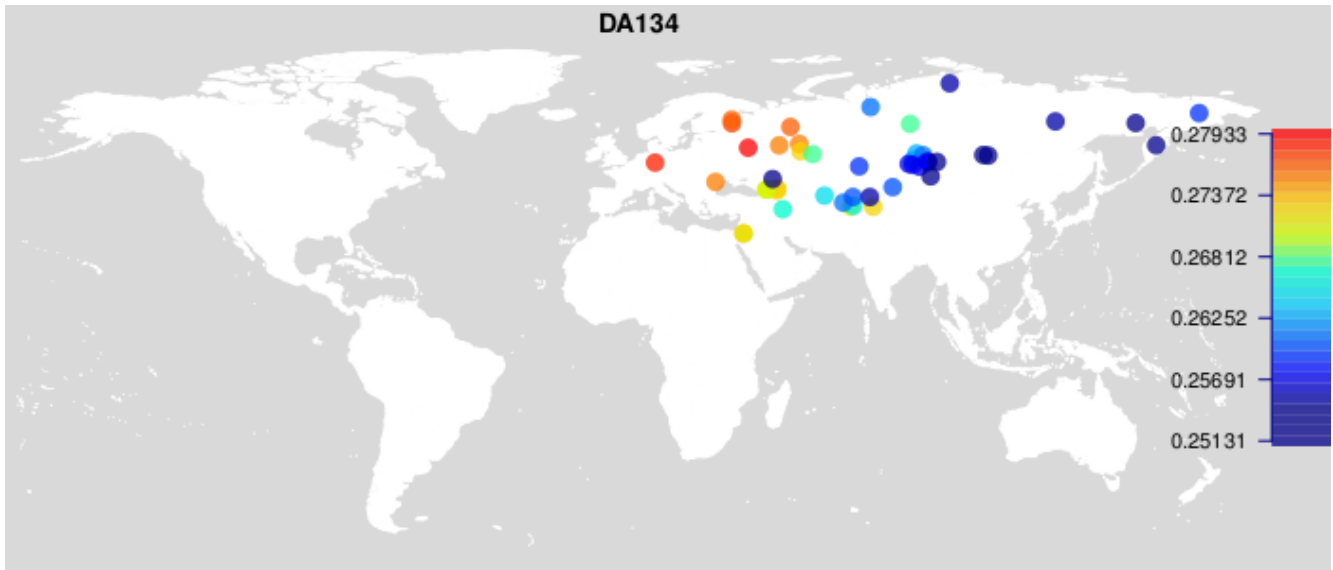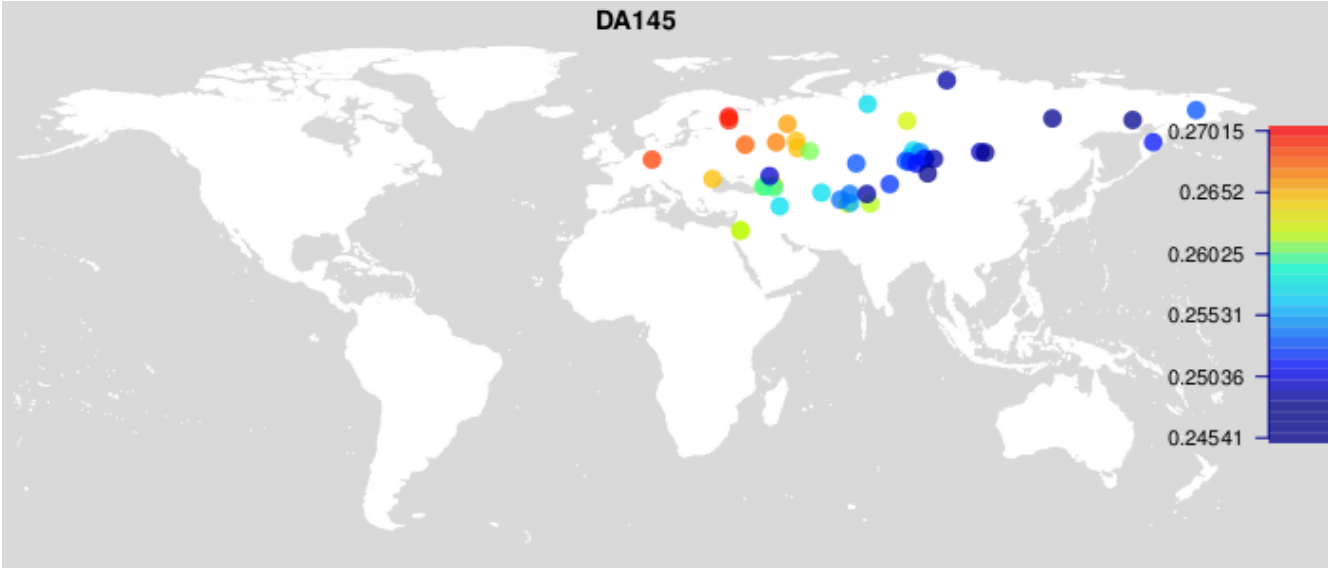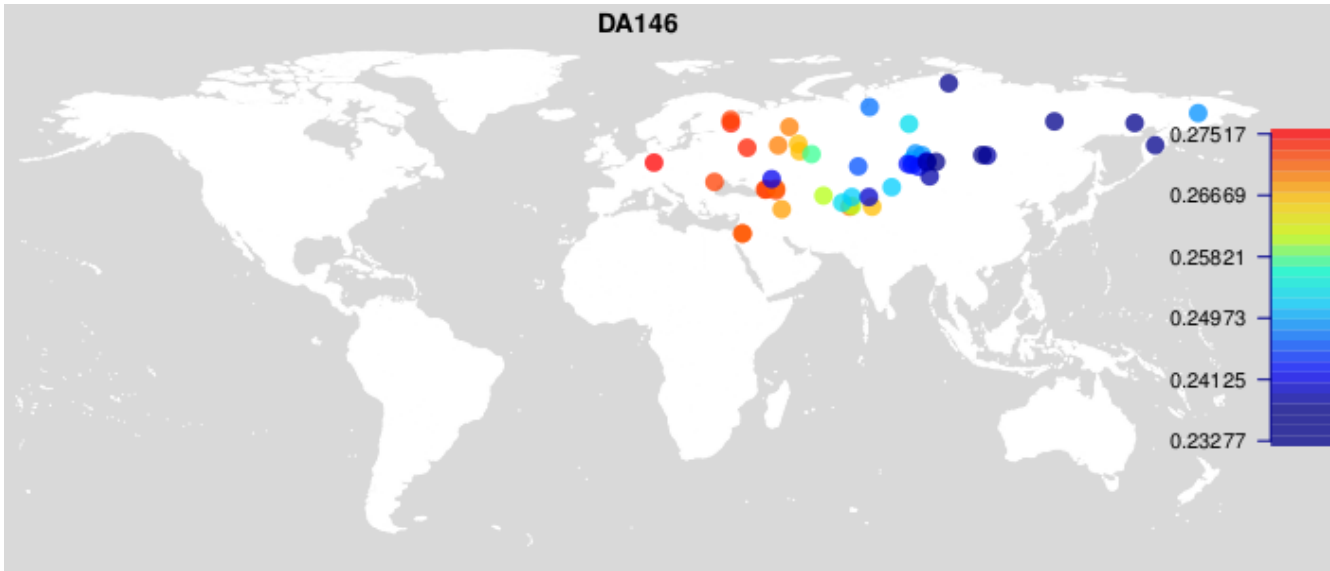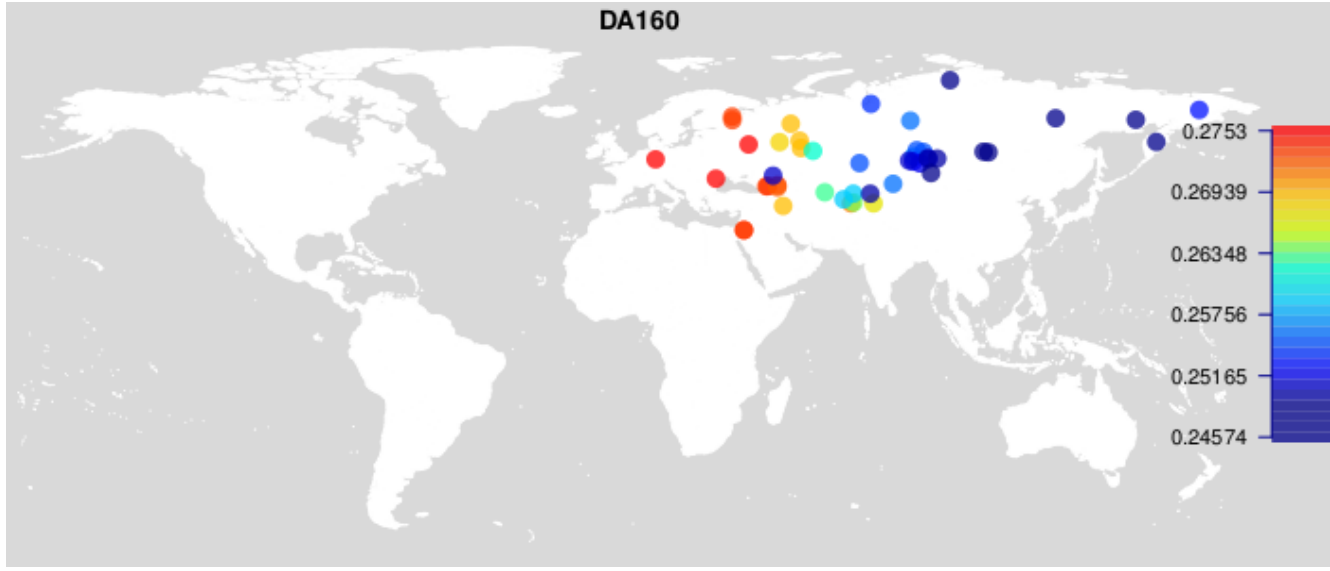
Supplementary Figure 8 - Outgroup-f3 statistics for sample DA134.

DA134 – Region: Rostov
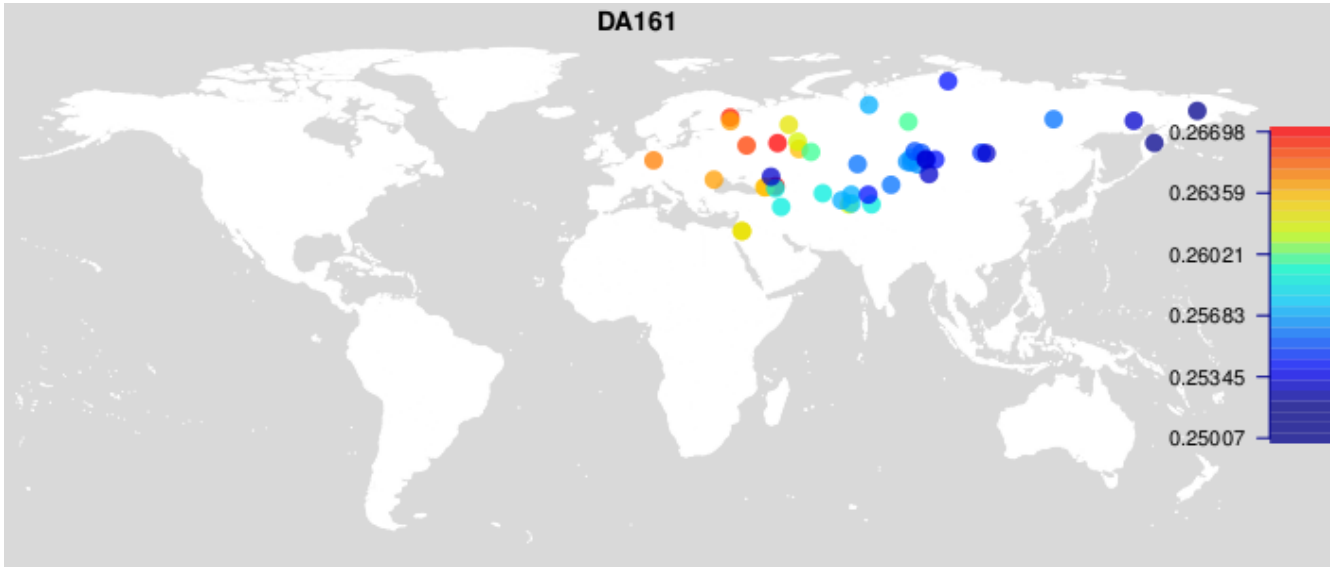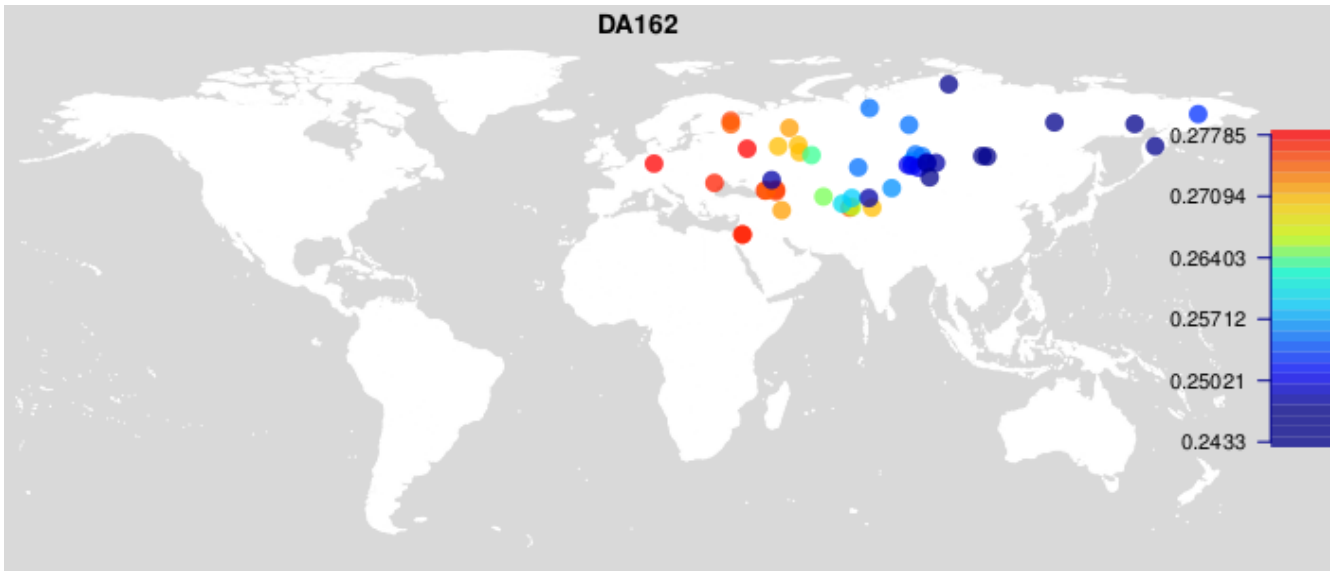**Period: 1st century AD**
Population label: Sarmatian
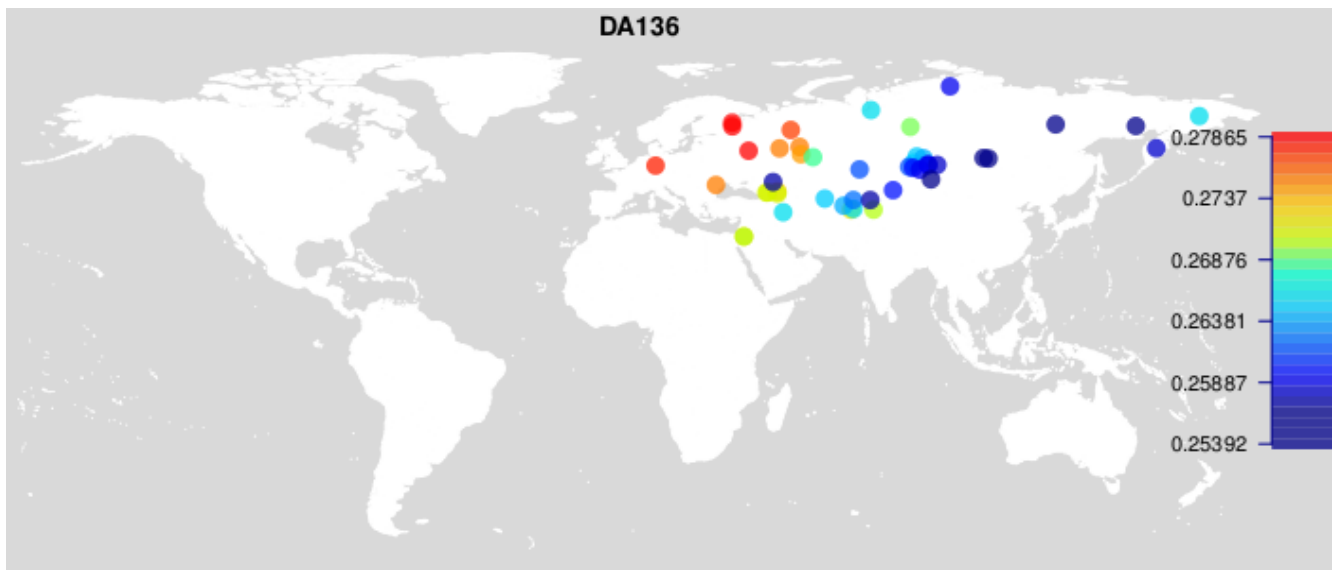
Supplementary Figure 9 - Outgroup-f3 statistics for sample DA136.

DA136 – Region: Rostov
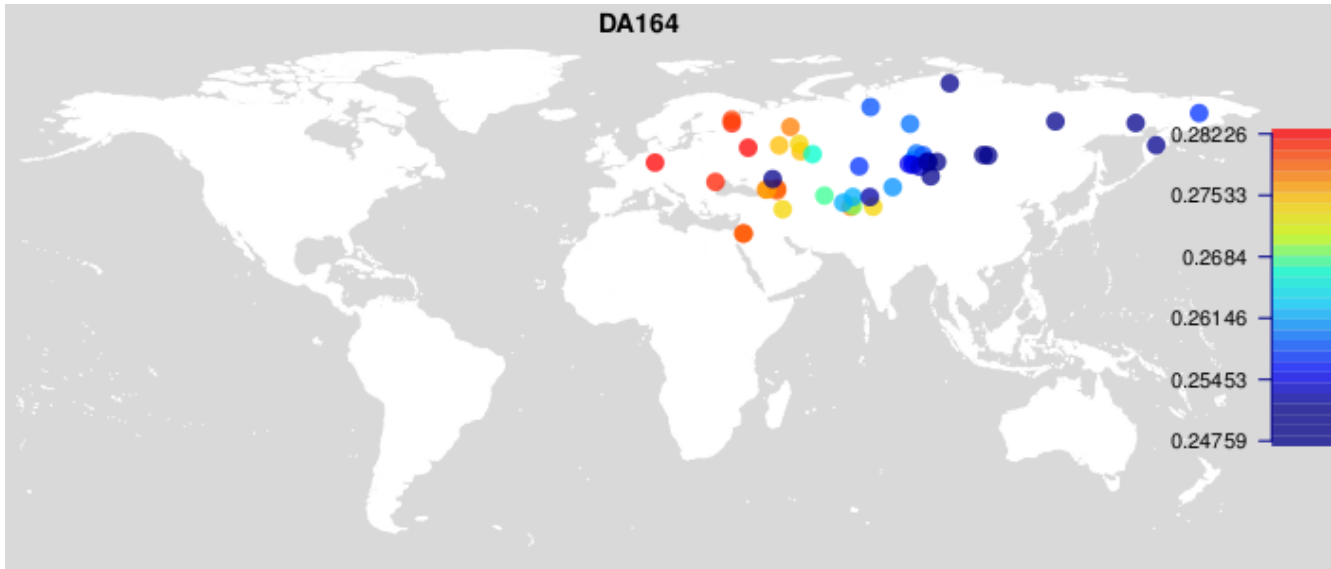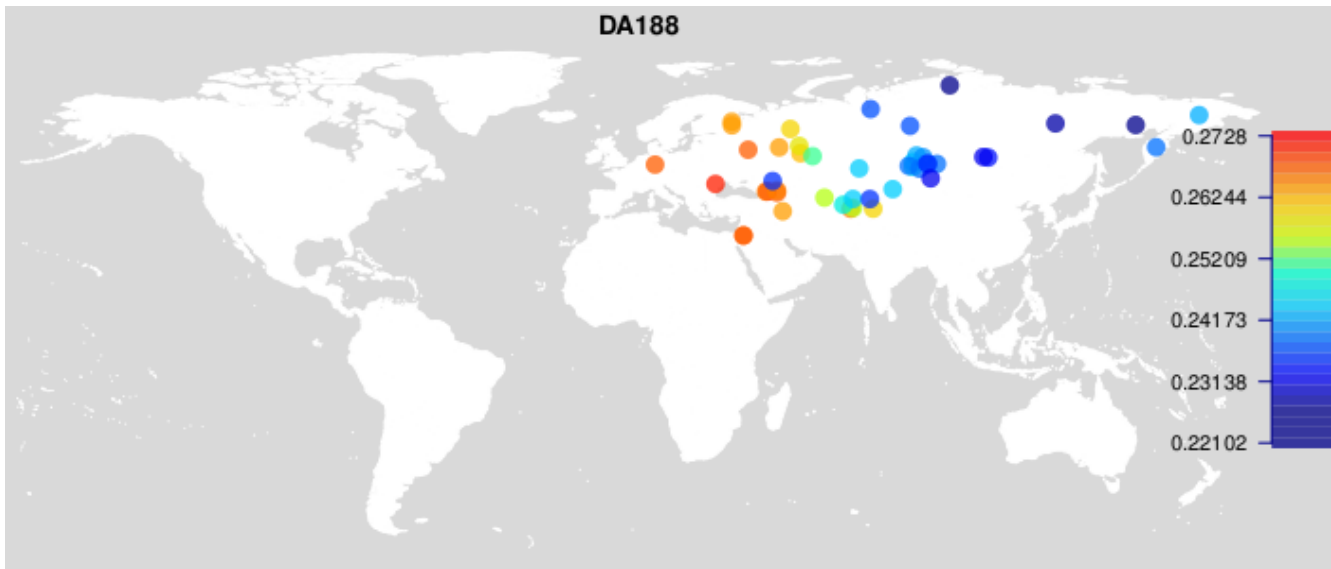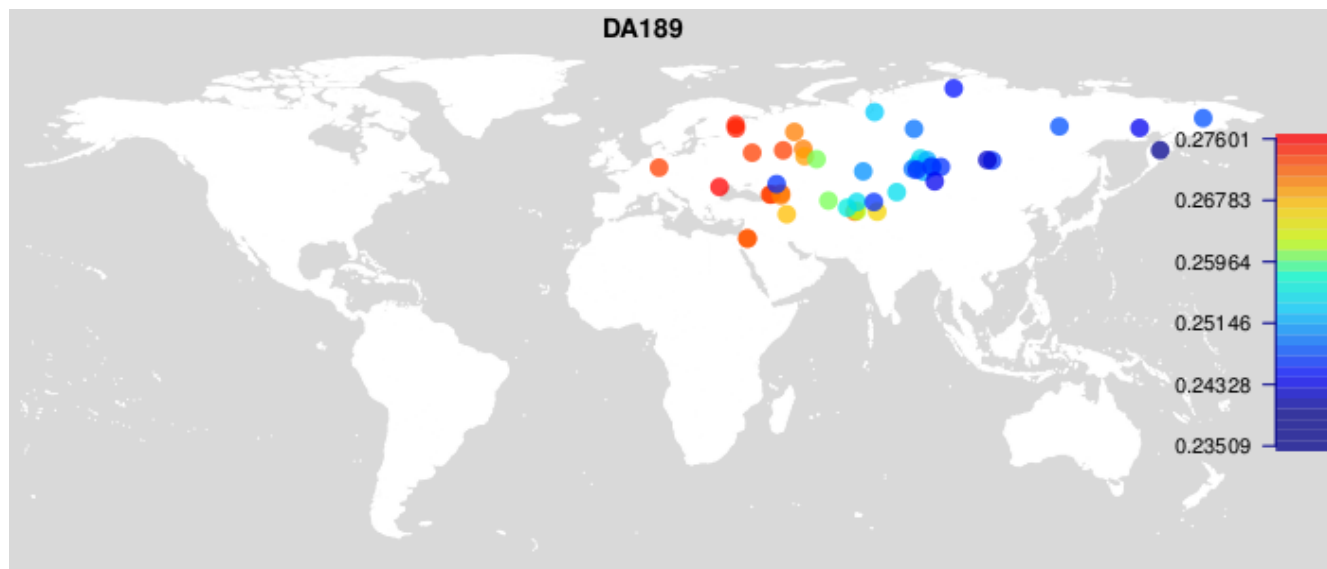**Period: 1st century AD**
Population label: Sarmatian
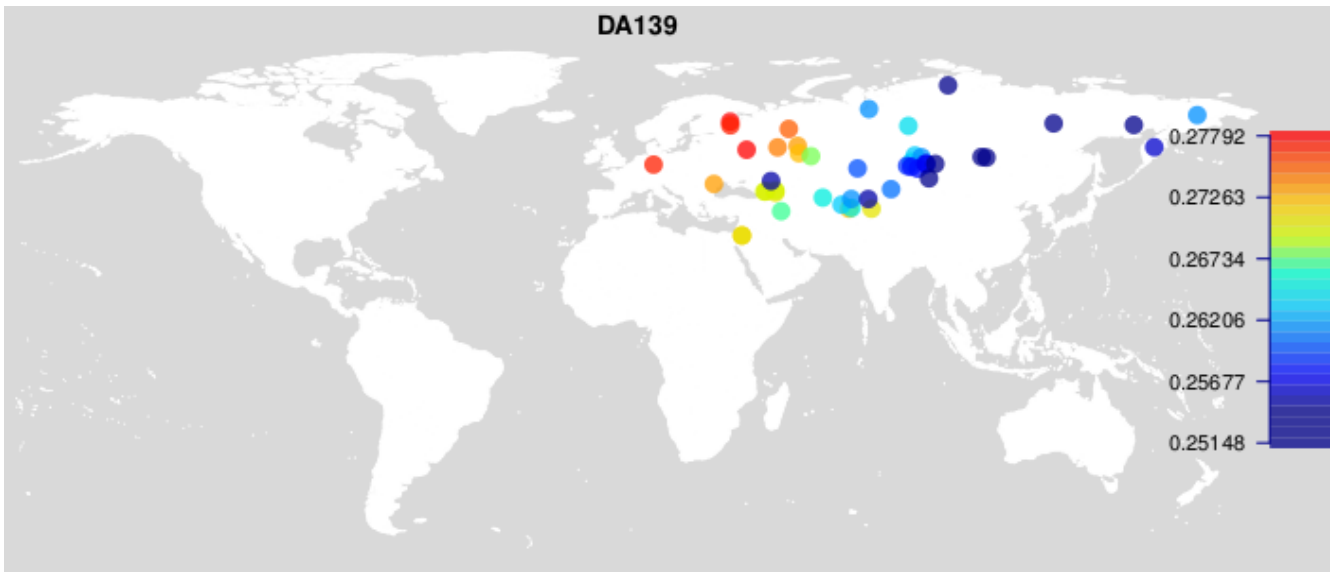
Supplementary Figure 10 - Outgroup-f3 statistics for sample DA139.

DA139 – Region: Rostov
Period: 1ˢᵗ century AD
Population label: Sarmatian
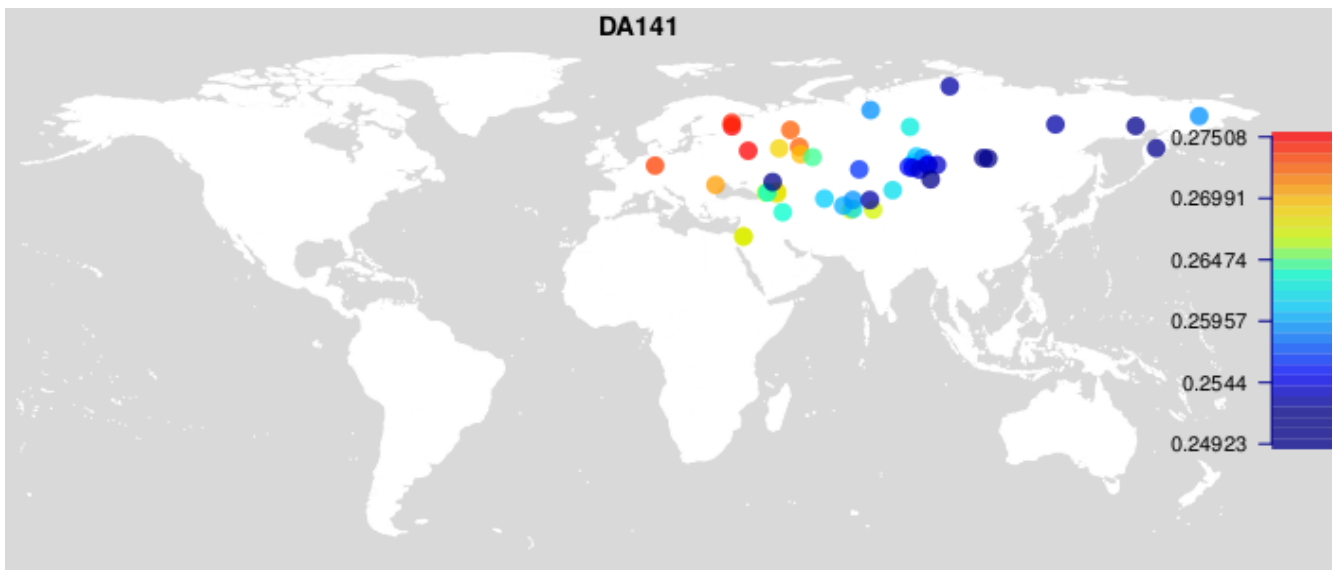
Supplementary Figure 11 - Outgroup-f3 statistics for sample DA141.

DA141 – Region: Rostov
Period: 1st century AD
Population label: Sarmatian
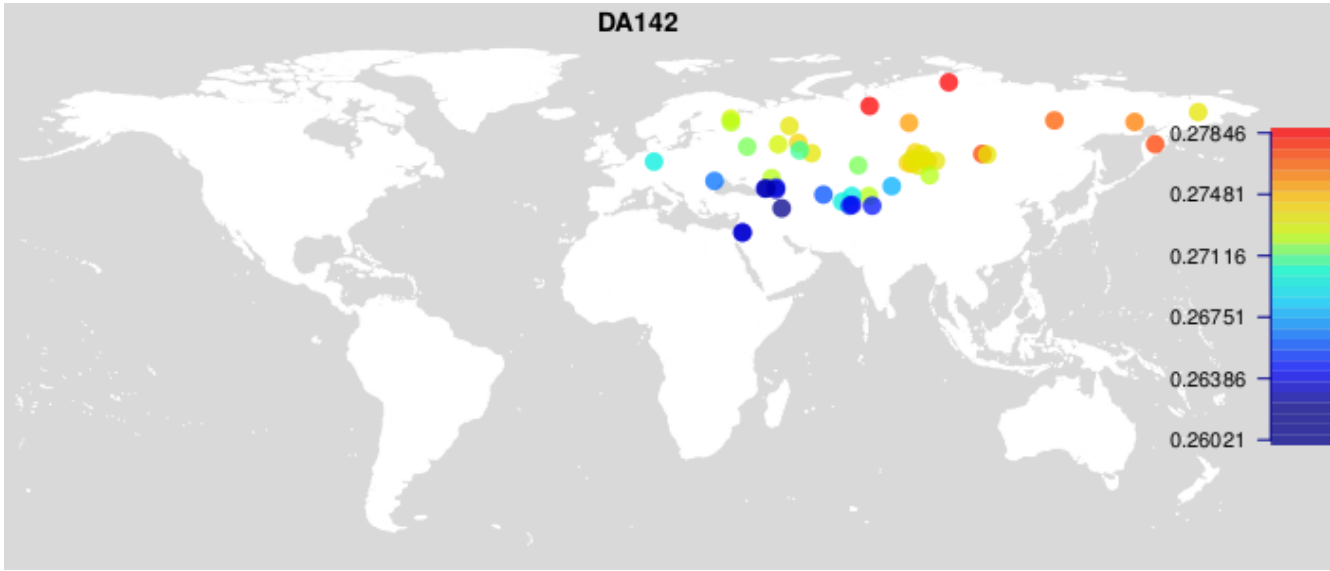
Supplementary Figure 12 - Outgroup-f3 statistics for sample DA142.

DA142 – Region: Rostov
Period: 12th – 14th century AD
Population label: Nomad_Med
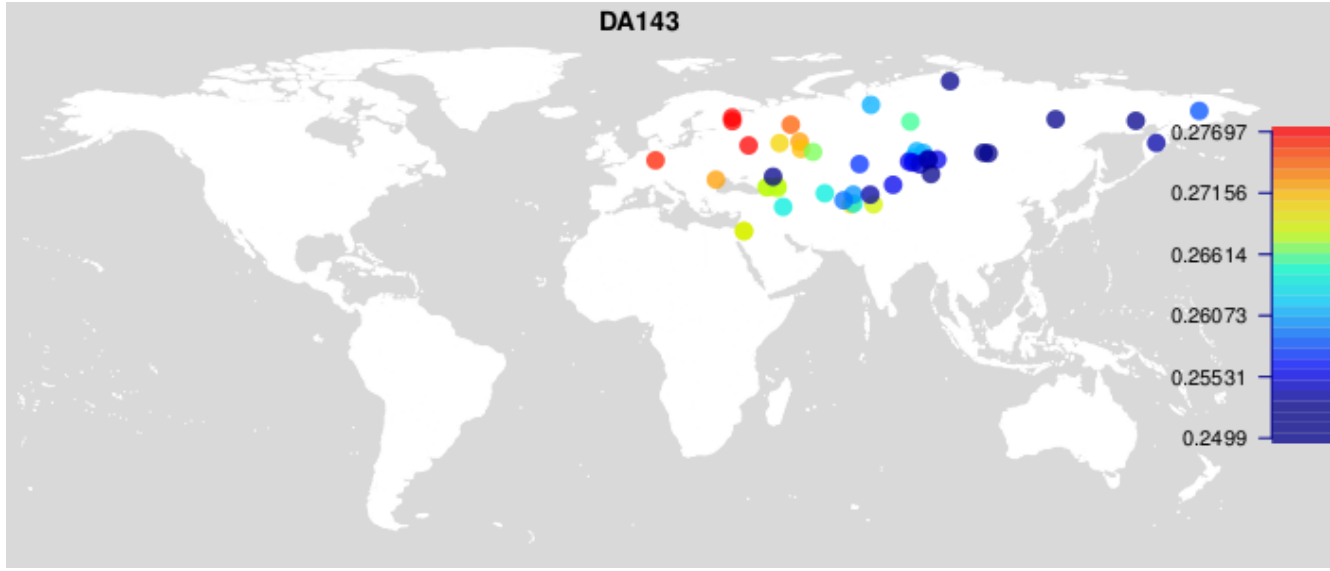
Supplementary Figure 13 - Outgroup-f3 statistics for sample DA143.

DA143 – Region: Rostov
Period: 1st century AD
Population label: Sarmatian
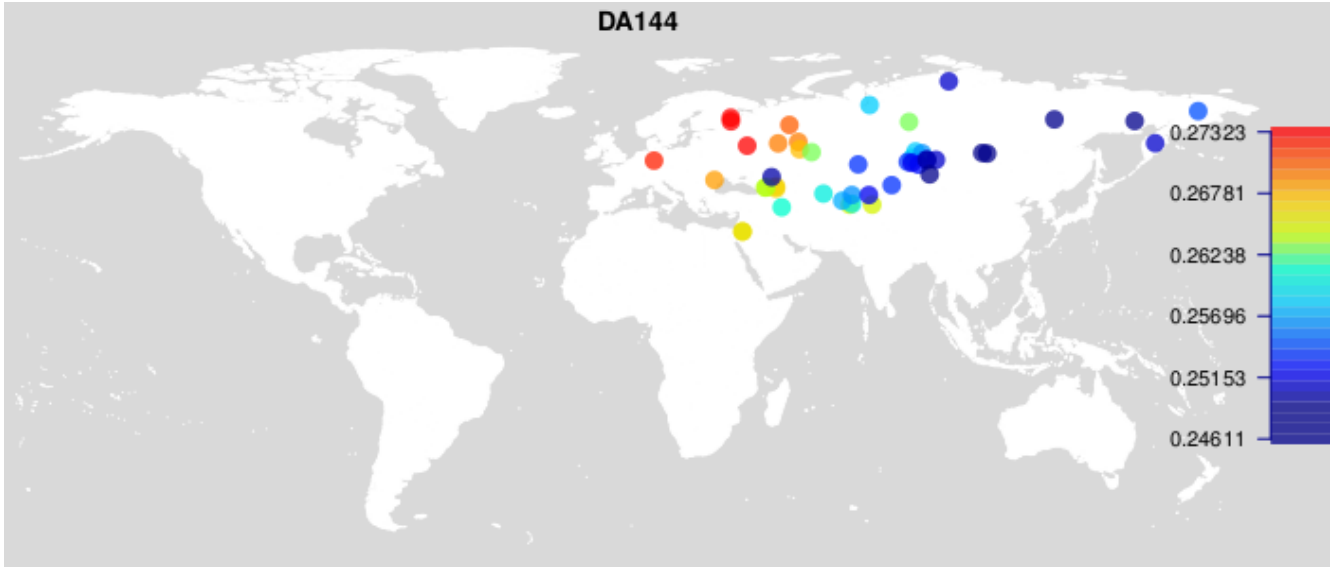
Supplementary Figure 14 - Outgroup-f3 statistics for sample DA144.

DA144 – Region: Rostov
Period: 1st century AD
Population label: Sarmatian

Supplementary Figure 15 - Outgroup-f3 statistics for sample DA145.

DA145 – Region: Rostov
Period: 1st century AD
Population label: Sarmatian

Supplementary Figure 16 - Outgroup-f3 statistics for sample DA146.

DA146 – Region: North Ossetia
Period: 6th-9th century AD
Population label: Alan

Supplementary Figure 17 - Outgroup-f3 statistics for sample DA160.

DA160 – Region: North Ossetia
Period: 6th-9th century AD
Population label: Alan

Supplementary Figure 18 - Outgroup-f3 statistics for sample DA161.

DA161 - Region: North Ossetia
Period: 6th-9th century AD
Population label: Alan

Supplementary Figure 19 - Outgroup-f3 statistics for sample DA162.

DA162 - Region: North Ossetia
Period: 6th-9th century AD
Population label: Alan

Supplementary Figure 20 - Outgroup-f3 statistics for sample DA164.

DA164 - Region: North Ossetia
Period: 6th-9th century AD
Population label: Alan

Supplementary Figure 21 - Outgroup-f3 statistics for sample DA188.

DA188 - Region: Belgorod
Radiocarbon 14C date: 1187 +- 31 BP uncal
Population label: Saltovo-Mayaki

Supplementary Figure 22 - Outgroup-f3 statistics for sample DA189.

DA189 - Region: Belgorod
Period: 750-900 AD
Population label: Saltovo-Mayaki
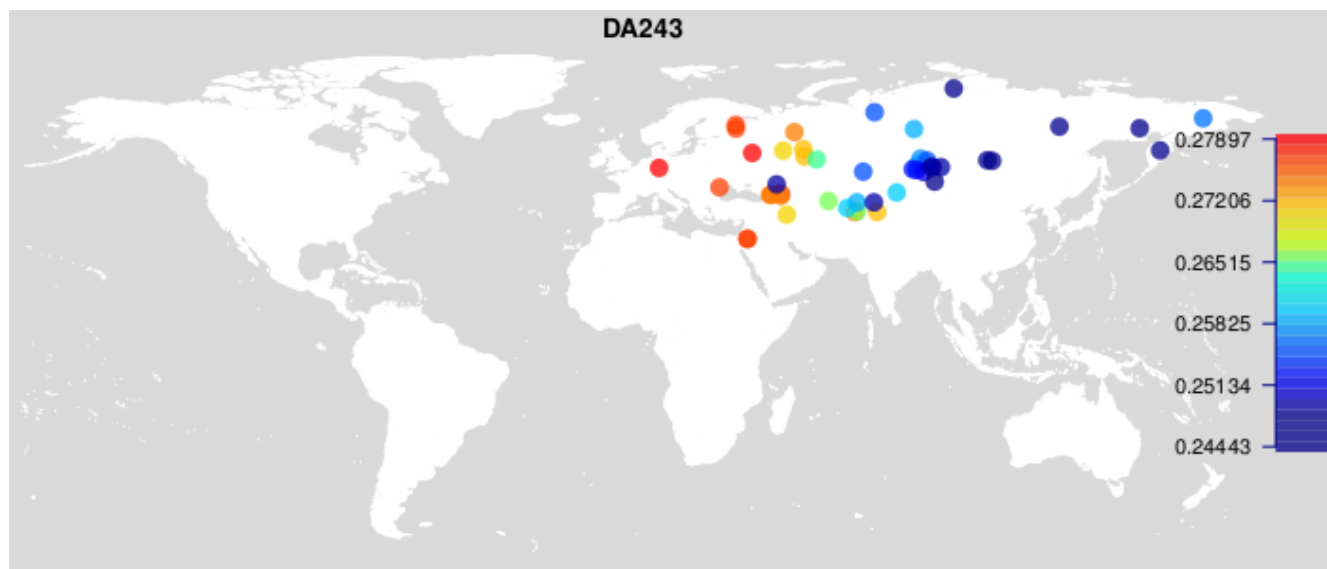
Supplementary Figure 23 - Outgroup-f3 statistics for sample DA243.

DA243 - Region: Pontic-Caspian steppe
Period: 4th century AD
Population label: Alan

Hungarian Scythians

By Václav Sĉmrka

The Prescythians (Sigynnas) lived in East Hungary from 900-700 BCE. Subsequently, the Scythians lived in East Hungary from 700-400 BCE (according to the archaeologist Oliver Gábor, 1 Dec. 2016). The Scythians that settled in Hungary belonged to tribes migrating from the Black Sea to the Poltava and Kiev regions. The reign of the Scythians in the Hungarian territory ended with immigration of the Celts.

Sites
1. **Tiszaszőlős-Csákányszeg** (Tiszafüred)
   - Jász-Nagykun-Szolnok county
Coordinates (Hungarian EOV68-114): 776687 248741; 47°33'34 and 20°42'29.
   - Bi-ritual Scythian cemetery (excavated by Csalog Zsolt in1960-1961)
Literature: Csalog Zsolt, Arch Ért 88(1961)285. Unpublished, but there are some finds here:
   http://library.hungaricana.hu/hu/view/MEGY_BEKE_GYULAIKAT_10/?pg=0&layout=s
   - Number of skeletons = 14 (6 children, 2 males, 5 females, 1 undetermined)

2. Sándorfalva-Eperjes
   - Csongrád county
Coordinates (Hungarian EOV 27-143): 736719112656; 46°20'40 and 20°09'45.
   - 75 graves of a bi-ritual Scythian cemetery (excavated by Galántha Márta)
   - Literature: GALÁNTHA 1982-83/1- Galántha Márta: Előzetes jelentes a Sándorfalva-eperjesi szkíta temető feltárásáról- Vorbericht über die Ausgrabungen des Skythenzeitlichen Gräberfeldes in Sándorfalva- Eperjes. MFMÉ1982-83/1. (1985.) 115-128
   - Number of skeletons = 39 (13 children, 25 adults of which 12 were male and 13 were female, 1 undetermined)

3. Árkus- Kőveshalom (Hortobágy) or, more precisely, **Balmazujváros-Hortobágy-Árkus**
Hajdu Bihar county
Coordinates (Hungarian EOV68-223): 799 458247755; 47°33´ 25 and21°00´55
   - Scythian cemetery (excavated by Horváth Attila in 1959)
   - Literature: archeological or anthropological points of view have not been published on this cemetery, apart from Apró Ágnes (1999) Szkíta kori humán leletek antropológiai vizsgálata Szakdolgozat, Szeget Témavezeto: Dr. Marcsik Antónia.
   - Number of skeletons = 8 (2 children, 6 adults: 3 male and 3 female)
-

Characteristic features of Scythian population in Hungary

The archaeologist A. Horváth excavated a cemetery in the Józan area of the village of Szabadszállás in the County of Bácz-Kiskun, and deposited material in the J. Katona Museum, Kecskemét.
The ratio of interments and cremations in the cemetery was estimated to be 108:72. Infant mortality appeared to be extremely high. There was 7% more females than males in the examined graves. Mortality was highest for males aged 30-35 and 25-34 for females. It is likely that the high infant

mortality and the higher death rate of women of reproductive age restricted population increase. However, burial rituals during this time could simply reflect social differences and may not be representative of population demographics. The majority of the population appeared gracile and of medium stature and lacked any Mongol element[169]. *Anthropologia Hungarica* VII, No 1-2, p.36-57According to[170], the series of skulls from the Scythian period is discernibly more differentiated than the skull series of from the preceding period. There seems to be great similarity of the Scythian skulls to the Alsonomedi series of the Copper Age examined by[171]. In addition, radiocarbon dates have revealed that the skeleton from Arkus (DA199) was buried in medieval times.
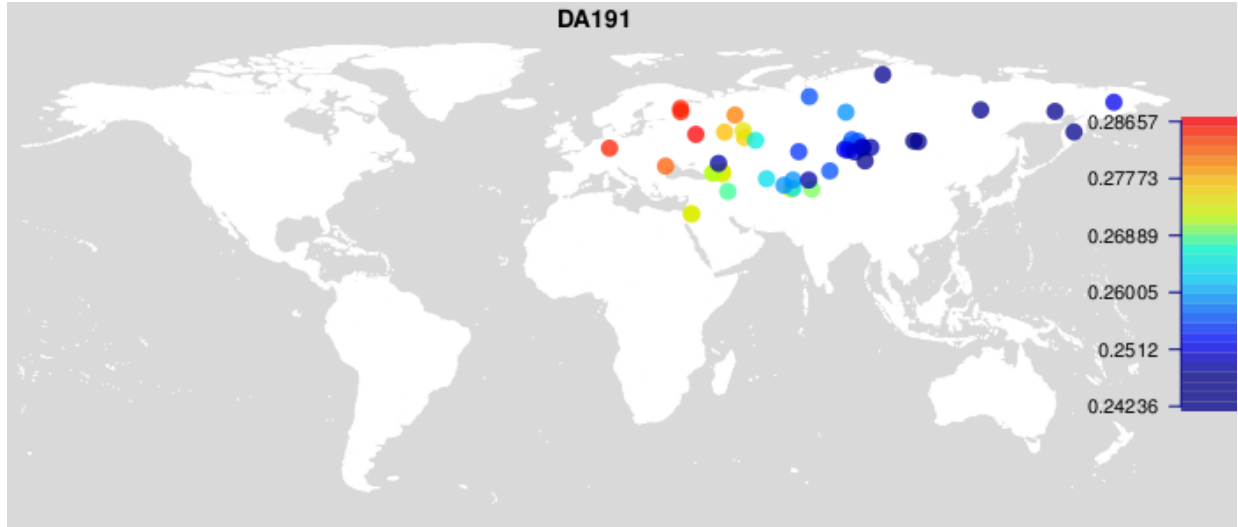
Supplementary Figure 24 - Outgroup-f3 statistics for sample DA191.

DA191 - Region: Hungary
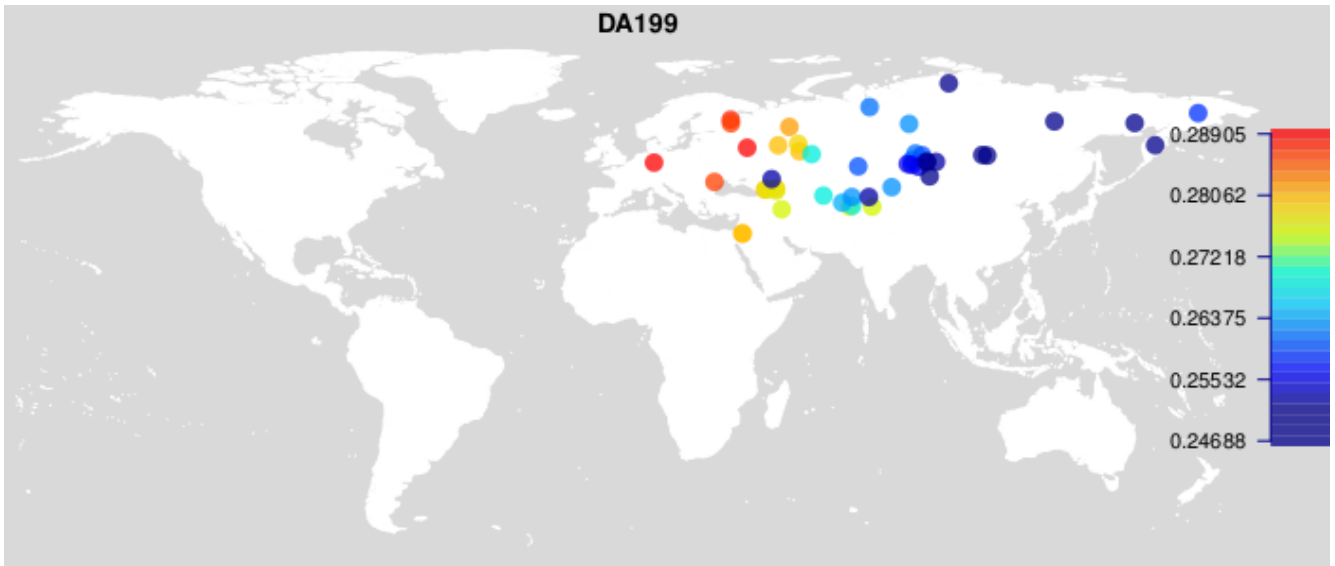**Radiocarbon 14C date: 2409 +- 37 BP uncal**
Population label: HungarianScythian
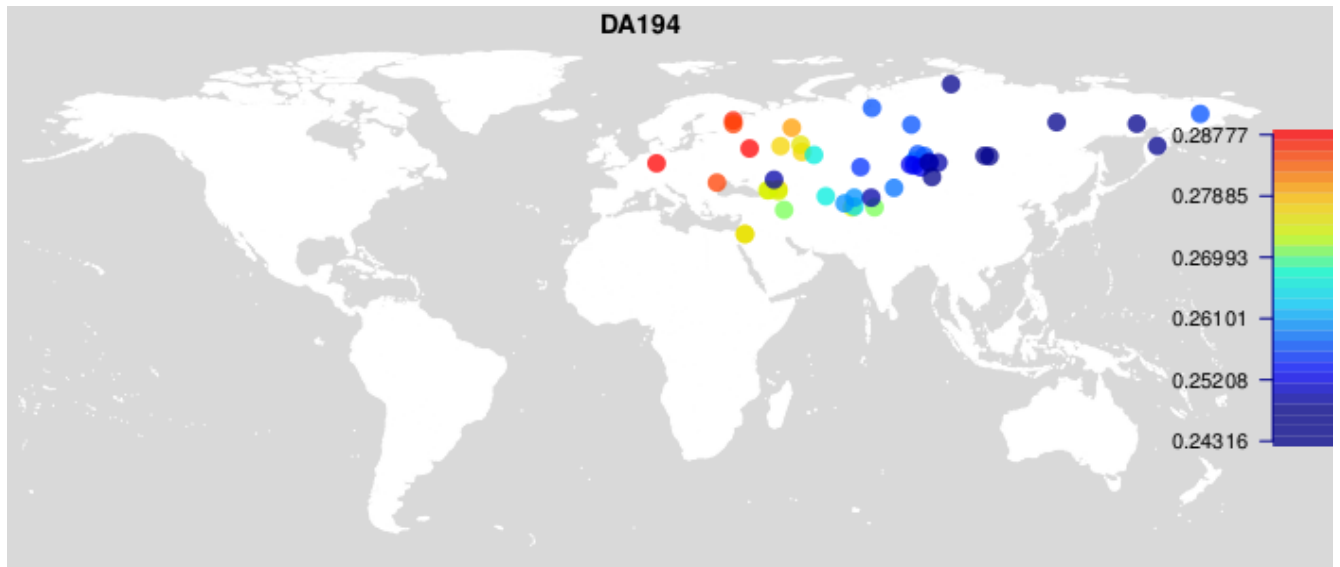
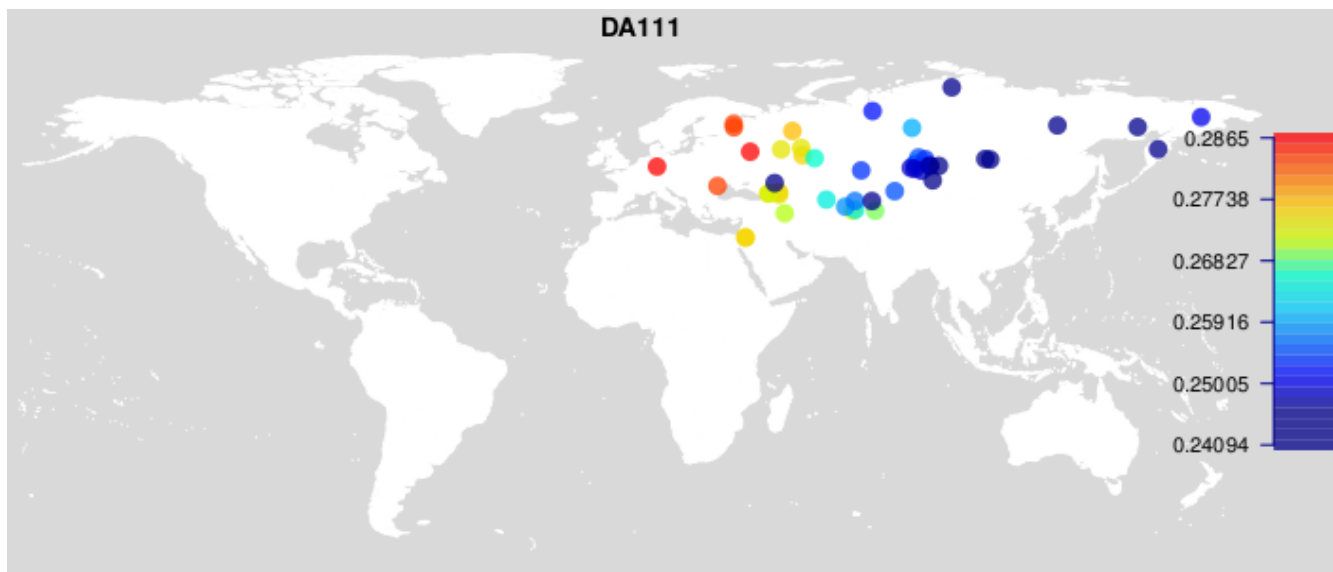**Supplementary Figure 25 - Outgroup-f3 statistics for sample DA194.**

DA194 - Region: Hungary
Radiocarbon 14C date: 2322 +- 36 BP uncal
Population label: HungarianScythian
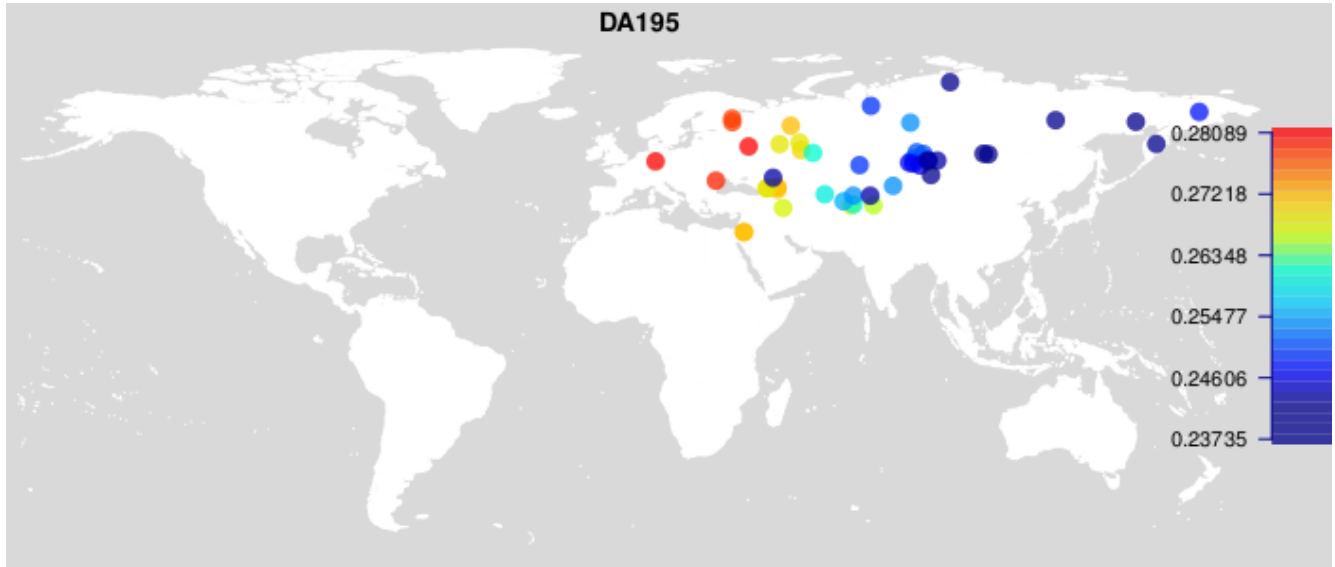
Supplementary Figure 26 - Outgroup-f3 statistics for sample DA195.

DA195 - Region: Hungary
Radiocarbon 14C date: 2479 +- 36 BP uncal
Population label: HungarianScythian
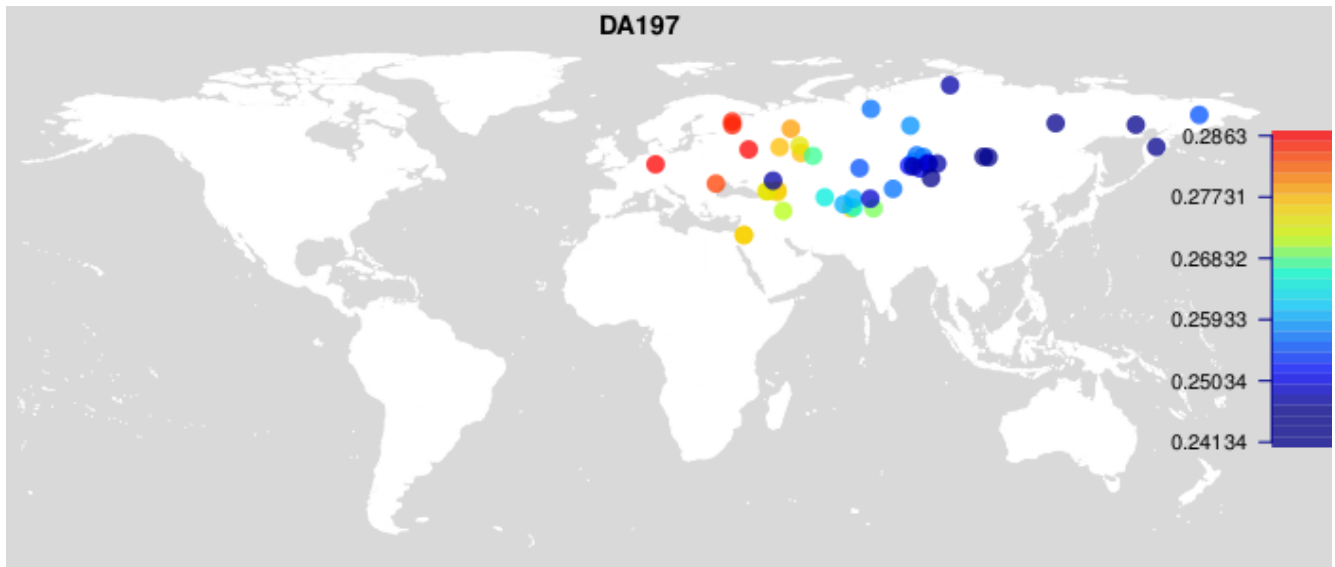
Supplementary Figure 27 - Outgroup-f3 statistics for sample DA197.

DA197 - Region: Hungary
Radiocarbon 14C date: 2479 +- 36 BP uncal
Population label: HungarianScythian
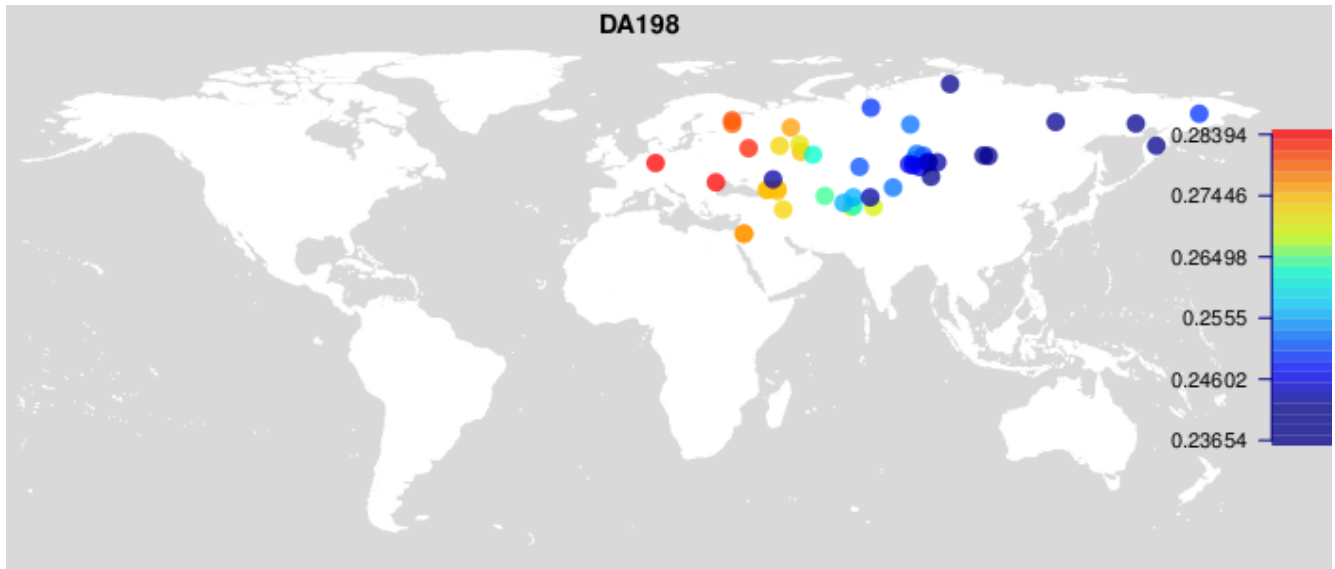
Supplementary Figure 28 - Outgroup-f3 statistics for sample DA198.

DA198 - Region: Hungary
Radiocarbon 14C date: 2479 +- 36 BP uncal
Population label: HungarianScythian

Supplementary Figure 29 - Outgroup-f3 statistics for sample DA199.

DA199 - Region: Hungary
Radiocarbon 14C date: 788 +- 30 BP uncal
Population label: Hungarian_Med

The Hallstatt-Bylany culture

By Václav Sĉmrka

The Lovosice II cemetery was excavated in 2002 by Půlpán and Blažek near the town of Litoměřice. Fifteen graves were excavated, representing 11 skeletal interments, 2 bi-ritual graves, and 2 cremations; although the site probably comprises 37 graves dispersed over 40 hectares. Lovosice is the most important cemetery of the HaC to HaD periods in Bohemia. The skulls of interment graves are aligned to the south, with the limbs pointing northwards. The arms are aligned along the body. The seven identified males were aged 20-35 years, and the three identified females were aged 24-35 years. The anthropologist J. Chochol hypothesized that cremations were of individuals of the local population, whereas the skeletal remains represented immigrant nobility.

Examples of long-distance contact are present in the form of a horse harness (probably Kimery horizon), a mounted stone characteristic of the Carpathian Basin and Black Sea region in Grave 1, and a pin in Grave 18 with bird motifs analogous to those found in the Caucasus.

Supplementary Figure 30 - Outgroup-f3 statistics for sample DA111.

DA111 - Region: Czech Republic
Radiocarbon 14C date: 2630 +- 48 BP uncal
Population label: HallstattBylany
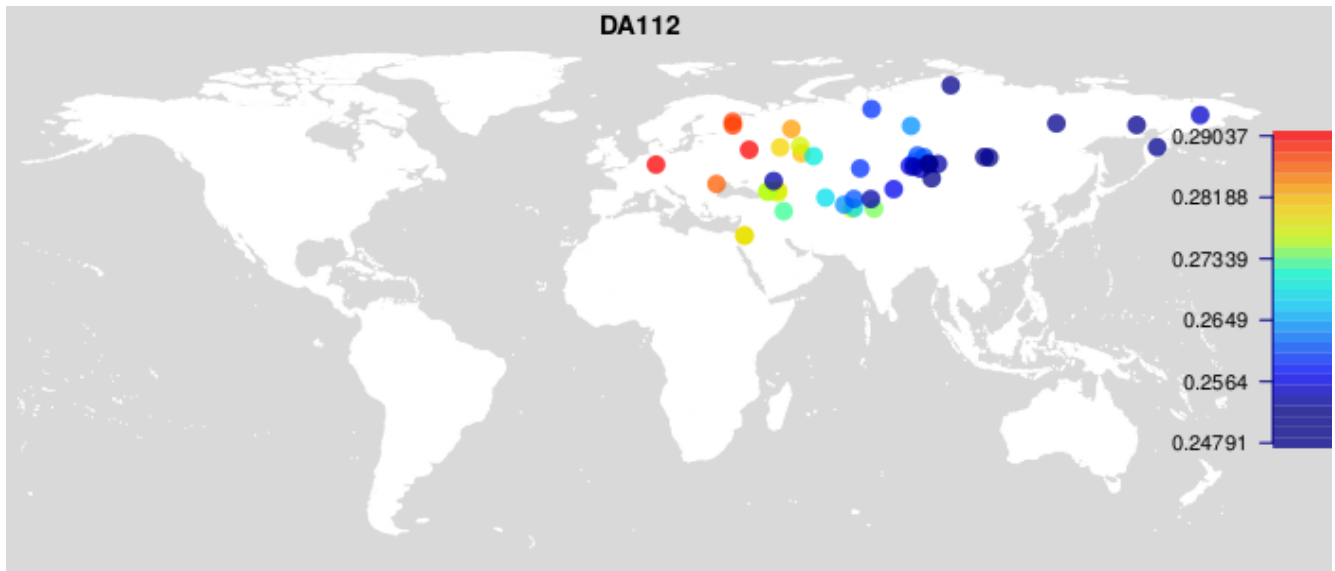
Supplementary Figure 31 - Outgroup-f3 statistics for sample DA112.

DA112 - Region: Czech Republic
Radiocarbon 14C date: 2430 +- 49 BP uncal
Population label: HallstattBylany

Descriptions of Mongolian samples

By Bazartseren Boldgiv

The Arkhangai site

Sample XiongNu 92 belongs to this site located at 48°00'63.82"N, 101°20'72.35"E. Sample XiongNu 92 comes from Grave #1 that was apparently dug for an aristocratic figure of that time. This grave was found in a place named Balgasyn Tal of Öndör-Ulaan Soum in the province of Arkhangai Aimag. The entire burial structure is enormous, with a length of 86 m that includes 37 m of an entrance into the burial site (Supplementary Figure 32). The main tomb had a 48 m long and 3.5 m tall rock wall on the east flank, a 48 m long and 2.2 m tall rock wall on the west flank, as well as a 46 m long and 4 m tall rock wall to the north. This is a very special finding because it represents the largest burial structure ever found in Central Asia, the largest burial site with accompanying sacrificial graves (31 accompanying sacrificial graves arranged in an arc to the east of the main grave), as well as the deepest grave yet reported (at 23 m). Unfortunately, the main grave had been robbed, but still yielded some rather astonishing artifacts that clearly suggest a burial ritual for kings of the Xiongnu period. The skeleton of the main grave (i.e. of the aristocrat) was extensively broken and, therefore, only some parts of the skull and some limb bones were found. The remains were estimated to belong to that of someone aged 35-45 years old. Thirteen pairs of worship mounds are arranged 10 m to the north of the main grave in two rows and span 20 m in length.

Rock coverings and sand filling alternate to a depth of 16 meters. On deeper excavation, the size of the rock structure was reduced. At a depth of 10 meters, at the rear of the rock structure, we found remains of more than 20 horses and 5-6 goats or sheep in a 5 x 8 m area. A charcoal layer of 60-120 cm was found at a depth of 16 m, where the remains of a horse-drawn cart colored in red, black, white and blue were found, as well as some accessories that included a silver-decorated leather bridle. Some other carts had been deliberately destroyed and burned either during or after the burial. Bronze and iron parts of these carts were found in four different locations. Below the charcoal layer, a 1 m deep rock layer was found, which lay above a three-compartment structure made of 20-30 cm logs. The first compartment at the rear of the mausoleum held vases, bowls, bronze pots, a bronze kettle and glass bowls. The second middle compartment held a 2.2 m-long casket that had been decorated abundantly with gold, most of which had been robbed (only three planks of the bottom left corner remained with some gold decorations). The second compartment also contained a 23 cm-diameter jade mirror. The third compartment, the most easterly part of the tomb, contained accessories for horses and horse-drawn carts made of gold, silver and bronze.

From an accompanying grave (No. 30), we found a blue-and-white glass bowl of diameter 7.5 cm and thickness 1.1 cm, which was probably made in ancient Rome (Supplementary Figure 33). The horse-drawn cart may have been delivered from the Han dynasty (currently China) only after the burial ritual had concluded and, therefore, it may have been included in the rock structure above the actual grave.

Supplementary Figure 32 - Grave #1 of Gol Mod 2.

Supplementary Figure 33 - A Roman-style glass bowl found in Grave #1 of Gol Mod 2.

The Hovsgol site

Samples XiongNu 91 and XiongNu 94 belong to this site. Sample XiongNu 91 came from Grave #18 that is located at 49°16'27.78" N, 101°42'56.67" E in Rashaant Soum of Hovsgol Aimag (province). The soil surface of the grave was covered with a flat, circular rock of diameter 3.8 m. The grave had been robbed, evidenced by a black vase that was left standing in the northwest corner of the grave, the destroyed thorax of the skeleton, and the single femur that was left in the middle of the bones of the upper body (Supplementary Figure 34). Both tibia were intact and pointed to the west, suggesting that the body had been strategically placed in the grave. Two horse heads had been placed at the feet of the body, both with their snouts pointing to the right.

Sample XiongNu 94 came from Grave #14, which is located at 49°16'27.78" N, 101° 42'56.67" E in Rashaant Soum of Hovsgol Aimag (province). This grave was also covered on the soil surface by a flat, circular rock of diameter 6.4 m. During excavation, we found a human skeleton that was separated from a horse skeleton and a cattle skull by a barrier made of large, thin rocks. The human head was pointing in a northwesterly direction, and the skeleton lay at a depth of 6.4 m. The skeleton below the waist appeard to be intact. In contrast, the upper body bones had been moved a great deal, with the ribs and vertebrae scattered and the lower jaw located near an arm (Supplementary Figure 35). The skull had been broken into pieces and lay at the same level as the upper part of the rock barrier.

Supplementary Figure 34 - Grave #18 that yielded sample XiongNu 91.

Supplementary Figure 35 - Grave #18 that yielded sample XiongNu 94.

The Omnogobi site

Samples XiongNu 96 and XiongNu 98 belong to this site, which appears to be a mass grave located at 42°30'93.2" N, 105°10'48.09" E. The site is located in Nomgon Soum (administrative unit) of Omnogobi Aimag (or province), south of the Hörhiin Nuruu Mountains and north of Borzon Gobi.

Clear signs of a clay-walled structure were found here. When the site was excavated in 2009, a grave was found on the silt bank of a small stream, 200 m east of the walled structure. The grave contained the full skeletons of 20 people and partial remains of another 33 people (Supplementary Figure 36). Judging from how these bones were arranged and how complete these skeletons were in this grave, we concluded that these people were victims of a fierce battle and had been killed by swords or other weapons. This find represented the first of its kind, providing clues about the material cultures that were found in the vicinity of this settled area in the Xiongnu period. It is also the only mass grave of the people from that time period.

Supplementary Figure 36 - Excavation of a mass grave in Omnogobi Aimag.

General information on Xiongnu-period artifacts found in Mongolia

A great deal of cultural and trade exchanges with other peoples at the time have been found for the Xiongnu people, evidenced by the artifacts found in Mongolia. Artifacts of Egyptian, Greek and Roman origin have been found in Xiongnu-period tombs in the country. For example, Noyon Uul tombs in north-central Mongolia have yielded textile fabrics of Greek-Bactrian origin, suggesting that the Xiongn people traded through Eastern Turkestan. The Xiongnu people also bought corals and crystals from Greece-Bactria, Middle Asia and Eastern Turkestan and traded them with Chinese people in the south. In 2006, ancient Roman silver decorations depicting male and female figures were found in Noyon Uul tombs in north-central Mongolia (Supplementary Figure 37). In 2003, excavation of a Xiongnu grave at Baga Gazryn Chuluu in central Mongolia yielded a nude male figurine depicting the Egyptian god Bes (Supplementary Figure 38) and a hand-shaped pendant dated to around 100 BCE to 200 CE (Supplementary Figure 39). Moreover, a clearly Roman glass bowl was found accompanying Grave #30 of Gol Mod 2 in Öndör-Ulaan Soum of Arkhangai Aimag. These artifacts show that Xiongnu was a hub for east-west trade.

Supplementary Figure 37. Greek-Roman gods depicted on a silver decoration, found in Grave #20 of Noyon Uul, north-central Mongolia.
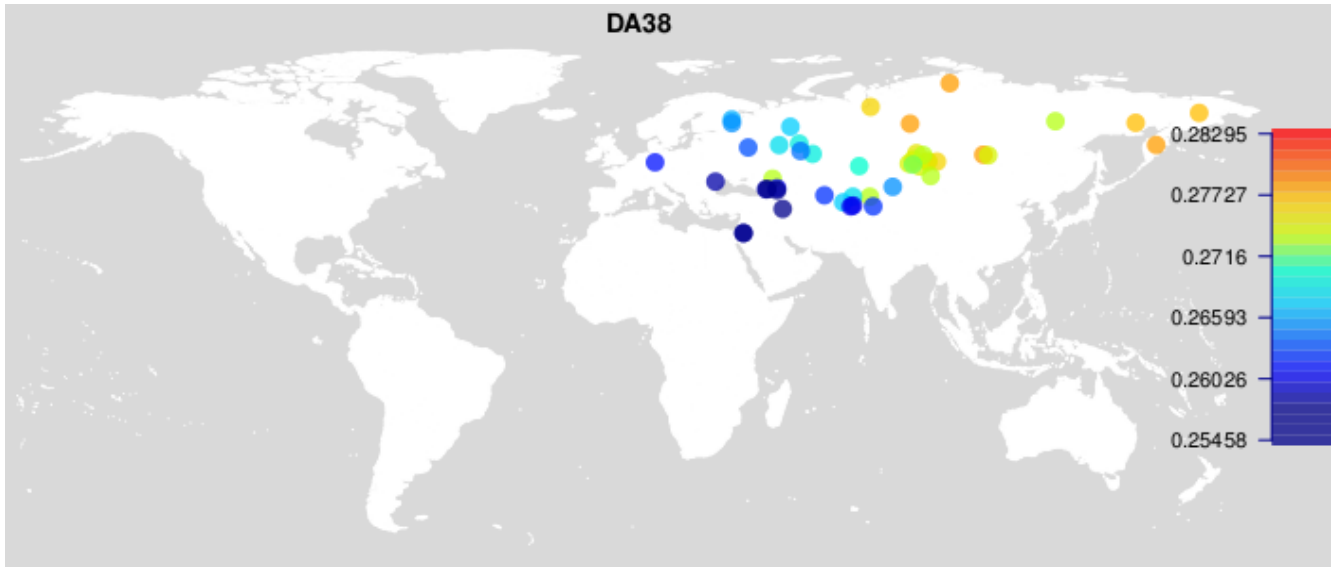

Supplementary Figure 38. Figurine of an Egyptian god, found in a Xiongnu grave in Baga Gazryn Chuluu, central Mongolia.

Supplementary Figure 39. A hand figure, found in a Xiongnu grave in Baga Gazryn Chuluu, central Mongolia.
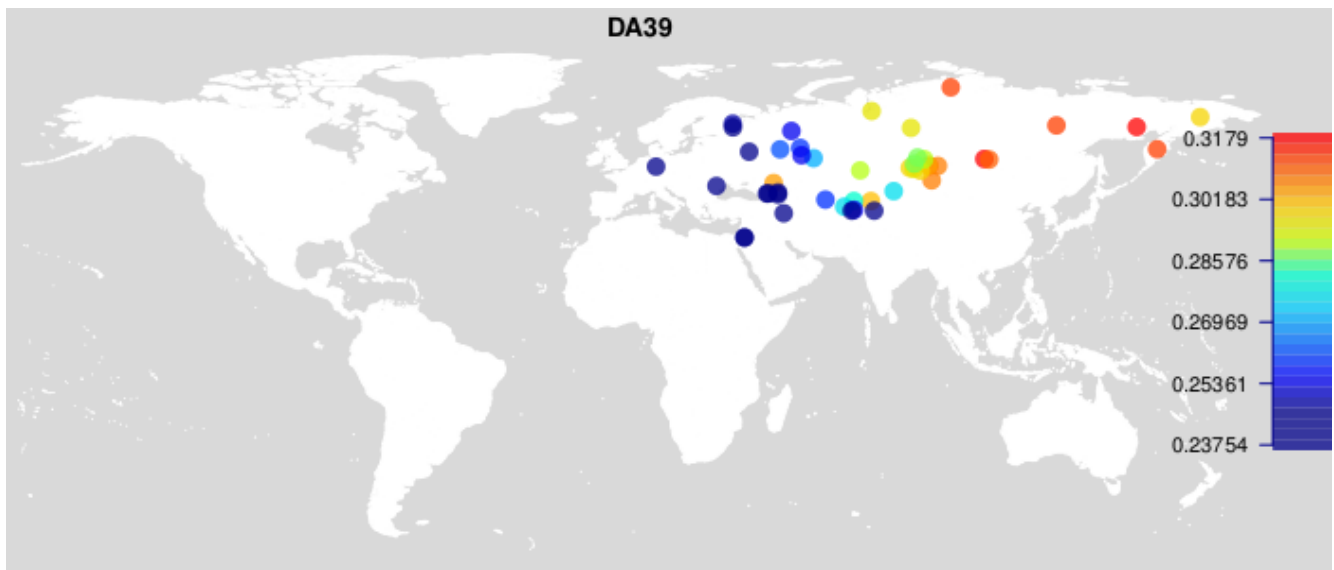

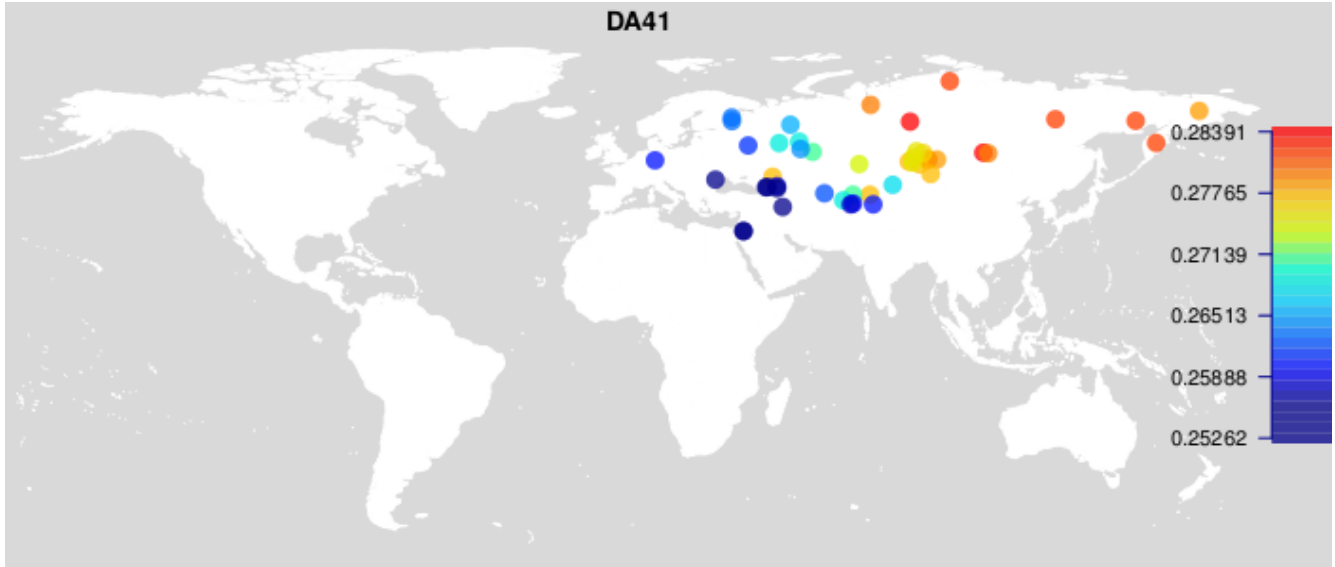**Supplementary Figure 40. A Roman-style glass bowl found in Grave #1 of Gol Mod 2.**

Supplementary Figure 41 - Outgroup-f3 statistics for sample DA38.

DA38 - Region: Mongolia
Radiocarbon 14C date: 2131 +- 26 BP uncal
Population label: XiongNu_WE

Supplementary Figure 42 - Outgroup-f3 statistics for sample DA39.

DA39 - Region: Mongolia
Period: Xiongnu
Population label: XiongNu

Supplementary Figure 43 - Outgroup-f3 statistics for sample DA41.

DA41 - Region: Mongolia
Period: Xiongnu
Population label: XiongNu_WE
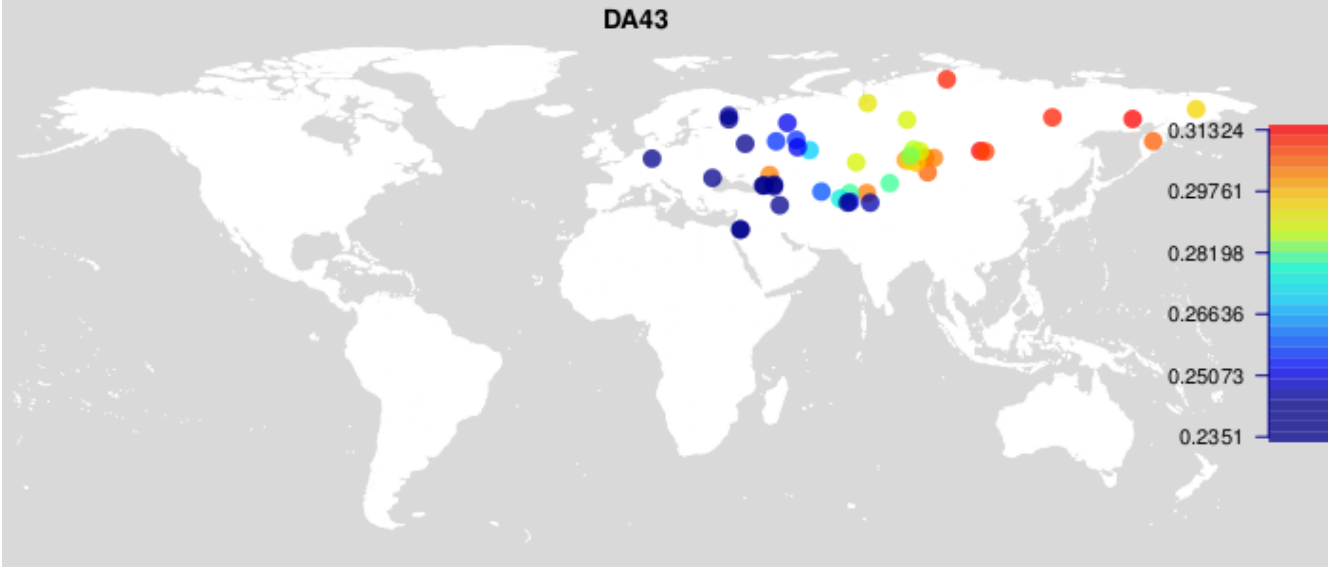
Supplementary Figure 44 - Outgroup-f3 statistics for sample DA43.

DA43 - Region: Mongolia
Period: Xiongnu
Population label: XiongNu
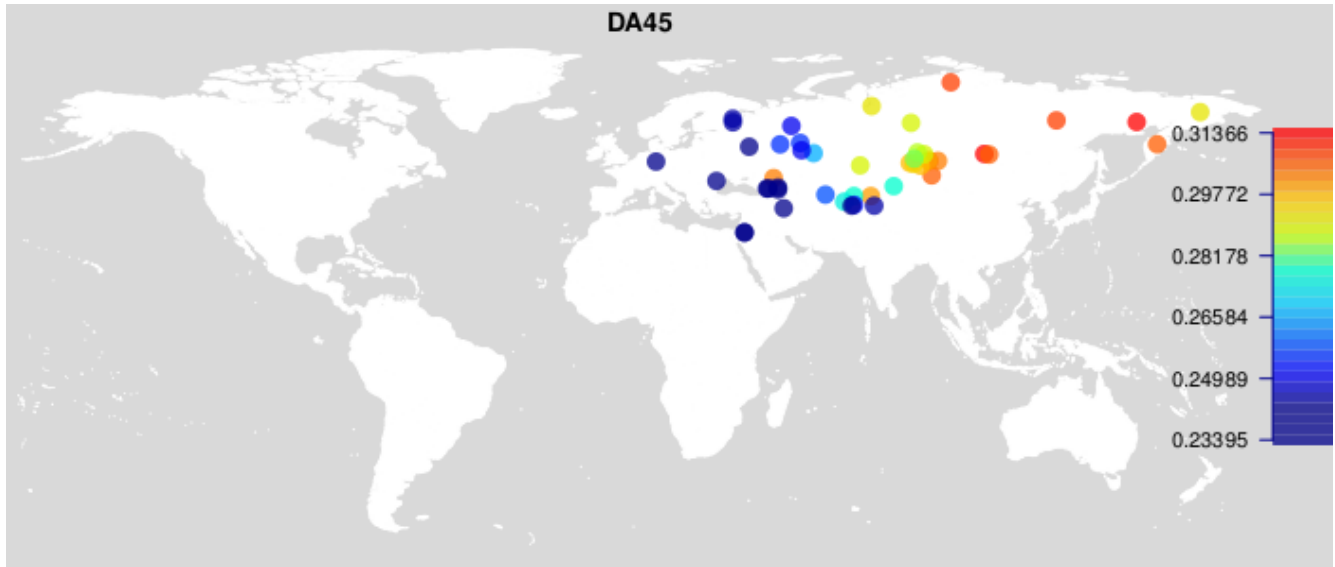
Supplementary Figure 45 - Outgroup-f3 statistics for sample DA45.

DA45 - Region: Mongolia
Radiocarbon 14C date: 2083 +- 27 BP uncal
Population label: XiongNu

The Sarmatian kurgan of the Naurzum Necropolis

By Evdokimov V.V. [1], Tkachev A.A. [2]

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The Naurzum Necropolis

The necropolis is located on a narrow sandy promontory, between the small and large Aksuat lakes (Kostanay, North Kazakhstan). In ancient times, the early Iron Age burial mound would have been located at the highest point of the central part of the cape. The kurgan mound was subsequently destroyed by erosion.

The funeral rite and inventory

In the center of the fenced area a rectangular subsoil pit measuring 2.1 x 1.4 m (2.5 m depth) was found, which was oriented NW-SE. Residue of organic decay and willow shrub formation suggest that in the process of burial, a woven willow basket with a strengthened wooden base was placed into the rectangular pit before the deceased was laid into it. The basket would then have been covered with a woven willow frame. At the bottom of the grave, inside the basket, we found the skeletons of a man, a woman and a child.

The buried man was laid on his back along the south-western wall, with his arms alongside his body and his head facing the southeast. An iron knife was located on the right side, near his waist. An iron sword was placed on his left side and an iron dagger was located at his right tibia. A clay jar was found in the north-west wall of the grave, near his feet. The buried woman was laid on her back parallel to the man, with her head in an extended position and also facing the south-east. A clay whorl was located at her left shoulder. The buried male child was located along the north-eastern wall of the grave. He was laid on his back, with his head position extended and facing the south-east. A bone tube was located at the child's pelvis and a vessel was found near his head. Bones of sheep and goats were found at the south-east wall of the burial pit. Analysis of the funeral rites and the inventory point to this monument being from the early Sarmatian period (end of the 4th-2nd (1st) century BCE).
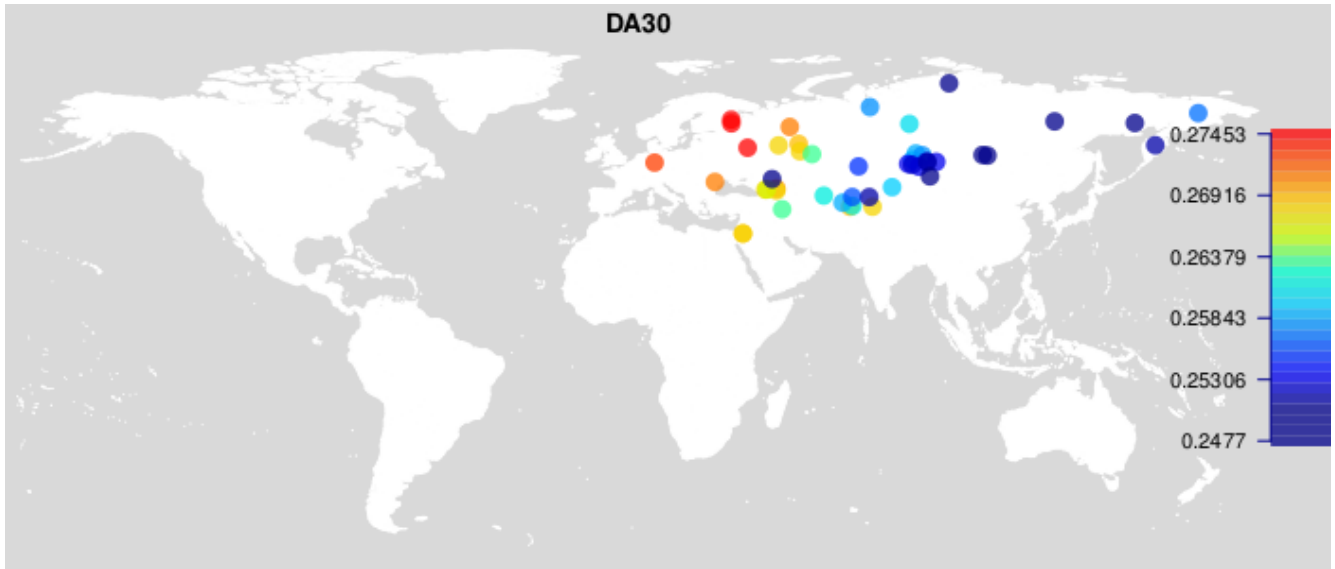
Supplementary Figure 46 - Outgroup-f3 statistics for sample DA30.

DA30 - Region: Central steppe
Radiocarbon 14C date: 2013 +- 32 BP uncal
Population label: Sarmatian

The Sarmatian burial of the Bestamak Necropolis

By Andrey Logvin[1], Irina Shevnina[2]

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[2]A. Baitursynov Kostanay State University, Kostanay, KZ

The Bestamak Necropolis.
The unpaved Bestamak Necropolis is located at the source of the river Ubagan (Kostanay, North Kazakhstan). The total area of the excavation at the moment is 9092 m². Most of the graves and altars of the necropolis date back to the 2nd millennium BCE (i.e. the Bronze Age), but some belong to later archaeological periods. Materials from Burial No. 138 belong to the early Sarmatian culture (4th-2nd centuries BCE).

The funeral rite and inventory

The burial site had a diameter of 24 m (width ranging from 2.5 to 4.5 m) and was 1.8 m deep. The sub-rectangular group burial pit measured 4.27 x 2.55 m, with a depth of 1.3 m. The narrow vertical entrance leading to the burial chamber was covered with poles laid crossways. The chamber itself was built with pre-weakening in the western part. Four skeletons had been laid in two pairs within the burial chamber, feet to feet at the center of the pit, with two heads pointing northwards and two pointing southwards. All skeletons had been laid on their backs and in the fully extended position. facing the south. All skeletons legs are directed towards the center of the pit. When cleaning and describing the skeletons were named No.1, No.2, No.3, and No.4 during cleaning and subsequent description. In our assessment, the inventory placed in the grave could be divided into "personal" and "shared" items. "Personal" items that might be needed in the afterlife were laid right next to the deceased. "Shared" items, including the sacrificial meal, were buried in pottery and wooden vessels. It is likely that the deceased's activity during life played an important role in the set of "personal" belongings added to the burial. Skeleton No.1, a male of 30-35 years, was attributed the highest status of the four deceased. He was perhaps a military leader, evidenced by the sword, dagger, the bundle of tipped arrows and the remains of an "armored" headdress found by his body. Skeleton No.2 was also a male, aged 40-50 years, had a ram's skull by his head and only bronze-tipped weapons were found beside him. The next highest-ranking individual was a female (Skeleton No.4), aged 10 years +/- 30 months (based on the backbone), alongside which were found typically feminine and obviously imported goods (such as a small ceramic whorl made on a potter's wheel, a vial, glassy pearl and stone beads, and a large painted earthenware bead). A female of 50-55 years (defined by the backbone, Skeleton No.3) was the lowest-ranking individual, given her sex, advanced age, and the fact she possessed the smallest inventory (no items placed by her body and only stone and pearl beads were recorded that had been embroidered onto her dress).

Date and cultural interpretation

Based on the funeral rite and associated inventory, Burial No.138 is categorized as early Sarmatian (4th to end of the 2nd (1st) century BCE). Sarmatian burials in the Turgai Steppe (such as Burial No. 138 of Bestamak Necropolis and the Nauzurum burial mound) belong to the eastern edge of Sarmatian settlements. The Sarmatians were an alliance of nomadic Iranian tribes such as the Aorses, Yazygs, Sirak, Roksolana, and Alans who lived in the steppe regions of Eurasia, from Western and Northern Kazakhstan to Eastern Europe. The Sarmatian culture formed in the South Urals and the West

Kazakhstan steppes. In the 4th century BCE, expansion of the Hun tribes ended the dominance of the Sarmatians, with some Sarmatian groups being destroyed and others joining the Hun tribes.
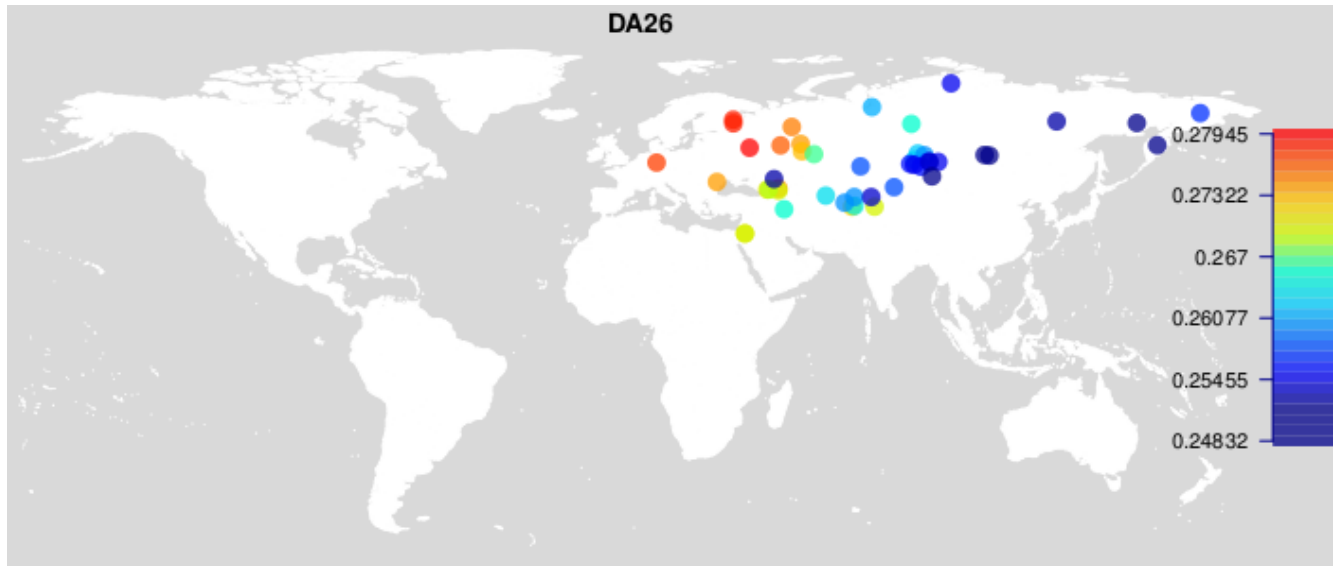
Supplementary Figure 47 - Outgroup-f3 statistics for sample DA26.

DA26 - Region: Central steppe
Radiocarbon 14C date: 2130 +- 32 BP uncal
Population label: Sarmatian

The Halvay 3 kurgan burial of the Hun period

By Andrey Logvin[1], Irina Shevnina[2], Alina Kolbina[3]

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[3]Kostanay Regional Historical Museum, Kostanay, KZ

The Halvay 3 kurgan is located on the left bank of the Tobol branch of the Karatomarsk Reservoir (Taran District, Kostanay, North Kazakhstan). The kurgan is 32 m in diameter (including the moat) and 1 m high. This kurgan was built during the Bronze Age (Sintashta culture), though some burials in the kurgan mound are from later archaeological periods (for example, Burial pit No.3A is from the Hunnish 4-6th centuries BCE).

The funeral rite and inventory

Burial pit No. 3A is oval-shaped, measuring 1.7 × 0.7 m and 0.55 m deep. An elderly man was buried lying on his right side in the pit, with his head pointing north. A horse's skull (mare) and all of its caudal vertebrae were located above his head and a ram's skull had been placed in front of his face. A sheep's pelvis was placed near to the man's pelvis, together with an iron knife and a clasp. In front of the buried man and along his body was a bow, the bony plates of which had been preserved but the drawstring was missing. A wooden quiver containing eight iron-tipped arrows was located near his legs and, at his feet, was bits of iron and a bone buckle.

Date and cultural interpretation

Burial pit No.3A of the Halvay 3 kurgan belongs to the Hun period, based on the funeral rite and inventory. The Hun culture was common on the steppes of Kazakhstan and Central Asia to Eastern Europe in the 2nd-5th (6th) centuries BCE and a few funeral monuments have been found. The Huns were an alliance of nomadic tribes that formed in the 2nd century BC to the 4th century CE when Central Asian tribes, i.e. the Xiongnu (Huns), migrated into the Ural-Kazakhstan steppes and incorporated the Sarmatians and other tribes. During the thcentury 4th century CE, the Huns created a powerful tribal alliance and moved westwards, initiating what can be termed the "Great Migration of Peoples".

Anthropological characterization

The skeleton in Burial pit No.3A is that of a man of old age, who was physically well-developed. The individual belonged to the mezocranial broad-faced type with admixed mongoloid features. Paleopathological study has revealed the presence of a number of diseases including osteomyelitis, periodontal disease and possession of a dental-maxilla apparatus, a deviated septum arising from a traumatic event, an altered periosteum (brow area, the occipital part of the skull) associated with the effects of cold stress, as well as degenerative-dystrophic changes in skeletal bones (spondylosis and vertebral osteophytes, curvature of the spine in the thoracic region, and anchylosis of the cervical spine, amongst others). In addition, the man had a pierced clavicle (perhaps an injury from a thrusting weapon), which had been broken and healed and that may have been re-set.
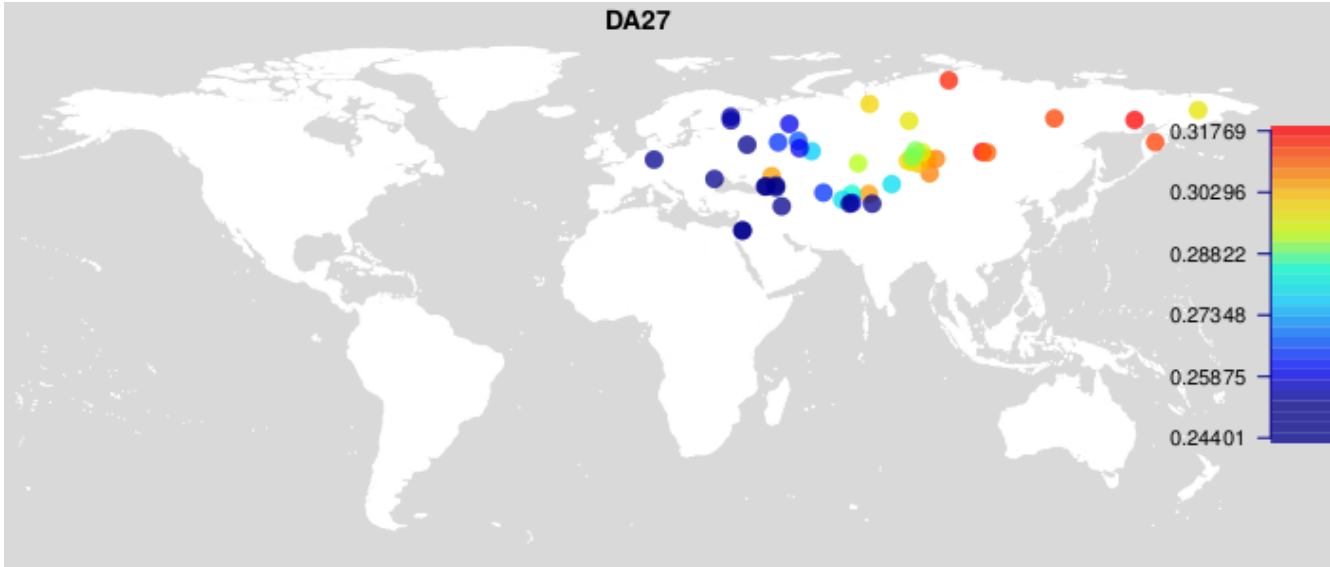
Supplementary Figure 48 - Outgroup-f3 statistics for sample DA27.

DA27 - Region: Central steppe
Period: Hun Period
Population label: Hun-Sarmatian

The Basquiat I burial site

By K.I. Tashbaeva

Department of Archaeology, Institute of History and Cultural Heritage of the National Academy of Sciences of the Kyrgyz Republic.

The Sakas culture from Tian Shan dates from the 8th-2nd centuries BCE and even just before the turn of these eras. Cemeteries of these early nomads contain from a few to several tens of burial mounds, often arranged in chains oriented north to south. Larger kurgans were often located in the central parts of these chains of burial mounds where the elite members of society (e.g. tribe leaders) were buried. The smaller surrounding burial mounds were used for the ordinary members of society. Graves were dug into the ground and were predominantly oriented west to east, with some deviations. Burial pits usually possess overlapping layers of wooden logs or large stone slabs. The northern walls of these pits often had niches for burial items. The mostly single human bodies the pits held were typically laid flat on their backs, with the heads oriented westward. For graves without niches, burial jars were usually placed at the northern wall of the pit, behind the left shoulder of the deceased. Due to grave-robbing committed in ancient times, few funerary items remain in the pits[172,173].

The funeral ritual of the burials at Basquiat I is slightly different to those of all other cemeteries based on the composition of funerary vessels and their locations. At Basquiat I, small, rough, specially-made vessels were placed in graves instead of the typical naturally-sized ceramic vessels of other cemeteries. Basquiat I funerary vessels were delivered into the burial pits on special hangers. This atypical behavior suggest that the nomads that built the Basquiat I burial pits had migrated from other places[174].

The culture of the tribes that created the Podboyno catacomb monuments dates from the 1st-5th centuries AD, i.e. the time of the "Great Migration of Peoples" (or Hunnic period). During this period, burials were made in funerary structures or catacombs and the skeletons sometimes display skull deformations. The deceased were often supplied with small wooden tables, decorative objects, household items, and various belt buckles. Burials were made in kenkolsk-type catacombs at Zhapyryk cemetery. Judging by the characteristics of the funerary structures and variations in the accompanying inventory, these cemeteries were left by tribes that had different origins, resulting in the somewhat different burial rites.
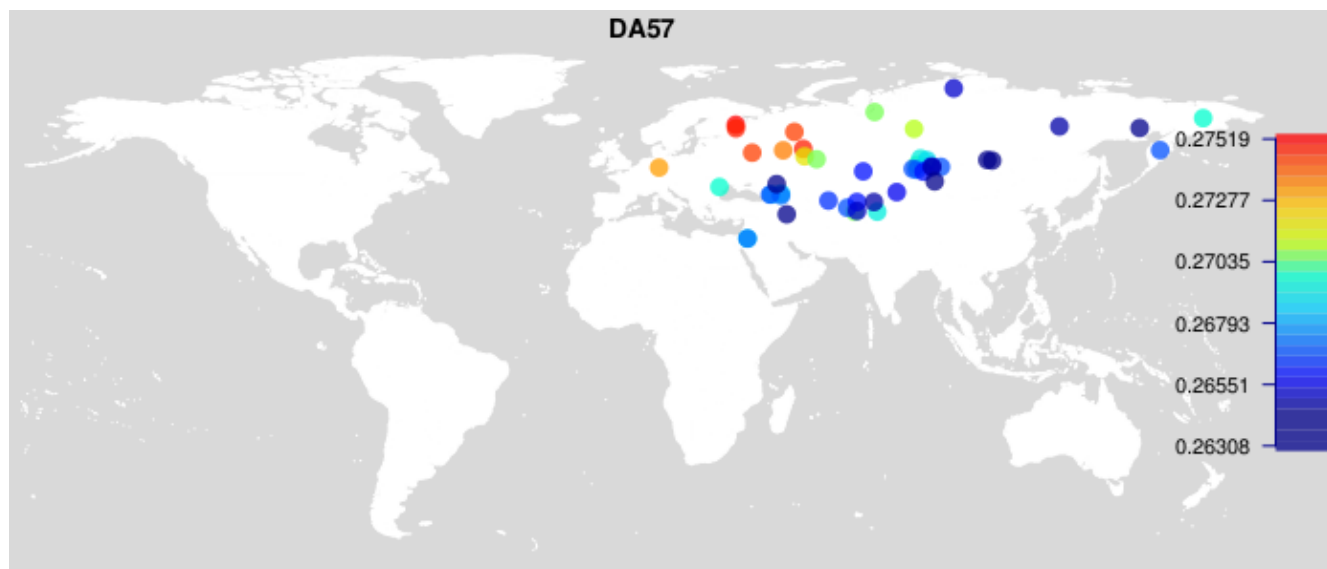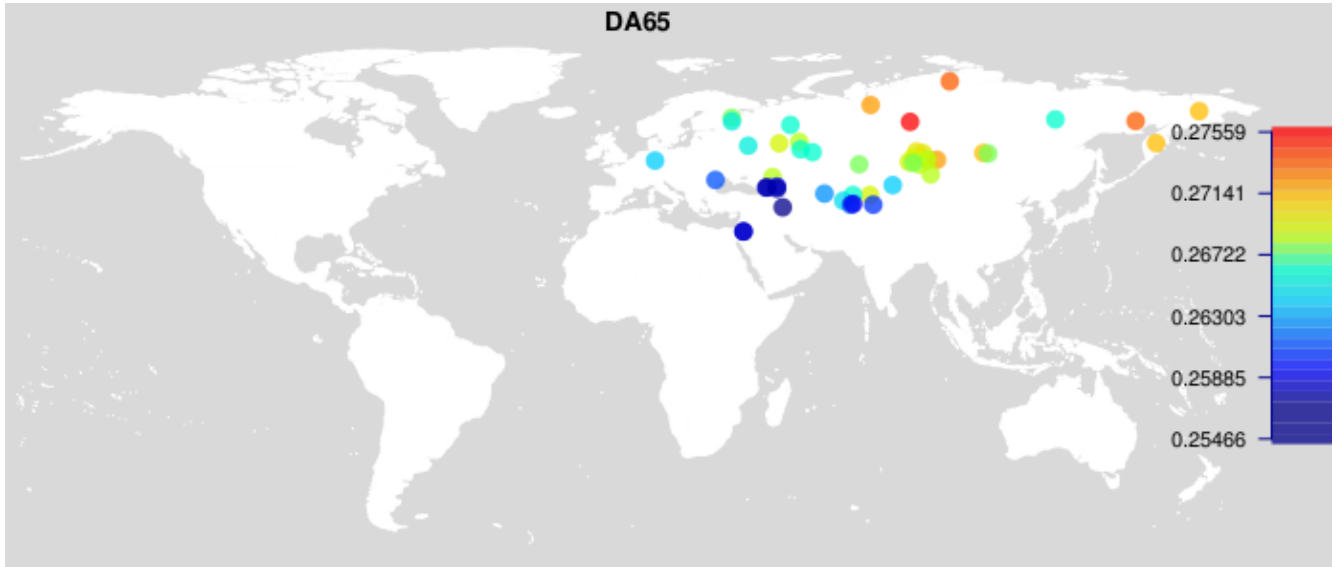
Supplementary Figure 49 - Outgroup-f3 statistics for sample DA57.

DA57 - Region: Tian Shan
Radiocarbon 14C date: 2099 +- 32 BP uncal
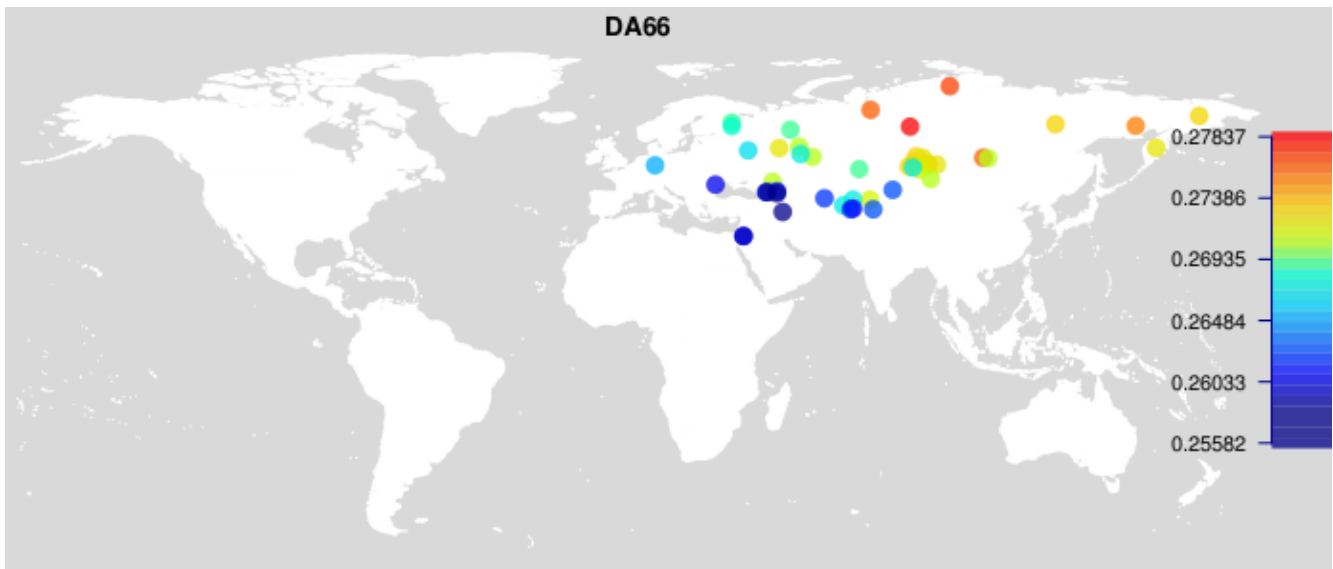**Population label: TianShanSaka**
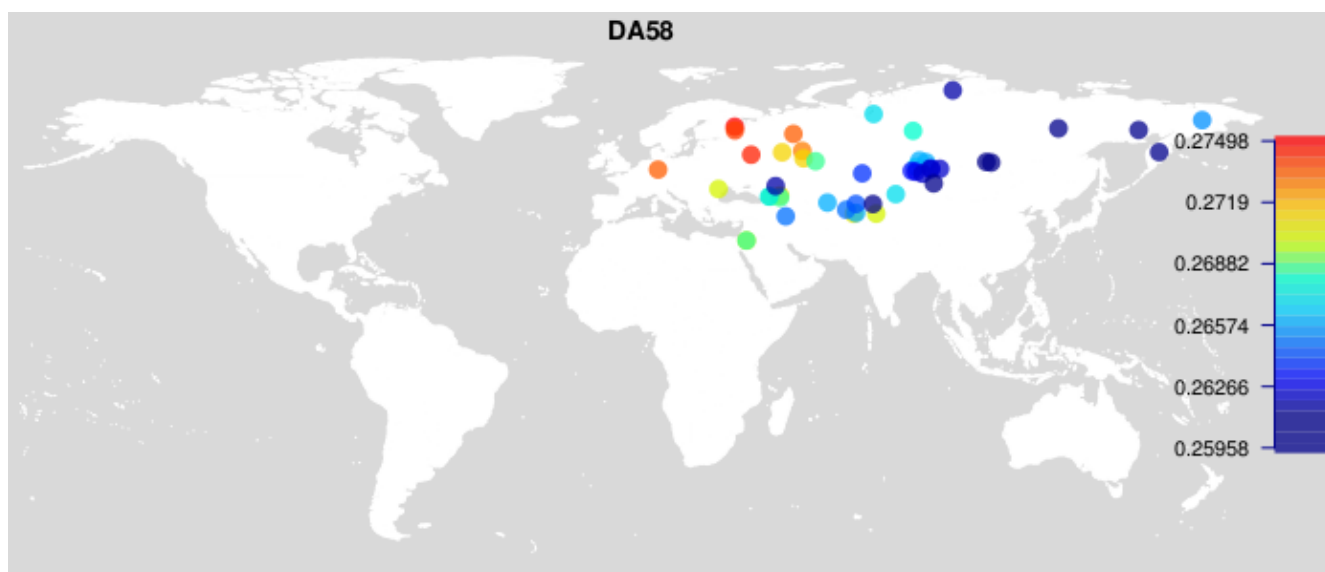
Supplementary Figure 50 - Outgroup-f3 statistics for sample DA58.

DA58 - Region: Tian Shan
Radiocarbon 14C date: 2094 +- 33 BP uncal
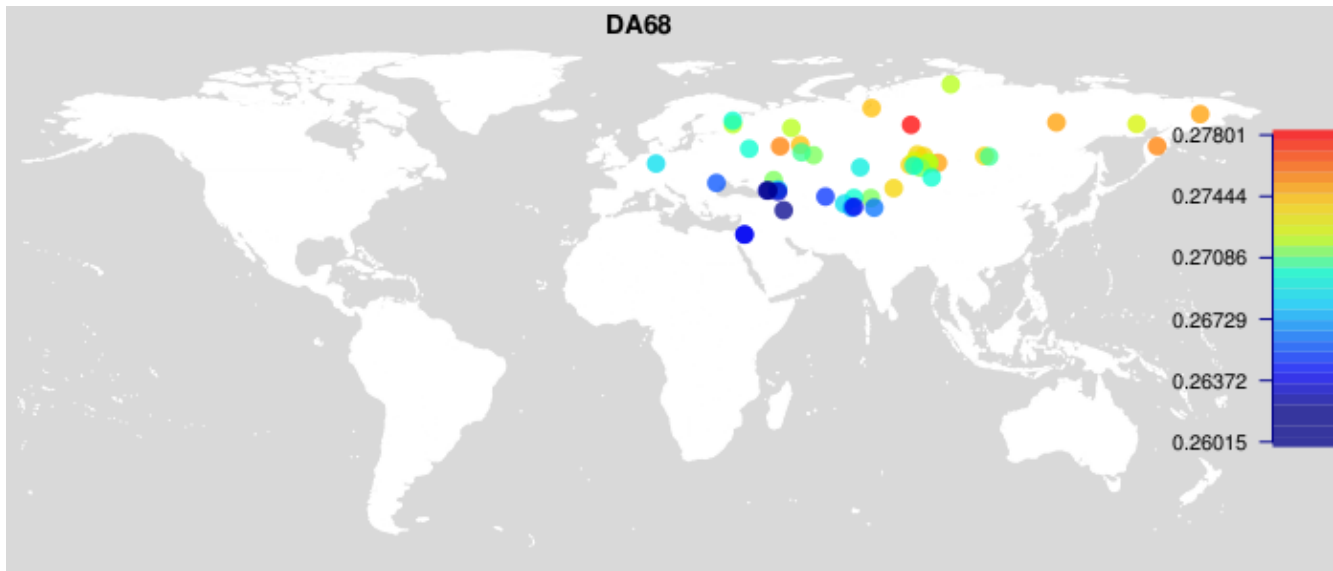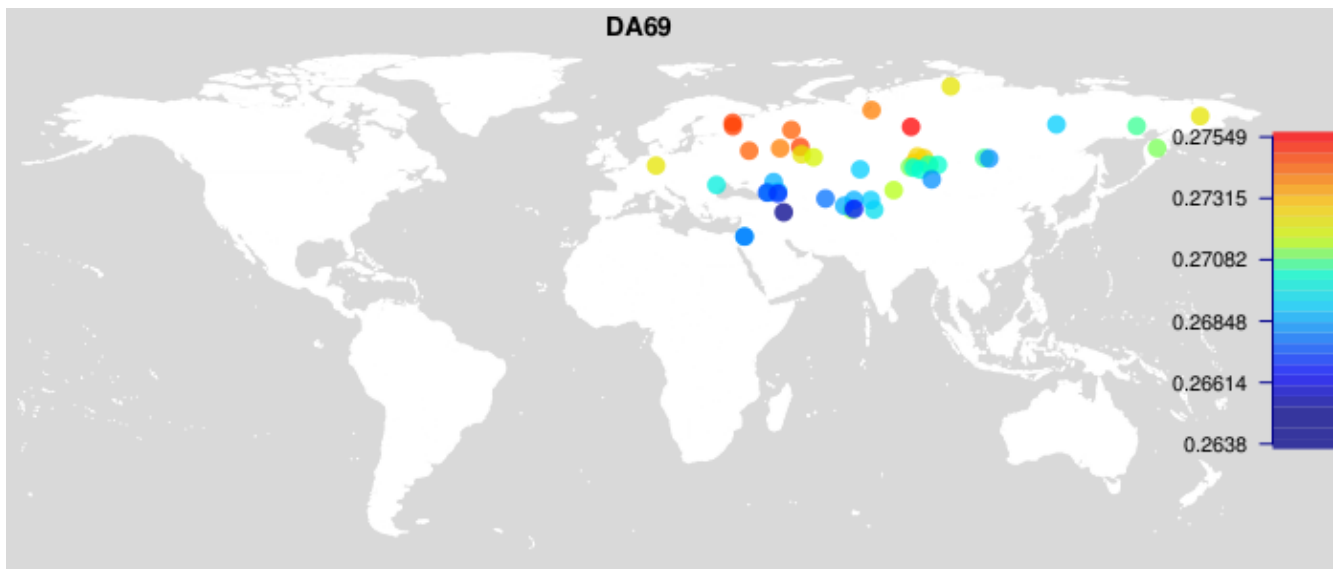**Population label: TianShanSaka**

Supplementary Figure 51 - Outgroup-f3 statistics for sample DA65.

DA65 - Region: Tian Shan
Radiocarbon 14C date: 1629 +- 40 BP uncal
Population label: TianShanHun

Supplementary Figure 52 - Outgroup-f3 statistics for sample DA66.

DA66 - Region: Tian Shan
Radiocarbon 14C date: 1546 +- 33 BP uncal
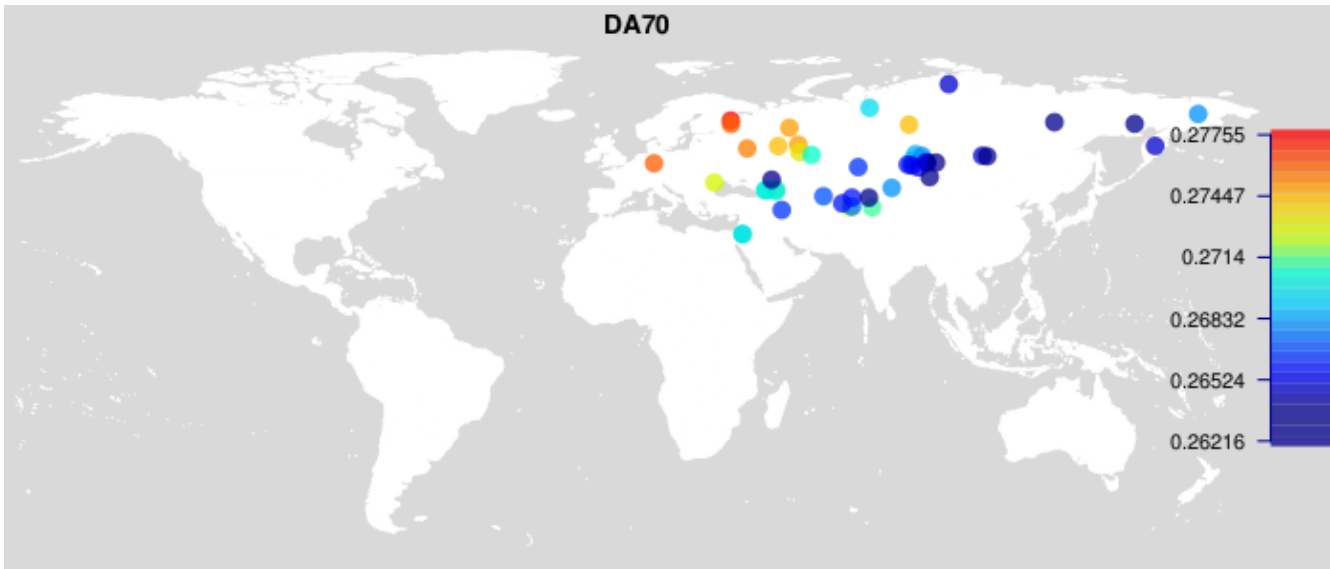**Population label: TianShanHun**

Supplementary Figure 53 - Outgroup-f3 statistics for sample DA68.

DA68 - Region: Tian Shan
Radiocarbon 14C date: 1479 +- 31 BP uncal
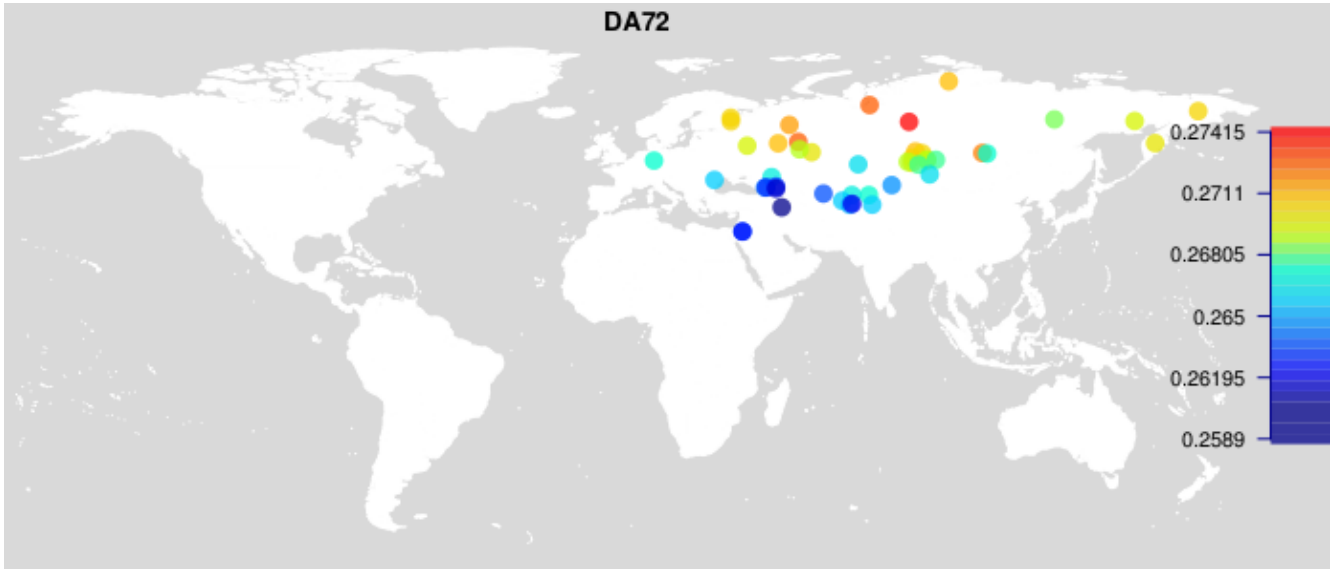**Population label: TianShanHun**

Supplementary Figure 54 - Outgroup-f3 statistics for sample DA69.

DA69 - Region: Tian Shan
Radiocarbon 14C date: 1642 +- 31 BP uncal
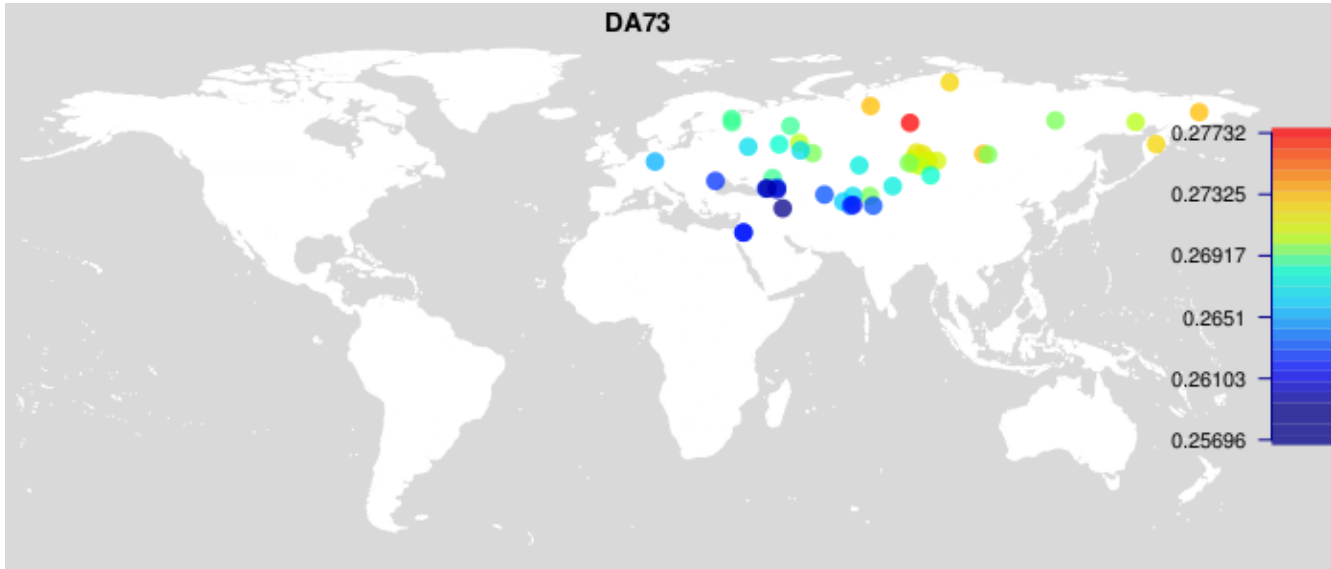**Population label: TianShanHun**

Supplementary Figure 55 - Outgroup-f3 statistics for sample DA70.

DA70 - Region: Tian Shan
Radiocarbon 14C date: 1891 +- 44 BP uncal
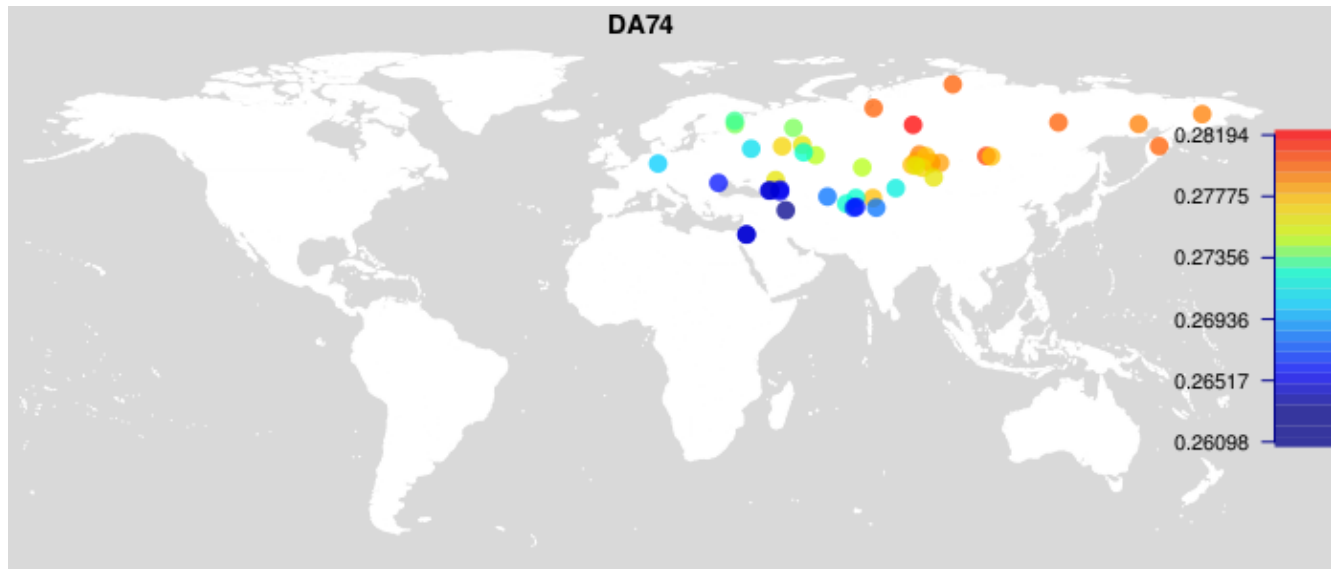**Population label: TianShanHun**

Supplementary Figure 56 - Outgroup-f3 statistics for sample DA72.

DA72 - Region: Tian Shan
Radiocarbon 14C date: 1679 +- 44 BP uncal
Population label: TianShanHun

Supplementary Figure 57 - Outgroup-f3 statistics for sample DA73.

DA73 - Region: Tian Shan
Radiocarbon 14C date: 1723 +- 48 BP uncal
Population label: TianShanHun
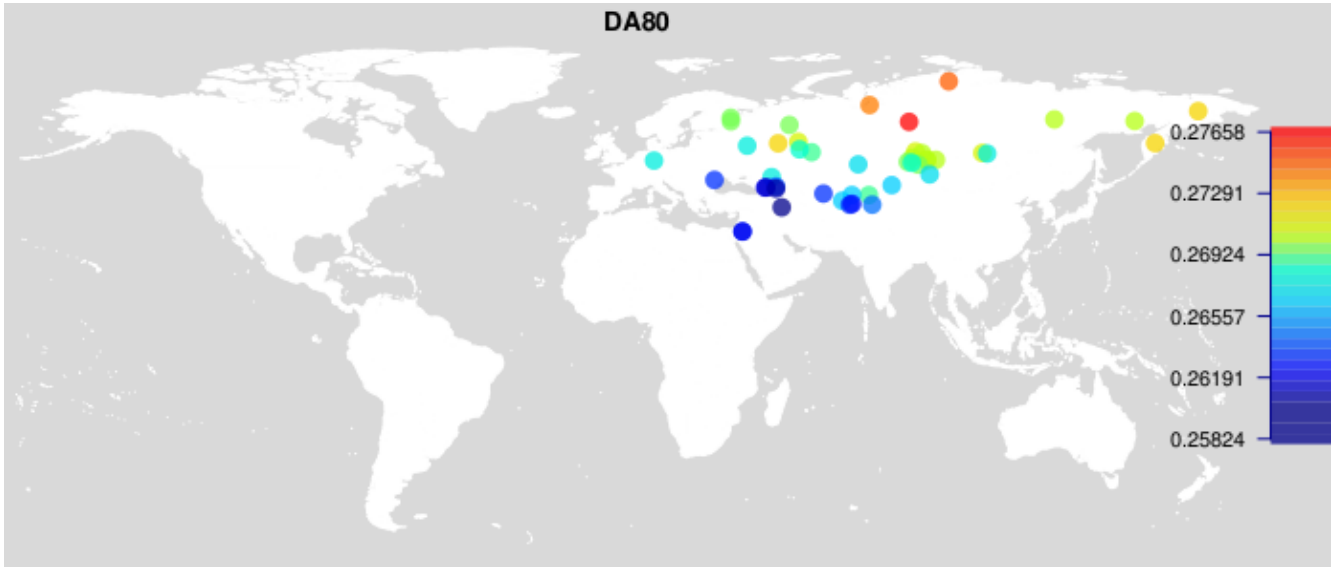

Supplementary Figure 58 - Outgroup-f3 statistics for sample DA74.

DA74 - Region: Tian Shan
Radiocarbon 14C date: 1624 +- 46 BP uncal
Population label: TianShanHun

Supplementary Figure 59 - Outgroup-f3 statistics for sample DA80.

DA80 - Region: Tian Shan
Radiocarbon 14C date: 1704 +- 52 BP uncal
**Population label: TianShanHun**

The Lchashen site in Armenia

By Levon Yepiskoposian & Zaruhi Khachatryan

Different complexes belonging to early and middle Bronze Age periods have been excavated in Lchashen. It is a famous archaeological site in the South Caucasus and the Armenian Highlands, being rich in unique Bronze Age cultural material. It is located 5 km southwest of the city of Sevan in the Gegharkunik region (2,000 meters above sea level, m.a.s.l.). The complex is more than 4 km long, and its width extends to 1.5 km at the necropolis close to the village of Lchashen, but is typically 200-300 m wide elsewhere.

At the surface, the tombs are represented by cromlechs ranging from 2.5 to 21 m in diameter that are packed with a 0.2 to 2.1 m thick sand and stone stuffing. Excavations were conducted at three sections. In the second section, the cromlechs are 2.5 to 16 m in diameter and some of the packed stone is mortared. We have found pieces of pottery from the 3rd millennium BCE that are not typical of this site. The third section is located to the east of the second section. There, the barrows are more intact and the cromlechs are 0.7-1.8 m in height and are 5 to 16 m in diameter. These tombs belong to the second quarter of the 2nd millennium BCE.

The tombs are irregularly laid out, except for the third section where several late-stage Middle Bronze Age burial mounds are configured in a single row. Tombs of all ages are common in this necropolis. Burial mounds of 2-21 m diameter (0.2-2.1 m height) are surrounded by cromlechs of 2.5-16 m in diameter. The burial mounds at different locations are stuffed with varying proportions of stone and sand. The burial chambers have been covered by 2-8 stone plates, based on a single-bay false-roof principle.
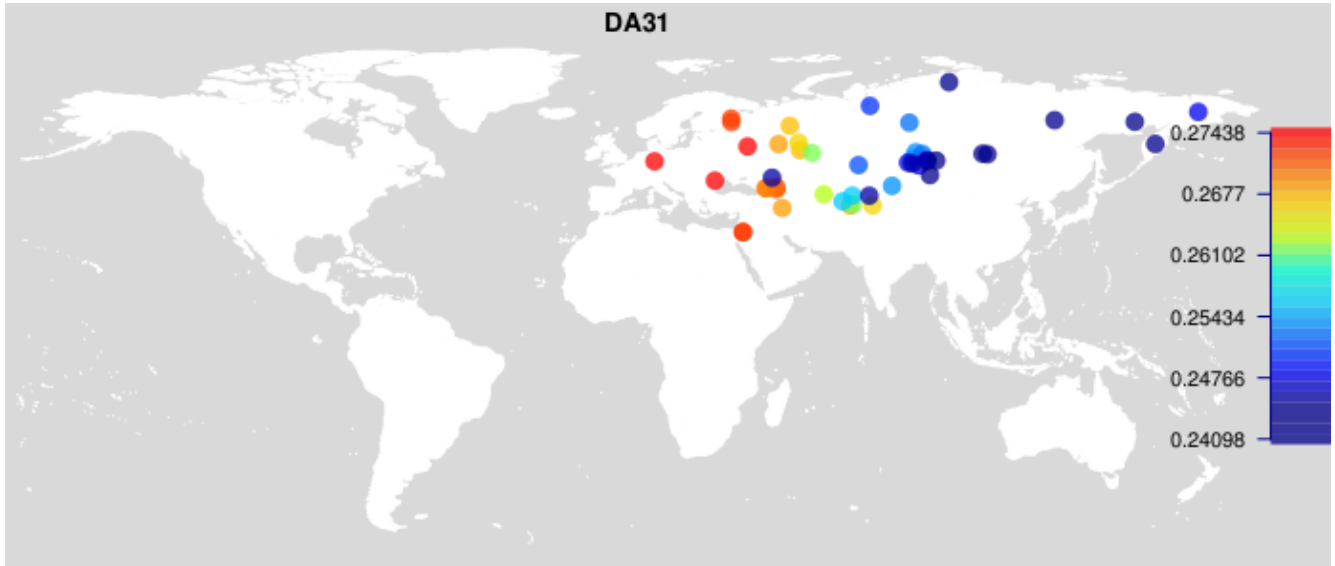
Supplementary Figure 60 - Outgroup-f3 statistics for sample DA31.

DA31 - Region: Caucasus
Radiocarbon 14C date: NA Period: early Caucasian Iron Age
Population label: LchaschenMetsamor
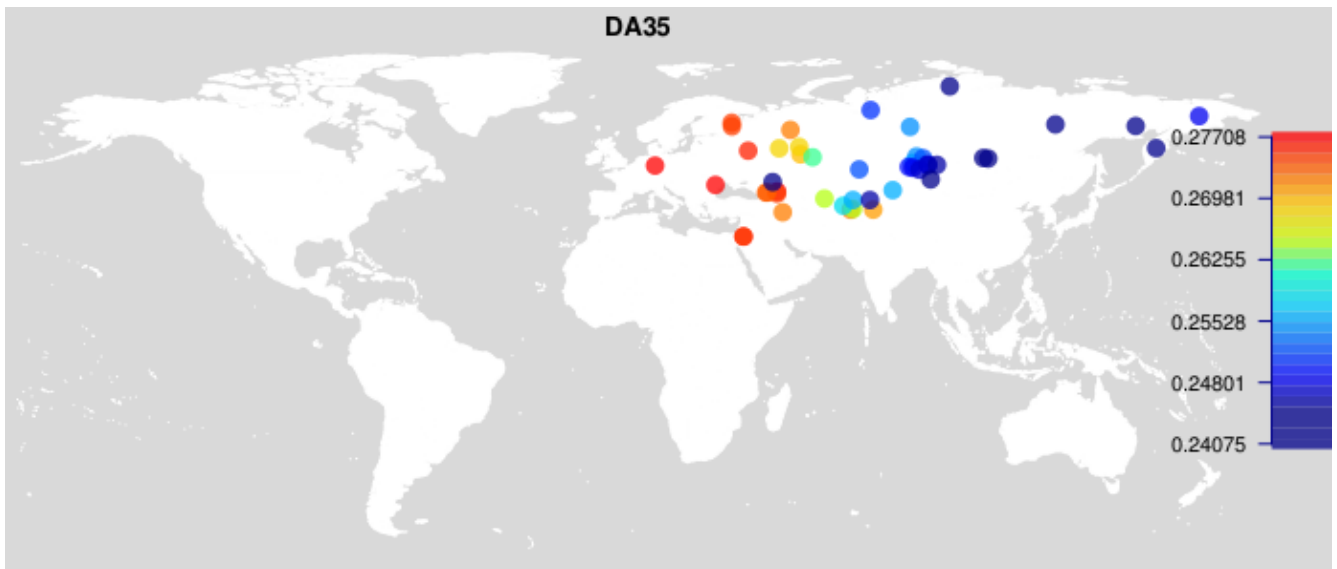
Supplementary Figure 61 - Outgroup-f3 statistics for sample DA35.

DA35 - Region: Caucasus
Radiocarbon 14C date: 3050 +- 42 BP uncal
**Population label: LchaschenMetsamor**

The Tian Shan Hun outlier at Kegen

By Gulmira Mukhtarova

Samples were taken from a skull found in one of the Aktas cemetery graves at the foot of Aktasty Mountain, which is 3 km north of the Kegen River and dates from the 2nd-5th century CE. The cemetery is located 12 kilometers south-east of the village of Kegen in the Raiymbek District of the Almaty region. The cemetery comprises a chain of mounds and fences encircling Aktasty Mountain from the west, south and east. The square-shaped mounds are characteristic of those of Xiongnu tribes and are built of stone. Fences were built closer to the mountain and beyond them is the chain of burial mounds, which is also a typical arrangement for Xiongnu tribal burials.

It is interesting that in this part of the Kegen Valley, monuments of all the tribes of the early Iron Age are concentrated, including the Saks, Hunnu and Usuns. A war was waged in ancient times in the fertile Kegen river valley. These monuments are interesting because they reveal the nomadic routes and funeral rites of the Saks era Aktas site; an interesting complex consisting of a chain of large royal burial mounds and another chain of much more modest burial mounds, with these latter belonging to the soldiers and combatants. These two chains begin at the mountains and are oriented towards the river in a north to south/southeast direction. This orientation coincides with the route of the ancient nomadic tribes. In ancient times, these chains of mounds would have shown and secured the rights to a specific nomadic route.

It is noteworthy that the spatial distribution of the burial mounds mirrors that of the nomadic system whereby high-status and rich people possessing a lot of cattle lived (and were buried) in central areas, retainers' homes (and burial mounds) encircled those of their masters, and the poor were restricted to living (and being buried) at the periphery. For the living, when an attack occurred, an ordinary herder could always inform their more noble neighbors living in the interior of the danger, and any stranger could be immediately expelled. Even if a herder suffered a cattle theft, he could easily be compensated from the reserves of the rich. For the dead, the system ensured the afterlife of the deceased and provided a burial order for members of the tribe.
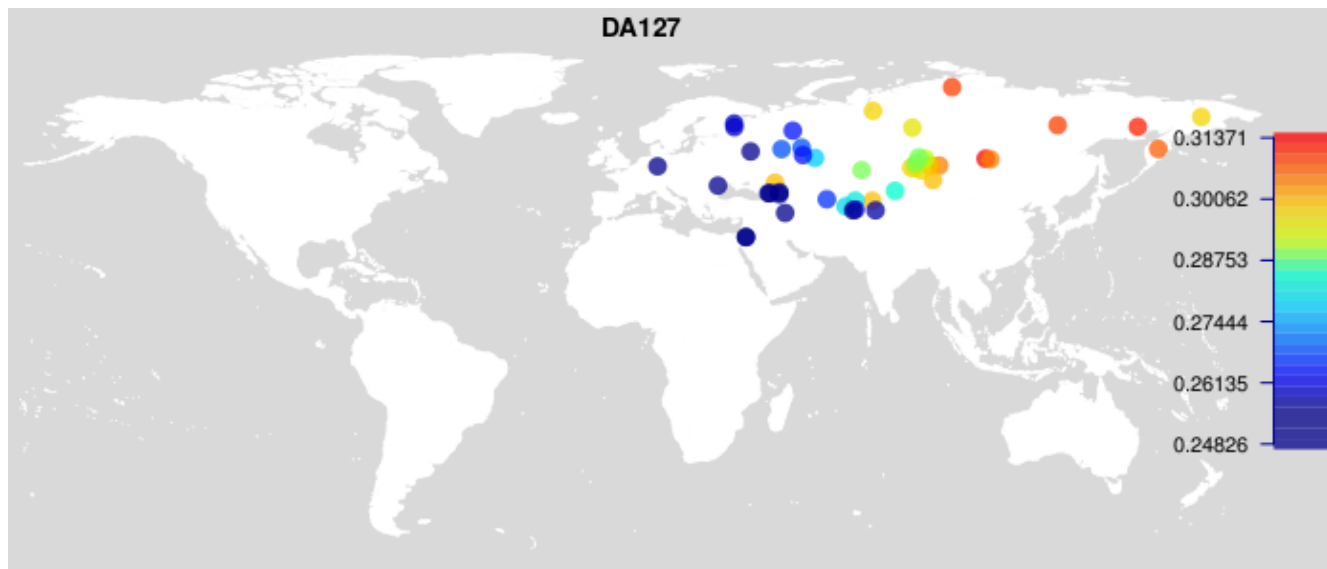
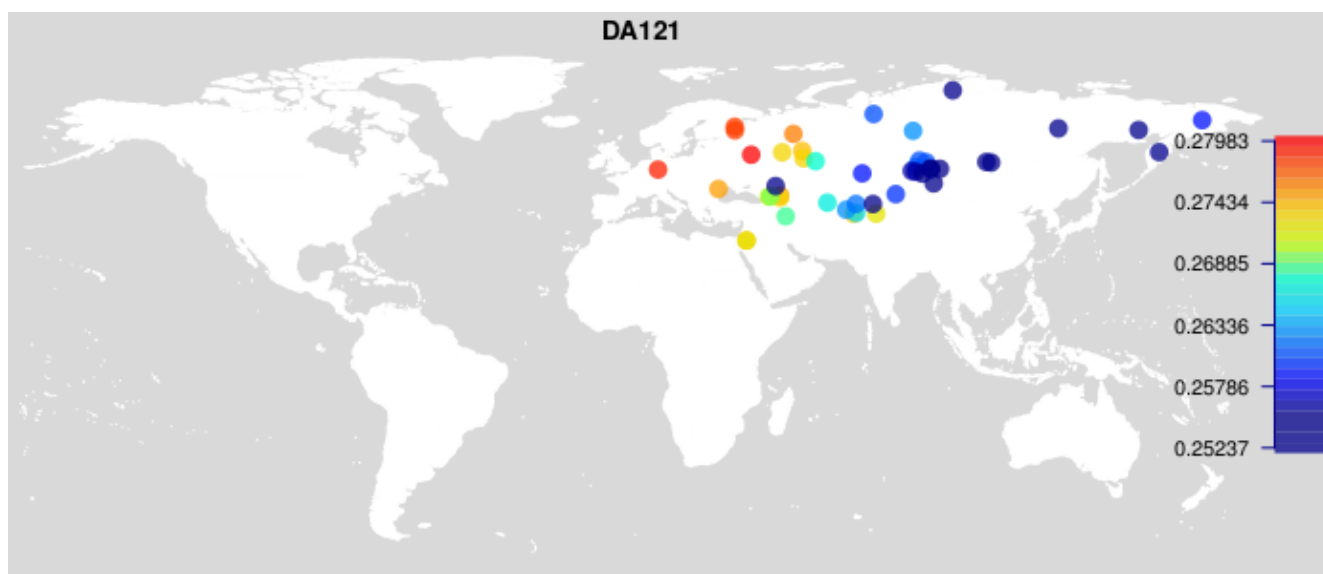**Supplementary Figure 62 - Outgroup-f3 statistics for sample DA127.**

DA127 - Region: Tian Shan
Radiocarbon 14C date: 1722 +- 55 BP uncal
Population label: OutTianShanHun

The Kangju nomads of Kok-Mardan

By Gulmira Mukhtarova

Bone samples were taken from skulls found in the graves of a cemetery located near the settlement of Kok-Mardan; a site that was excavated by Bekmukhanbet Nurmukhanbetov. Kok-Mardan, on the left bank of the Aris River, is one of the largest towns (along with Pshuk-Mardan, Kostobe, Seytmantobe, Ahaytobe, and Choltobe) in the Otrar oasis (covering an area of about 100 km^2 of South Kazakhstan) and has acted as the focus of a large group of settlements and towns since the beginning of the 1st millenium B.C. up to the 8th century CE.

Interesting findings have been obtained from the Kok-Mardan settlement, with thick cultural layers indicating long-term permanent residence. Human skeletal remains and accompanying equipment have been found in the graves of a Molnik (cemetery) near the town. Typically, pottery containing food and water, as well as weapons and decorative items were placed in the graves. Besides manufacturing pottery, Kok-Mardan residents were also able to smelt iron and make essential equipment like sickles, knives and arrowheads, evidenced by the round iron billets from which the smiths forged these items.
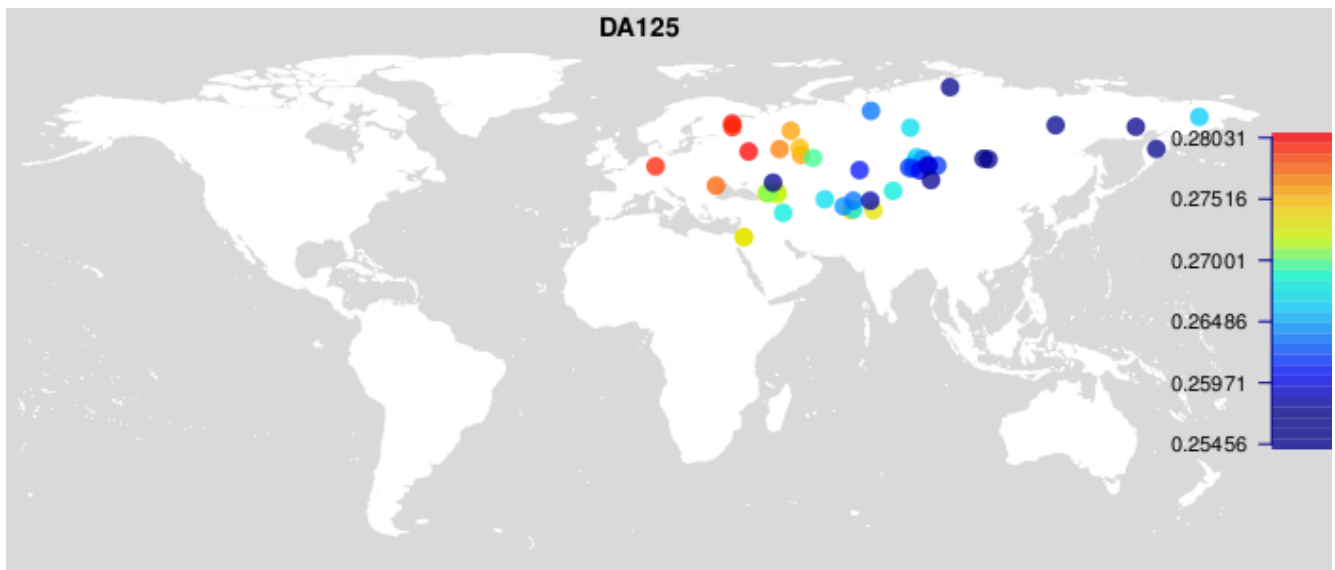

Supplementary Figure 63 - Outgroup-f3 statistics for sample DA121.

DA121 - Region: South Kazakhstan
Radiocarbon 14C date: 1687 +- 37 BP uncal
Population label: Kangju
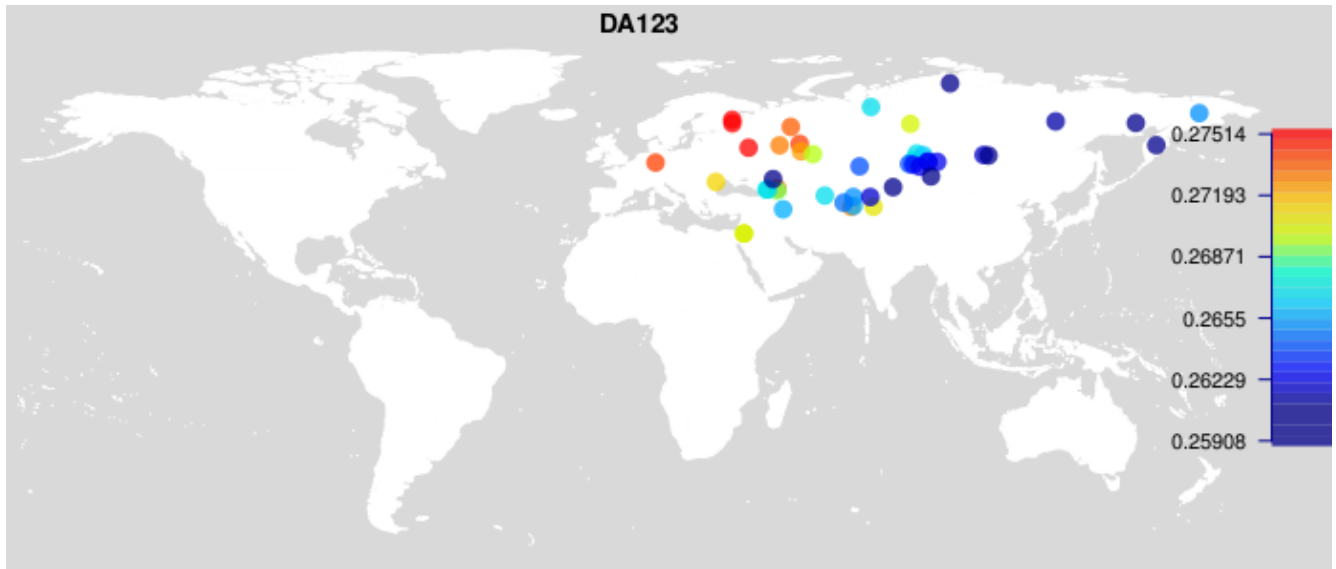
Supplementary Figure 64 - Outgroup-f3 statistics for sample DA123.

DA123 - Region: South Kazakhstan
Period: Hun Period
Population label: Kangju

Supplementary Figure 65 - Outgroup-f3 statistics for sample DA125.

DA125 - Region: South Kazakhstan
Radiocarbon 14C date: 1804 +- 28 BP uncal
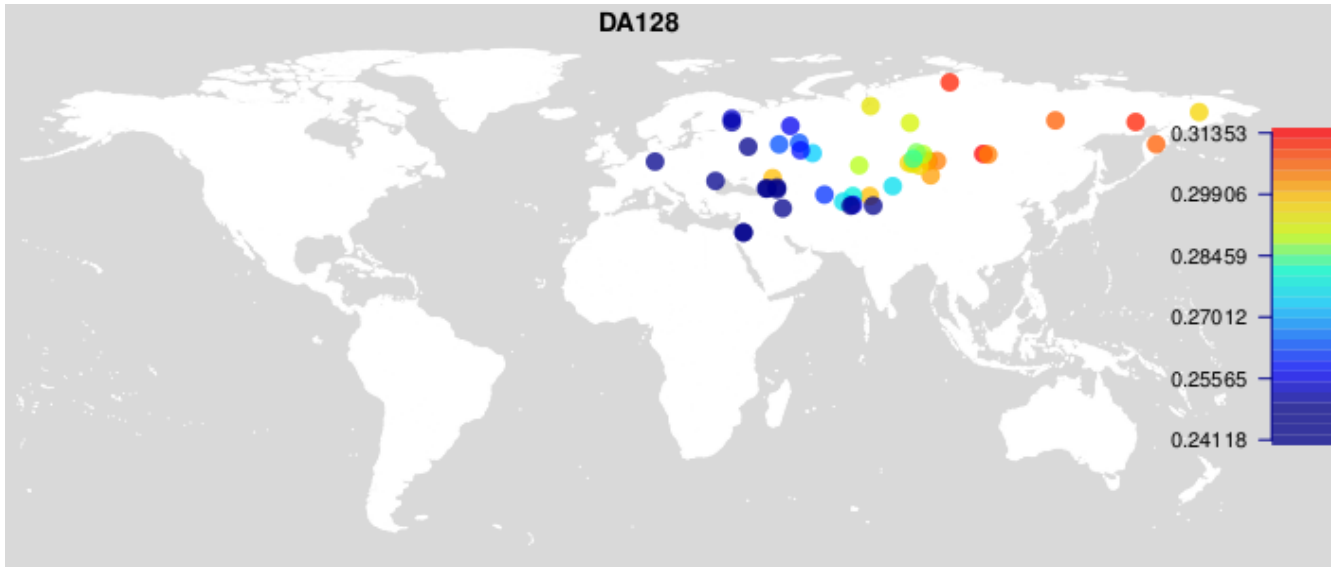**Population label: Kangju**

The Medieval Zhanaturmy nomad

By Gulmira Mukhtarova

Samples were taken from a skull found in a grave located in part of a modern Muslim cemetery in the village of Zhanaturmy, which is near the town of Issyk in the district of Enbekshikazakh of the Almaty region. Half of the burial site had been destroyed by a modern grave-digger. Some of the inventory (for instance, bronze plaques from the belt set and fragments of a metal broadsword) were collected from the resulting spoil heap. An excavation was conducted in June 2011 when these artifacts were found. On excavating to a depth of 1.38 m, a horse burial in a narrow oval grave pit was found. On excavating further to a depth of 2.10 m the skeleton of a warrior was found at the western wall of the grave pit and 20 cm from the north-western part of the wall. The burial site appeared to have been robbed, resulting in scattering of the warrior's bones. Except for bronze objects in the burial pit (a bronze buckle with an iron latch and elongated ironwork around the waist of the deceased), nothing more of the inventory was found.

Supplementary Figure 66. Burial site of the Zhanaturmy nomad.

Supplementary Figure 67 - Outgroup-f3 statistics for sample DA128.

DA128 - Region: Tian Shan
Radiocarbon 14C date: 761 +- 28 BP uncal
Population label: Nomad_Med

The Medieval Issyk nomad
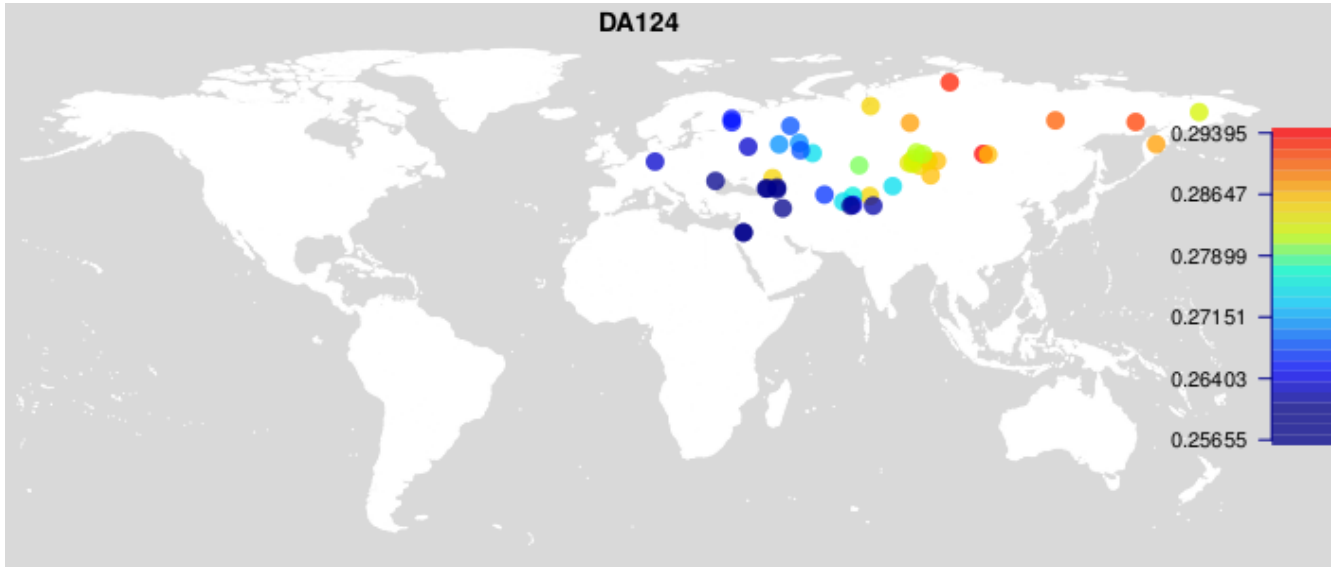
By Gulmira Mukhtarova

Bone samples were taken from a skull found in a burial site in the territory of Issyk Mogilnik, located 50-55 km east of the city of Almaty, that spans both sides of the Issyk River in the immediate vicinity of the town of Issyk at the center of the Enbekshikazakh district of the Almaty region.

Recent data has shown that the cemetery covers a larger area than previously thought, including both banks of the river Issyk, extending for up to 10 km. More than 300 medium and large burial mounds have been identified in this necropolis, together with a large number of smaller ones (i.e. <0.5 m in height). One of the four parts of the cemetery has been completely covered by the residential and commercial buildings of the city of Issyk. Other parts have also been subjected to demolition or modification in the course of human activities.

The location of the Issyk necropolis has been known since 1936. The most significant expedition to the site was that of 1969-70. Arising from rescue excavations following construction of a parking lot, a royal burial ground was found that had been undisturbed by robbers. This burial site is known as the "Golden Man".

Supplementary Figure 68 - Burial location of the Issyk nomad.

Supplementary Figure 69 - Outgroup-f3 statistics for sample DA124.

DA124 - Region: Tian Shan
Radiocarbon 14C date: 1332 +- 32 BP uncal
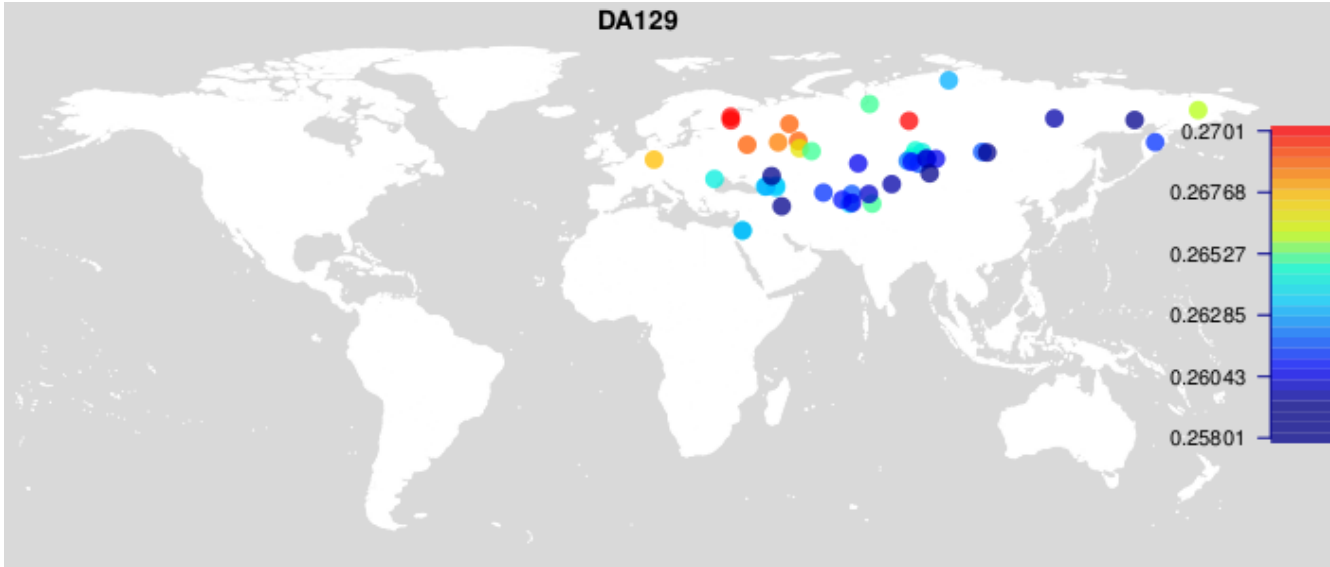**Population label: Nomad_Med**

The Iron Age Kyzylasker nomad

By Gulmira Mukhtarova

Samples were taken from a skull found at a burial site near the village of Kyzylasker in the Zhambyl district of the Almaty region. The burial was located in a field on a natural hill and had been disturbed by inhabitants of the village. Initially, the burial site had been excavated down to the skull of the deceased, near which was found a ceramic vessel. From the untouched side of the crypt, the rest of the bones were gradually exposed, revealing that the male individual had been laid on his back, with his head oriented to the west. His arms were bent at the elbows so that the forearms lay on the pelvis and the remaining parts were buried *Iin situ*. The long axis of the rectangular grave pit was oriented east to west. It was 0.8-1 m wide and 1.5 m deep (from the current surface). A bronze earring was found in the vicinity of the jaw. The funeral inventory is limited to the buried ceramic vessel and the bronze earring.

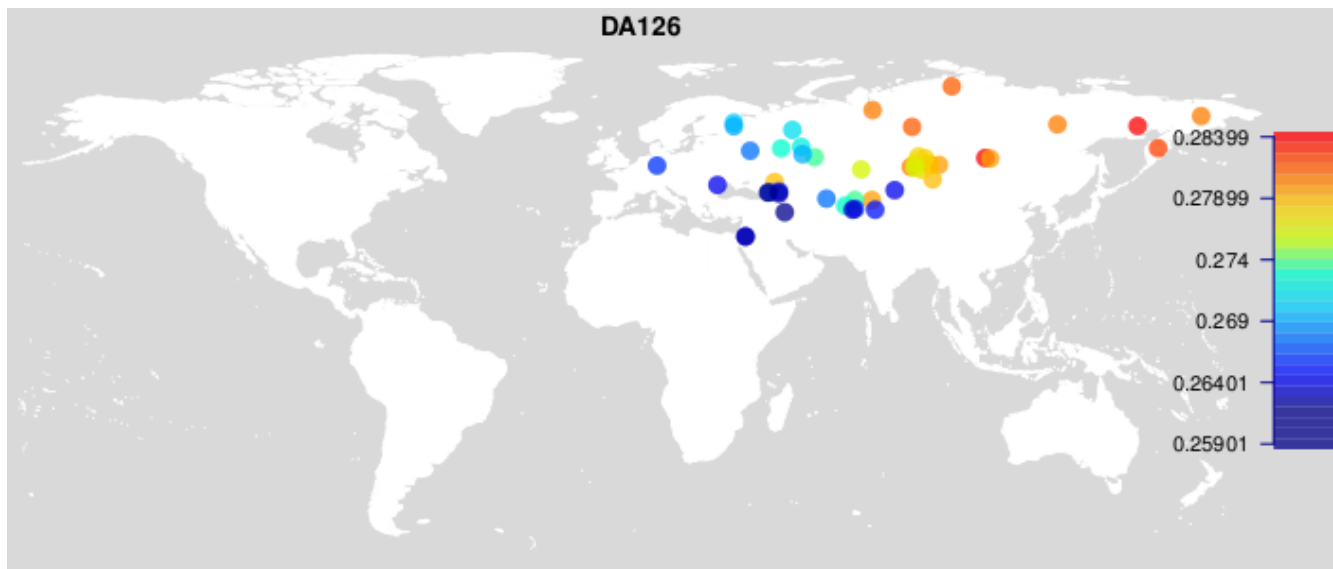**Supplementary Figure 70 - Burial site of the Kyzylasker nomad.**

Supplementary Figure 71 - Outgroup-f3 statistics for sample DA129.

DA129 - Region: Tian Shan
Radiocarbon 14C date: 2324 +- 42 BP uncal
Population label: Nomad_IA

The Medieval Almaly nomad

By Gulmira Mukhtarova

Samples were taken from a skull found in a burial site within the modern Muslim cemetery of Almaly village in Enbekshikazakh district of the Almaty region. The site was excavated from November 2011 to May 2012. At the beginning of the excavation in 2011, six pieces of a bronze filigree plate with the image of a dragon were found at a depth of 80 cm below the surface. Below that, at a depth of 1 m, was found the remains of a silver bowl with a bronze relief sleeve. On resumption of archaeological work in 2012, human remains were found at a depth of 180 cm from the surface. The individual had been buried inside a wooden box, evidenced by wood fragments near the bones of the left hand and characteristic brown spots to the right of the skull and leg bones. Fragments of a metal object were found to the left of the skull, a bead was recovered next to the left clavicle, and a bronze bracelet had been placed on the wrist of the right hand. Through the lumbar vertebrae, in the gap between the lower ribs and the left pelvic bone, further fragments of the previously discovered silver bowl were found.

Supplementary Figure 72 - Outgroup-f3 statistics for sample DA126.

DA126 - Region: Tian Shan
Radiocarbon 14C date: 1078 +- 37 BP uncal
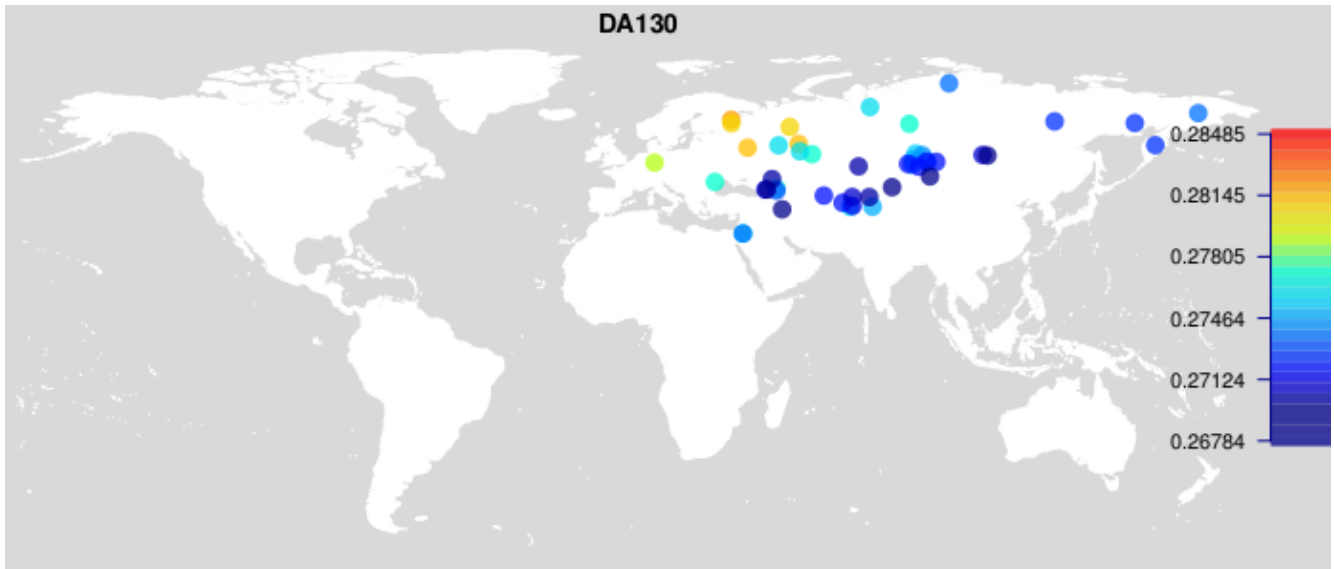**Population label: Nomad_IA**

The Saka from Ornek

By Gulmira Mukhtarova

Samples were taken from a skull found in one of the graves of the Ornek cemetery as part of the archaeological expedition "Issyk" in 2015. This burial ground is located on the northwestern outskirts of the village of Ornek in Enbekshikazakh district of the Almaty region within a vast swampy lowland.

Archaeological research on the burial sites is ongoing. Selected sites have been scrutinized in terms of their architecture, construction sequence, as well as the ritual and ceremonial activities that are representative of the major religious and mythological views of Saka population culture. The cemetery consists of chains of earthen mounds, each consisting of 5-7 mounds of diameter 20-45 m and height 1-2 m. These funerary constructions consist of half-buried crypts of medium-sized river stones. The bone material taken for genetic analysis was removed from Chain I, Mound No.2. This mound was 1.64 m in height and had a diameter of 19.6-20 m. The central part of the embankment was removed to the surface level, with a recess of 20-30 cm. The burial structure (length 3.5 m, width 2.6 m) was located in the center of the burial mound, at a depth of 0.40 below the ancient surface level, and was constructed of stones to form a rectangular area with rounded corners. Two rectangular crypts were found below the ancient surface level, constructed of river stones, crypt No.1and crypt No.2. Crypt No.1 was cleared by parsing the stones and simultaneously cleaning the walls. A clear outline of the original crypt was revealed at a depth of 30 cm from the surface of the buried soil. The burial chamber measured 1.5 m wide, 3 m long and was 1.8 m high. The ceiling of the chamber was 1.2 m below the current level of the soil surface.

A skeleton was found at the bottom of the grave. The deceased had been laid on their back with the legs extended, the arms alongside the body, and the head oriented towards the west. Evidence of disturbance to the burial site by robbers was found from the lower parts of the skull to the pelvis. Three shallow bowls were found to the right of the skull. Fragments of ironwork were found between the vertebrae. Two golden plaques, a bronze object and a broken bowl were found next to fragments of the pelvic bones. At the right edge of the crypt wall, seven ceramic vessels were found intact. This burial, as well as the mound, has been dated to the 5th-6th centuries BCE.

Supplementary Figure 73 - Plan of the Ornek cemetery.

Supplementary Figure 74 - Outgroup-f3 statistics for sample DA130.

DA130 - Region: Tian Shan
Radiocarbon 14C date: 2199 +- 32 BP uncal
Population label: Tian Shan Saka

The Saka of Tian Shan

By K. I. Tashbaeva

Head of the Department of Archaeology, Institute of History and Cultural Heritage, The National Academy of Sciences of the Kyrgyz Republic

The Saka culture of Tian Shan dates from the 8th to the 2nd century BCE, and even up to the turn of these eras. Burial grounds of the early nomads comprised from a few to several dozen kurgans, often placed in rows aligned north to south. Typically, a row of large kurgans would be located at the centre of the burial site where members of the society's elite (i.e. heads of families and tribes) were buried. These kurgans would be surrounded by smaller kurgans for the ordinary members of society. Burials were made in dug graves aligned west to east, with some deviations. The graves were covered with a layer of wooden logs or large stone plates. Often there would be a niche in the northern wall of the grave for burial paraphernalia. The bones of the buried individuals, mostly representing a single person, were usually lying fully extended on their back, with the head oriented to the west. In graves lacking niches, burial vessels stood at the northern wall of the grave, at the left shoulder of the buried individual. Due to grave plundering committed in ancient times, other burial paraphernalia was usually scarce[172–174].

The Baskiya-1 (Saka) burial ground is located 6 km south of Dzherge-Tal, in the centre of the Dzhany-Talap collective farm of the Naryn district, on a flat mountain plateau, in an area called Baskiya. The burial ground was discovered and examined by a team headed by K. I. Tashbaeva in 1981. The burial ground comprises a large number of kurgans that had been placed at the edge of the plateau. Among them, a row of 13 kurgans is prominent, stretching from north to south along the eastern part of the burial ground. It was these kurgans that were examined in 1981. All excavated kurgans possessed earth cairns capped with a small stone. Cairn diameter and height varied from 7 to 13 m and from 0.2 to 0.7 m, respectively. Cross-sections of the cairns of all kurgans revealed arc-shaped shielding stone coverings positioned 10-15 cm below the kurgan surface. Occasionally, large boulders were laid out in circles (i.e. cromlechs) at the base of cairns. The oval or rounded-rectangular grave chambers were located in the centres of these circles. The chambers were unusually narrow and shallow, with their axes aligned west to east. Only single buried individuals were found (except for kurgan No.10 which was a double burial), with the deceased lying stretched out on their backs, with their heads oriented to the west.

The burial ritual in Baskiya-1 differed somewhat from all other burial grounds found in Inner Tian Shan. Here, the ceramic vessels were not full-size, but were small, specially-made vessels that were placed on special ledges in the side walls of the grave chambers, either at the bottom or approximately halfway up it. This burial ritual has also been encountered at the Ferghana burial grounds of the Saka period, suggesting that the nomads who constructed the Baskiya-1 burial ground came from other locations[174].

The Keden burial ground is located within the territory of the March 8 state farm of Ak-Kuduk village in the Naryn District. It was examined over the course of three field seasons (1984, 1988, and 1989) by a team headed by K. I. Tashbaeva. The burial ground was located on the southern part of the second terrace above a flood plain on the right bank of the Naryn River, 8-9 km southwest of the centre of the state farm. Approximately 100 kurgans had been placed in separate compact groups all along the edge of the broad even terrace. A row of eight large kurgans, aligned north to south, stood out in the central

part of the burial ground. Over the three field seasons, 71 kurgans were excavated, including these eight large ones. Burials were conducted in dug graves in the smaller kurgans, which were aligned west to east and covered with wooden logs or large stone plates. In the eight large kurgans, burials were made in wooden encasements made of juniper logs that had been lowered into the grave chamber. Grave chambers were not deep and, accordingly, the logs were not tall (typical height 1-1.2 m, but in two cases up to 2 m). However, the chambers were spacious (length 2.8-3.7 m, width 2-3.5 m), and were covered with the same kind of logs as the walls.

The majority of the burials at this site were executed in the Saka period, but four kurgans, placed somewhat apart from the others, are related to a later period (possibly, the Migration Period).

# Landmarks of the Hun period in Tian Shan

By K. I. Tashbaeva
Head of the Department of Archaeology, Institute of History and Cultural Heritage, The National Academy of Sciences of the Kyrgyz Republic

The culture of the tribes of the "lateral chamber/catacomb" landmarks in Tian Shan dates from the 1st to the 5th century CE, i.e. from the Migration Period (or Hun period). Burials were made in lateral chamber-type or catacomb-type structures. Landmarks of this period are also amply represented in Inner Tian Shan, some of which were examined as early as the 1940s and 1950s.

An archaeological team headed by K. I. Tashbaeva examined two burial grounds of the period. The Baskiya-II burial ground is located not far from the Baskiya-I burial ground, on the bank of the Dzhergetal River. It was examined in 1983. The burial ground comprises 39 kurgans, of which 35 are catacomb constructions and 4 are dug graves. The catacombs have somewhat unusual passageways, located not at right angles to the burial chamber/catacomb as is typical, but as a kind of appendix alongside the catacomb. These passageways are also quite short, 1.5-2 m. In some cases, the buried individuals had a deformed skull. Quite frequently they had been equipped with a small wooden table, adornments, household utensils, and various buckles for straps or belts.

The Zhapyryk burial ground is located in a secluded high mountain area, approximately 3,000 m.a.s.l. It was examined in 1990. The burial ground consists of 12 kurgans, in which different types of grave design have been found. Burials here were made both in catacombs with long, straight passageways of the Kenkol type, as well as in graves featuring a lateral chamber. Some interesting material has been found in these kurgans, including jewellery such as earrings, nakosniks (braid accessories for unmarried women), and bracelets made in the polychrome style, as well as a large number of buckles.

Judging by the details of the burial constructions, and the differences in the accompanying paraphernalia, these burial grounds were left behind by tribes of different origins and thus having somewhat different burial rituals.
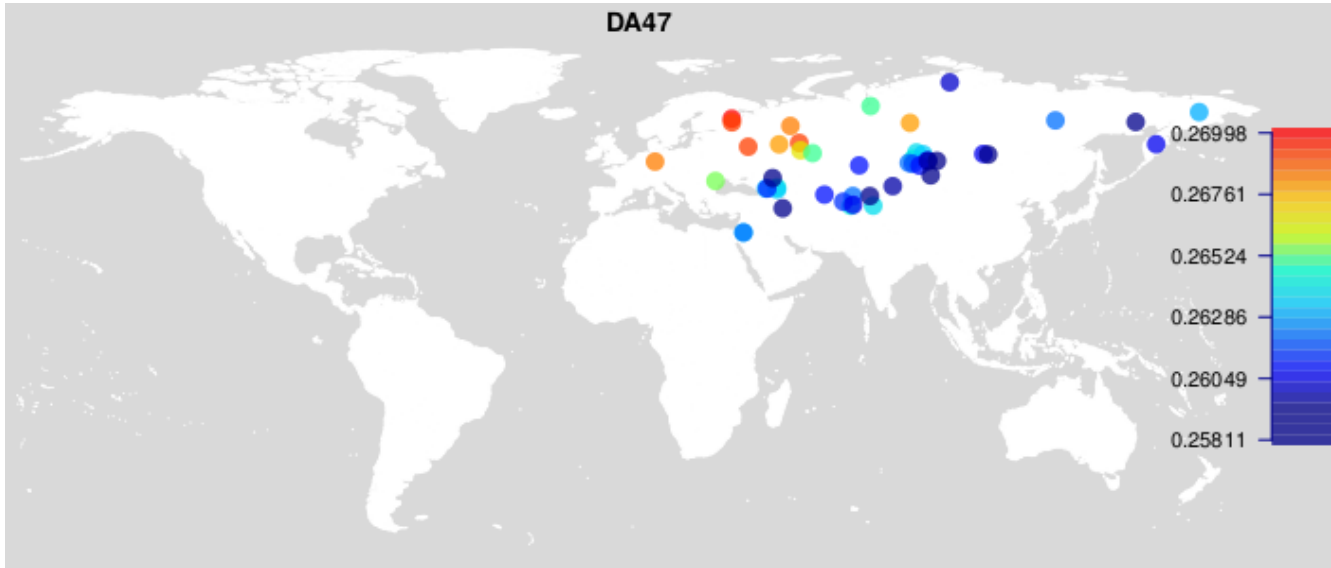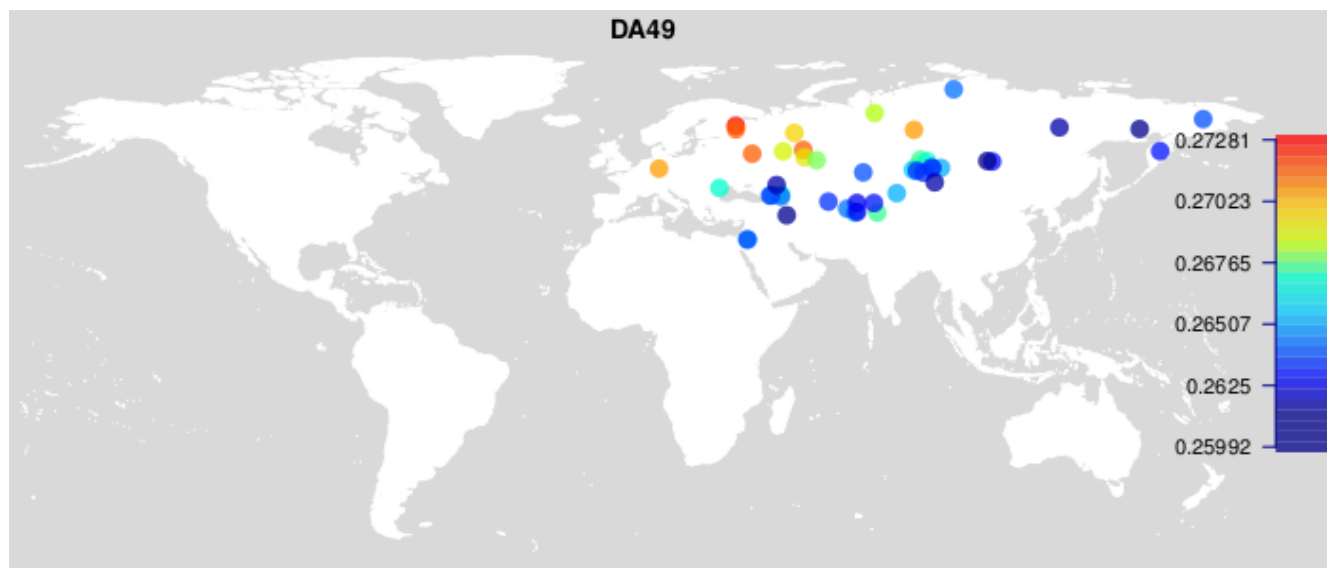
Supplementary Figure 75 - Outgroup-f3 statistics for sample DA47.

DA47 - Region: Tian Shan
Radiocarbon 14C date: 2093 +- 43 BP uncal
Population label: TianShanSaka
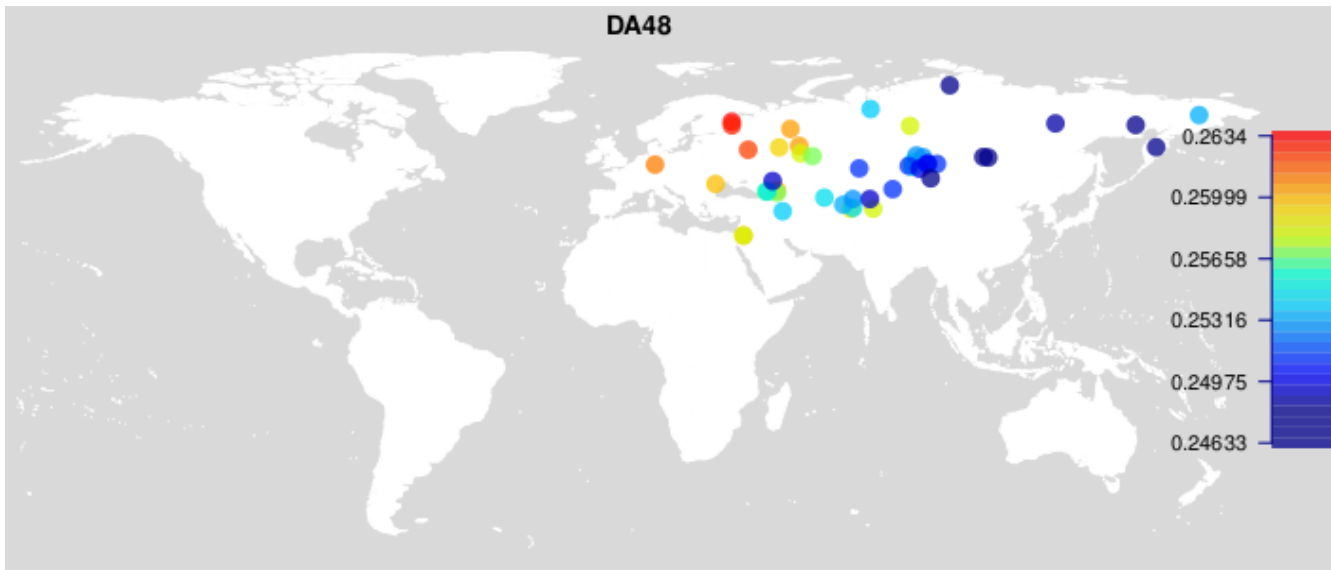
Supplementary Figure 76 - Outgroup-f3 statistics for sample DA48.

DA48 - Region: Tian Shan
Period: Iron Age
Population label: TianShanSaka

Supplementary Figure 77 - Outgroup-f3 statistics for sample DA49.

DA49 - Region: Tian Shan
Radiocarbon 14C date: 2186 +- 35 BP uncal
Population label: TianShanSaka

Supplementary Figure 78 - Outgroup-f3 statistics for sample DA50.

DA50 - Region: Tian Shan
Period: Iron Age
Population label: NoDateTianShanSaka

Supplementary Figure 79 - Outgroup-f3 statistics for sample DA52.

DA52 - Region: Tian Shan
Radiocarbon 14C date: 1606 +- 33 BP uncal
Population label: TianShanHun

Supplementary Figure 80 - Outgroup-f3 statistics for sample D53.

DA53 - Region: Tian Shan
Radiocarbon 14C date: 2344 +- 34 BP uncal
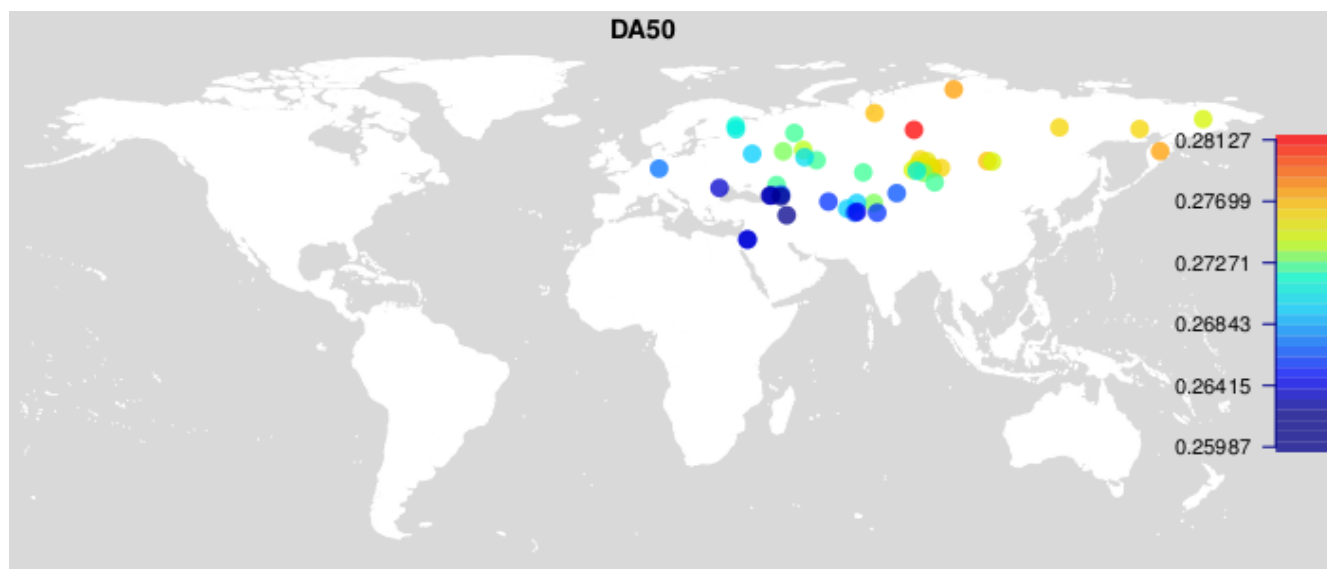**Population label: TianShanSaka**

Supplementary Figure 81 - Outgroup-f3 statistics for sample DA54.

DA54 - Region: Tian Shan
Radiocarbon 14C date: 1693+- 31 BP uncal
Population label: TianShanHun
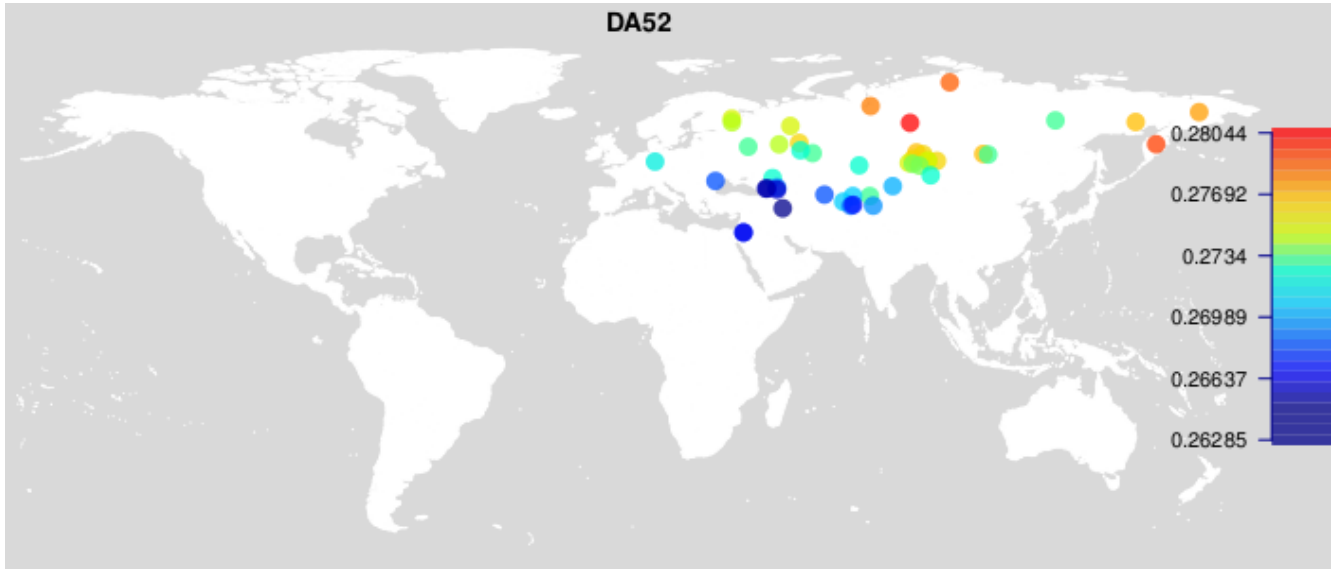

Supplementary Figure 82 - Outgroup-f3 statistics for sample DA56.

DA56 - Region: Tian Shan
Radiocarbon 14C date: 2079+- 34 BP uncal
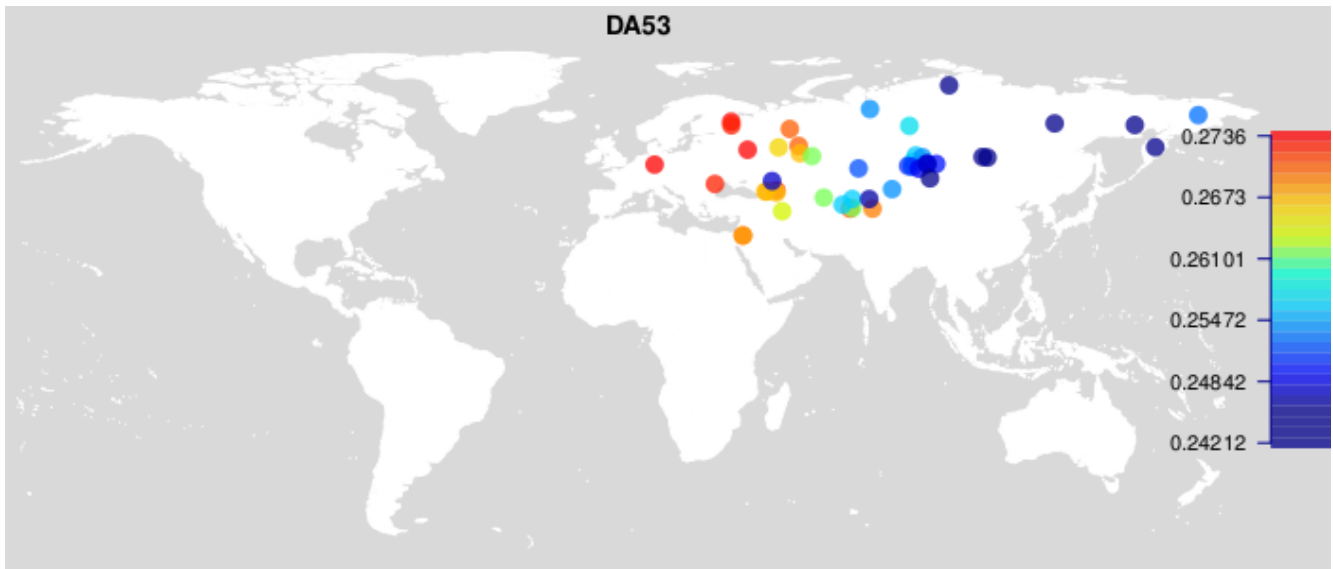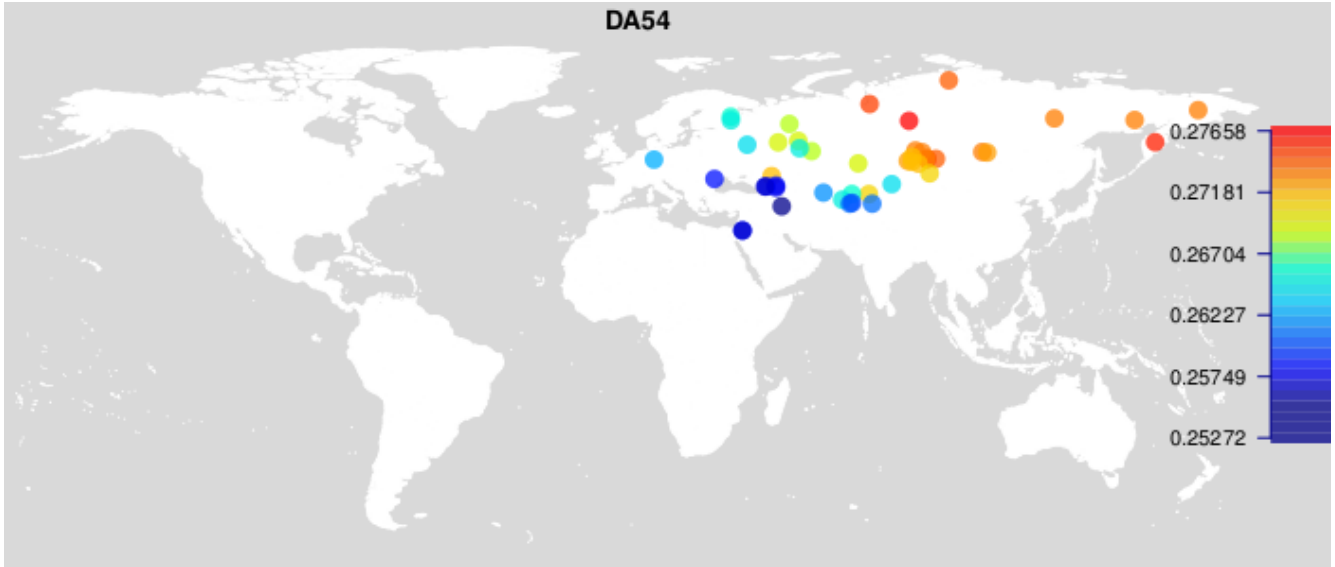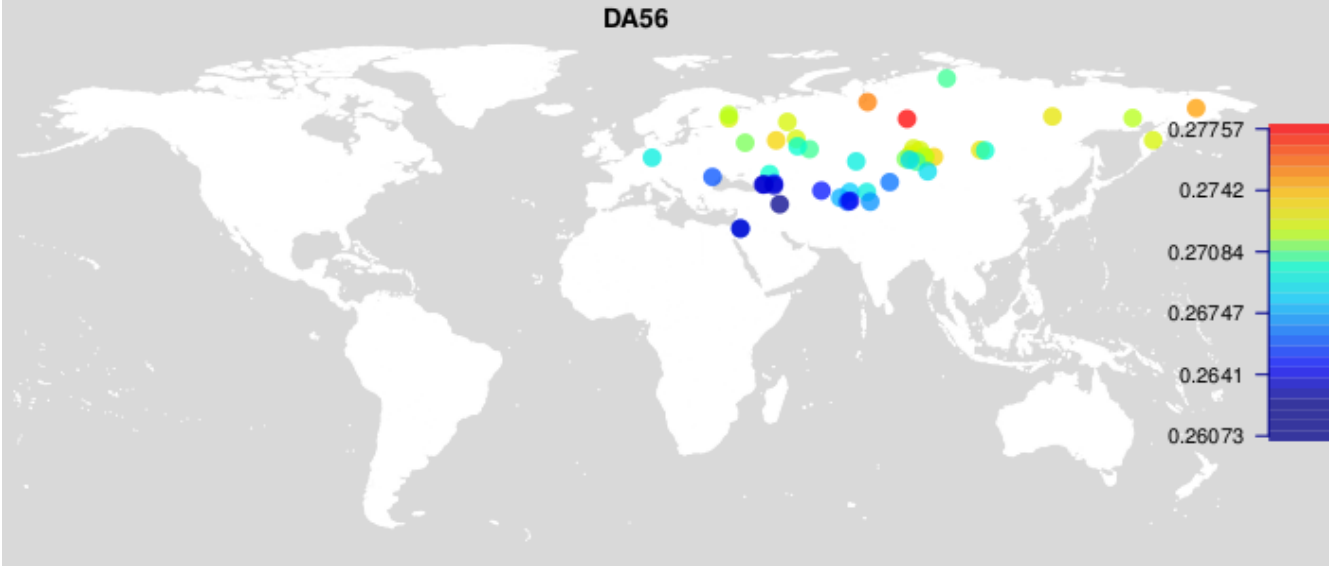**Population label: OutTianShanSaka**

The Tasmola Sakas

By Arman Beisenov

The Taldy-2 burial

The Taldy-2 burial is located in Karkarala district of the Karaganda region. It is located on the left bank of the Taldy River, 50 km to the south of the city of Karkaraly. The cemetery has seven large burial mounds of the Saka period. Kurgan No.5 has been dated to the 7th-6th centuries BC. Before excavations began, Kurgan No.5 was a hemispherical earth mound of diameter 29.5 m and height 2.1 m.

The structure is composed of two layers. The uneven upper layer consists of stones and earth, with its thickness decreasing with increasing height of the mound; at the bottom the layer is 0.5 m thick, whereas at the top it is 0.2 m. This layer was constructed of stone, but over time became covered by soil and turf. This layer functioned as an anchoring shell, i.e. a sort of protective stone armor that prevented the mound from slipping. The next layer is the main part of the kurgan. It is composed of soil blocks and other layers. These soil blocks were elongated, gray, dense structures made of clay, sand and silt that had been pre-cooked into lumpy primitive brick-like shapes that replaced stone. The blocks were shaped before final drying, in an apparently premeditated action. An additional element in the thickness of this layer is the presence of a thin seam (5 cm) of wood and branches. The layer is 1.5 m thick at the centre of the mound, but is thinner at the edges (1.2 m on the eastern edge). It can be assumed that after construction of the first part of the mound, which was 1.5 m high in the centre, some processes were carried out that necessitated the thin seam of wood and branches, and then the mound was raised by another 0.6 m.

Burial of the deceased was carried out on the surface, i.e. without digging a grave pit. The burial space is marked by six round holes (diameter < 30 cm), depth 35 cm) in which residues of wooden logs were found. On examining some other burial mounds, such as in the Serekty-1 cemetery, the head of the Taldy-2 excavation (Arman Z. Beysenov) admitted that Kurgan No.5 might have had a cavity inside it, as in other burial mounds of Taldy-2. The dead soldier would have been placed on the old surface and above him would have been a hollow space with a vaulted ceiling so the kurgan took the form of a hemispherical dome.

The kurgan was robbed in antiquity, with the crypt being penetrated through a narrow tunnel dug at an angle of about 40 degrees. The nature of the robbery is unknown, but many items were left by the ancient robbers. The skull and much of the skeleton survived intact and in articulated form, suggesting that the robbery occurred before skeletization of the corpse. More than 20,000 items were found around the remains of the deceased, mostly small beaded items, gold jewellery, 14 bronze arrowheads, and 150 stone beads.

The inventory indicates that this deceased Saka warrior was laid to rest in the clothing of a tribe leader, representing one of the Saka "Golden Leaders" of the Kazakhstan steppes. According to anthropological studies, the remains belonged to a man aged 35-40 years. A single skull trepanation had been made in the back of the head. According to A. Beysenova, there was a strong tradition of craniotomy in the Tasmolinskiy culture of Central Kazakhstan. Thirteen cases of trepanation are known among materials of the Tasmolinskiy culture; one on a woman, another on a child, and the remainder on men. A. Beysenov believes that trepanation was conducted in the course of embalment to preserve the body of deceased members of the nobility until the funeral.

Supplementary Figure 83 - A gold plaque representing a quiver mounting from the Taldy-2 Kurgan No.5 burial mound.
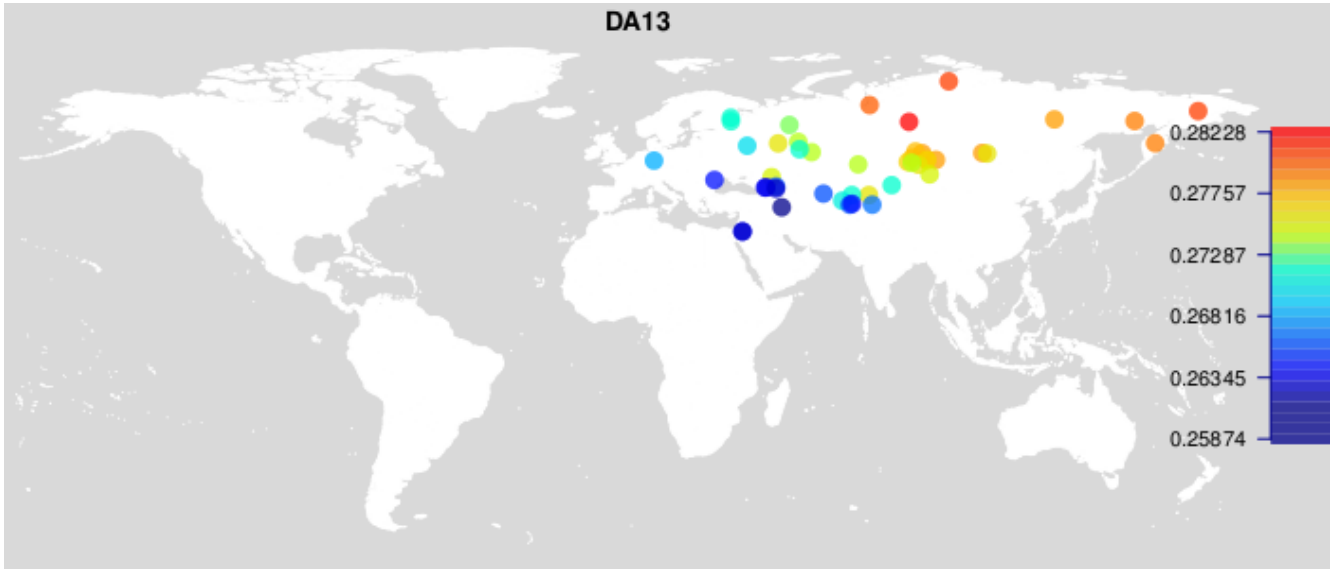
Supplementary Figure 84 - Outgroup-f3 statistics for sample DA13.

DA13 - Region: Central steppe
Radiocarbon 14C date: 2471+- 31 BP uncal
Population label: CentralSaka

The Nazar-2 cemetery, Kurgan No.1.

The mound of Kurgan No.1 in Nazar-2 cemetery has a diameter of 23 m and a height of 1.7 m. A round-layer fence of two rows of stacked flat plates is located at a distance of 1.9 m from the edge of the mound. The mound, hemispherical in shape but with a flattened top, consists of three layers of stone and earth, beneath which lies the central part of the main stone structure that was built around and above the burial chamber. The top layer is turf with small-sized stones. At the top of the mound, this layer is up to 0.3-0.4 m thick, but at the base the thickness increases to up to 1 m. This upper stone impingement, often called the "stone shell " or "stone face", is characteristic of the mounds from the Tasmolinskiy culture of Central Kazakhstan, as well as for a number of burial mounds in other regions.

Beneath the top layer is the basic structure of an earth mound, comprised of two parts. The first is the base layer of ground units, below which lies a fairly loose soil layer of light brown to reddish hue. Oblong-shaped ground units have been encountered in many large mounds of Central Kazakhstan. Under the layer of earth in the center is a stone structure (6.75 x 6 m, height 0.9 m) lined with horizontal slabs of stone that surround the grave pit. The grave pit measured 2.6 x 1.8 m, with a depth of 0.9 m. The grave has a dromos on its east side, with dimensions of 1.8 x 1 m.

Within the grave pit, which had been plundered, we found a bronze arrowhead in the western corner 18 cm above the base. As a result of the robbery, the human skeleton was not intact, solely comprising a few scattered bones and a skull at the base of the pit. The skeletal remains belonged to a 25-35 year old man. Also discovered with the human remains were the skull and two metapodials of cattle (perhaps from a bull). The barrow has been linked to the early stage of Tasmolinskiy culture, i.e. from the 8th-6th centuries BC.

Supplementary Figure 85 - Bronze arrowhead from the Nazar-2 cemetery, Kurgan No.1.
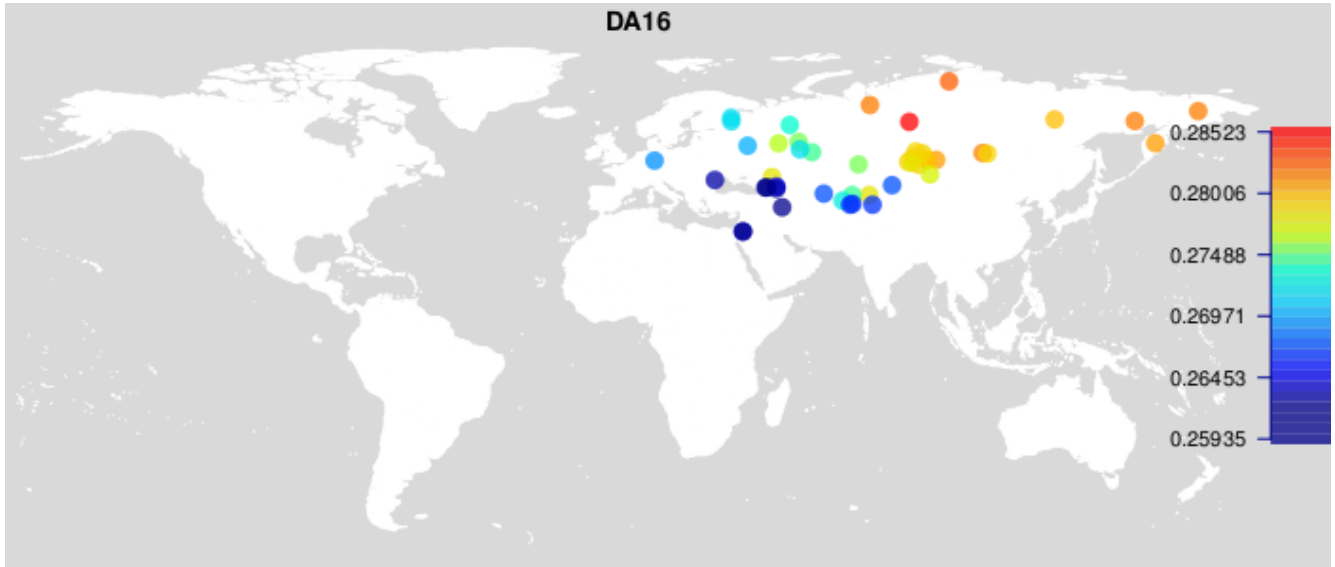
Supplementary Figure 86 - Outgroup-f3 statistics for sample DA16.

DA16 - Region: Tian Shan
Radiocarbon 14C date: 2459+- 28 BP uncal
**Population label: OutTianShanSaka**

The Karasjok-6 burial, mound No.1.

This rounded burial mound of crushed stone and earth has a diameter of 7m and a height of 0.5 m. The central part of the mound is flattened and has a small depression. Excavations have revealed that the central part of the mound was considerably damaged by ancient robbers. The main component of the mound's stratigraphy is a stone layer that is 0.35 m thick at the periphery. This layer is composed of stone plates and debris, and initially was probably hemispherical in form with a height of about 0.4 m at the centre. The upper layer is comprised of small stones, which served as the stone covering for the entire structure. As a result of grave-robbing, the central parts of the structure have been disrupted and, at the time of excavations, was a mixture of earth and stones.

The burial pit is located in the center of the mound and is rectangular with rounded corners. Its long axis is oriented east to west. The burial pit measures 2.2 m long, 1 m wide and 1.1 m deep. During excavations of the mound, human bone fragments were discovered in different leyers. These bone fragments were poorly preserved due to moisture penetration after the robbery. The skull and some long bones of the hands were found in the western part of the pit, whereas the pelvic bone was recovered from the eastern part. Two corroded bronze arrowheads were found in the central part of the burial pit. The buried individual was a 25-35 year old male. Based on the funeral rites and features of the recovered arrowhead, the barrow is attributable to early-stage monuments of the Tasmolinskiy culture of Central Kazakhstan (8th-6th centuries BCE).

Supplementary Figure 87 - Bronze arrowheads from Karasjok-6 burial mound No.1.
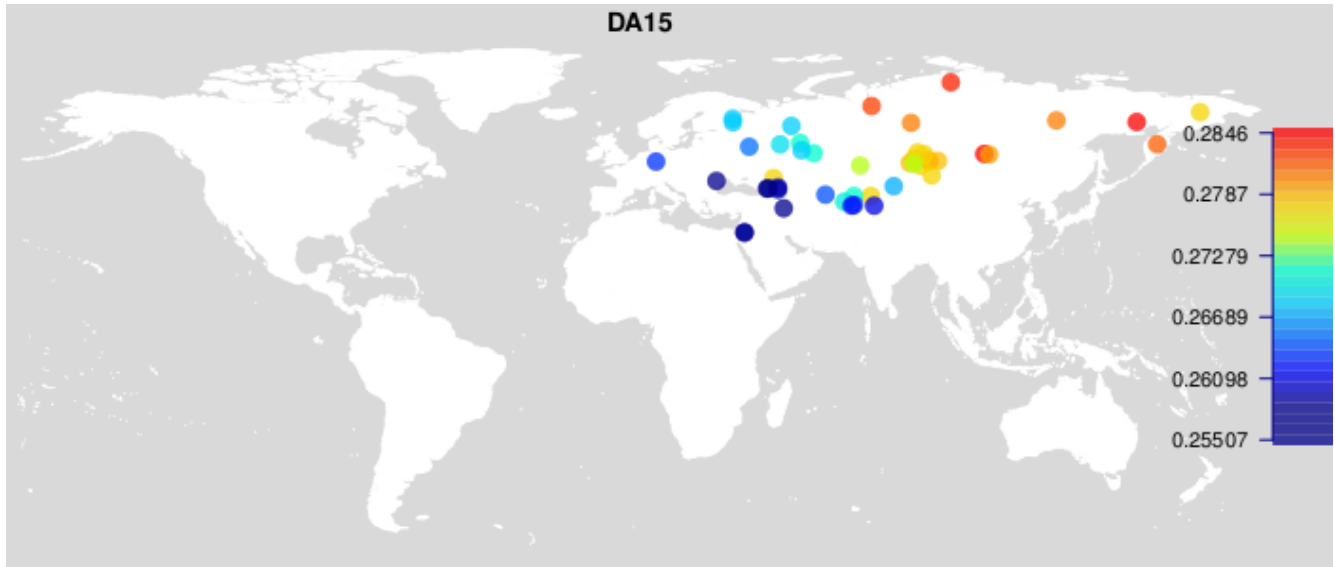
Supplementary Figure 88 - Outgroup-f3 statistics for sample DA15.

DA15 - Region: Central steppe
Radiocarbon 14C date: 2470+- 43 BP uncal
Population label: CentralSaka

This burial ground is located in the territory of the Karkaralinsky district of the Karaganda region. Burial mound (or barrow) No.8 has a diameter of 25 m and a height of 1.8 m. The mound is flattened, the edges are flat and, in the center, there is a depression, which indicates that it had been robbed in the past. The mound is extensively covered in turf; the thickness of the sod at the crown does not exceed 15 cm, but it reaches 25 cm at the periphery and at the crypt. Three large slabs lay on the surface at the top of the mound, which apparently were deposited there when the site was robbed. These slabs may have formed part of the closure of the sepulchral chamber.

An earth layer lies below the turf layer. Its soil is gray sandy loam with lenses of dark gray and black. Below this soil layer lies masonry of large- and medium-sized plate fragments. These horizontal plates goriontally, withoutlack a binder solution. The largest plates are 1 m long and 0.5-0.7 m wide. The masonry is rounded and tapers to the top, forming a truncated cone. The height of the remaining masonry is more than 1 m, but the top of the masonry was destroyed during the robbery of the mound. The masonry may have initially formed a dome, inside of which would have been a hollow space, forming a stone crypt by the false arch method.

Inside the stone structure a grave pit had been dug into the ground. The grave pit is rectangular, with its long axis oriented south-southeast to north-northwest. The grave pit is 3.37 m long, 1.3 m wide in the middle, and 1.25 m deep. A dromos of length 0.8 m and width 0.5 m is located on the southeast side. Where the dromos abuts the grave wall, it is 0.75 m deep.

The burial mound was considerably plundered. Human skull and bone fragments were found at the

bottom of the grave and partly in the filling. The skull is partially damaged. White and green beads of various shapes and sizes were also found. At the bottom of the grave, a unique gold earring with a conical suspension was recovered. Graining and scanning techniques were used in the design of the earring. The skull is partially damaged. Anthropological studies have shown that a woman of 25-35 years was buried in the mound.

Supplementary Figure 89 - Gold earring from the Karashoka burial ground, Mound No.8.
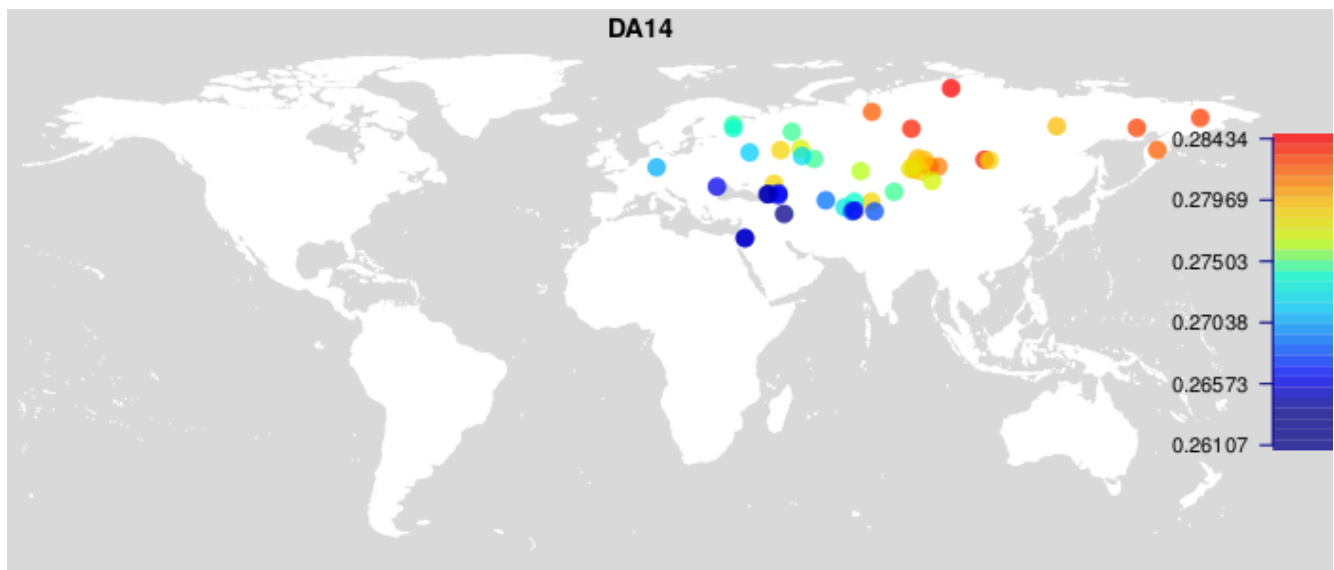
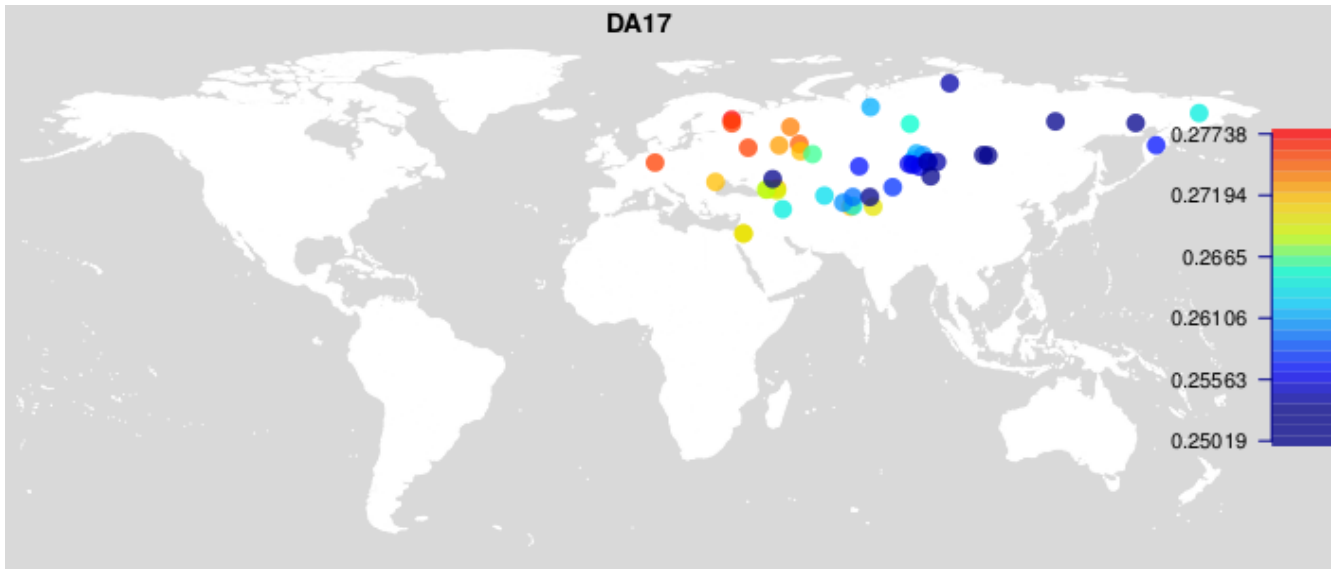**Supplementary Figure 90 - Outgroup-f3 statistics for sample DA14.**

DA14 - Region: Tian Shan
Radiocarbon 14C date: 2468+- 39 BP uncal
Population label: CentralSaka

The Birlik burial mound No.12 is 9.5 m in diameter and 0.35 m high. It is flattened at the top and a krepidycircular crypt built from large flat plates is found at the base. Part of the stone mound in the western sector was probably used for construction of later burial mounds nearby. An unusual rock structure is present in the upper layer of the mound, below which is a ground layer. A grave is located in the center of the mound, formed by large stone plates arranged subrectangularly. The long axis of the grave is oriented in a southeast to northwest direction. On the southwestern side of the grave, at the level of the bedrock, a horse skull was found. Under the central stone structure, there is a subrectangular burial pit with dimensions of 2.7 x 1.6 m and a depth of 2 m. The pit was filled with stones. A stone box was found at the bottom of the pit made of vertical stone plates and covered with six long boards laid crossways. The lower edge of the box had been recessed into the soil to a depth of 18 cm. Inside this box on the sandy bottom was a layer of clay to a depth of up to 10 cm. The stone box is rectangular with dimensions of 2.35 x 1.1 m and a height of 0.75 m. The orientation of the box was the same as that of the burial pit.

A human skeleton was excavated from the bottom of this stone box. The deceased had been laid on his back in the extended position, with the head oriented to the northwest. A heavily corroded iron knife was located to the left of the skull. Three bronze arrowheads were found ner the left knee. Anthropological studies have shown that the skeletal remains belong to a man aged 25-35 years.

Supplementary Figure 91 - Three bronze arrowheads from the Birlik burial, mound No.12.

Supplementary Figure 92 - Outgroup-f3 statistics for sample DA17.

DA17 - Region: Tian Shan
Radiocarbon 14C date: 2577+- 30 BP uncal
Population label: CentralSaka

Descriptions of the burials of the early Iron and Middle Ages of Pavlodar Irtysh

By Victor K. Mertz, Ilja V. Mertz

Burial No.1 in the Shidertinskoye 2 settlement
(Burial 1, Sjigerkinskoje 2, Early Saksky period, Child, Shiderty River, Pavlodar pd 28)
The Shidertinskoye-2 settlement is located 4 km south-west of Shiderty Station in the Ekibastuz district of the Pavlodar Region. It was sited to the south of a ballast quarry, on the eastern slope of a mountain that forms the right bank of the Shiderty River. Two burials were discovered at the settlement. Burial No.1 in square 3-B was partly destroyed when a foundation pit was dug for a dwelling of the Tasmola culture (Early Iron Age). The grave was made at a depth of 0.1 m from the ancient daylight surface and covered with stones. A young man was buried in it, lying on his left side, with the head oriented to the north-east and the bones of his arms folded at the elbows and laid across his breast. The leg bones were missing; apparently they had been destroyed during works on the foundation pit in the Early Iron Age. There was no accompanying paraphernalia. The design of the featureless grave had been almost completely demolished as a result of Early Iron Age and Modern Age anthropogenic activities.

Judging by positioning of the in the grave and the fact that he was buried on the ancient daylight surface, this burial could be attributed to the Sargarino culture of the Late Bronze Age in Central Kazakhstan[175]. This interpretation has been contradicted by radiocarbon dating of the man's bones, which places him as having lived between 763 and 416 BCE [cal. 2 Sigma; radiocarbon dates have beenwere calibrated using the CALIB 7.0 software[176] and the IntCal13 calibration curve[177]. This chronological interval corresponds with the so-called Hallstatt plateau of the radiocarbon calibration scale[177], so the chronological interval of the specimen in question is very broad. Consequently, the time when the burial was conducted could, with equal likelihood, be determined as any time between the 8th and 5th century BCE.

It should be pointed out that in Central Kazakhstan, both during the transition period and the early Saka period, burials on the ancient daylight surface[178,179], as well as the remains being positioned in a crouched posture, can be found in the Arzhan and Shanching (spelling uncertain) burial grounds in Tuva[178]. These parallels, as well as the obtained radiocarbon date, prompt us to attribute Burial No.1 at the Shidertinskoye-2 settlement to the early Saka period, dating it to the 8th century BCE.

**Supplementary Figure 93 - Burial No.1 in the Shidertinskoye 2 settlement**
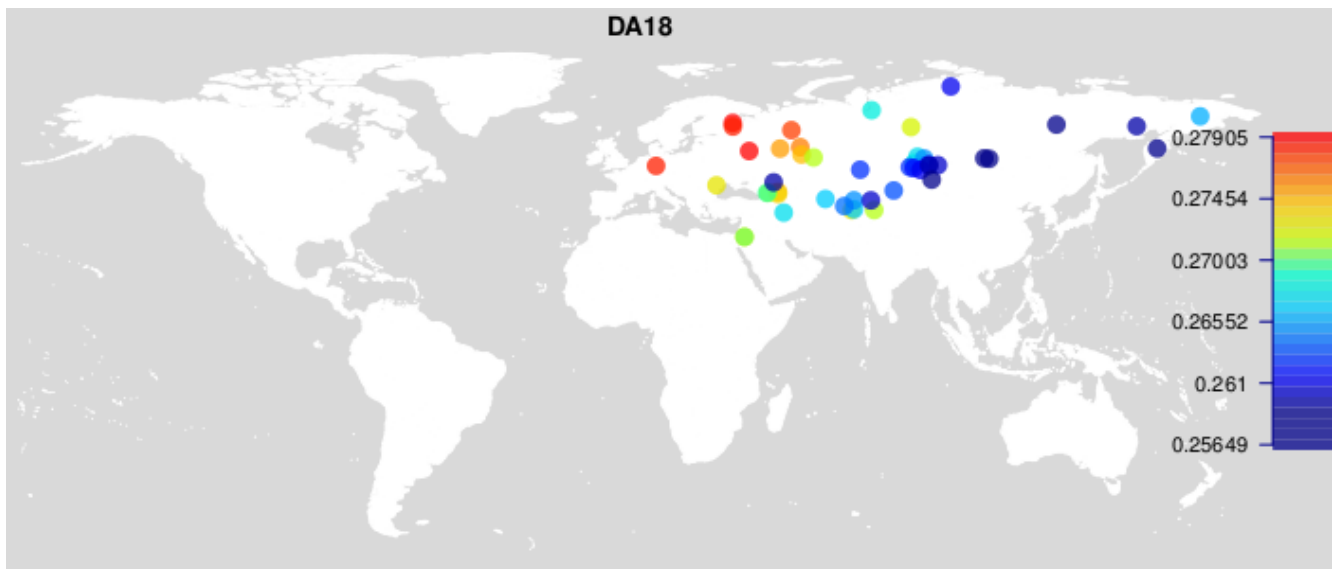
Supplementary Figure 94 - Outgroup-f3 statistics for sample DA18.

DA18 – Region: North-Western Saryarka
Radiocarbon 14C date: 2463 BP +- 45 BP uncal
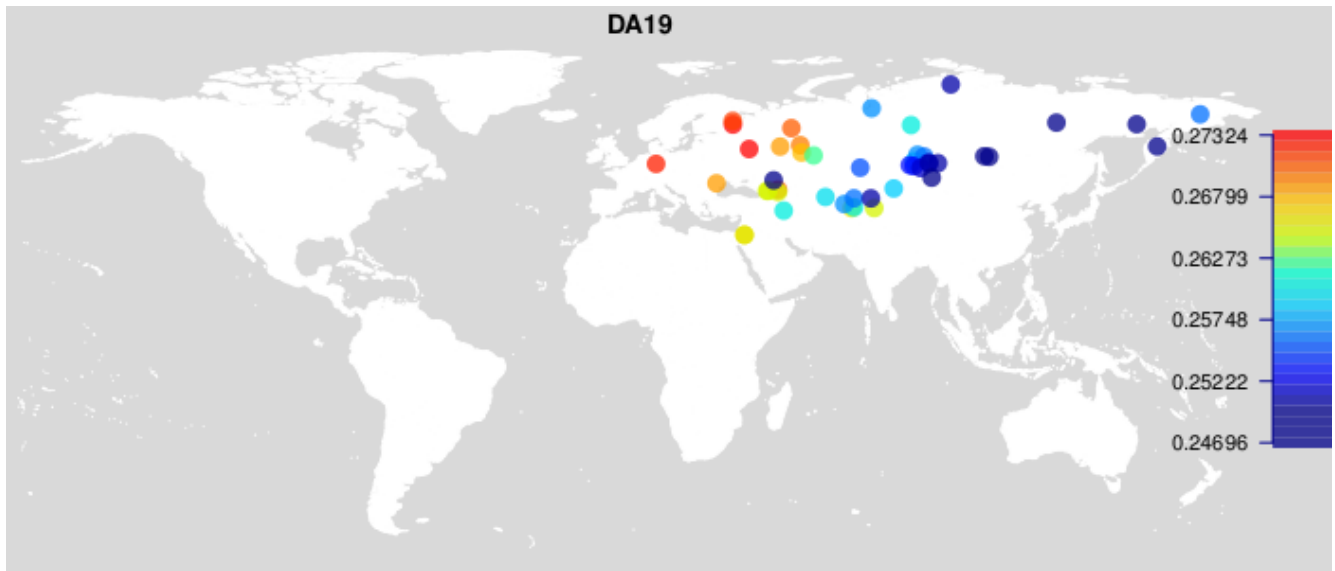**Population label: Nomad_IA**

Destroyed Saka burial from the village of Karaterek
(Burial 1, Karaterekh, Sak, M2 teeth, Maiskij rajon)

During archaeological fieldwork in 2000 in the Maysk District of the Pavlodar Region by an expedition from the Centre of Archaeological Studies at Pavlodar State University, information was obtained from an inhabitant of the village of Karaterek that he had found human remains on the bank of the Irtysh River. On indicating the approximate location of his discovery, he handed over his findings to V. K. Merz. The findings included a skull and the remains of a postcranial skeleton, as well as an oblong whetstone (knife-grinder) with a hole drilled into one end for fastening (Supplementary Figure 95). Inspection of the indicated location revealed that the burial had been sited on the edge of a high terrace that was already disintegrating. No additional finds were discovered at that location.

Such whetstones are typical of male burials of the Saka period[180], prompting us to date this burial to the Early Iron Age. Radiocarbon dating of the man's bones revealed that he lived between 810 and 540 BCE (cal. 2 Sigma). This chronological interval also corresponds with the so-called Hallstatt plateau of the radiocarbon calibration scale[177], so the chronological interval of the specimen in question is very broad. Consequently, the burial could have been made any time between the end of the 8th to the first half of the 6th century BCE.
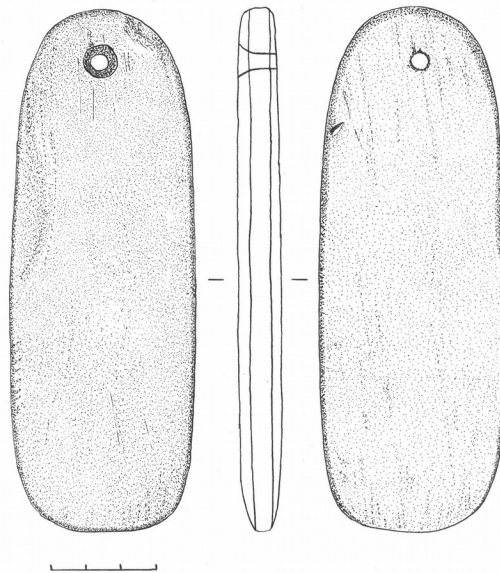
Supplementary Figure 95 - A whetstone from the Saka burial near the village of Karaterek

Supplementary Figure 96 - Outgroup-f3 statistics for sample DA10.

DA19 – Region: Irtysh River
Radiocarbon 14C date: 2555 +- 46 BP uncal
Population label: OutCentralSaka

Burial near the village of Kenzhekol

(Kenjekol, Karjer, excavation 2010)

In 2011, a single destroyed burial, located in a 1.85 m deep dug grave chamber, was discovered in a sand pit on the south-eastern outskirts of Kenzhekol (a southern suburb of Pavlodar). At the bottom of the 0.8 m wide grave chamber were the remains of the upper part of a well-preserved skeleton that had been placed lying with the head oriented to the north-east. The part of the skeleton below the lumbar vertebrae had been destroyed and was found in the pit (Supplementary Figure 97). A small bronze bead spun from copper sheet was discovered at the right-hand side of the skull. No further objects were found, but copper oxides on the pelvic and lumbar bones indicate that there may have been others.

Radiocarbon dating of the individual's bones established the burial to have been conducted between 91 BCE and 130 CE (cal. 2 Sigma). The largest value on the radiocarbon dating calibration curve coincides with the end of the 1st century BCE, linking the burial to the Hun-Sarmat period.

Supplementary Figure 97 - Burial near the village of Kenzhekol, Karjer, excavated in 2010.
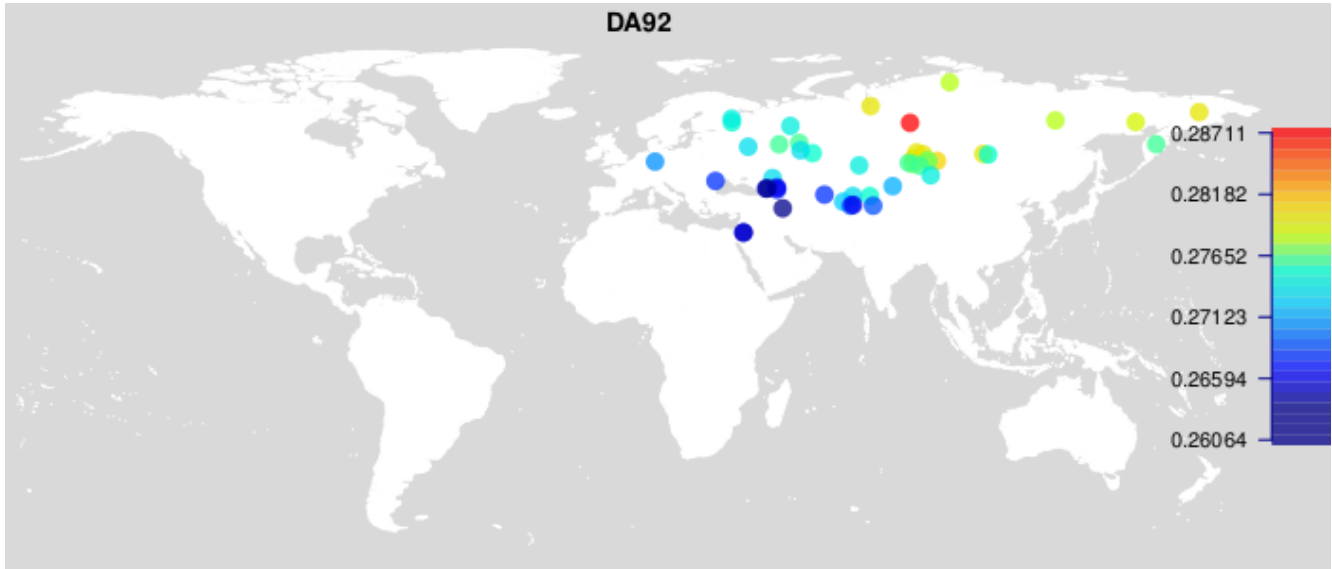
Supplementary Figure 98 - Outgroup-f3 statistics for sample DA92.

DA92 – Region: Middle reach of the Irtysh River (right bank)
Radiocarbon 14C date: 1972 +- 47 BP uncal
Population label: Nomad_IA

Burial near the village of Komaricyno

(Burial near Kamarishyno village Pavlodar Kar6)
During a fieldwork expedition in 2000 in the Pavlodar Region, a destroyed burial was discovered while examining the riser of the first terrace above the flood plain of the Irtysh River near the village of Komaritsino. It was located 500 m south-east of the village on a steep slope of the terrace, covered with high dunes. The terrace is constantly subjected to erosion, so ancient burials are exposed occasionally. During another examination of the terrace slope, bleached and nearly destroyed bones of a pair of legs and a right arm were found. Pelvic bones were found protruding from the ground a little higher up the slope, which were in the original location of the burial.

A small excavation was made around the pelvic bones, which uncovered the remains of a chamber measuring 0.7 by 1.05 m. Within the chamber was found the upper part of the skeleton of an old woman, who had been placed lying on her back with her head oriented to the north-west. The bones and skull were well preserved, except for the facial area that consisted of very thin bones. The upper jaw teeth were completely absent and only the incisors remained in the lower jaw. A sheep's shoulder blade, anklebone and heel bone were found under the skeleton's left shoulder and at her bended elbow of the right arm (Supplementary Figure 99). Bean-shaped gold wire earrings with thin elongated ends in the form of stalks (Supplementary Figure 100) were found in the area of the auricles. No further objects were found, making it difficult to date the burial and determine its cultural affiliations. Unfortunately, no radiocarbon date has been established for this burial, further inhibiting efforts to date it.

Attempts to find comparative earrings to the ones found in this burial have not been successful. However, it is well-known that earrings made of bronze, gold or silver wire were widely used by early nomads on the steppes of the Eurasian zone. For instance, similar wire earrings of a roundish form were found in the Vorobievo-1 burial ground, ascribed to the Gorokhovskaya culture. Items similar in form were found in materials from the Slavyanka burial ground in Eastern Kazakhstan. These latter include golden earrings in figure-of-eight form or in the shape of a small ring with a small oval pendant, both of which started to appear at the end of the 1st millennium BCE in cultural artefacts of the Kulazhurginskaya culture. Similar bronze earrings are known from in-ground burials in the Mysok burial ground of the Tastyk culture. A similar type of adornment is also characteristic of artefacts from the 3rd to the 1st century BCE of the early nomads from South Kazakhstan and the Baba-Ata and Berkkara burial grounds of the Tashkent Oasis. Thus, the majority of these objects, which are similar in form and technology, are characteristic of many early nomad cultures at the end of the 1st millennium BCE.

This timing is also supported by anthropological data, according to which Mongoloid physical features gain strength during this period, especially among the female population of East Kasakhstan . Judging by the marked flatness and width of the facial skeleton, and also by the roundish cranium, the individual buried in the grave in Komaritsino was a female representative of the Mongoloid race. Elements of the burial ritual, such as the presence of sheep bones placed behind the left shoulder and at the right elbow, prompt us to relate this burial to the Hun-Sarmat period, the burials of which were characterized by the presence of remains of sacrificial food in the form of a sheep's shoulder blade and legs within the burial chamber.

Supplementary Figure 99 - Burial near the village of Komaricyno
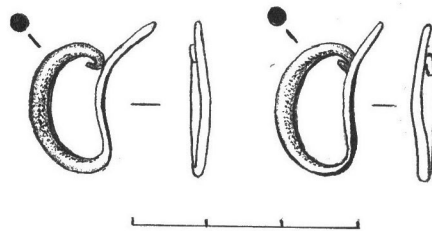
Supplementary Figure 100 - Earrings from a burial near Kamarishyno village
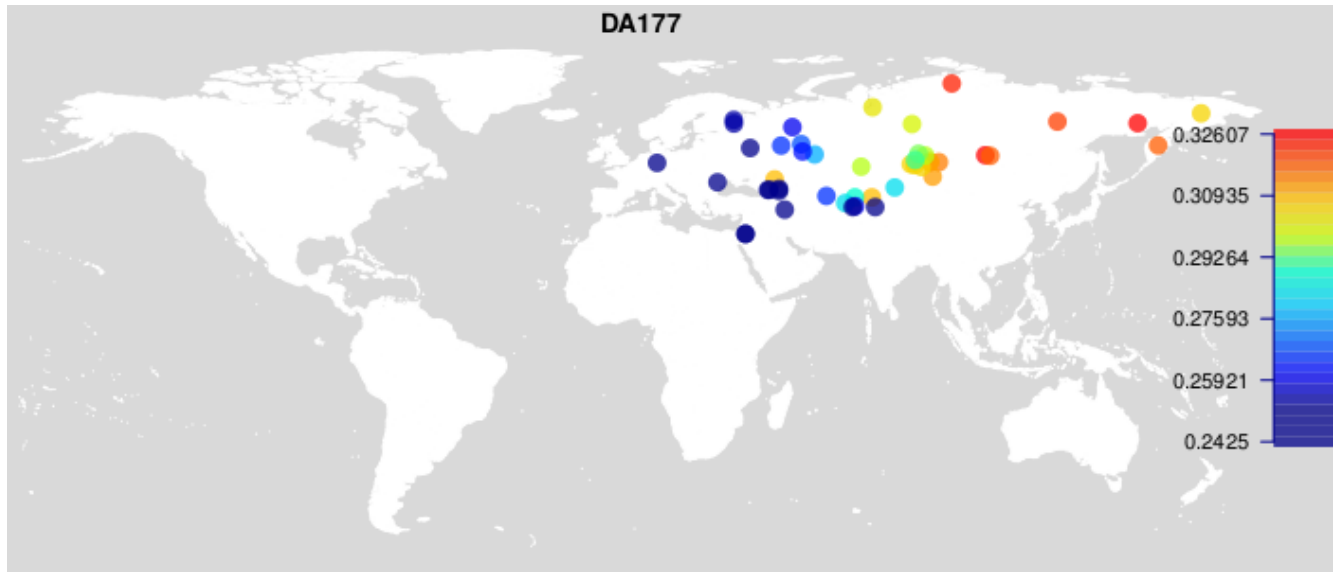
Supplementary Figure 101 - Outgroup-f3 statistics for sample DA177.

DA177 – Region: Middle reach of the Irtysh River (right bank)
Period: Hun period
Population label: Nomad_HP

(Burial 1, Kurgan Sjiderti 18, Gunno-Sarmat, 2 teeth, Sjiderte, Pavlodar pd 57)

The Shiderty-18 group of kurgans is located 7.5 km south of Shiderty Station on the right edge of a dry ravine falling into the Shiderty River, 50 m north-west of the Shiderty-17 kurgan, on the slope of a mountain. It consists of three stone and earth cairns that were thoroughly examined in 2002.

Cairn 3 adjoins more northerly kurgan-1, and is an ovally-shaped cairn of regularly spaced stones, each of which is more than 3 m long, 1.7 m wide, and 0.2-0.25 m high. Beneath the cairn lies stone walling that forms a rectangular grave chamber with rounded corners, measuring 2.4 x 1 m and 1 m deep (as measured from the ancient surface). The grave was aligned west to east, and heavily packed with several layers of stone slates (Supplementary Figure 102), under which a composite stone box was found at a depth of approximately 1 m, containing a human burial.

The skeleton of an adult male was found in the stone box, positioned on his back with his arms stretched out alongside his body and the head aligned to the east (Supplementary Figure 102). A small bronze buckle was found where a belt would have been located, as well as a rounded, convex, metal plate and an oval ring (Supplementary Figure 103). To the right-hand side of the pelvic bones lay a horse's shoulder blade and rib. Further down, next to the wall of the stone box, was a small oblong, hairpin-like bone object of uncertain function, and a bronze cocker hook (Supplementary Figure 103). Under the horse's shoulder blade lay a 14 cm-long iron knife (Supplementary Figure 103). Four three-flanged, tanged iron arrowheads (2.5-3 cm long and 1 cm wide) were found near the left knee-joint (Supplementary Figure 103).

Behind the wall of the stone box, at the head of the buried body, a large sacrificial altar was found, containing 29 skulls of domesticated animals: 11 horses, and 18 sheep and goats. On examining the sacrificial altar, a round iron bridle bit was found under the lower jaw of one of the horse skulls at the base of the sacrificial altar (Supplementary Figure 103).

Judging by the burial ritual and design, it can be attributed to the Korgantas culture of Central Kazakhstan. Similar burials date from the 3rd to the 1st century BCE and belong to the Hun-Sarmat period[179,181,182]. This dating has been corroborated by radiocarbon dating of the man's bones, which established the burial to have taken place between 363 and 198 BCE (cal. 2-Sigma), i.e. between the middle of the 4th and the beginning of the 2nd century BCE.

Supplementary Figure 102. Korgantas burial from Shiderty burial ground – 18 before (left) and after (right) removal of stone deposit.
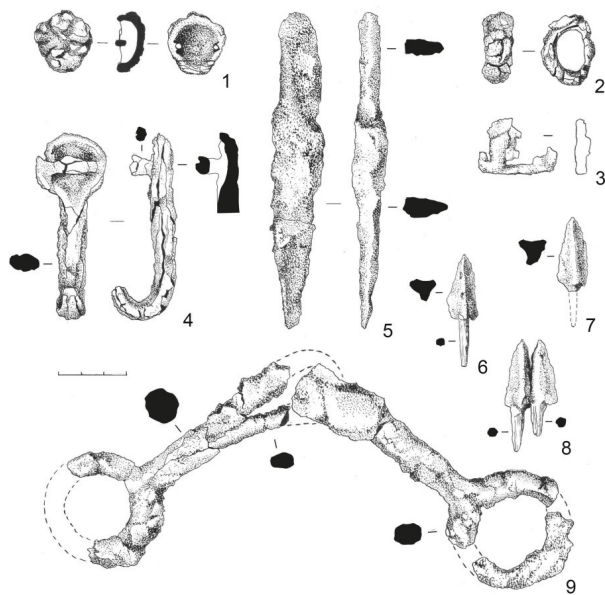
Supplementary Figure 103. Selected inventory from the Korgantas burial of Shiderty burial ground - 18
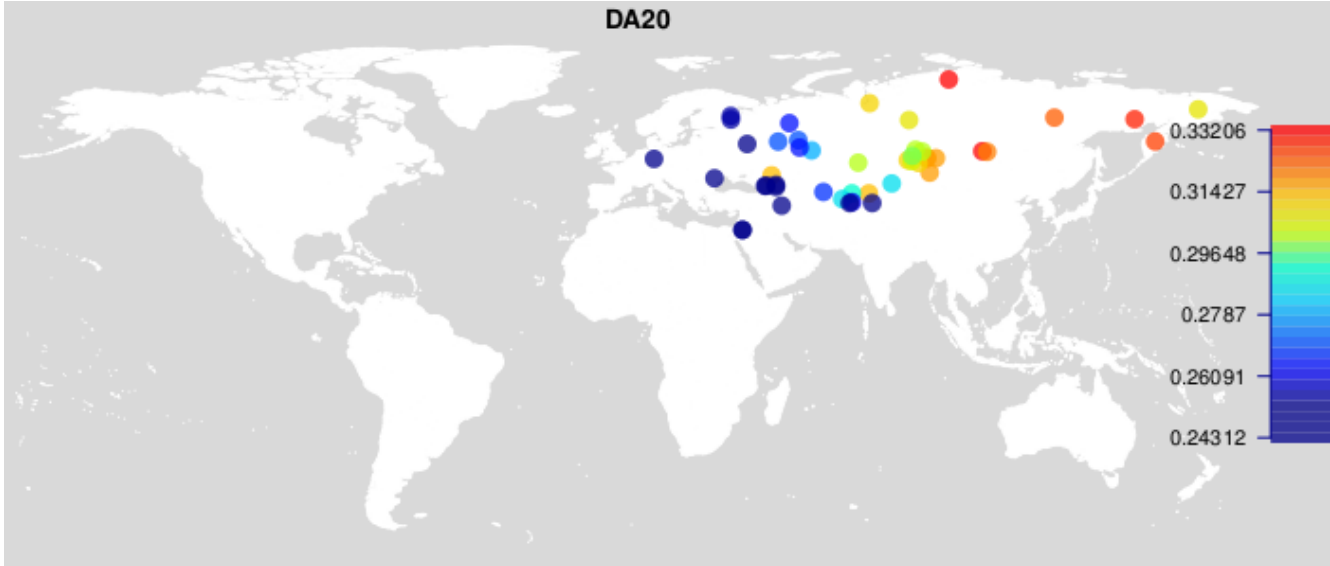
Supplementary Figure 104 - Outgroup-f3 statistics for sample DA20.

DA20 – Region: North-Eastern Saryarka
Radiocarbon 14C date: 2203 +- 27 BP uncal
Population label: Nomad_Hun-Sarmatian

Medieval burial in the village of Beregovoe

(Berygavoya, 1991 god, Medieval Turk, Middle reach of the Irtysh River (right bank), Pavlodar PAV7)

During archaeological fieldwork by a Pavlodar archaeological expedition in 1991 at the village of Beregovoe in Zhelezin District, a mediaeval burial was discovered[183]. The burial was located 0.9 km north-west of Beregovoe on the surface of a sand dune, located on the edge of the first terrace above the flood plain on the right bank of the Irtysh River. The even dune surface, rising 25 m above the flood plain, was well covered with grass. A depression (diameter 20 m; depth 0.4 m) was found in the northern part of this location. A test pit of 0.6 x 0.6 m was dug to a depth of 0.3 m, which revealed a human skull. The test pit was widened to a small excavation measuring 2.5 x 1.5 meters, aligned west to east, which uncovered an in-ground grave (2 m long, 0.6-0.65 m wide) at a depth of 0.4 m under the present-day surface. The grave had been dug 0.1 m into the underlying yellow sand and was aligned west/south-west to east/north-east.

A human skeleton was found in the grave, positioned on its back, with the head pointing towards the west/south-west. The bones of the right arm were extended alongside the body, whereas the bones of the left arm were flexed at the elbow (Supplementary Figure 105). At one elbow lay tanged iron arrowheads (Supplementary Figure 106), and at the forearm was a piece of steel perhaps for striking sparks from flint. A knife was found at the thigh of the left leg, remains of what seemed to be spurs were recovered at the heel bones and, at the north-eastern edge of the grave, the remains of a bridle (an iron bit with a two-holed horned cheek-piece) were found.

This latter piece is the most significant of the discovered artefacts from the burial. It resembles bridle bits found in Kirghiz graves of the Yenisei basin, attributed to the 7th and 8th centuries by A. A. Gavrilova[184]. A radiocarbon date from the individual's bones established the burial as having taken place between 638 and 853 CE (cal. 2 Sigma). The largest value on the radiocarbon dating calibration curve coincides with the second half of the 7th and the beginning of the 8th century CE, linking the burial to the Turkic period.

Supplementary Figure 105 - Medieval burial in the village of Beregovoe.
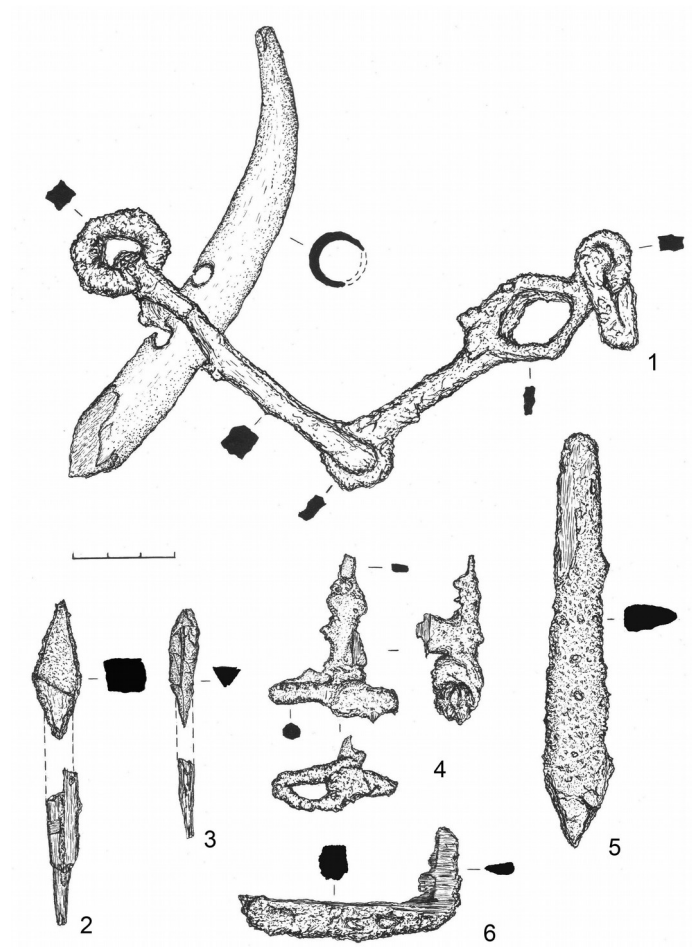
Supplementary Figure 106 - Artefacts recovered from the medieval burial in the village of Beregovoe
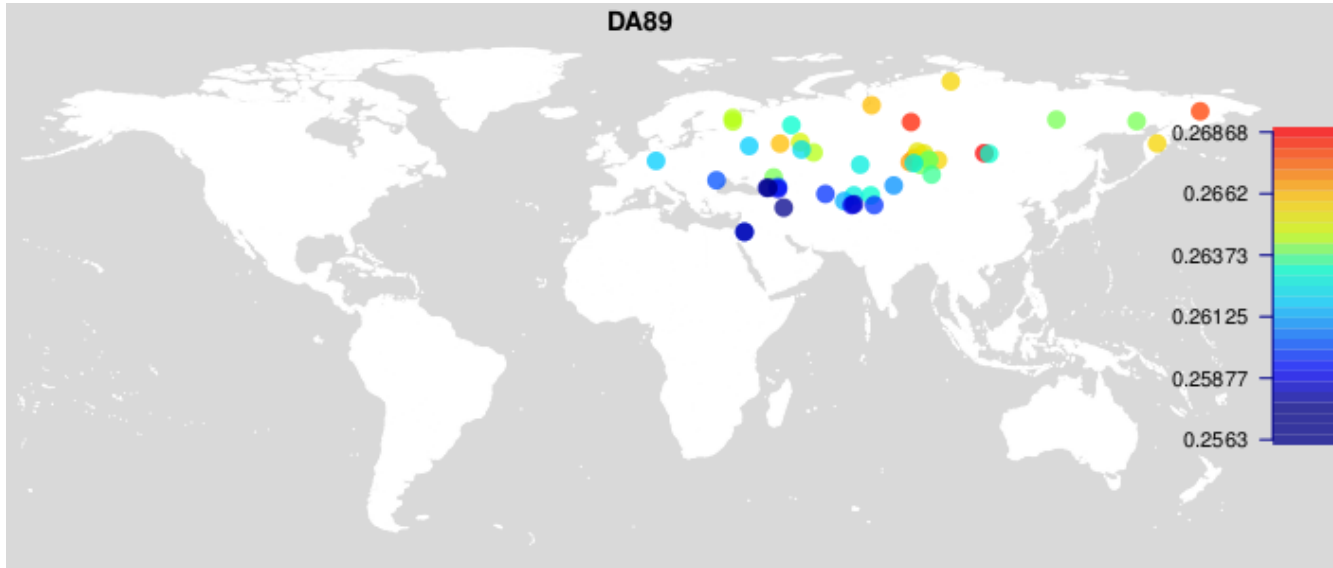
Supplementary Figure 107 -Outgroup-f3 statistics for sample DA89.

DA89 – Region: Middle reach of the Irtysh River (right bank)
Radiocarbon 14C date: 1315 +- 45 BP uncal
Population label: Turk

The Pohrebenye burial from the Grigoryevka-4 burial ground

(Grigorjevka 4, mogila 1, Medieval, Kimak, Pavlodar, PAV1)

The Grigoryevka-4 burial ground is located 1.4 km north/north-west of the village of the same name in the Pavlodar district of the Pavlodar region. It is sited on the first terrace above the flood plain of the right bank of the Irtysh River, 0.3 km north-west of the Kazakh cemetery. This area is traversed from south to north by a dozen, approximately 1.5 m-wide trenches. A mediaeval burial was discovered in 2012 in the lateral profile of one of these trenches. No grave design was documented. An excavation covering approximately 12 m^2 was undertaken at the burial site. After removing the upper layer, an elongated patch of discoloured soil (oriented west to east and measuring 2 x 0.6 m) was identified in the central part of the excavation at a depth of 0.2 m below the daylight surface. The eastern side of this patch had rounded borders. The excavation revealed ceramic fragments decorated with traverse comb-scored marks and a piece of grinding stone.

Within the discoloured patch to the east, in an area measuring 0.8 x 0.6 m and at a depth of 0.04 m into the natural soil, a horse skull lacking the lower jaw and with a heavily damaged cranium was discovered, sitting on its base. Wood charcoal was found next to this horse skull. Further to the east, the grave chamber gradually descended into the natural soil to a depth of 0.24 m. The grave chamber was filled with charcoal and baked sandy clay, in which fragments of ceramics decorated with comb impressions were found. A human skeleton was found at the bottom of the grave, positioned on its back, with the head pointing to the east. The leg bones of the buried individual were raised relative to the trunk and reached the level of a sacrificial altar (Supplementary Figure 108). A grinding stone lay in the space between the bones of the rib cage and the left side of the pelvic bone. Two black balls (2 cm in diameter and potentially of clay) lay under the pelvic bones. An iron knife was found below the groin (Supplementary Figure 109). A bone strap or belt buckle with an iron prong and sleeve, as well as a tanged armour-piercing arrowhead, was found next to the right forearm. Another buckle without a prong lay on its side at the northern end of the grave. The sides and bottom of the grave chamber had been scorched and were brown.

Two radiocarbon dates have been produced for the burial. The first one, DA87, was obtained from the human bone sample, and it defines the age of the burial within 608-768 cal AD (2σ). The second date, UCI-182867, obtained from the horse teeth found in altar was dated to 733-882 cal AD (2σ). The discrepancy in the radiocarbon dates suggest a possible reservoir effect on the human bones, making these appear older. In the middle reaches of the Irtysh River, this phenomenon was recorded for Early Bronze Age human skeletons (for Shauke 8B, the offsets between individual fish and terrestrial samples range from 97 ± 59 to 301 ± 47 14 c yr, with the overall mean freshwater reservoir offset of 210 ± 65 14 c yr). For this reason, the date from the herbivore bones from the altar of tomb 1 of Grigorivka 4 appears to be the most reliable; it determines the interval of the burial as the second half of the 8th – third quarter of the 9th c. CE, attributing it to the Kimak period.

Supplementary Figure 108. The Pohrebenye burial from the Grigoryevka-4 burial ground
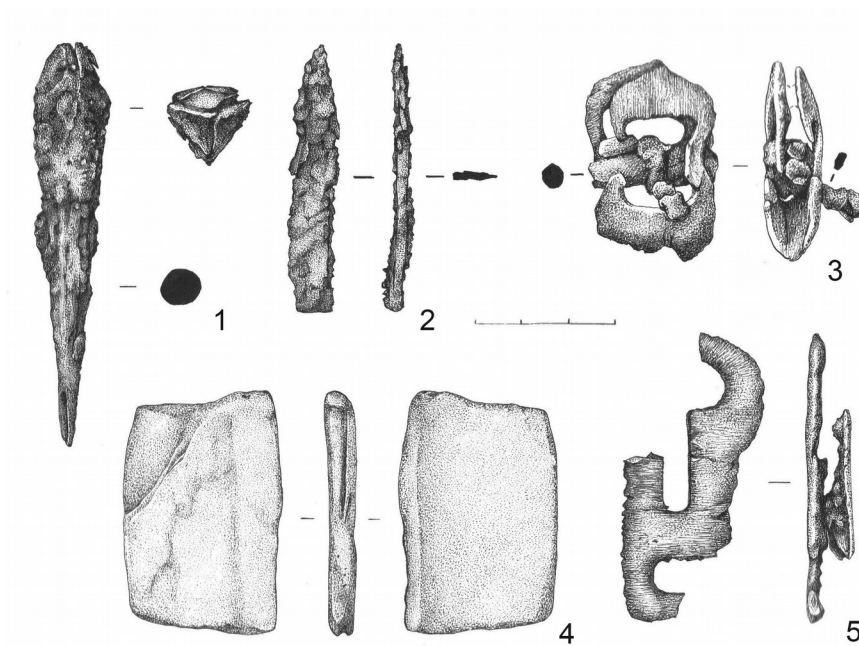
Supplementary Figure 109. Inventory from a Pohrebenye burial at the Grigoryevka-4 burial ground
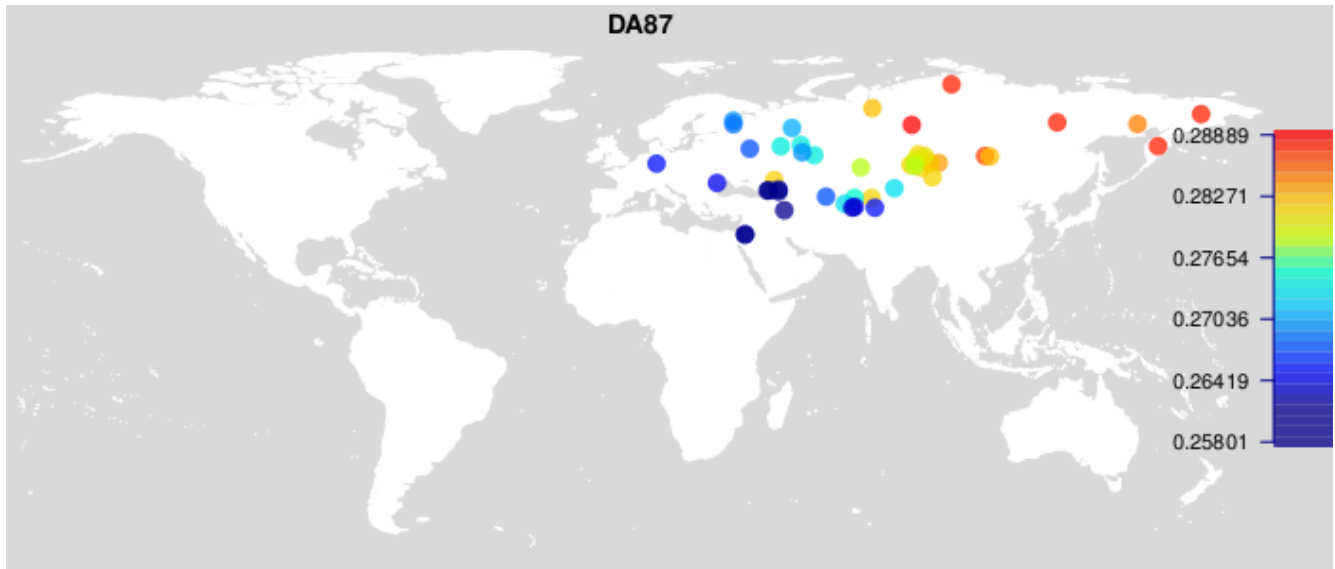
Supplementary Figure 110 - Outgroup-f3 statistics for sample DA87.

DA87 – Region: Middle reach of the Irtysh River (right bank)
Radiocarbon 14C date: 1352 +- 45 BP uncal
Population label: Kimak

Ruined burials from the village of Karaoba (Spartak)

(Spartak, kurgan 1, burial 4 (DA93), Early Medieval, Unknown, 2 teeth, adult Pavlodar; Spartak, kurgan 1, burial 5 (DA94), Early Medieval, Unknown, 1 tooth, Pavlodar)

As a result of activities being carried out in the village of Karaoba (Spartak) in Aktogay District at the beginning of the 1990s, an earth kurgan was destroyed, under which several mediaeval burials were found. Bones belonging to adults and adolescents were recovered. How the bones and associated inventory (a single bronze buckle) had originally been positioned is uncertain.

The burial ritual, which involved interring several individuals under one kurgan mound, is characteristic of the Early Bronze Age population in the Irtysh area. Thus, the remains appear to be related to this period. Radiocarbon dating from bones of these individual revealed the burial to have taken place between 685 and 963 CE (cal. 2 Sigma). The largest value on the radiocarbon dating calibration curve coincides with the middle of the 8th and the beginning of the 9th century CE, linking the burial to the Turkic period.

Supplementary Figure 111 - Outgroup-f3 statistics for sample DA93.

**DA93 – Region: Middle reach of the Irtysh River (right bank)
Radiocarbon 14C date: 1203 +- 50 BP uncal
Population label: Nomad_Med**
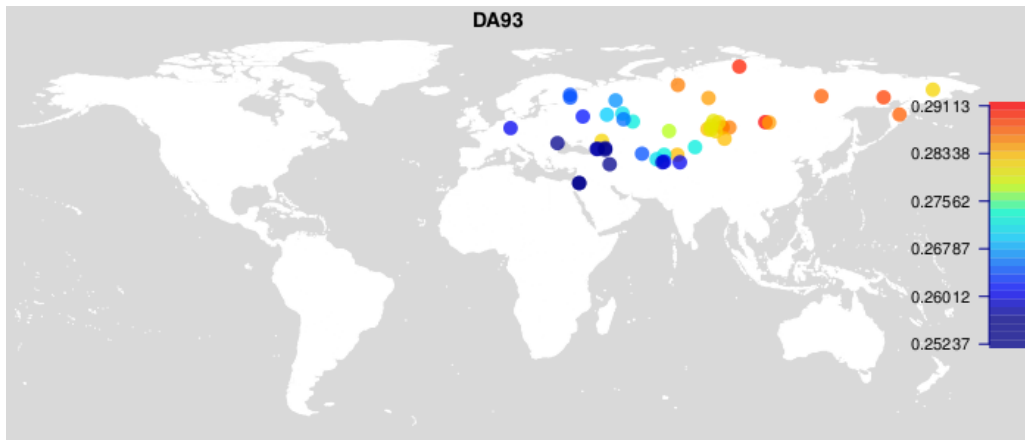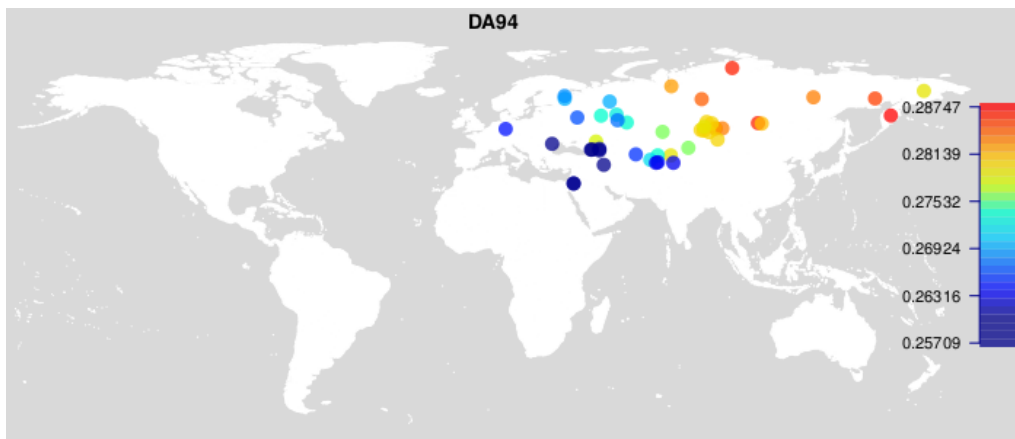

Supplementary Figure 112 - Outgroup-f3 statistics for sample DA94.

**DA94 – Region: Middle reach of the Irtysh River (right bank)
Radiocarbon 14C date: 1203 +- 50 BP uncal
Population label: Nomad_Med**

The Uch-Kurbu monument of the second stage of the Great Migration

By Tabaldiev Kubatbek, Ashyk Alpaslan

One of the turning points in the fate of the nomadic lifestyle was the era of intensive migration of nomadic groups from the eastern regions of Central Asia, which began in the 3rd century BC. Under the influence of the Huns, significant changes occurred in the lifestyle of the nomadic agricultural population of Eurasia. Signs of Hun culture are evident in archaeological materials from Southern Siberia, Altai, Northern China, and progressively into Eastern Europe. The Huns penetrated into the eastern spurs of the Tien Shan Mountains in 201 BCE. Subsequent ethnic processes associated with the Huns occurred around 2000 years ago in Prityanshan and Fergana of Eastern Turkestan.

In Eastern European history, the era of the Great Migration of Peoples, associated with the Huns, dates back to the 4th century CE (from 370-378 years CE). Archaeological materials typical of Central Asian Huns within Kyrgyzstani territory (Tien Shan, Fergana, Semirechye) have not yet been identified. In addition, burials similar to those of Eastern European Huns are not yet known from that area. However, isolated archaeological data exists that can be associated with Central Asian and Eastern European Huns. Therefore, when studying archaeological monuments of the Hunnu (Sünnu, Hun) era, two periods have been identified within the territory of present-day Kyrgyzstan[185]: first, after strengthening of the Central Asian Huns from the 3rd century BCE to before the turn of the first century CE; and, second, with the advance of the "Northern Huns" from Zhungaria and the Eastern Tien Shan westwards into Eastern Europe (2nd-5th centuries CE).

In our opinion, the rare Hunnic elements could have been introduced as a result of political events when the Huns (Sünnu) were infiltrated by local tribes of the Tien Shan, Semirechye and Fergana. A written source states that "In 98 BCE, after the battle of Usun Kunmo, Unguimi captured 40,000 Hunnic warriors" [Tabaldiev, 2008, p. 90]. It is likely that this event left some kind of archaeological evidence. Captured by the Usuns, the Central Asian Hun warriors and Hun groups infiltrated by the Usuns might well have borne their own cultural elements into the Tien Shan and Semirechye. Thus, eastern Hunnu elements should be reflected in funerary monuments and associated inventories. However, as yet, there is no such evidence.

Archaeological materials from the 2nd-5th centuries CE found within the territory of Kyrgyzstan allow us to express our opinion on a rather motley ethno-cultural situation[172]. The results of the Uch-Kurbu excavations have since confirmed this opinion. Below, we outline some of the results of archaeological research on the Uch-Kurbu monument. The study was carried out by the Department of History of the Kyrgyz-Turkish Manas University[186]. The kurgans of Uch-Kurbu burial ground are located in the southern part of Issyk-Kul Lake, in the foothills of the Teskey Ala-Too mountain massif. Traditionally, many nomadic burial grounds are located above river floodplain terraces and Uch-Kurbu is no exception. The kurgans of Uch-Kurbu are located on the second terrace of the Tosor River. It was the exterior structures of the mounds that attracted initial attention.
One of the most characteristic external features of these kurgans are that they are made of stones and boulders, are usually square or rectangular in shape and are surrounded by massive boulders. Massive, oblong stones have been installed vertically at the corners of the mounds. Groupings of kurgans indicate cohesion, perhaps indicating family ties, such as members of different generations of the same family or clan. We have termed these kurgans "barrows with corner stones".

Initially, it was difficult to establish an approximate date for the monument based on ceramics discovered at the site. Hand-crafted vessels with vertical edges were rare in these nomadic barrows.

However, there were other characteristics of the first half of the 1st millennium CE. Complex bows possessing massive terminal and medial bone linings were found with two buried soldiers. A three-lobed iron arrowhead was recovered during excavations and wooden tables were found at two burial sites. In one of the burial mounds, which had been disturbed by robbers, a skull was found with a circular deformation. One of the characteristic signs of Tian Shan burials from the first half of the 1st millennium CE is the presence of half of the pelvic bone of a ram near the mounds[185]. These elements are characteristic of kenkol-type monuments of the 1st-5th centuries CE[187] from the Talas, Chui and Ketmentyubinsky valleys of Kyrgyzstan. The tribes who created the Uch-Kurba barrows apparently did not live in isolation from these regions, as evidenced by some similarities in elements of the funerary inventory.

However, the Uch-Kurbu barrows are different in terms of their structure. In other valleys, "barrows with corner stones" are very rare. The burial mounds of this period in other valleys have an ordinary earthen embankment, under which lies a long dromos leading to the catacomb. Uch-Kurbu entrances (dromos) into the funerary chambers are well-shaped and the burial chambers are not large, sometimes more resembling a grave. Pots are missing from the funerary chambers of Uch-Kurbu, which is very uncommon in other monuments of the era of the Great Migrations. Instead, bowls with straight vertical or slightly marked sides have been found in Uch-Kurbu chambers.

Another distinguishing feature of the barrows of the Uch-Kurbu burial ground is reflected in their organized clustering. Burial grounds of the era of the Great Migration often exhibit a chaotic scattering of ordinary mounds around larger ones. After studying these "barrows with corner stones", new opportunities opened up for purposeful research into the cultures that left them. We discovered similar burial mounds in the northern and southern foothills of Issyk-Kul at the following locations: Alabash, Tosor, Darkhan, Ornok, Cholpon-Ata. They are much less common beyond the Issyk-Kul basin. This tradition did not completely disappear during the early Middle Ages. Medieval barrows of a similar construction were investigated by L.P. Zyablin in the northern foothills of Issyk-Kul[188]. At that time, these Huns lived in close proximity to Kenkoltsy, Yuezh, Kangyuan and Usun groups and, in the early Middle Ages, were assimilated among Turks, as evidenced by the burial of a man and horse in one of the Koy-Suu burial mounds. Burial with a horse is a characteristic feature of barrows of the early Middle Ages (6th-9th centuries CE). These findings indicate that the process of tribes mutually influencing the building of "barrows with corner stones" began in the era of the Great Migration and continued thereafter. A group of related graves in Priissykkulye is presenting new opportunities for further research into this little-known period of Central Asian archeology.

 They could be one of the ethnic groups that came from the eastern regions of Central Asia or their culture was formed in this territory in the era of the Great Migration of Nations. At this time, they co-existed in close proximity to kenkoltsami, Usuns, Yuezhs, Kangyuans.
Archaeological materials testify to close cultural ties between the tribes of this epoch, borrowing from each other individual elements of funeral rites. Over time, new elements arose that determined the new common traditions that led to tribes burying their deceased in flaws and ordinary pits. On investigating cranial material from the Hunnu period, the anthropologist S.S. Tour stated that, among the Kenkolts (i.e. burials of the 2nd-5th centuries CE in the Talas Valley), there are no signs of anthropological material from Central Asian Huns. However, Central Asian Mongoloid features that are characteristic of Huns have been found in materials of the Ketmen-Tyube Valley[189].

The anthropological material from Uch-Kurbu is currently being studied by a physical anthropologist. Preliminary findings indicate that, among the skeletal assembly, there are no Central Asian Mongoloids, there are representatives of mixed populations of Caucasoids and Mongoloids, and there

are long-faced Caucasians.

Thanks to the support of our foreign colleagues and the management of the Kyrgyz-Turkish Manas University, we have received a number of radiocarbon dates. Previous radiocarbon analyses were conducted in the USA and Scotland, and more recently in Denmark. The results of these tests practically coincide, indicating that burials at Uch-Kurbu date between 260-330 years CE (i.e. 1750-1890 ± 40 BP). We hope that the results of genetic analysis will strengthen our interest in studying the monuments of different epochs in Tien Shan, Fergana and Semirechie.
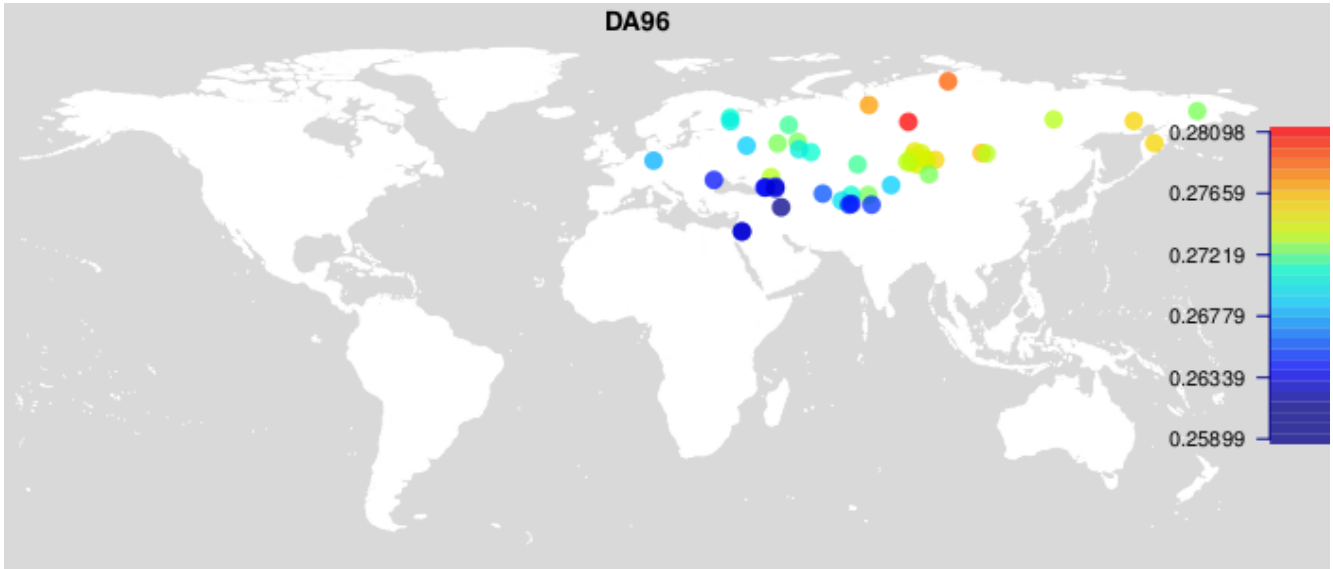
Supplementary Figure 113 - Outgroup-f3 statistics for sample DA96.

DA96 - Region: Tian Shan
Radiocarbon 14C date: 1709 +- 34 BP uncal
Population label: TianShanHun
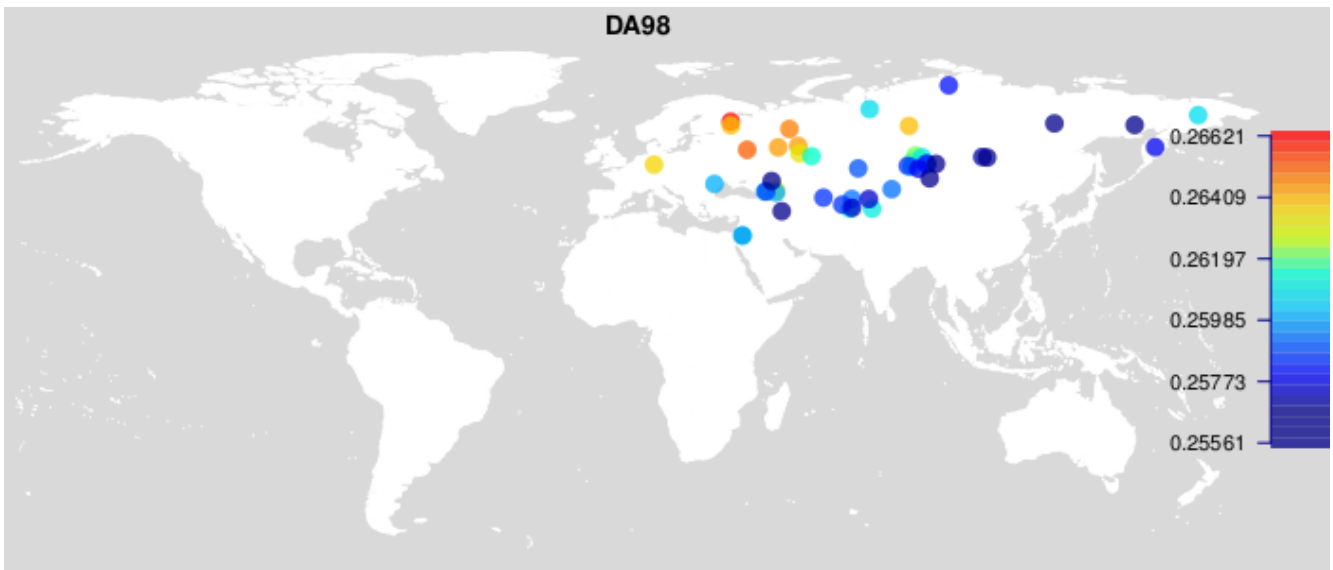
Supplementary Figure 114 - Outgroup-f3 statistics for sample DA98.

DA98 - Region: Tian Shan
Radiocarbon 14C date: 1890 +- 46 BP uncal
Population label: TianShanHun

Supplementary Figure 115 - Outgroup-f3 statistics for sample DA100.

DA100 - Region: Tian Shan
Radiocarbon 14C date: 1719 +- 48 BP uncal
Population label: TianShanHun

Supplementary Figure 116 - Outgroup-f3 statistics for sample DA101.

DA101 - Region: Tian Shan
Radiocarbon 14C date: 1783 +- 29 BP uncal
Population label: TianShanHun

Supplementary Figure 117 - Outgroup-f3 statistics for sample DA104.

DA104 - Region: Tian Shan
Radiocarbon 14C date: 1833 +- 32 BP uncal
Population label: TianShanHun
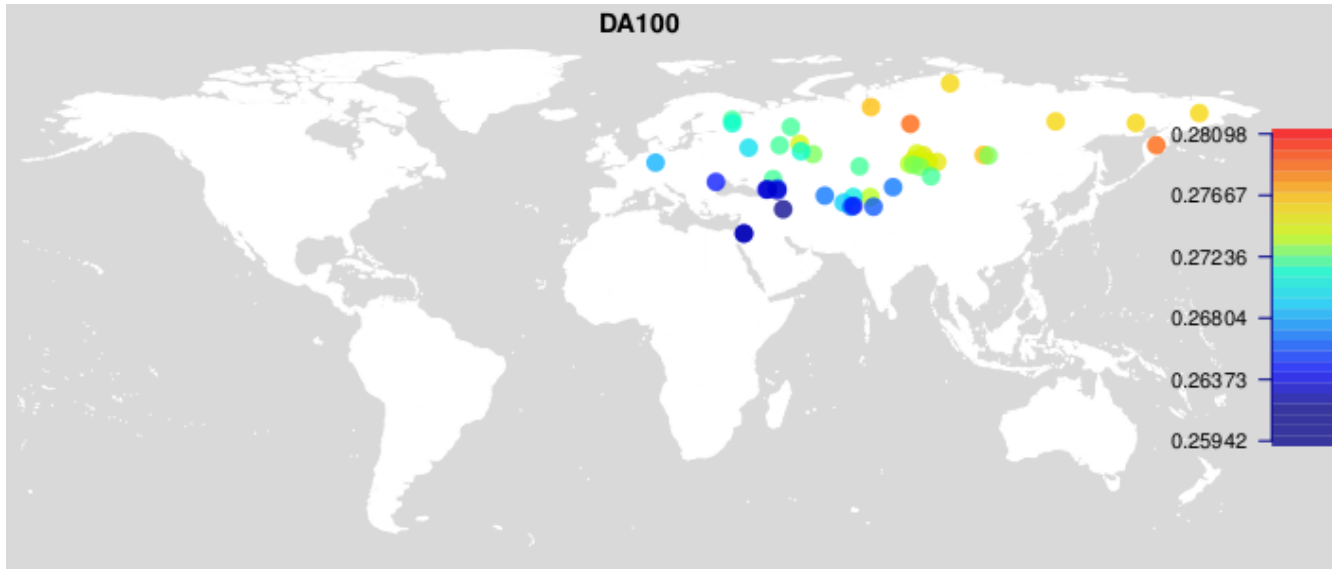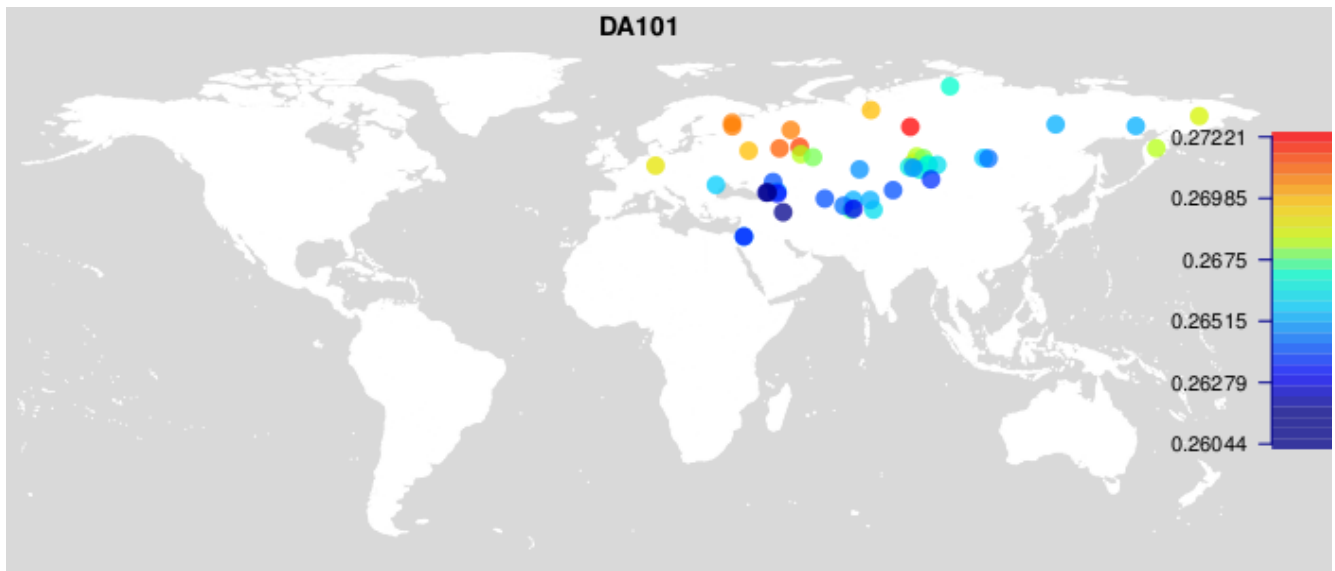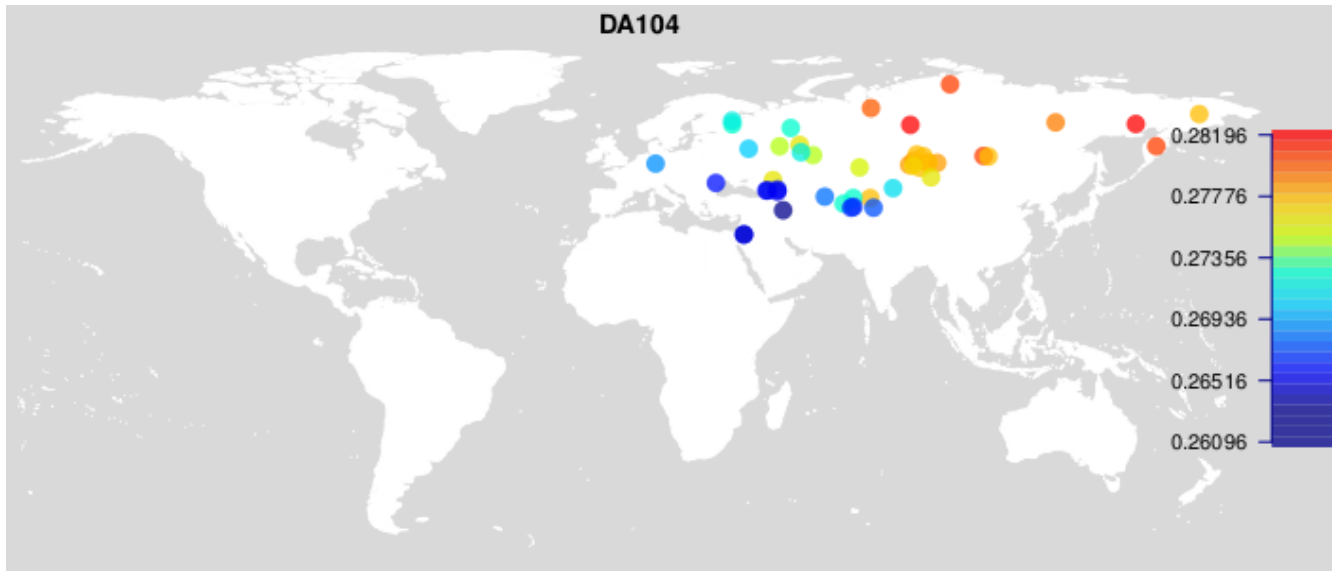
Burials from the medieval burial grounds of Boz-Adyr and Kyzyl-Too

By Tabaldiev K., Akmatov K., Orozbekova Zh.

The burial grounds of Boz-Adyr and Kyzyl-Too are located on the southern side of Lake Issyk-Kul, in a valley at the foothills of the Teskey Ala-Too mountain range. This narrow valley, 7 km in length and 1 km wide at its widest point, surrounded by mountains, served as a safe haven for ancient and medieval tribes. Its particular climatic conditions - low snowfall in winter, year-round water availability, and the absence of strong winds - allow the development of cattle-breeding and farming. We have found all types of archaeological monuments in the valley, including burials, settlements, ritual objects, and rock paintings. We found 10 different burial grounds in the Tuura-Suu valley.

A compact group of medieval burials is located in the burial grounds of Boz-Adyr and Kyzyl-Too. There are about 20 burial mounds in the Boz-Adyr burial ground, located in the northern part of the valley, stretched along the length of the southern slope of a mountain in an east to west line[190]. The mounds are a mixture of stone and earth, with oval or round embankments. Oval mounds measure up to 4.5 m by 3 m, while rounded mounds have diameters of up to 5.5 m. All mounds were flattened. According to our experience, rounded barrows were built mainly in the early Middle Ages, i.e. during the era of the Turkic Khaganates. Oval mounds are most typical of the 11th-15th centuries CE. Inner-grave constructions in the mounds of the Tien Shan have also been dated to the 11th-15th centuries CE. Under the mounds, at the level of the ancient day surface, the contours of the entrance pits are visible, which usually have a stone-earth filling. The long sides of the burial pits are oriented along north-south or northeast-southwest lines. Pits are up to 2.5 m long and up to 1 m wide. The western parts of the entrances to graves have been cleared to a depth of 1-2 m. Entrances were usually covered with wooden poles or stone slabs. The deceased were laid in the graves in the extended position, with the head pointing to the north or north-west. Rarely, the bodies were placed in the grave on a wooden stretcher. Typically, a tibia and shoulder of a ram (sheep) had been placed by the head; a long tradition of providing "food for the deceased"[191]. Personal belongings were also placed next to the body. Headdresses of birch bark, as well as earrings, combs, wooden utensils, etc., have been found in the graves of women. Arrowheads, bone linings, and knives have been inventoried in the graves of men. Saddles, bridles and stirrups have seldom been described in burials of the 11th-15th centuries CE[192].

The above-mentioned funerary monuments and funeral implements from burials represent invaluable materials for studying the formation of the cultures of Kyrgyz, Turkic and Mongol peoples of Central Asia. Their cultures at that time had significant similarities. Many features of the material culture of nomadic and semi-nomadic tribes of the 11th-15th centuries CE were formed on the basis of the prior cultures of the early Middle Ages (6th-9th centuries CE). Early medieval burial mounds at Boz-Adyr form an insignificant part of the total burials. Only three such burial mounds have been excavated. The burial rite differs from that of burials of the 11th-15th centuries CE described above. The deceased were buried in grave pits, accompanied by a horse. Whereas the head of the deceased pointed to the east, that of the horse faced the opposite direction, i.e. to the west. Below, we provide a description of some of the excavated mounds.

Boz-Adyr, Kurgan No.16
This mound is located on a gentle slope of a small loess hill (Geographical coordinates: N 42 ° 04'34.2", E076 ° 57'56.5"; height above sea level - 2046 m). Before excavation, this stone-earth,

circular burial mound had a diameter of 5 m. After removing the sod layer, a pile of irregularly shaped stones 1.6-1.8 m in length, with the long sides oriented in a line ESE to WNW, was detected in the central part of the embankment. A mixture of rock and earth filled the pit.

At a depth of 1.4 m from the ancient day surface in the north-eastern part of the grave pit, among the stones, a human skull was found in an inverted form, i.e. parietal bone down, as well as one cervical vertebra and, separately, a lower jaw. Under the skull, at a depth of 1.5-1.6 m from the ancient day surface, a decapitated adult man accompanied by a horse was found. The skull of the deceased had been resting on his breastbone. The deceased lay stretched out on his back, oriented in an ESE to WNW direction. The right arm was slightly bent at the elbow, and the left arm was laid alongside the trunk with the hand touching the left femur. A birch bark quiver with a pocket and widening gradually towards the base was located above the right lower limb and lumbar vertebrae. The quiver has two layers of birch bark and the bottom is wooden. Its overall length is 92 cm; the length of the receiver is 74 cm, the length of the lid is 18 cm, the width of the receiver at the base is 16 cm, the width of the lid is 8 cm, the maximum lid width is 21 cm, and the lid width at the base is 12 cm. Three lines are marked along the edges and in the center, the distances between which varies from 3.5 cm to 8 cm. Inside the lower part of the quiver, fragments of three highly corroded trilobate iron arrowheads were found, as well as a fragment of a bone whistle. It seems that the arrows had been placed tip-first into the quiver, which is not typical for this type of quiver. Round-shaped iron plaques and what may be a buckle were found under the lid of the quiver. These same plaques had been fixed on the right hip. Near the quiver and above the right femur of the deceased, an elongated rectangular bone lining for a quiver was found with rounded corners and holes bored through the ends. A pair of central and lateral bone linings for a bow was found in the quiver, between the femur bones of the human skeleton. A severely corroded iron knife with the image of a tree scratched in the handle was found above the right ribs. A bronze buckle was located at the right ulna. At the right collarbone, a highly corroded ring-shaped iron object, probably a buckle, was found.

To the left of the deceased, on the same horizon, a horse had been laid on its stomach, slightly turned to the right and backed by two boulders. The legs were bent and the head was pointing to the west, but a slight curve of the neck meant its face was turned to the north. The following items were found with the horse: a severely corroded iron bit in the mouth; a fragmented and severely corroded iron stirrup above the bones of the front leg; the tibia of a ram; wooden parts from the saddle on the back of the horse, including . Between the deceased and the skeleton of the horse lay fragments of wooden poles that are probably the remains of a structure that served as a partition. Three large boulders had been placed in a N-S row on the eastern edge of the grave.

Boz-Adyr, Kurgan No.28
Before excavation, the mound was a rocky earthen embankment with an irregular rectangular shape, with the long N-S-oriented sides measuring 4 m (width 1.5 m). A pile of stones formed a semicircle on the eastern base of the embankment. After removal of the sod layer down to the ancient day horizon, an elongated oval-shaped stone construction was found, measuring 1.6 m along the long N-S axis. The contours of the grave pit could not be identified at this point, so a sub-rectangular excavation was made among a pile of stones. In the process of working from a depth of 0.8 m below the modern surface to a depth of 1.5 m, hand phalanges and a human elbow bone were found in different parts of the pit, as well as fragments of an iron stapes with a flat straight footrest, ornamented bony linings for a quiver, a heart-shaped piece of iron wrapped in a cloth holding a miniature bronze plaque, fragments of corroded flat iron arrowheads, and a fragment of the tibia and shoulder blade of a sheep with traces of iron oxidation.

The skeleton of an adult woman was revealed at a depth of 1.6 m from the modern surface, laid out on her back with her head oriented to the north. The right leg was slightly bent at the knee and touched the lower epiphysis of the left femur. The elbows are absent. The head of the deceased had been laid on an arched pillow (perhaps made of felt), to the right side of which had been fixed hemispherical iron plaques and other iron objects. Another piece of iron was found just to the north-east of the skull. In addition, severely corrugated iron stirrups with a flat curved footboard were found directly under the pillow. Above the right hip bone of the buried individual lay a leather-cloth bag with a bronze plaque. In the space between the left ribs, ulna and pelvic bones, fragments of the bony lining of a quiver were found.

Boz-Adyr, Kurgan No.31
This mound consisted of a bunch of irregularly shaped stones, 1 m in diameter. After disassembling the external structure, no traces of a grave pit were found. The center of the mound was excavated, which revealed large boulders that served as a catacomb. Within the catacomb lay the skeleton of a child, stretched on their back, with the head pointing to the north and the face turned to the west. The body had been wrapped in a shroud, which was preserved in parts around the skeleton. There were no other finds. Kurgan 31 turned out to be late Kyrgyz, Muslim.

Apparently, the Boz-Adyr cemetery is different from others. There, the dead were buried as in the early or late Middle Ages, and later their descendants were buried as in the middle of the 19th century AD. The distance between the Boz-Adyr and Kyzyl-Too cemeteries is small, only about 1 km. Because of the turf overlay, it is impossible to count the number of mounds at Kyzyl-Too. Kurgan No.2 at Kyzyl-Too is round. After removing the stone outline to a depth of 80-120 cm, fragments of human and horse bones were found. These bones were established as belonging to an early medieval burial. Burying horses with the deceased is a characteristic of the Turkic-speaking tribes of the 6th-9th centuries AD. Later, in the 12th-13th centuries AD, another burial was made. Then, curiously, the bones of the skeleton from early medieval times were placed in a heap and a later burial was performed next to it without the accompaniment of a horse. After approximately 400 years, another burial occurred in the same mound, despite the abundance of plots nearby. This peculiar funerary rite was also twice encountered at Boz-Adyr cemetery. Genetic analysis could establish if there was any link between the buried individuals.
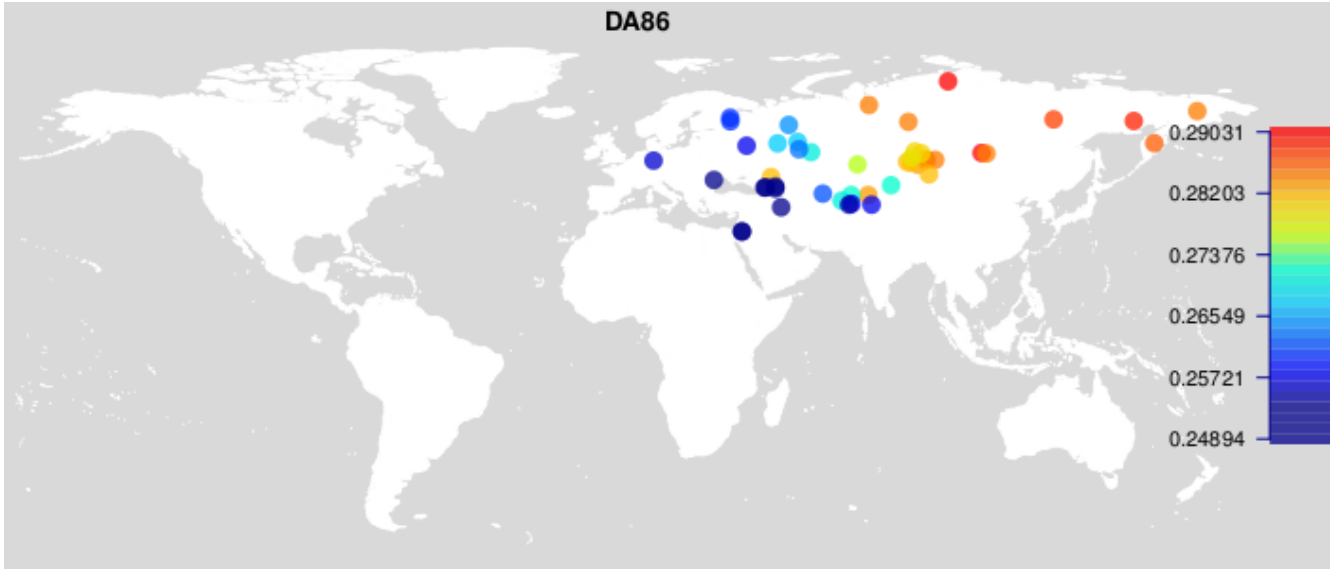
Supplementary Figure 118 - Outgroup-f3 statistics for sample DA86.

DA86 - Region: Tian Shan
Radiocarbon 14C date: 1582 +- 42 BP uncal
Population label: Turk
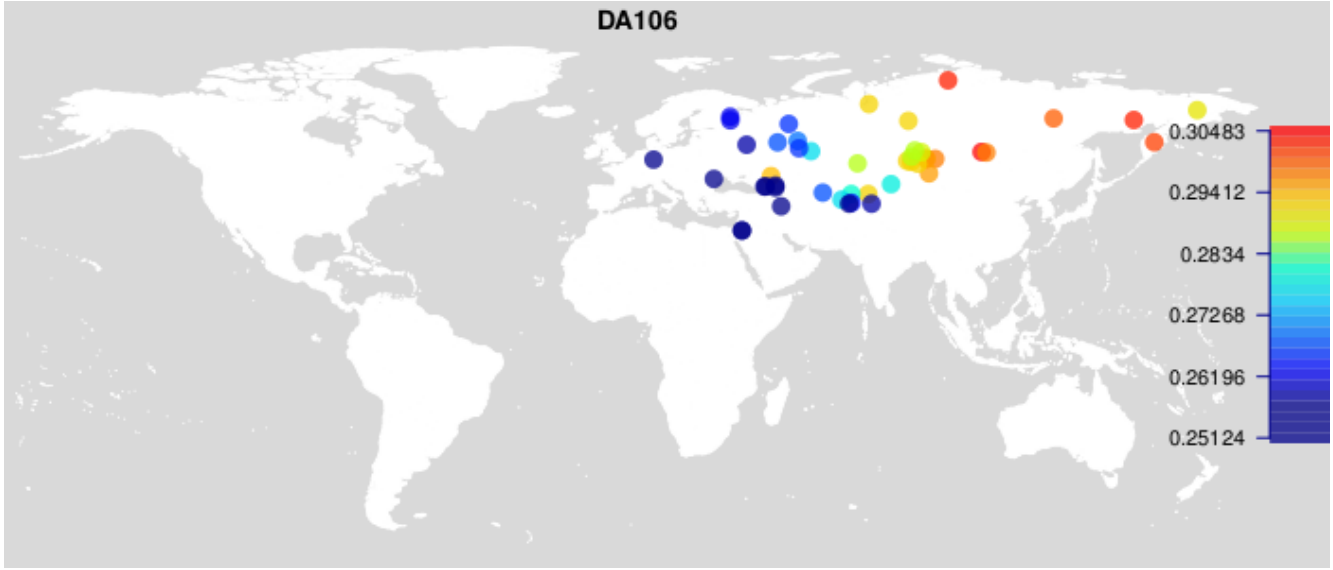
Supplementary Figure 119 - Outgroup-f3 statistics for sample DA106.

DA106 - Region: Tian Shan
Radiocarbon 14C date: 833 +- 34 BP uncal
Population label: Nomad_Med

Supplementary Figure 120 - Outgroup-f3 statistics for sample DA116.

DA116 - Region: Tian Shan
Radiocarbon 14C date: 856 +- 36 BP uncal
Population label: Nomad_Med

Supplementary Figure 121 - Outgroup-f3 statistics for sample DA117.

DA117 - Region: Tian Shan
Radiocarbon 14C date: 143 +- 27 BP uncal
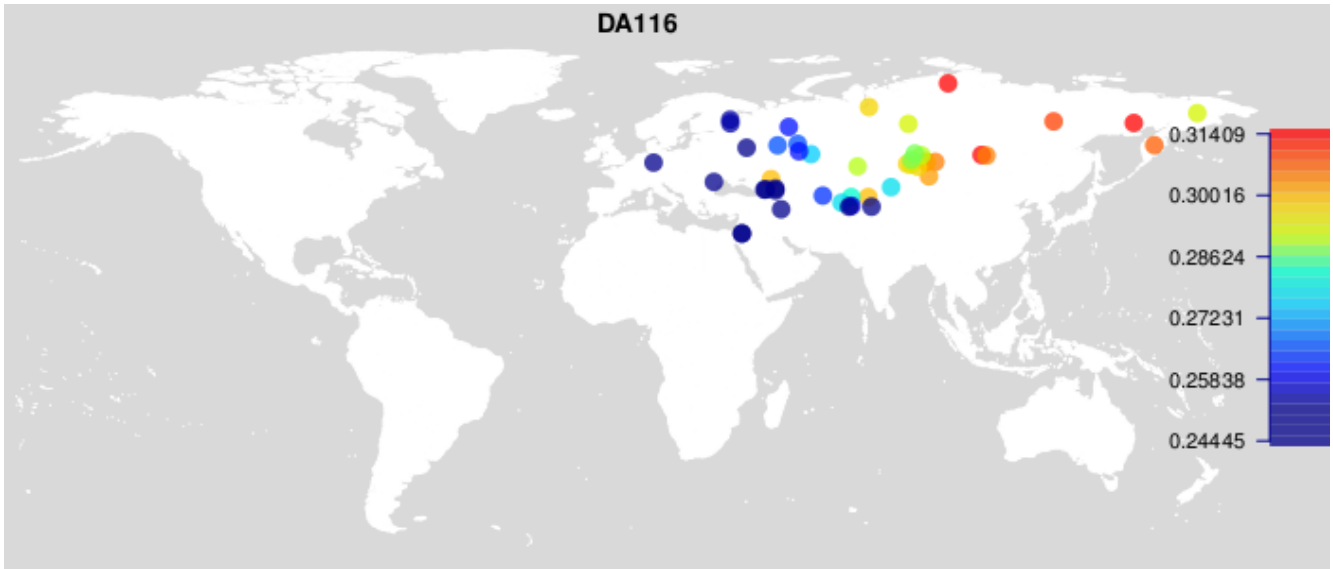**Population label: Nomad_His**

Supplementary Figure 122 - Outgroup-f3 statistics for sample DA118.

DA118 - Region: Tian Shan
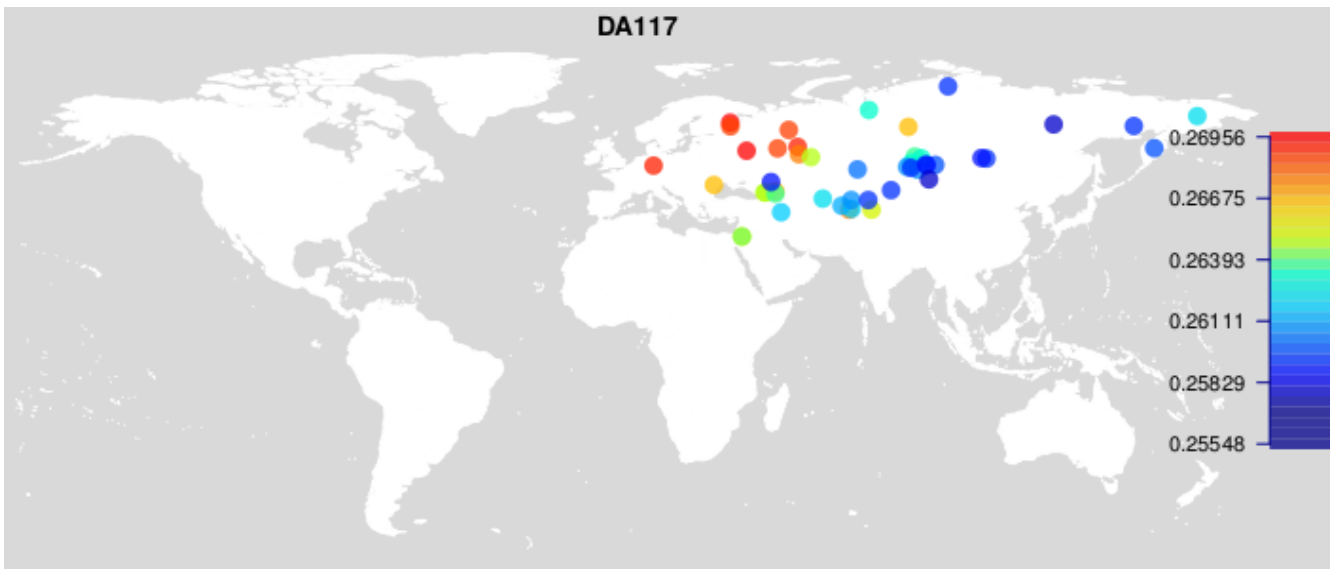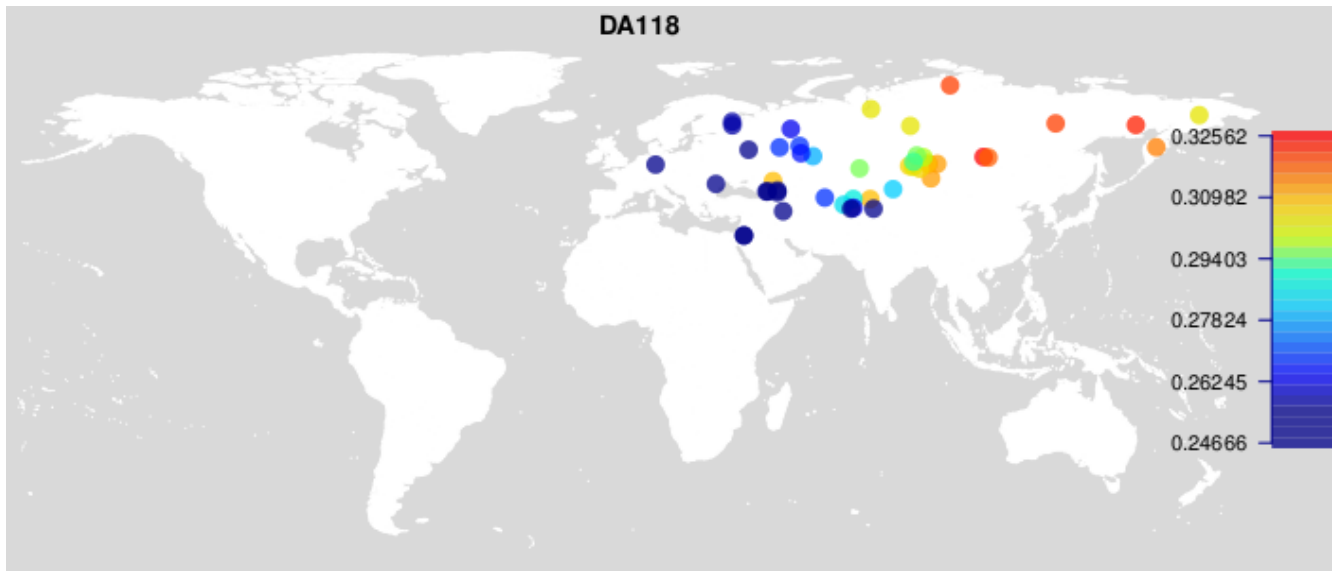**Radiocarbon 14C date: 950 +- 27 BP uncal**
Population label: Nomad_Med

# From Andronovo to historical Kazakh samples

By Dmitry Voyakin and Egor Kitov

Besinchitobe
Besinshitobe is located 0.5 km to the north of the settlement of Pshakshitobe. It is a comparatively low but extensive hillock about 100 m in length and 70 m wide, with a SW orientation. It is more than 5 m high. The flattened upper hill area is shifted to the NE. No excavation work had previously been carried at the site so, on the steepest northwestern slope of the hillock, we laid a large stratigraphic trench (30 m long, 2 m wide) to study the stratigraphy of the monument. The trench revealed that the monument lay in a single layer, at the base of which were the ruins of a very large monumental structure, in which burials had been made. Apparently, over a long period of time, the site had gradually disintegrated and, by the time of the early Middle Ages, it had already acquired its contemporary form of a flattened broad hillock. Over time, the local population had used it as a cemetery.

Burials were mainly carried out in loose overflows of the upper horizon, at depths of 0.5-1.3 m from the modern day surface. Six burials were found in total, including five along the trench. When the trench was opened, it was not possible to determine the shapes of the burial pits. Burial numbers 2, 3, 4 and 6 belonged to adults. With skeletons No. 2 and No. 3 A small number of funeral implements accompanying the deceased were found with skeletons No. 2 and No. 3. A pitcher was found in two burials, both completely exfoliated. The pitcher found in burial No. 2 was located to the left of the skull. A pitcher with a handle, found in burial No. 3, was installed on the right side of the head (Figure 1:4). Both vessels are close to globular in shape, with a straight, shallow throat and a triangular cross-section (diameter 10-11 cm). The fragments show that they were red clay pitchers, the outer surface of which are covered with a dark red engobe and carefully clamped. In addition, an iron knife with a petiole and a round iron buckle with a short tongue were found in burial No. 3, both of which are typical of the Turkic era, which is also confirmed by the non-Muslim burial ritual.

There were no funerary items in either of the child graves. Burial No. 6 was opened from behind the head of the skeleton in the end wall at the beginning of the trench near the top of the hill at a depth of just over 1.0 m. For all burials (except for No. 4), all deceased had been laid on their backs with their heads pointing to the north-west (i.e. parallel to the long axis of the trench). In the two child burials, their arms were bent at the elbow and the hands were laid on the stomach. One child had the right leg slightly bent at the knees. The skulls of the buried children rested on the right temporal bone and were facing the south. Skulls were not found with burials No. 2 and No. 4.
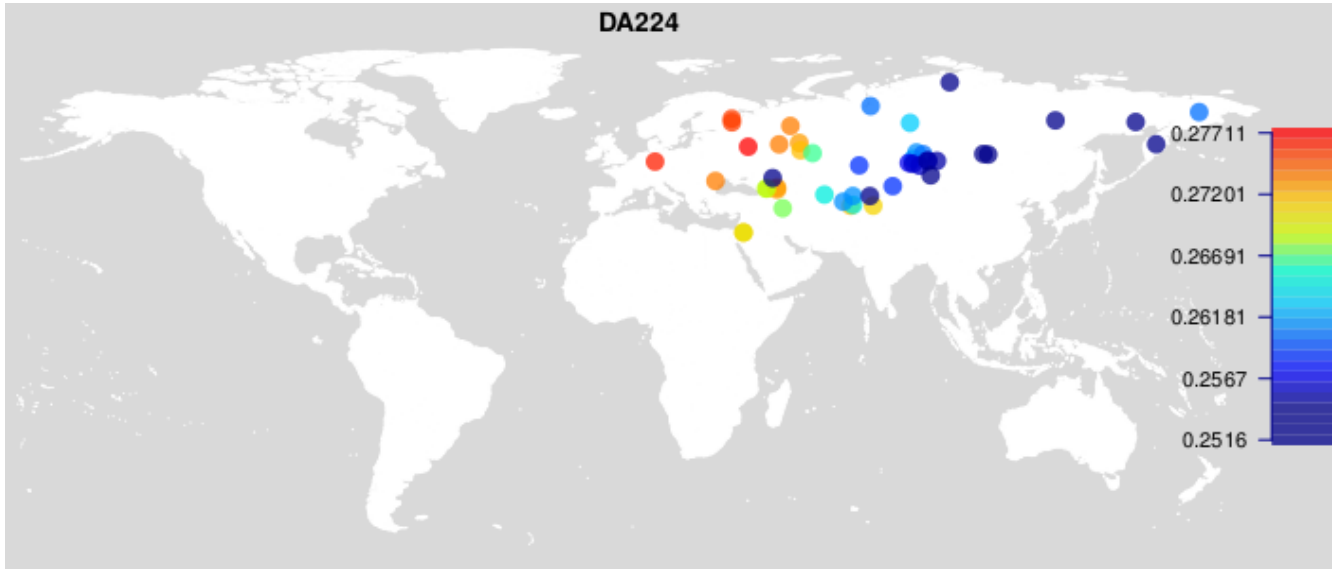
Supplementary Figure 123 - Outgroup-f3 statistics for sample DA224.

DA224 - Region: South Kazakhstan
Radiocarbon 14C date: 1685 +- 39 BP uncal
Population label: OutTurk
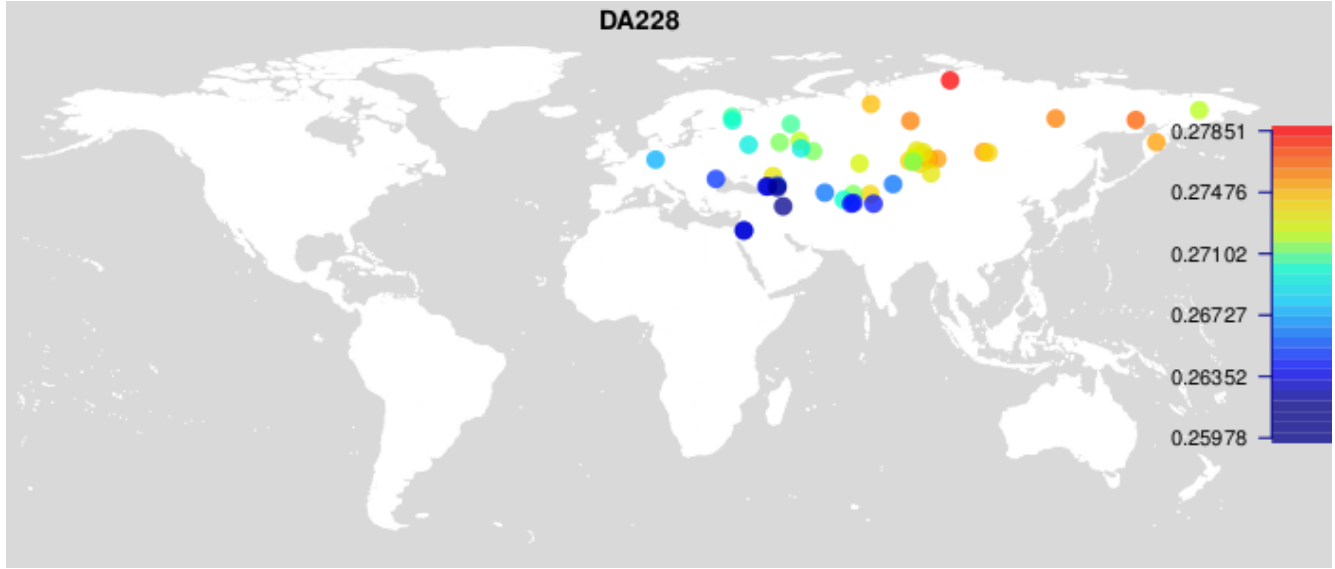
Supplementary Figure 124 - Outgroup-f3 statistics for sample DA228.

DA228 - Region: South Kazakhstan
Period: Turk
Population label: Turk

Report on field studies of the Botatikan Organization on the topic "Exploration of the Bronze Age Butak-I earthquake settlement in the field season of 2010".

By A. Kh. Margulan
(MES RK IA program: "Cultural heritage: monuments of archeology in the territory of the city of Almaty". Headed by the Director of the Institute of Archaeology of the Ministry of Education and Science of the Republic of Kazakhstan, K. Baypakov. Performers: NA IA MON Goryachev AA SNA IA IA RK Motov Yu.A. Almaty, 2009.)

The Butak-I archaeological complex is located on the south-eastern outskirts of Almaty, 500 m southeast of the 9 km Medeo track. The monument is located on a flat terrace (1.5-2 km long and up to 1 km wide) of the right bank of the Zharbulak (Kazachka) River, resting on the spurs of the northern slope of the Zailiysky Alatau Ridge. Only the western part survives in the form of a flattened hill dominating the nearby terrain, truncated by a steep and deep ravine. Remains of funerary structures and fragments of settlement ceramics have been recorded on the site, which measures 200 m long and up to 50 m wide.

The monument was discovered in 1996 and was greatly endangered due to economic and construction activities. As a result, in the seasons of 1997-2008, staff of the Institute of Archeology of the Ministry of Education and Science of the Republic of Kazakhstan made emergency rescue archaeological surveys to date the complex. The surveys revealed one Bronze Age dwelling below an Early Iron Age site and 30 burials from the Early Iron Age and Middle Ages. Excavations in 2010 shifted to the south of the main excavation (covering 15 4 x 4 m squares and covering a total of 240 m^2), where the remains of an Early Iron Age site and a series of early Iron Age and Middle Age burials were recorded.

Butak-I Burial No.32
Burial 32 was located in Square B-7 (Supplementary Figure 125). Holes were found at the level of the ancient surface around the grave, with traces of pillar fencing on the south, south-west and south-east sides. A long narrow drain was marked on the surface by separate large rounded river boulders. The drain was oriented from south-southeast to north-northwest and measured 1.95 m long and 0.65 m wide. A step of 0.32 m had been cut at the base of the west-southwest longitudinal wall.

The funerary chamber was oval, with a length of 2.02 m and a width of up to 0.78 m. The grave had a depth of 1.54 m. The floor of the chamber had a fence of wooden blocks. A tree stump with three trunks (a symbol for trees) was found in an upright position in front of the fence and north of the deceased. The skeleton of a 25-30 year-old female was found laid on her back, with the head pointing north-north-west, but facing south-west. The limbs lay parallel to the body. Two sets of paired earrings and 25 beads of various forms were recorded in the area of the cervical vertebrae.

Butak-I, Burial No.34
Burial No.34 is located in squares Ж-7 and Ж-8 (Supplementary Figure 126). As for Burial No.32, holes were found at the level of the ancient surface, indicative of pillar fencing on the south, south-west and south-east sides. A long narrow drain (1.63 m long, 0.72 m wide) stretched from the southeast to the northwest. A step of 0.43 m had also been cut into the base at the southwestern longitudinal wall.

The burial chamber is oval in shape, 1.85 m long and up to 0.54 m wide. The burial took place at the bottom of the grave, at a depth of 1.32 m. The deceased, a man aged 50-55 years, was laid on his back in the extended position, with his head oriented north-northwest, but facing south-west. The limbs were

aligned parallel to the body. This burial had been disturbed since the bone of the sternum and adjacent vertebrae had been destroyed, as had the right hand and right foot. No funerary material was found.

Butak-I, Burial No.25
Burial No.25 is located in the southwestern part of Square Zh-6. A long narrow drain (2.4 m long, 0.57 m wide) stretched south-southeast to north-northwest. At the west-southwestern wall, a step 16 cm deep had been cut at the base. The funerary chamber is 2.02 m long –and up to 0.79 m wide. The entrance was closed by two long wide scaffolds made from the chopped trunk of a Tien-Shan fir.

At the bottom of the funerary chamber, at a depth of 1.31 m from the , the remains of a young man 18-20 years old were buried in an extended position lying on his back, with his head oriented to the , but slightly turned to the right. His hands had been folded over the pelvic bones. No funerary inventory was found. At the surface of the excavation, traces of a pillar fence was found oriented from the west to south-east, which would have joined a line of pits in the neighboring burial site.

Supplementary Figure 125 - Archaeological complex Butak-I, Burial No.32. Excavation in 2010.
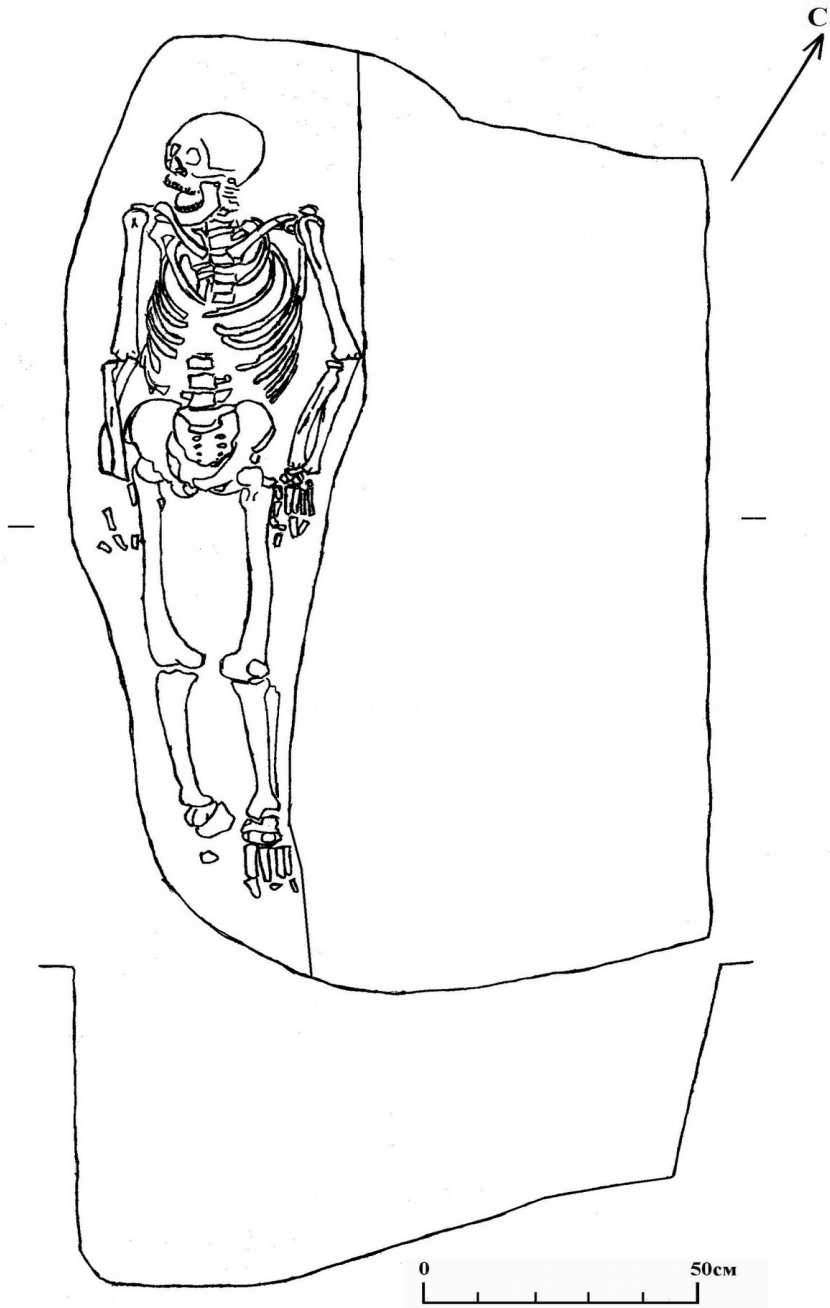
Supplementary Figure 126 - Archaeological complex Butak-I, Burial No.34. Excavation in 2010.
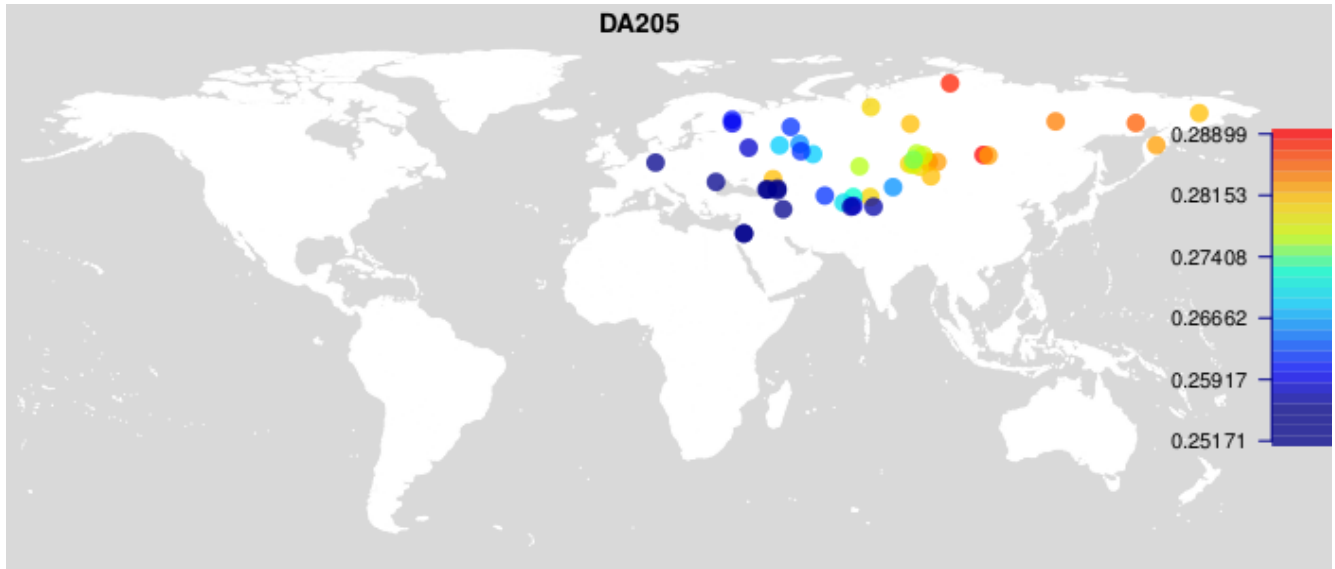
Supplementary Figure 127 - Outgroup-f3 statistics for sample DA205.

DA205 - Region: TianShan
Period: Karakhanid
Population label: Karakhanid
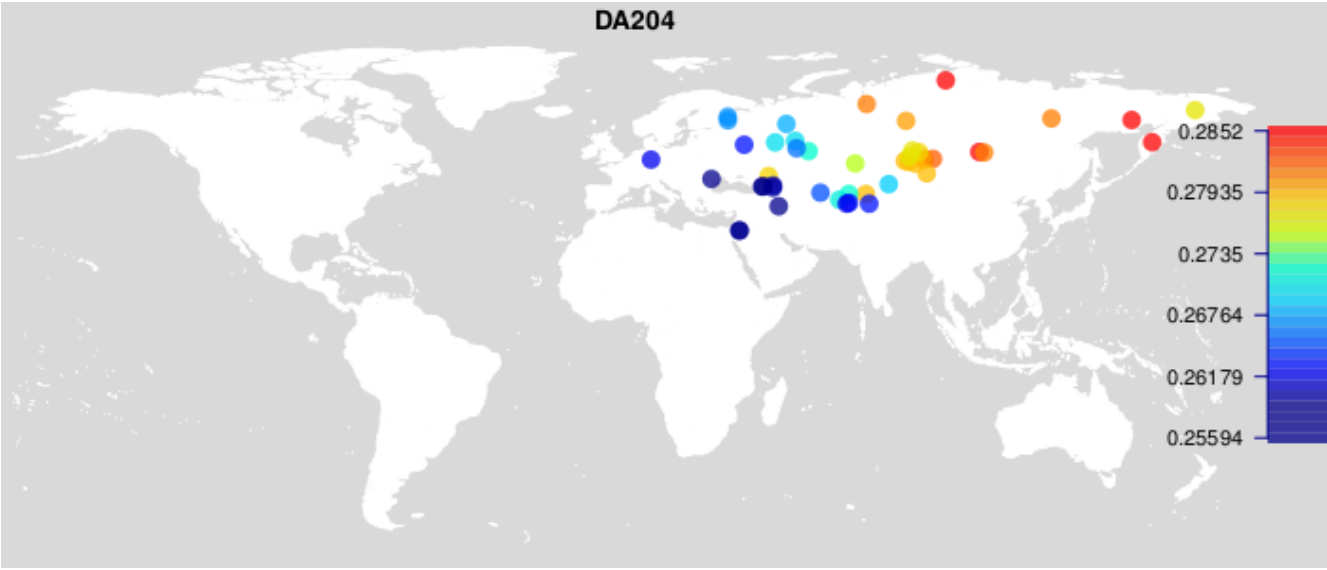
Supplementary Figure 128 - Outgroup-f3 statistics for sample DA204.

DA204 - Region: Tian Shan
Period: Karakhanid
Population label: Karakhanid
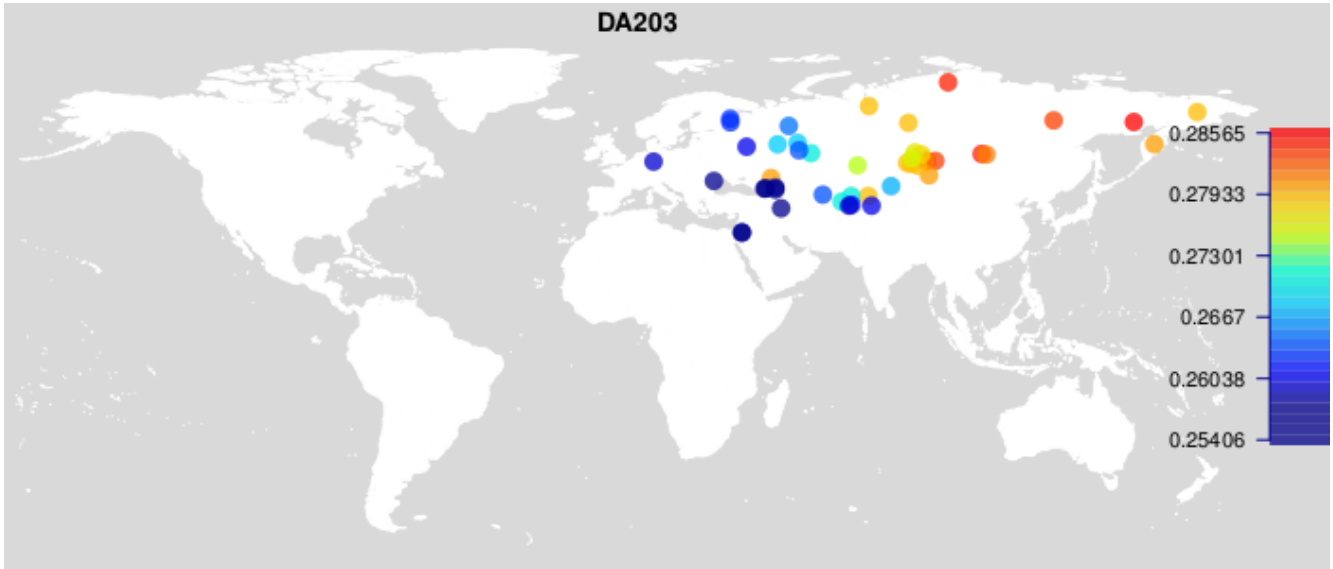
Supplementary Figure 129 - Outgroup-f3 statistics for sample DA203.

DA203 - Region: Tian Shan
Period: Karakhanid
Population label: Karakhanid

Grave 2 of Tengyz Cemetery (Facility 23)

Facility 23. Burial ground

This burial ground is located 800 m to the southeast of Well No. T-123, 700 m north-east of Well No. T-6743, and 200 m east of the Zholy road. The site lies at the top of a sand dune and has been destroyed by wind erosion from the development of a sand pit. The main interest in the site is associated with remnants of scattered Sarmatian burials, as well as pottery from the Early Bronze Age and Neolithic stone artifacts. On discovery of the repository in 2008, the site boundaries were incorrectly defined, so a security fence was only installed around the top of the dune. However, almost all of the discovered burial mounds lay outside of the fence, contributing to destruction of the site, with one of the fence supports even being directly driven into Burial No.1, destroying it. In total, the remains of 11 southern-oriented burials have been found and investigated near to four clusters of ceramics and various artifacts. Burial No.2 is located along the north-south line. At the head of the grave were found two ceramic spindles and three entire vessels of pottery and a jar with a narrow neck and strongly bent element, as well as two iron knives (both single-edged and petiolate). The lengths of the remaining parts of the knives reach 11 cm and the blade section is sub-triangular. A small jar with a rounded bottom is decorated around the upper part with an ornamental girdle of mesh and horizontal lines. Fragments of the upper part of an unadorned pottery vessel were found at the feet of the deceased, near to where a biconic ceramic spindle of diameter 3.8 cm was found. In addition, fragments of a round bronze mirror, apparently broken in half in antiquity, were observed together with single small blue-glass beads and a lead rod from a cosmetic set. The inventory indicates that the burial belonged to a woman. A well-preserved skull was taken for anthropological examination.
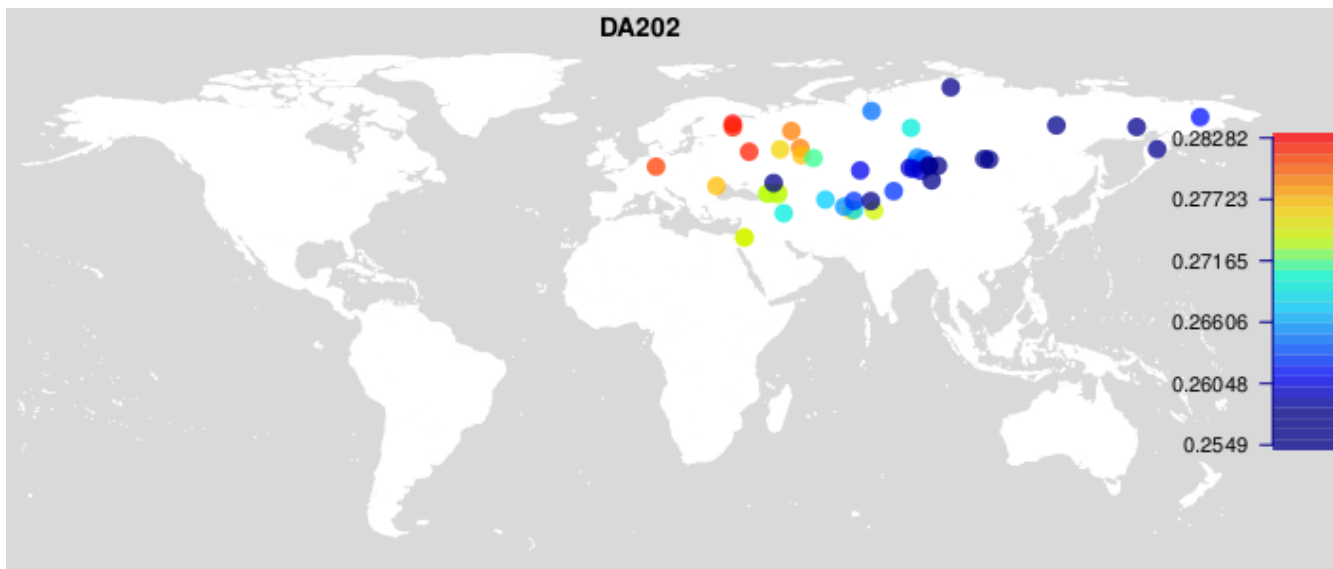
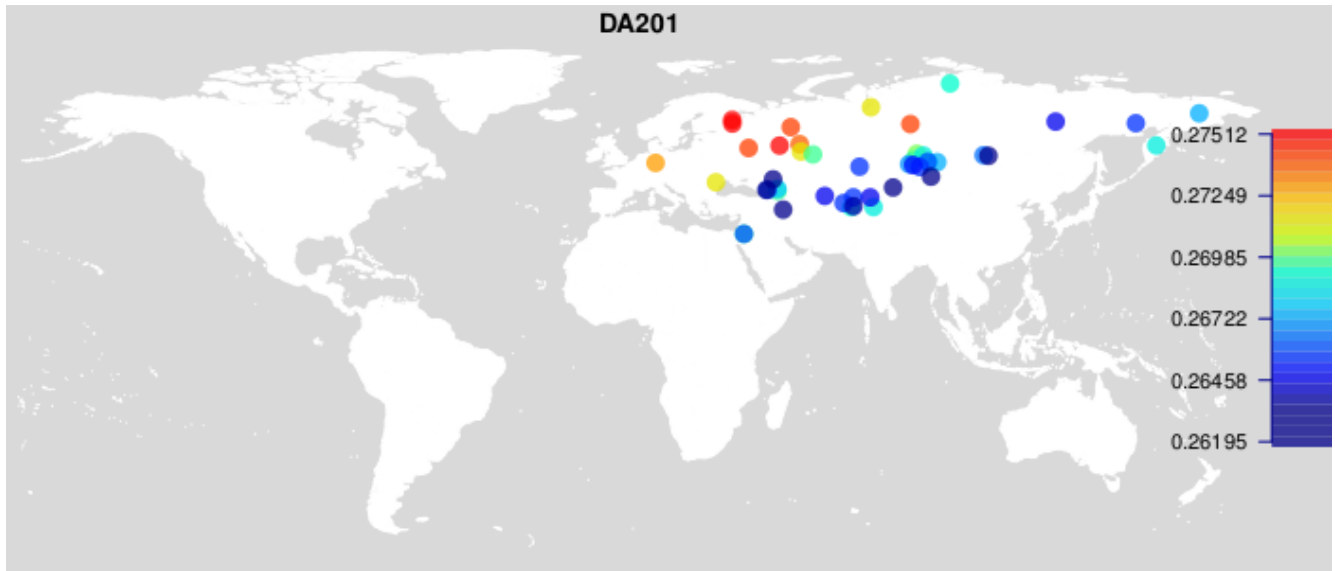**Supplementary Figure 130 - Outgroup-f3 statistics for sample DA202.**

DA202 - Region: Caspian Sea
Period: Sarmatian
Population label: Sarmatian

The Turgen-2 archaeological complex of the Bronze Age and Early Iron Age in the upper reaches of the Turgen Gorge was discovered in 1996 during the Semirechye expedition to study Bronze Age monuments (in the SNA - Maryashev A.II. and MNS - Goryachev A.A.). The complex includes the settlements of Turgen-P, Kyzylbulak-IV and Kyzylbulak-V, as well as the Kyzylbulak-I, Kyzylbulak-P and Kyzylbulak-VI burial grounds.

Systematic research on the Turgen-P site began in the 1998 field season. This site is located on the level ground of an ancient moraine, 500 m northeast of the confluence of Kyzylbulak Creek and Kyzylbulak River and 2km southeast of the Kyzylbulak-I burial ground. Turgen-P is a multi-layered monument consisting of a Bronze Age settlement, and Saka and Usun period burial grounds. The structures of seven Usun burial mounds, three Late Saka dwellings, one Late Andronian dwelling and all ceramics were investigated over the course of field seasons between 1998 and 2008. In addition, extensive ceramics and osteological materials were discovered relating to Saka period layers, dating back to the 1st millennium BCE. The Bronze Age settlement has been dated by the nature and type of ceramics to the turn of the 13th-12th centuries BCE and to the boundary of the 2nd-1st millennium BCE.

Kurgan 10 of the Turgen-2 complex is located in squares A-7 and A-8. The circular mound is made up of earth and stones. Its stone base is 5 m in diameter, over which large stone river boulders have been laid flat in 2-3 layers. The southwestern part of the rock embankment partially extends beyond the excavated area. The inner part of the rock embankment forms a continuous outline of medium and large stones. Around the perimeter of the mound are traces of a stone ring created from large boulders interspersed with small and medium-sized stones. Only the northern sector of the fence has survived, with the remainder having been reduced to small and medium-sized stones. The width of the fence structure is up to 0.5 m and the total diameter is 6-6.5 m. During removal of stones from the central part of the mound, stone beads, the fragment of an iron item, an iron tip, and buckles were found. Iron arrows were also recovered from the southern and northern sides of the mound. In the western part of the masonry, a rounded stone sacrificial altar was found (0.5 m diameter).

Burial 2 of Kurgan 10 is located in the central part of the funerary structure. The burial pit is oval-shaped, measuring 1.4 x 0.7 m and 0.6 m deep and oriented along a north-west to south-east axis. The entrance to burial 2 is cut into the south-west wall and is oval in shape, measuring 2.3 x 0.75 m, with the floor lowered by a 35 cm step. At a depth of 96 cm, at the bottom of the grave, the skeleton of a man aged 18-20 years was found in the extended position, arms alongside the body and the head pointing northwest. A ceramic vessel with a handle was found at the right side of the skull. Near the southeast wall, at the base of the feet of the deceased, lay a small ceramic pot on a pallet.

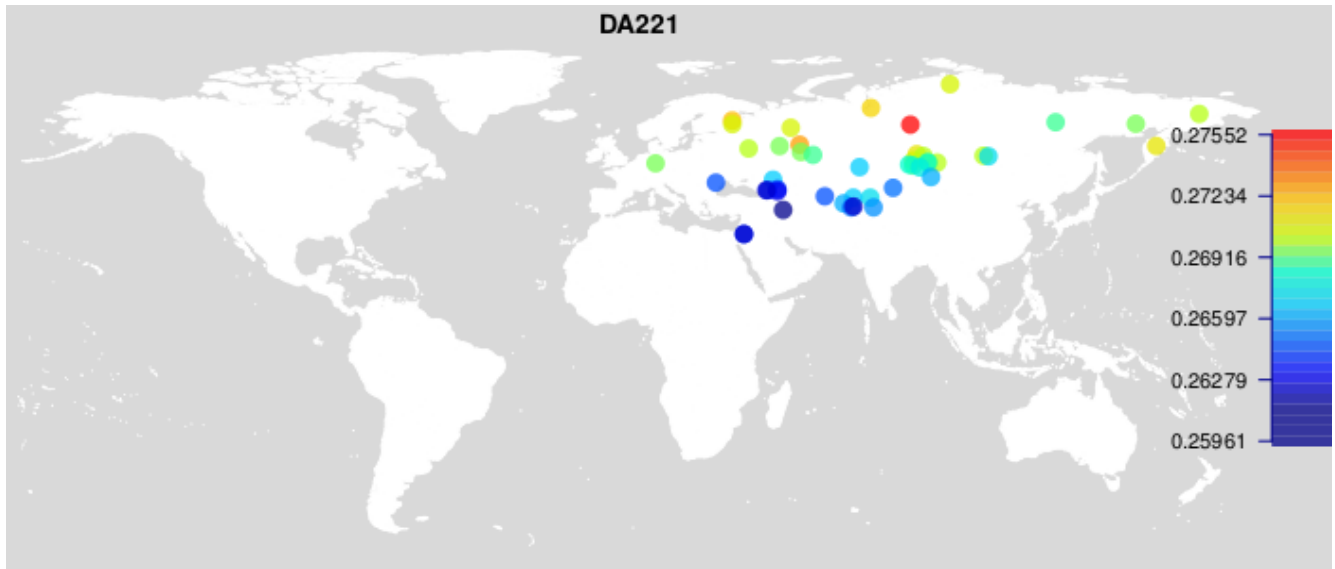**Supplementary Figure 131 - Outgroup-f3 statistics for sample DA201.**

DA201 - Region: Tian Shan
Period: Wusun
Population label: Wusun

The Kargaly-1 burial site, graves 9 and 11

By Motov Yu.A. Goryachev A.A.

Kargaly 1. The Kargaly-1 monument is located 1.1 km to the north of the village of Fabrichnoye in the Zhambyl district of the Almaty region. This archaeological complex of Bronze Age and Early Iron Age monuments was discovered by the local historian V. V. Sarayev. Seven Bronze Age burials and three Early Iron Age burial mounds were investigated in 1989, 1991 and 2005, all of which were critically threatened. The monument is located on the banks of the Uzyn-Kargaly River, 0.35 km east of the current riverbed and 0.3 km north of the Almaty-Uzynagash highway. The monument is part of a number of archaeological complexes (settlements and burial grounds) located on a terrace that were preserved after extensive leveling of the area while laying a motorway north of the village of Fabrichnoy in the 1980s. Ostanets is a hill of 130 x 30 m of contiguous contours, with a gentle natural slope to the river and a steep eastern edge. It has been continuously eroded by the local population through clay extraction. Burials with stone structures or a distinctive exposed emerging layer were revealed at the edge of the mound. Six burial mounds form a north to south line on its surface. These mounds were built of earth with a stone cover, with diameters ranging from 5 to 8 m and heights from 0.2 to 0.6 m. On the western slope of the hill, 150 m beyond the burial ground, a section of a water conduit has been preserved.

Burial 11 was revealed by the stone grave that opened into the north-eastern edge of the hill. The mound has a diameter of 4.5 m and a height of about 25 cm. It is covered with sediments 0.2 m thick. Excavations in 1991 indicated that the northern edge of the burial mound is blocked by the stone shell of the mound. An oval pit (dimensions 1.96 x 0.70 m; depth 1.30 m), oriented along an east-west axis, was uncovered under the center of the mound and had been filled with river boulders.
At the northern longitudinal wall of the pit, the sub-slab was cut (2.2 Kh, 0.97 m) to a depth of 1.54 m. The skeleton of a mature individual was found, buried in the extended position on their back, with the head oriented westward. The arms were positioned alongside the body, with the left arm slightly apart and bent at the elbow. The skull was turned to the left and the legs were slightly apart. The corpse had been laid at the inner wall. A cup-shaped vessel with a vertical handle was found facing the western wall. Between this vessel and the skull lay a bronze knife on the floor of the grave. The knife is 131 cm long, the length of the sharp blade is 70 cm and it is 1.1 cm wide.

Supplementary Figure 132 - Outgroup-f3 statistics for sample DA221.

DA221 - Region: Tian Shan
Radiocarbon 14C date: 2526 +- 40 BP uncal
Population label: Nomad_IA

The Kaynarbulak-2 burial site, mound No.11, skeleton Nos. 1 and 2

(Scientific report on research works carried out on the monuments of historical and cultural heritage located in the zone of construction of the motorway bypass of Shymkent City as part of the "Western Europe - Western China" highway 2011)

This burial ground is located 1 km to the north of the village of Kaynarbulak in the Sayram district of the South Kazakhstan region. The monument includes 13 mounds stretched along a steep east-west arc. The site probably contained more burial mounds in the past, but its use as a military training ground resulted in many mounds being destroyed. Most of the remaining burial mounds show evidence of robberies in the form of funnels at the centers of the mounds. There are also traces of trenches dug for heavy military equipment.

Burial mound No.1 was used during the Soviet era as a cattle graveyard, which destroyed it. Thus, at the time of research, the cemetery was in an extremely critical condition. The diameters of the remaining mounds vary from 11.5 to 27.9 m, and heights range from 0.2 to 1 m. These mounds were built of loess earth. Virtually all the embankments, except for mound No. 2, are oval in shape and the long axes predominantly have a southwesterly orientation. Some variation in the orientations suggests that the oval form is original and not due to later modification by plowing, etc. Excavation of the mounds was carried out with the help of excavation equipment along one ridge oriented along a north-south line, passing where the microrelief of the center of the mound allowed. Removal of the embankment was carried out in strata before any elements of the funeral construction or burial were exposed.

Barrow No.11 is located in the western part of the burial ground. This burial mound is composed of loess, is oval in shape and oriented along a northeast-southwest axis. The mound is 19.5 m long, 16.7 m wide and 1 m high. A grave pit was discovered after the central part of the mound had been removed. The grave is oriented on its longer axis along the S-B4 line and is 2 m long, 1.34 m wide, with a depth from the upper contours of the grave of 0.2 m. The skeletons of two adult individuals were found at the bottom of the grave (Supplementary Figure 133).

Skeleton No.1 (examined by E.P. Kitov) belongs to an adult woman. The deceased had been laid stretched out on her back with the head oriented to the east. The arms were extended alongside the body. The lower part of the body was almost completely absent. Preservation of the bones is very poor and the thorax and skull are completely crushed. Skeleton No.2 (examined by E.P. Kitov) belongs to an adult male. The deceased was also laid stretched out on his back, with his head pointing eastwards. The arms are extended alongside the body and the legs are parallel to the long axis of the body. The bones of the hands were found in a disjointed state. The preservation of the bones is very poor, and the thorax and skull are completely crushed. Fragments of a ceramic vessel were found between the pelvic regions of the buried individuals. It was not possible to reconstruct the form of the vessel due to poor preservation.

Supplementary Figure 133 - Burial in the catacomb of Mound 11 (Skeleton No.1 and Skeleton No.2) from the Kaynarbulak-2 burial ground (view from above).
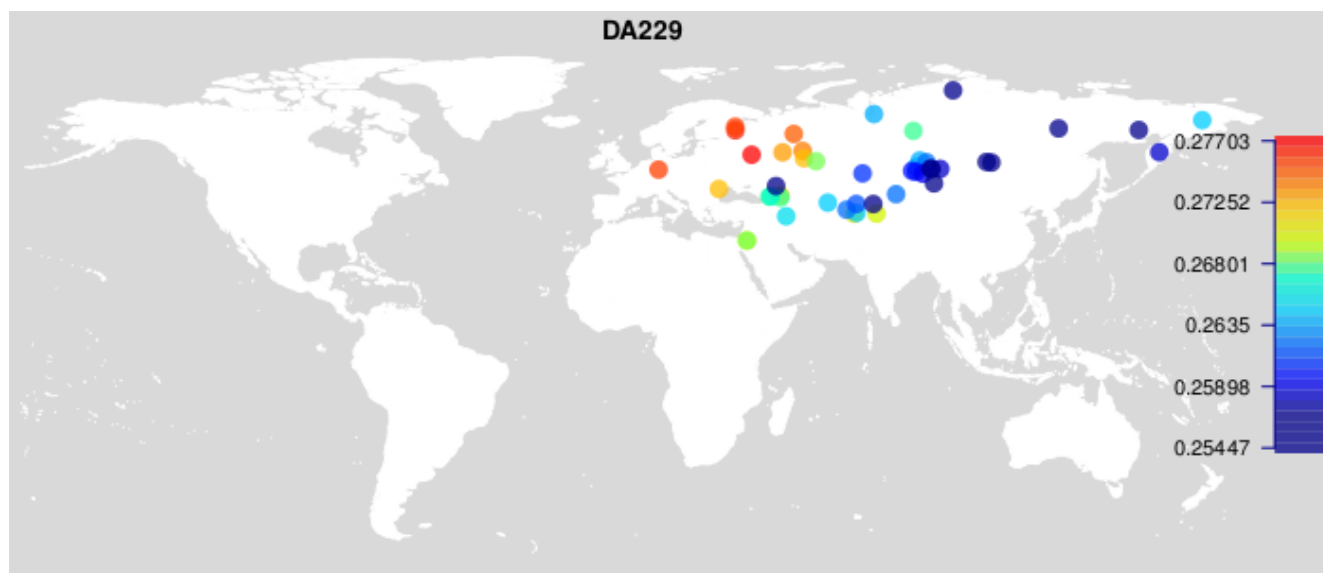
Supplementary Figure 134 - Outgroup-f3 statistics for sample DA229.

DA229 - Region: Tian Shan
Period: 2ⁿᵈ cent BC – 2ⁿᵈ cent AD
Population label: Kangju

The Konyrtobe burials

The burial ground of Konyrtobe is one of the best-studied monuments of the Otrar Oasis. It is located 0.3-0.4 km to the west of the ancient settlement and covers an area of 12-13 hectares. There is a preserved oval mound with a flattened summit up to 2.5 m high covering an area of 35-45 m^2 in the southern part of this area. During excavations of this mound, about ninety burials were discovered close to each other. Burial depth varied from 0.4 to 1.5 m from the highest point of the modern day surface. Burials were made in shallow grave pits, laid in the lower part of the mound, as well as in simple rectangular pits. The burials had not been disturbed; bones lay in anatomical position and accompanying funerary items were *in situ*.

Within grave chambers of 0.6-0.75 x 1.8-2.2 m, the deceased had been laid on organic material that appeared as a black layer. Skeletons lay on their backs, with arms alongside the body and the hands either on or under the pelvic bones or lying on the floor. Legs were typically extended, but sometimes were crossed. Skulls faced upwards. More often at the legs, but sometimes near the head, a ceramic jug occasionally with a mug was found. The bones of the anterior legs of sheep and a scapula were commonly encountered, which is typical for sub-catacomb Central Asian burials.

Male and female burials were clearly distinguishable based on the funerary inventory. A preliminary anthropological survey of a series of 20 skulls established that 15 of them possessed an annular deformation. For burials of men, iron belt buckles are common; either simple round buckles with a movable tongue, buckles with an iron clip-receiver, or iron buckles with a frame around the circumference of the belt. In one case, two belts with bronze buckles and bronze "zigzag" pads were found on the deceased's backbone, tightly covering part of the belt (20-25 cm) near the buckle. Bronze buckles have been found in other burials. A unique buckle was found in a damaged burial; its round frame had been carved from green jade, and the tongue and movable flap with three rivets were made of bronze. Also in men's burials, in addition to the small iron knives found in women's burials, were found iron daggers without crosses and pommels (blade lengths of 30-40 cm), as well as three-lobed iron petiolate arrowheads and, in one case, decaying bone plates probably from bow linings. Burials of women are characterized by a variety of beads (rock crystal, glass paste, carnelian, gagat, coral, amber) distributed around the neck and wrists, sticks with pieces of graphite, bronze amulets in the form of goat figurines, bronze mirrors, and bone hairpins with a curled end.

The orientations of skeletons also differed between burials of men and women. Female skeletons are mainly oriented with the head to the south-southeast, whereas males are usually oriented to the north-northeast. Though the bulk of the adult burials followed the same funerary rite, a series of burials with the corpse laid on its side and two burials conducted in large storage vessels (kumas) are notable. In a number of burials, wall traces around the skeleton could not be detected. Skeletons lying on their right or left side had the arms folded over the chest and the legs exhibit varying degrees of bending. In one vessel burial, a teenager lay on their side with the head oriented north-northeast. The skeleton lay on ash-coal bedding, but the head did not fit into the vessel so it was placed on a large potted vessel ornamented with ring-shaped impressions on the shoulder. No other inventory was found with this burial. In the other vessel-based burial nearby was the skeleton of an adult male, with the head pointing to the northeast. The skeleton lay on a layer of vessel fragments, sprinkled with coal and covered with two halves of a vessel with corollas. An earring in the form of a bronze ring with open ends was found to the left of the skull. A knife and a round iron buckle with a receiver were found under the pelvic bones, as was another knife with a curved back.

Child burials were made in shallow pits or in large vessels, such as pitchers or kumas. In some cases, children had been buried with women. Child skeletons were accompanied by small mugs (usually of type 2), sometimes with 2-3 beads or cowry shell pendants.

An interesting funerary rite was noted during excavation of the burial with bronze belts. In that case, the deceased was laid on a thin layer of charcoal and the body was then sprinkled with red-hot coals; a ritual noted in other burials. In some cases, thin copper plates (3 to 5 cm wide and 8 to 10 cm long) were found on the facial bones of the skull, usually on or below the lower jaw, in the mouth, or across the face. Three embossed round protuberances were found on three of these plates, forming a simple pattern. The purpose of the plates remains unclear. They may have been laid on the lips or eyes, with the face covered by a veil. The surfaces of the plates usually show traces of decayed tissue.

In terms of the funerary inventory, clay jugs and mugs were found in 90% of excavated burials. Two types of pitchers are represented, i.e. those with or without a spout. Jugs with a large spout, 75-85 cm high, with sloping shoulders and handles linking the shoulders and the upper part of the neck are also present. Their corollas are bent and profiled and the throat is usually marked with circular piercings or ridges. These ridges sometimes cover the upper part of the jug. The jug handles are flattened and possess a longitudinal groove at the back. In some cases the handles have a characteristic bend in the middle. Jugs without spouts possess the same features, but are somewhat smaller (up to 70 cm high). Pitchers are covered with an engobe coating of various shades of red, and less often black or dark brown. Mugs can also be divided into two types according to the nature of the handle; those with handles in the form of a ring attached to the shoulders or middle part of the mug, and those with handles connecting the shoulder and the corolla. These latter mugs are usually more robust, including large chamotte grains, thick walls, and incomplete firing. Analogs of such ceramics are widely represented in the monuments of the Syr Darya Kaunchinoid cultures of the first half of the 1st millennium AD. Beads are the most commonly Are beadsfound items. These are large round or faceted beads made of crystal and carnelian, ribbed or round glazed beads, large flattened beads of black material, small cylindrical coralline beads, and round or flattened amber beads. An interesting ceramic bead in the form of a miniature jug was also encountered.

In several cases, a single earring was found in both male and female burials, but of different types. These include simple open bronze rings with a thickened middle and pointed ends and other bronze rings one end of which forms a spiral-conical suspension. The suspension could be in the form of a hollow conical ring soldered from a thin sheet of bronze. One silver earring with a flattened bottom in the form of a lunette was also found. A pair of bronze amulets in the form of standing goats was found in three female burials between the spine and the right elbow. These were part of a chest necklace set with large crystal, carnelian and pastel beads. In one case, the necklace included a bronze bell and a large needle. In another female burial, the necklace contained only one amulet in the form of a goat, as well as a pendant of the incisor of a large rodent and the metacarpus of a large predator. The hair of buried women was decorated with bone pins. On their necks, the women wore a bronze chain with a lock in the form of two rings. An interesting silver oval pendant was also recovered with a red stone (garnet) inset, surrounded by fine crystals with another row of crystals at the edge. The Kirkesken burial ground, dated to the 2nd-4th centuries, has exhibited similar funerary rites and inventory, as has a cemetery near the ancient settlement of Kok-Mardan.

Konyrtobe Burial No.15
This burial is of a woman of advanced age. The head is oriented to the NE. Her arms were extended alongside the body, hands resting on the floor next to the pelvis. Between the legs was a wide-necked pitcher of yellow clay, without a spout. The left shoulder displayed a cosmetic device; a stone-

sharpened tetrahedral flattened stick (8 cm long) with a hole in the thickened part and holding a piece of graphite with a hole. Near the skeleton lay the front leg bone and scapula of a sheep. A crystal hexahedral bead was found on the belt. A spherical ceramic and a ceramic suspension in the form of a wide-necked jug was also found.

Konyrtobe Burial No.19
Well-constructed gray bricks lined the crypt of this burial. Debris and entire bricks formed the in-fill of the inner chamber. The skeleton lay on its back on a black layer of decayed matter, with the arms extended along the body. Between the legs lay fragments of a jug. There were no other finds.
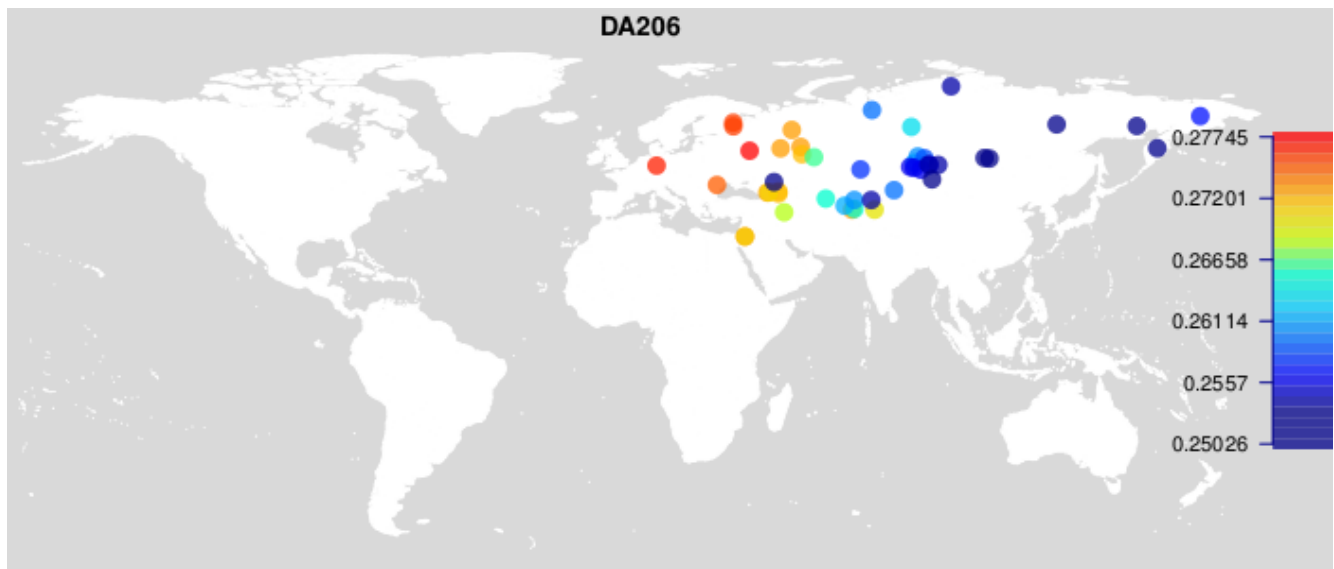
Supplementary Figure 135 - Outgroup-f3 statistics for sample DA206.

DA206 - Region: Tian Shan
Radiocarbon 14C date: 1805 +- 49 BP uncal
Population label: Kangju
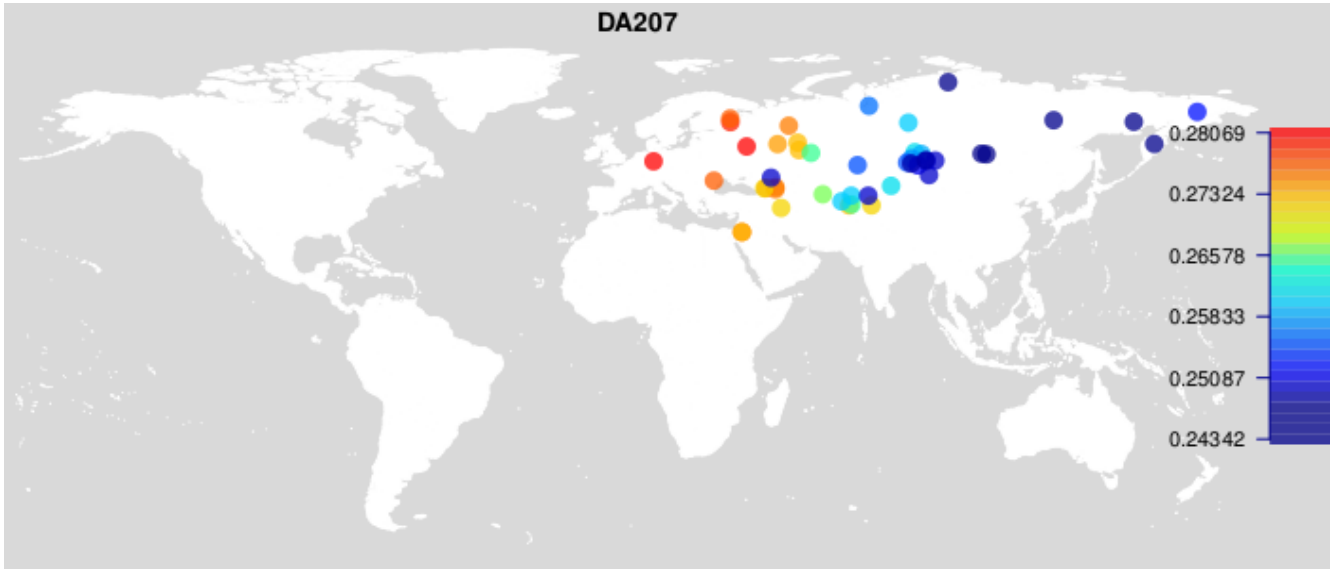
Supplementary Figure 136 - Outgroup-f3 statistics for sample DA207.

DA207 - Region: Tian Shan
Period: Historical
Population label: Kazakh_His
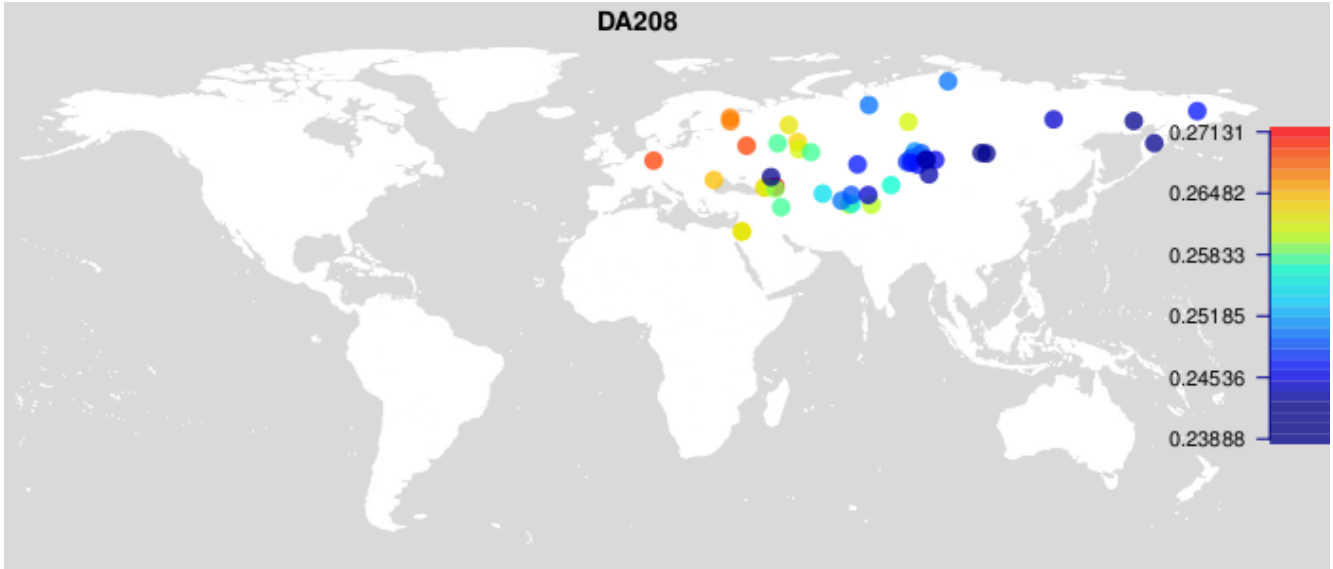
Supplementary Figure 137 - Outgroup-f3 statistics for sample DA208.

DA208 - Region: Tian Shan
Period: Historical
Population label: Kazakh_His

The Karasuyr burial site of Buddhist Mongol warriors from Central Kazakhstan, dated to the Golden Horde

By Emma R. Usmanova[1], Irina Panyushkina[2] and Alina V. Kolbina[3]
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DNA-sampled burials
Karasyur is a Golden Horde burial site of a small combat group that probably died in battle. The site has been dated to the mid 13th century. Bone materials from burials No. 1 and 5 have been subjected to DNA analysis. The skeleton from burial No.1, a Buddhist warrior, was attributed to an adult male of the Central Asian Mongoloid races, which include the Buryats, Mongols, and Kalmyks. The skeleton from burial No.5 was probably a slave or servant and was attributed to an adult Caucasian male race.

The Karasuyr burial site
The Karasuyr site (47°10′ N 65°30′ E) is located in the Ulytau Mountains of Karaganda oblast, Kazhakstan. It is a small cemetery (1.5 km^2) comprising 12 burials, four of which were excavated by E. Usmanova in 2011. The Karasuyr cemetery has been dated to the Jochi Ulus in the heart of the Golden Horde Mongol State ruled by the Jochi Khan and his clan (son Ordu) between the late 13th and early 14th centuries. The territory of the Golden Horde encompassed the Emba and Irtysh Rivers of Southern Siberia and the low reaches of the Syr Darya River.

Burial rite, and cultural and anthropological context
The considerable concordance of the burial architecture suggests that the cemetery was developed over a short time interval. The burial structures are about 4-5 m long, 2 m wide and 0.5 to 0.7 m high. The pits (1.2 m below the surface) are covered with flat stones and large boulders arranged in an oval shape without cementation. In each pit was interred a single human. The skeletons are of young adult males, three of which are Mongoloid (burials No.1-3) and one is Caucasian (burial No.5). The skeletons were placed in the fully extended position, lying on their backs, with their heads pointing to the north and the skulls tilted slightly to the east or the west. Three males (burials No.1-3) had weaponry placed along their left side. The weaponry includes birch bark quivers with sets of arrows, iron knives, iron hooks and iron flints. Burial No.1 had fragments of plated armor and a sheep blade for divination near the skull. Burial No.2 had a ritual bronze bell. Weaponry was not found with the Caucasian male from burial No.5, but an iron flint and a fragment of iron chain were found. The warrior from burial No.1 appeared to have the highest status in the group. Several sheep bones were placed randomly in the burial pits, which is consistent with Mongolian funeral offerings. Burials No.1 and 2 are associated with Buddhist customs. The gravestone of burial No.1 had a carved image of Buddha. Burial No.2 included a Buddhist metal bell with a handle shaped like a question mark.

Age of Karasuyr cemetery
Dating of the weaponry recovered from the site against Eurasian weaponry chronologies suggests that the Karasuyr cemetery was constructed between the 13th and 14th centuries CE. The fragment of lamellar iron-plated armor is characteristic of Mongol armor of the 13th-15th century CE. Radiocarbon dating of a rib bone from the male skeleton of burial No.1 (AA103462: 707/+-44) indicate the intervals 1260-1370 cal years CE (1σ) or 1220 -1350 cal years CE (2 σ), with the highest probability peaks at 1262 cal years CE (1σ) and 1223 cal years CE (2σ). The cemetery age is likely to be from the mid 13th century CE.

Supplementary Figure 138 - The Golden Horde Karasyur burial No.1.

Supplementary Figure 139 - The Golden Horde Karasyur burial No.5
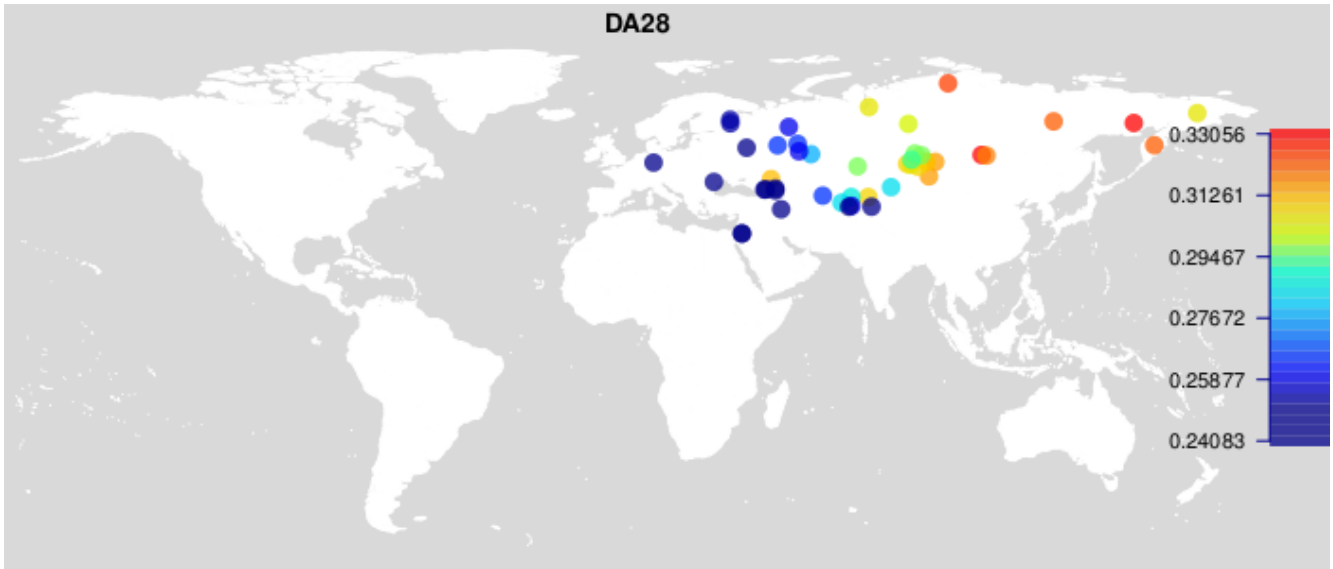
Supplementary Figure 140 - Outgroup-f3 statistics for sample DA28.

DA28 - Region: Central steppe
Period: Medieval
Population label: GoldenHordeAsian
(Burial 1)
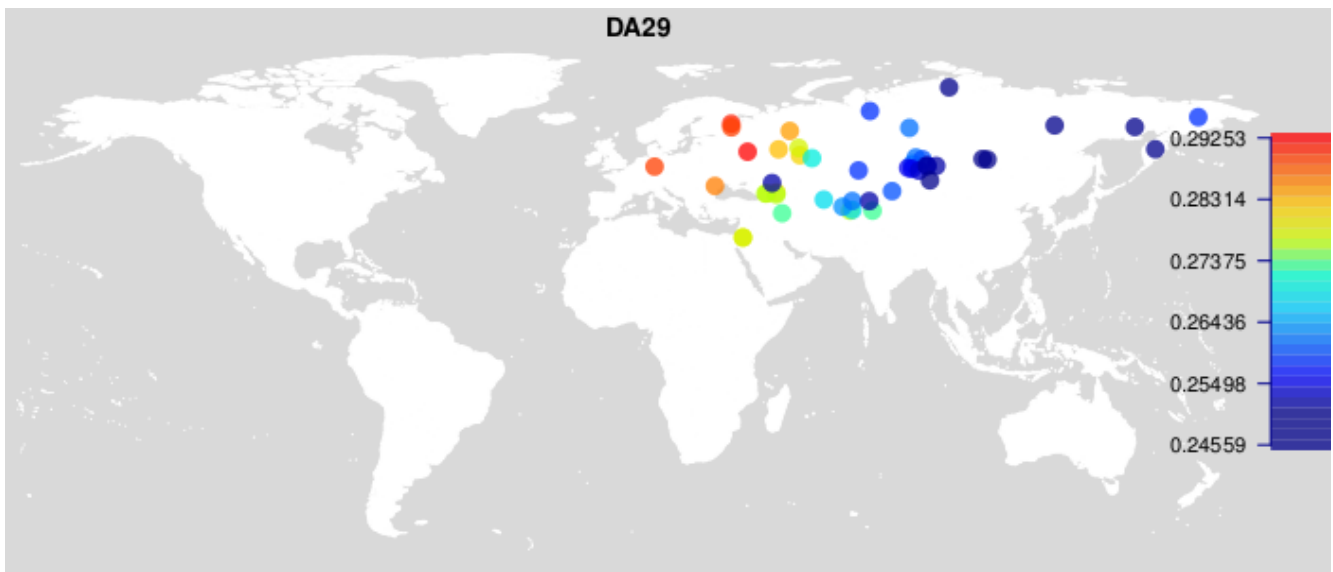
Supplementary Figure 141 - Outgroup-f3 statistics for sample DA29.

DA29 - Region: Central steppe
Period: Medieval
Population label: GoldenHordeEuropean
(Burial 5)

The "Kipchak" mound of the Lisakovsk-I burial site

By Emma R. Usmanova
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Lisakovsk burial site
The Lisakovsk archaeological complex is located in the steppe landscape of the upper Tobol River valley in the Kostanay oblast region of Kazakhstan (52°32′13″N, 62°29′37″E). The site includes six cemeteries (numbered 1–6) and one Bronze Age settlement. A few mounds belong to the late Iron Age and Middle Ages, one of which, "Kipchak", attributed to the Middle Ages was excavated by E. Usmanova in 1995.

Burial rites and funerary inventory
The "Kipchak" kurgan is bordered by a stone enclosure and has a diameter of 5 m. The oval-shaped grave pit had a stone in-fill. The dimensions of the burial pit are 2.4 x 0.85 m, with a depth of 1.2 m. The skeleton of a male was fully extended and lying on his back, with his head pointing to the west and his skull tilted to the north. Weaponry was found along his right side, including an iron knife, three iron arrows, and one iron javelin, as well as iron horse bits, fragments of a bridle and two iron stirrupsiron knife, three iron arrows and one iron javelin. Two bone plates of a bow had been placed on the pelvis. A silver ring and agate bead had been placed to the right of the head.

Dating and cultural interpretation
This burial has been linked to the pre-Mongolian period of history of the Central Eurasian Steppes when the population of Desht–i–Kipchak was not a single ethnicity community. This group is typically known as the Kipchak or Polovtsian (Russian interpretation) nomad people of Turkic-speaking origin. Kipchak tribes inhabited the Eurasian Steppe from the Danube to the Urtysh before Mongolian conquest and the foundation of the Golden Hordes (i.e. in the middle of the 13th century C.E.), and later mixed with the Mongols. According to archaeological data, this burial can be interpreted as belonging to a Kipchak warrior, dated to the 11th or beginning of the 13th century C.E. based on characteristics of the funerary inventory and burial rite.

Preliminary anthropological definition
Facial reconstruction based on a skull recovered from the "Kipchak" burial at Lisakovsk-1 by Galina V. Lebedinskya (Moscow) indicated that it belonged to a male Caucasoid with an admixture of Mongoloid features.
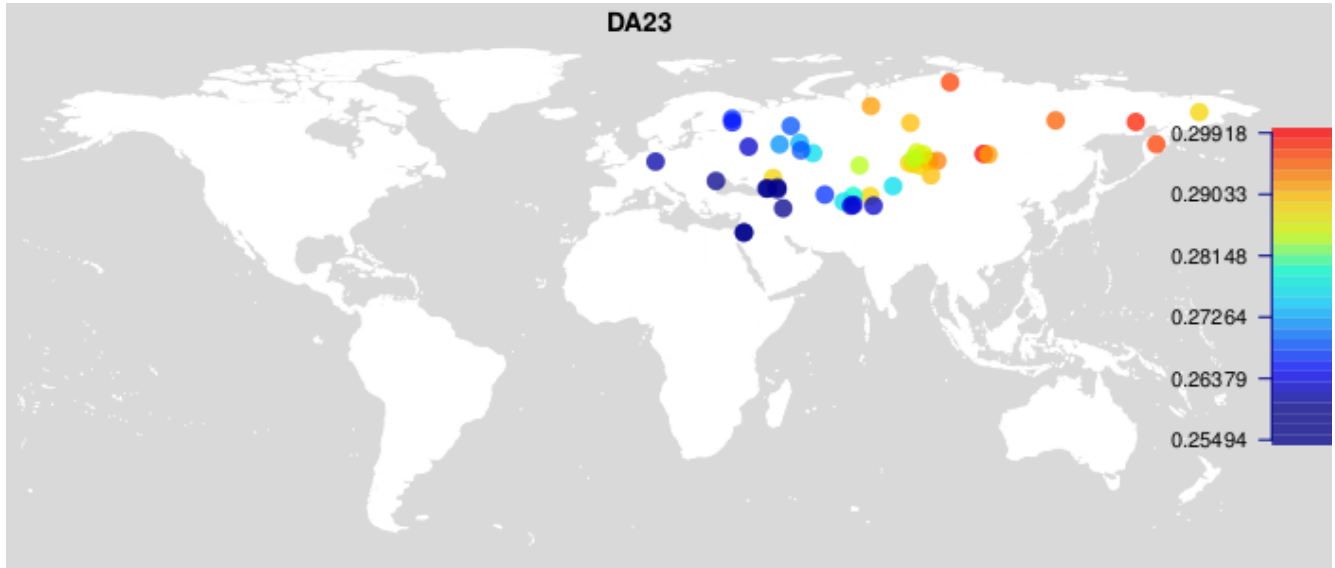
Supplementary Figure 142 - Outgroup-f3 statistics for sample DA23.

DA23 - Region: Central steppe
Radiocarbon 14C date: 920 +- 25 BP uncal
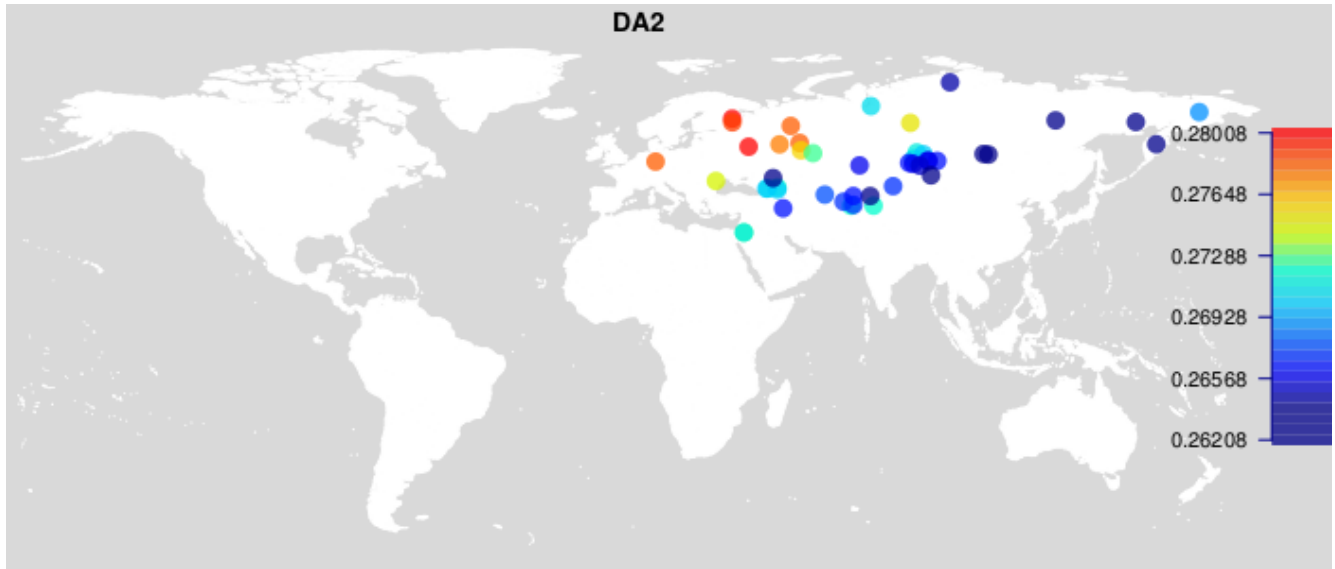**Population label: Kipchak**

The Tagar Scythians

By Vyacheslav Moiseyev

The Tagar culture (7th-1st centuries BCE) is possibly the best archaeologically studied Early Iron Age Siberian culture. First excavations of the early Iron Age kurgans in the Minusink basin were conducted by D. G. Messerschmidt in 1722. He and P.J. Strahlenberg were the first researchers to draw attention to the obvious similarities between Tagar and Scythian bronze art objects and weapons (Vadetskaya, 1986). The first archeological description of the very specific Early Iron Age culture located in the Minusinsk basin (Republic of Khakassia, Russia), and originally termed "Minusinsk Kurgan culture", was provided by Teploukhov in the 1920s[193]. His periodization formed the basis of most later schemes[194,195], but the culture was renamed as Tagar. Recent computer simulations of the evolution of several of the most diagnostic Tagar artifacts suggest the absence of a strict linear evolutionary development of Tagar culture[196]. In addition, most modern researchers exclude Tes' sites (2nd-1st centuries BCE) from Tagar culture, instead regarding them as transitional cultures to the later Tashtyk culture that was considerably influenced by Hunnu tribes[197]. Today, the areas where Tagar monuments have been found include the whole of Khakassia and some adjacent areas. It has been suggested that Tagarians had a complex economy that included cow, sheep and goat breeding, as well as farming with elements of irrigation.

The Grishkin Log-1 burial ground located near the abandoned Saragash village (Krasnoyarsk province) was excavated by a number of researchers. Currently, the site is submerged under the Krasnoyarsk Water Reservoir. Archaeologically, Grishkin Log has been attributed to the earliest stage of Tagar culture (i.e. 7th century BCE). Whereas most Bainovo burial grounds are characterized by single burials placed in square or rectangular stone enclosures, at Grishkin Log-1 one to five individuals can be buried within one enclosure. In contrast, in later periods, Tagarians practiced fully collective burials of up to 100 individuals. It has been argued that changing Tagar funeral traditions reflect social evolution of Tagar society[198].

Given the numerous human remains excavated from Tagar kurgans, the population history of Tagarians has also been well studied by physical anthropologists. The Tagar people are mostly viewed as being descendants of the Bronze Age peoples of southern Siberia, which themselves were migrants from the European part of Russia and Ukraine. The role of specific Bronze Age groups in Tagar population history is debated, but most researchers accept that the Tagarians are a mixed population of descendents from different Afanasievo and Andronovo groups[199]. Indeed, special roles for the Kazakh Andronovo[200] and Tuva Bronze Age groups[201] have been suggested.

Supplementary Figure 143 - Outgroup-f3 statistics for sample DA2.

DA2 - Region: South Siberia
Radiocarbon 14C date: 2725 +- 31 BP uncal
Population label: Tagar
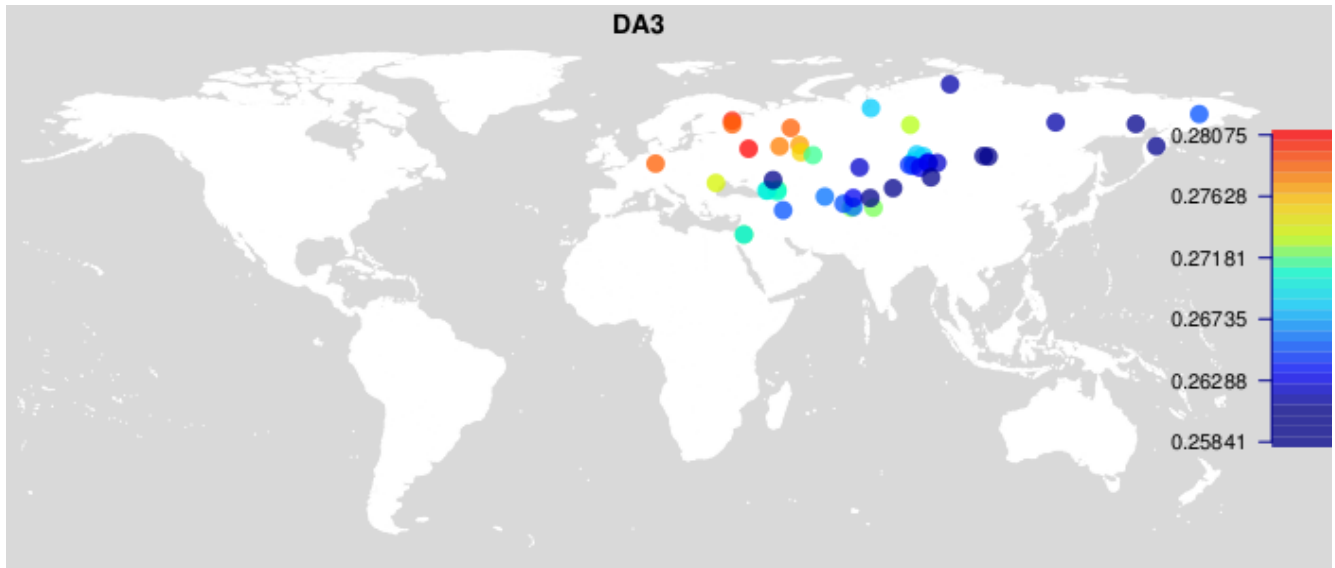
Supplementary Figure 144 - Outgroup-f3 statistics for sample DA3.

DA3 - Region: South Siberia
Period: Iron Age
Population label: Tagar
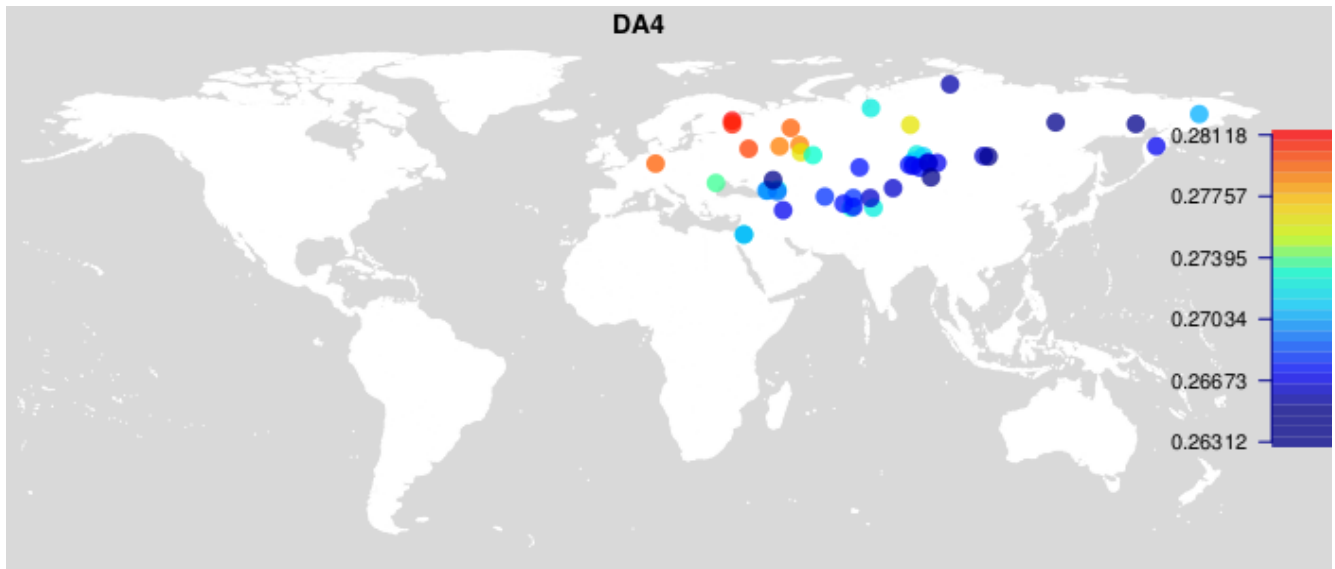
Supplementary Figure 145 - Outgroup-f3 statistics for sample DA4.

DA4 - Region: South Siberia
Period: Iron Age
Population label: Tagar

Supplementary Figure 146 - Outgroup-f3 statistics for sample DA5.

DA5 - Region: South Siberia
Period: Iron Age
Population label: Tagar

Supplementary Figure 147 -Outgroup-f3 statistics for sample DA6.

DA6 - Region: South Siberia
Period: Iron Age
Population label: Tagar

Supplementary Figure 148 - Outgroup-f3 statistics for sample DA7.

DA7 - Region: South Siberia
Period: Iron Age
Population label: Tagar
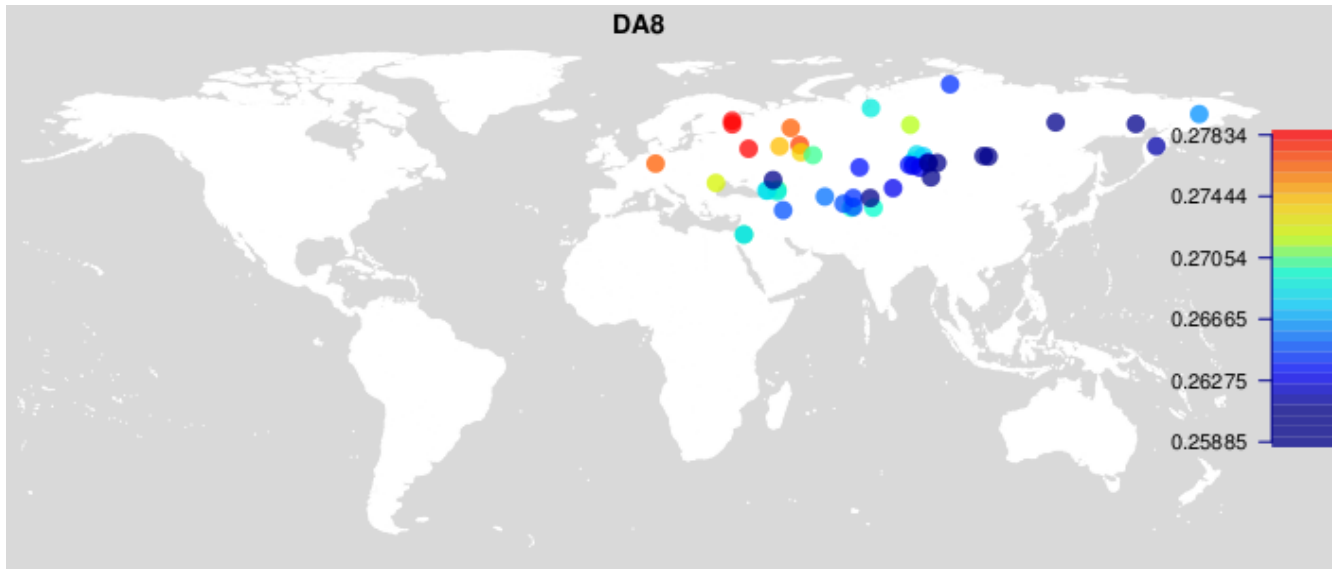
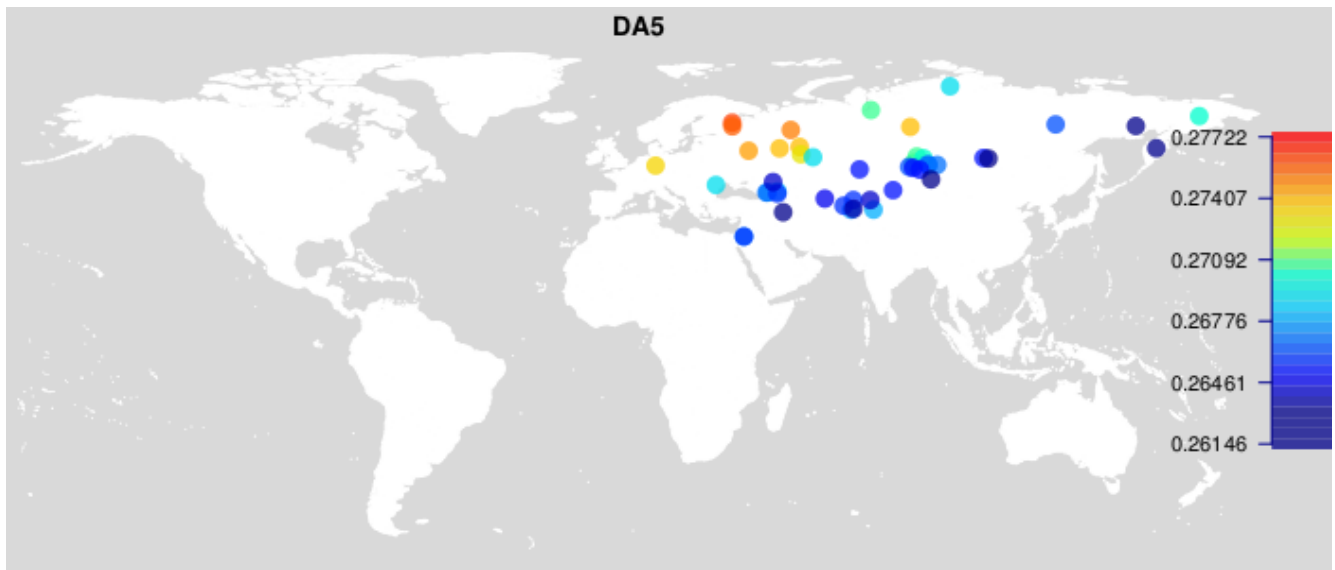**Supplementary Figure 149 - Outgroup-f3 statistics for sample DA8.**

DA8 - Region: South Siberia
Period: Iron Age
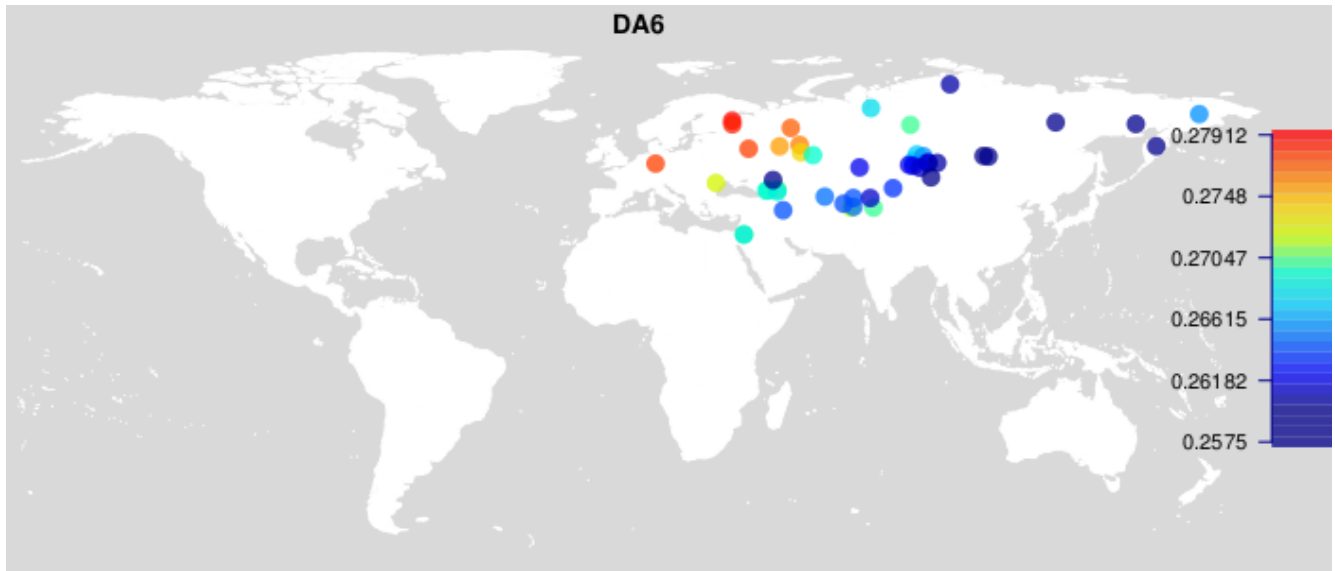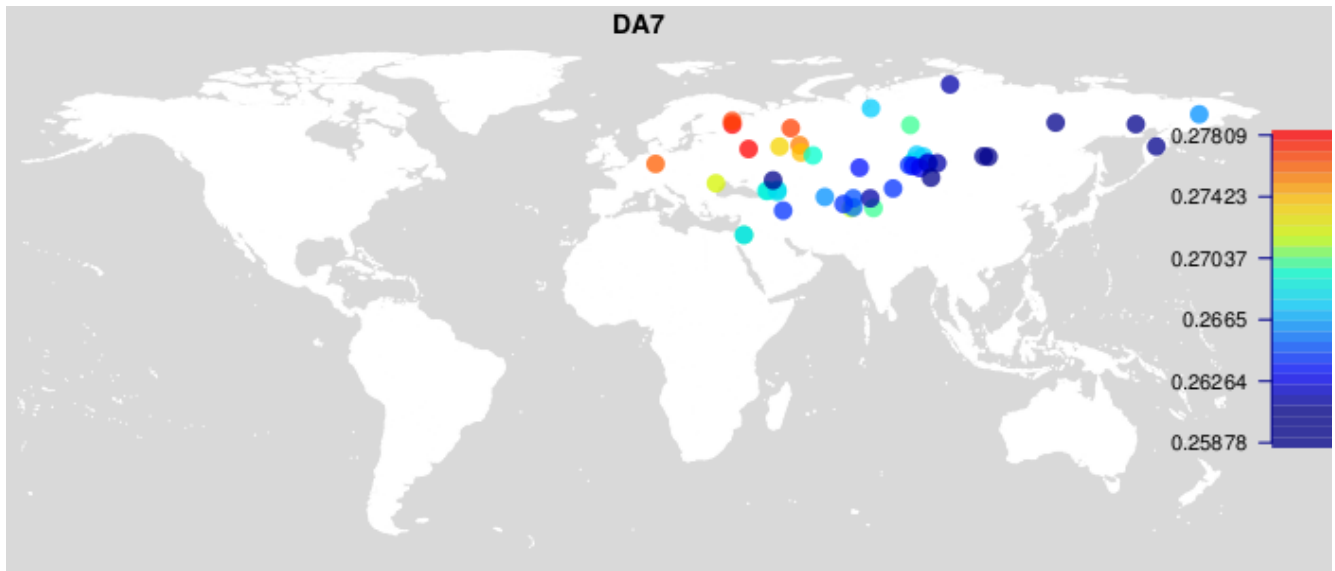**Population label: Tagar**
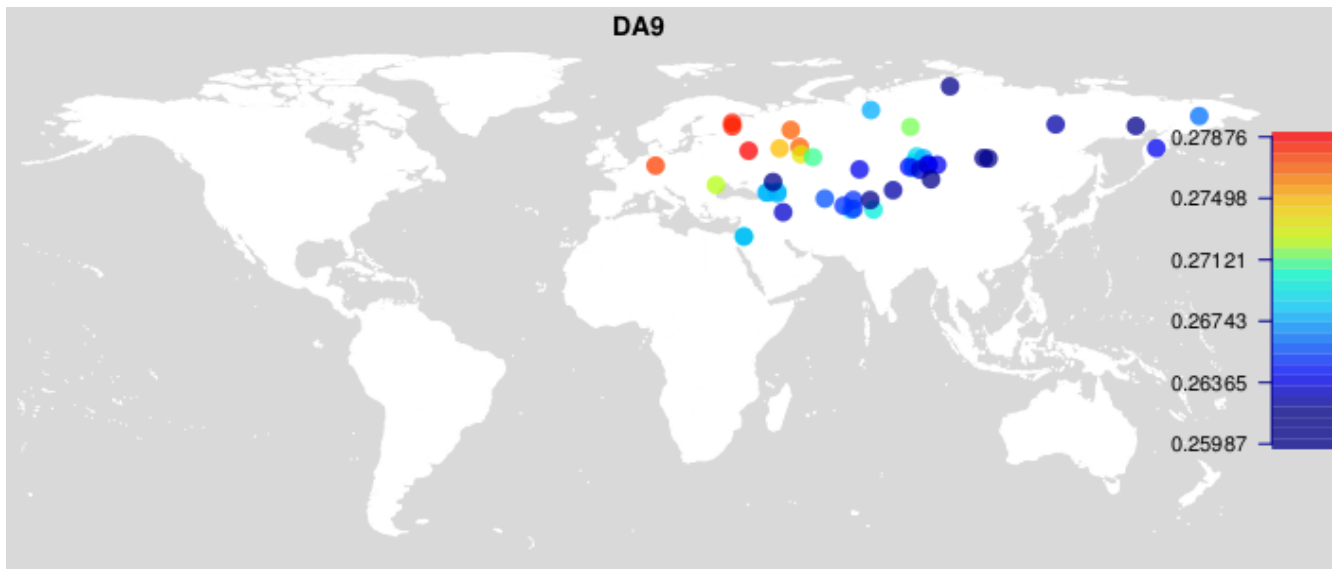
Supplementary Figure 150 - Outgroup-f3 statistics for sample DA9.

DA9 - Region: South Siberia
Period: Iron Age
Population label: Tagar

The Borli Barrow (CGG_2_015449. KG17)

By Valeriy Loman[1], Igor Kukushkin[2]
[1]Buketov Karaganda State University, Saryarka Archaeological Institute, Karaganda, KZ
[2]Buketov Karaganda State University, Saryarka Archaeological Institute, Karaganda, KZ

This barrow is situated 107 km northeast of the city of Karaganda. It was investigated by an expedition of the Saryarka Archaeological Institute from Buketov Karaganda State University. The barrow has a mound built of large stones with a diameter of 10 m and a height of 0.5 m. After removing the rocks, a grave pit was found measuring 1.7 x 0.65 m, with a depth of 0.9 m and oriented NW-SE. The upper perimeter of the pit was blocked by stone slabs of various shapes and sizes. At the bottom of the grave, a human skeleton was found lying on its back, with the head pointing to the northwest and the arms extended alongside the trunk. On the right side of the skeleton, partially under the pelvis and arm bones, a bronze mirror with a loop on the reverse side was found. The mirror has a diameter of 16.5 cm and in the middle is 0.4 cm thick. According to preliminary assessments, the skeleton belongs to a mature woman with Caucasian features. Such mirrors without flanges and a central looped handle have been recovered mainly from burial complexes of the 6th-5th centuries BCE. They are known from sites of the Tasmola culture in Kazakhstan, as well as in the Southern Trans-Urals, north of the Baraba forest-steppe, burial grounds of the Gorny Altai, Barnaul and Priobye, and in burials of the Pazyryk culture. The mirror from the Borli mound can be dated to the 6th-5th century BCE.

Рис. Борлы курган. зеркало

С

А — Б   А — Б

0   4 м

С

зеркало

0   40 см

А — Б

0   40 см

0   4 см
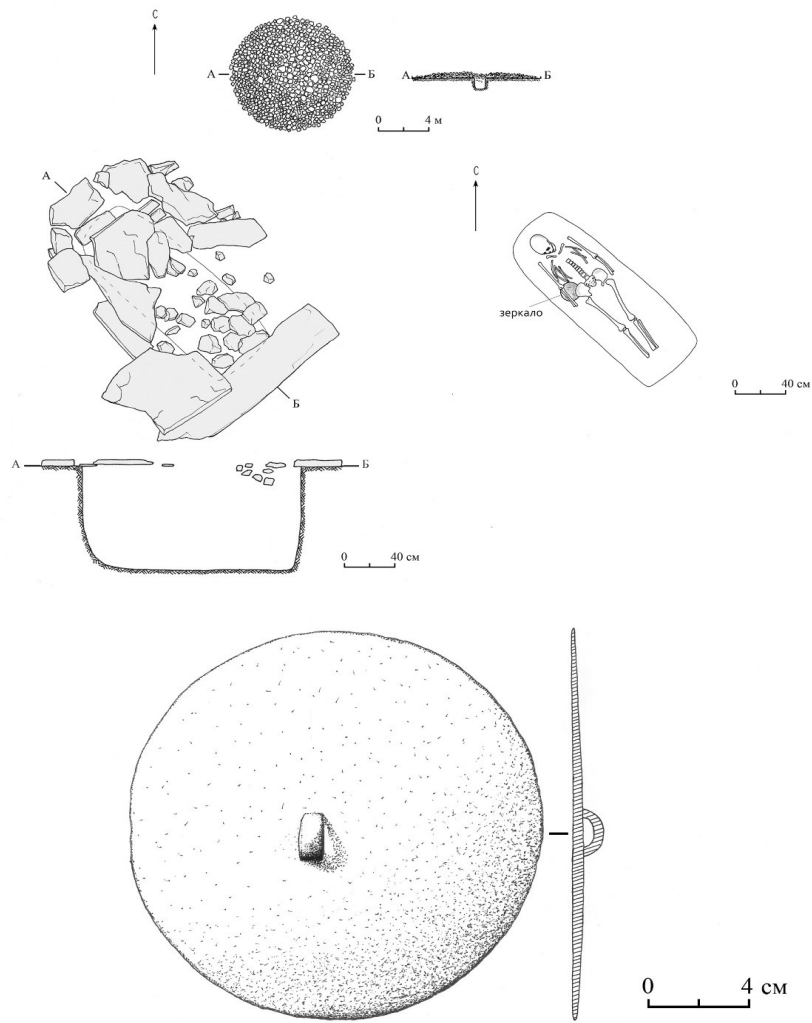
Supplementary Figure 151 - The Borli barrow.

Supplementary Figure 152 - Outgroup-f3 statistics for sample DA11.

DA11 - Region: Central steppe
Radiocarbon 14C date: 2489 +- 39 BP uncal
Population label: CentralSaka

The Nurataldy-2 burial ground (CGG_2_016112, Kar17)

By Valeriy Loman[1], Igor Kukushkin[2], Alexey Kukushkin[3], Evgeniy Dmitriev[4]
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[2]Buketov Karaganda State University, Saryarka Archaeological Institute, Karaganda, KZ
[3]Buketov Karaganda State University, Karaganda, KZ
[4]Buketov Karaganda State University, Saryarka Archaeological Institute, Karaganda, KZ

The Nurataldy-2 burial ground is located in the Shet district of the Karaganda region, 85 km southeast of the city of Karaganda, on the left bank of the Taldy river. Expeditions of the Saryarka Archaeological Institute of the Buketov Karaganda State University in 2011 and 2015 found three burials in enclosures made of adobe bricks.

The funeral rite and inventory
Burial structure No.2 at the Nurataldy-2 burial ground is an earth burial mound, 13 m in diameter and 0.4 m high. After removing the mound, the remains of the walls of a rectangular fence made of raw bricks (5.8 x 4.7 m) were exposed. A burial was discovered in the fence in a ground pit of overlapping massive stone slabs that had slipped inside the grave. The skeleton of a man of 25-35 years was found at the bottom of the pit (sex and age determinations were performed by K.N. Solodovnikov). He had been laid on his back in an extended position, with his head pointing to the north-west Supplementary Figure 153). The skull was slightly tilted towards the left shoulder. The left arm was aligned along the body and touched an iron pin, which was located in the region of the pelvic bones. The right arm was bent at the elbow and the bones of the legs were aligned with the width of the shoulders. The remains of wooden boards were fixed under the skeleton as well as on top of it. In the central part of the burial pit, fragments of a birch bark quiver and two ornamented bone linings for a quiver were found. At the feet of the buried remains was a poorly preserved leather item and a set of horse harnesses including two iron stirrups, a bit, a crocheted buckle, a saddle ring, and a lyre-shaped buckle. An iron arrowhead was found in the northern corner of the grave.

Date and cultural interpretation
The funeral rite and accompanying inventory are analogous to Kipchak burial grounds of the 13th-14th centuries CE. (i.e. the Golden Horde period). Materials of the Nurataldy-2 burial ground are unpublished.
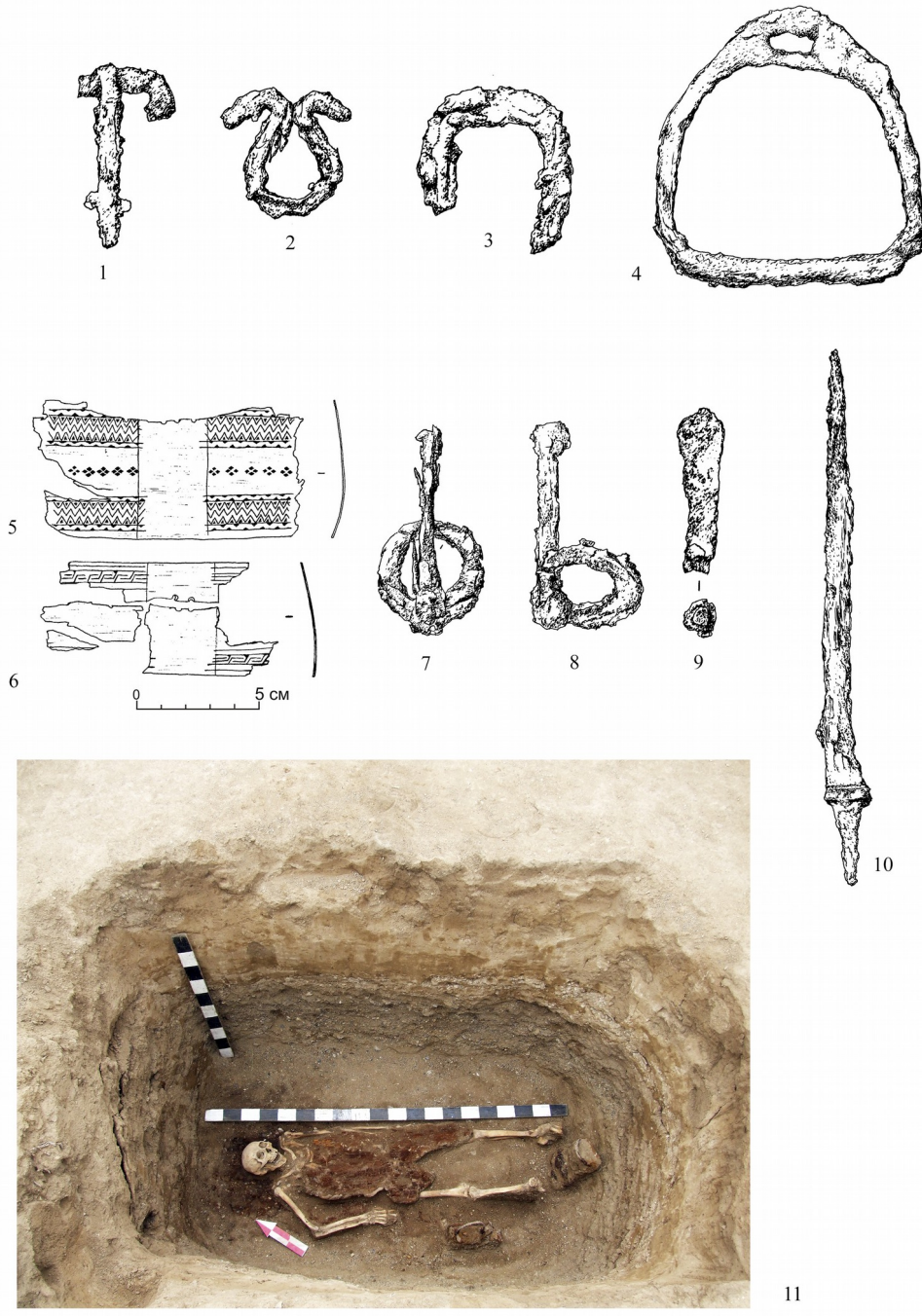
Supplementary Figure 153 - The Nurataldy-2 burial ground, burial structure No.2 and inventory.
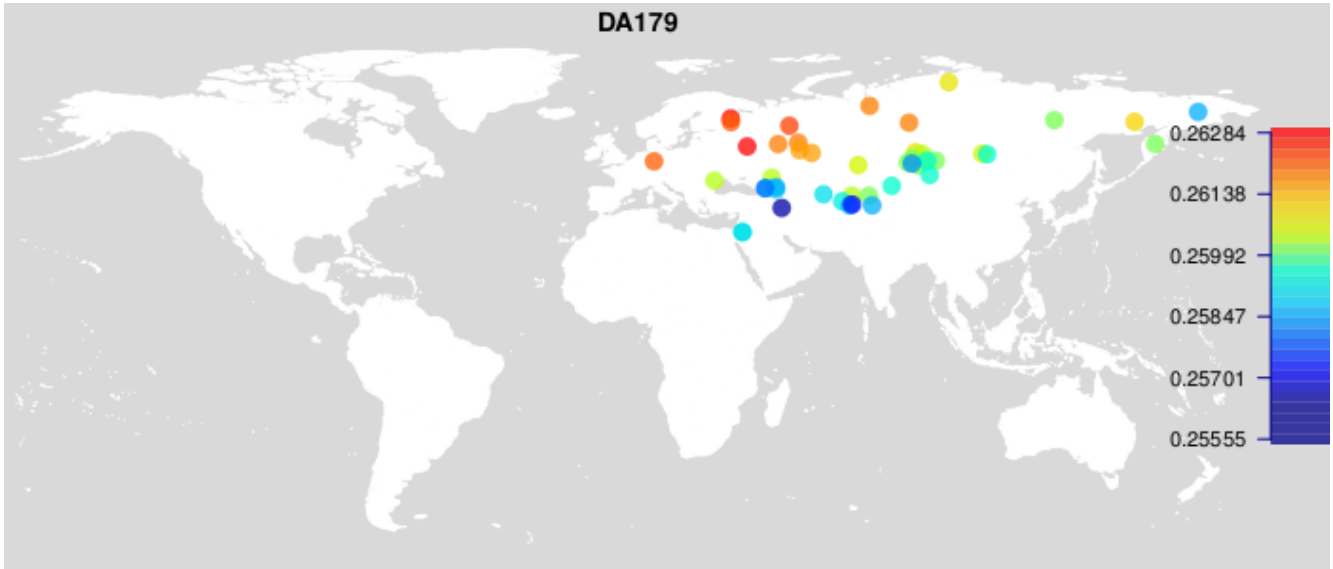
Supplementary Figure 154 - Outgroup-f3 statistics for sample DA179.

DA179 - Region: Central steppe
Period: Medieval
Population label: Kipchak
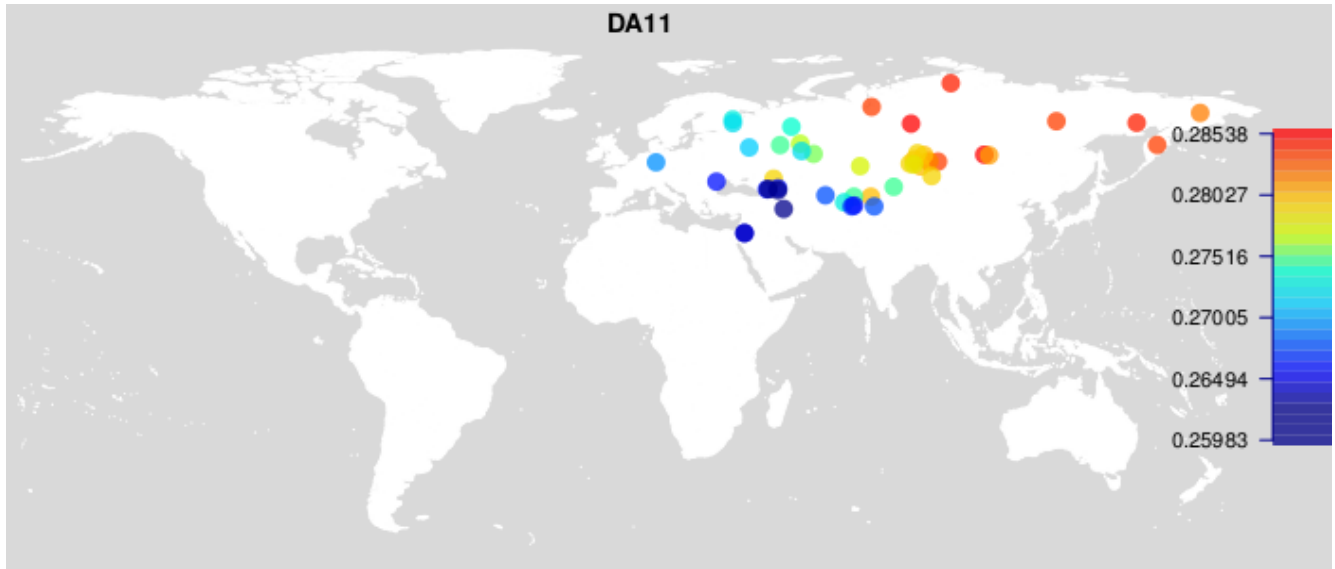
The Zhartas (Sjartas) Barrow (CGG_2_015448. KG16)

By Igor Kukushkin[1], Valeriy Loman[2]
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The Zhartas kurgan is situated 72 km south of the city of Karaganda. The kurgan has a diameter of 8.0 m and a height of 0.4 m, and was constructed from a combination of stones and earth. The burial of a young woman was found under the kurgan. The deceased had been placed on her back and her head was oriented to the northwest. A ceramic vessel, bronze mirror and stone beads accompanied the deceased. Research into similar funerary inventories indicates probable contact of the Central Kazakhstan population with tribes of the Sayano-Altay community. This research, which included Scytho-Sakas sites situated in Toowa of the Altai Mountains of northwest Mongolia, dates the kurgan to the 6th-5th–V centuries BCE.
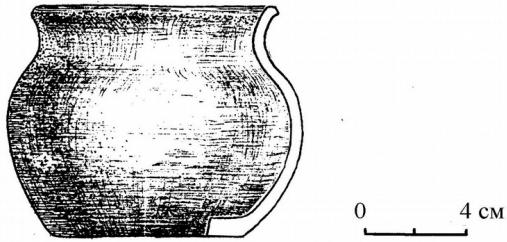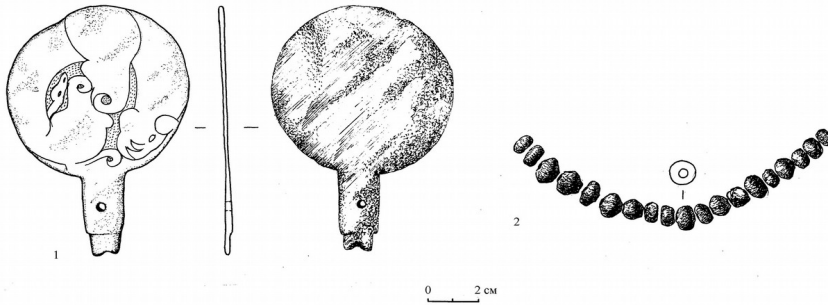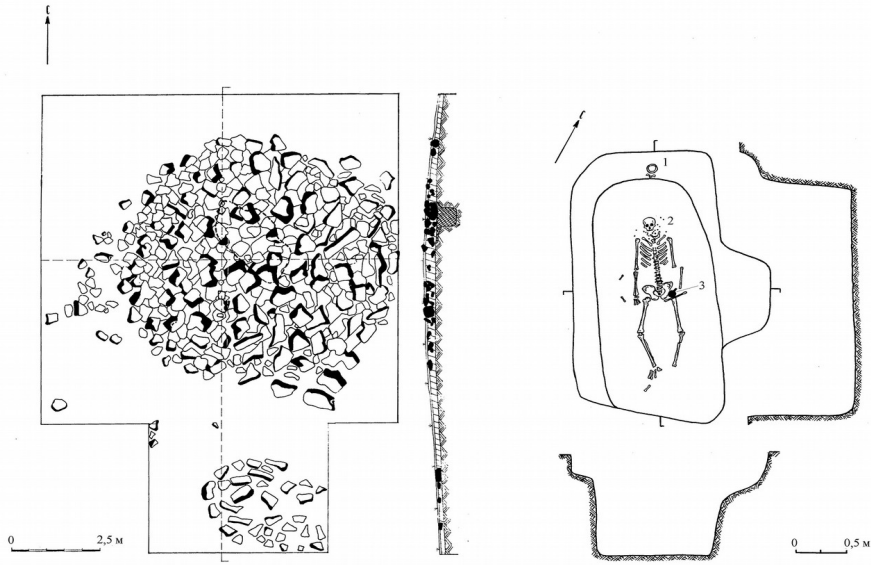
Supplementary Figure 155 - The Zhartas barrow.
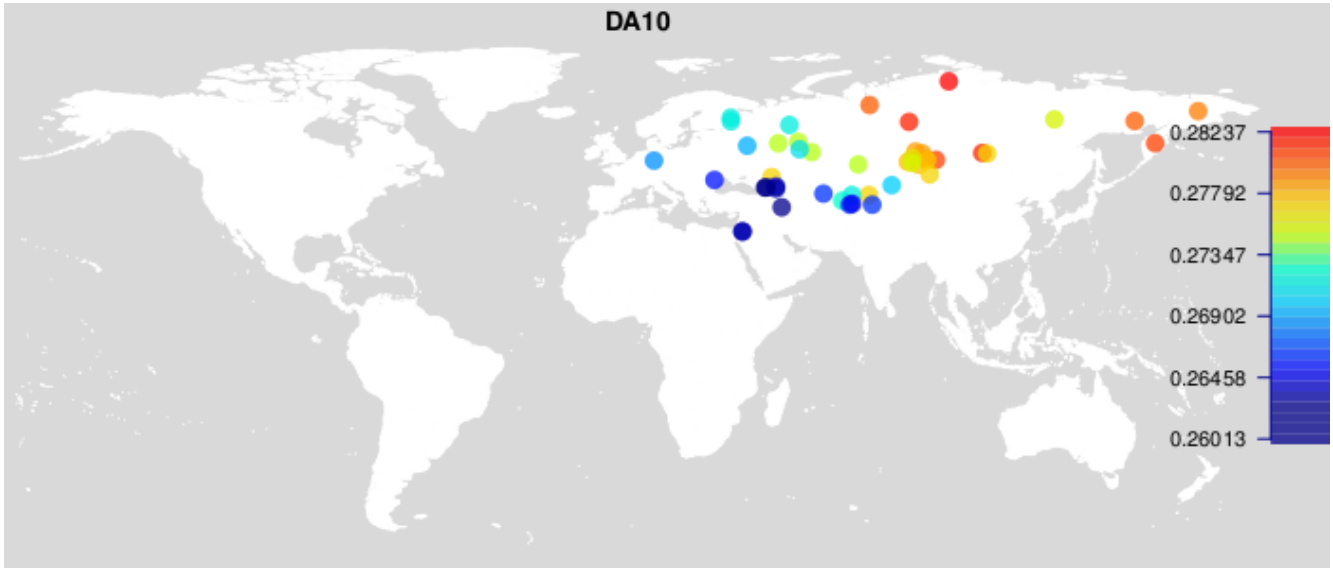
Supplementary Figure 156 - Outgroup-f3 statistics for sample DA10.

DA10 - Region: Central steppe
Period: Iron Age
Population label: Central Saka

The Chieftain grave from Poprad-Matejovce, Slovakia

By Karin Margarita Frei, Tereza Štolcová, Nina Lau, Karol Pieta

The archaeological site
In 2005, a double-chambered grave made of wood was discovered at Matejovce in Slovakia. Excavation revealed that the grave belonged to a chieftain ^{14}C-dated to 380 +/-27 CE., which corresponds to the Early Migration Period[202,203]. The Matejovce site is located at the southeastern foot of the High Tatra mountain chain near the town of Poprad in northern Slovakia. The chamber contained abundant organic remains including wood, textiles, leather and wickerwork[202,203], which is very rare in Slovakia due to unfavorable soil conditions that rarely allow the preservation of organic remains.

The chamber was surrounded by silt layers and had been flooded by groundwater. The wooden construction appeared at a depth of 2.5-3.0 m below the ground and was itself c. 5.0 m deep. It consisted of an outer and inner chamber, aligned in a north-south direction. The outer log-built chamber measured 3.95 x 2.70 m and was 2.0 m high. The impressive construction was covered by no less than 12 wooden beams. The inner chamber served as a kind of sarcophagus, built in a muntin-and-plank type of construction, covered by a gabled roof. Both chambers were made of European larch wood (*Laryx decidua* Mill.)[202]. Unfortunately, the grave had been robbed in ancient times, causing some disturbances. Nevertheless, archaeological excavation uncovered amongst other items a golden pendant (solidus of the Emperor Valens, minted in 375 CE), a bronze Hemmoor bucket, a bronze arrowhead, a silver clasp, fragments of a silver mirror, a silver awl with a wooden handle, an iron knife, and pottery. Most importantly, it yielded a large amount of organic objects, such as c. 60 pieces of wooden furniture, golden textiles and leather fragments. Additionally, c. 50 hazelnuts were scattered in the inner chamber. The costly construction of the chambers, as well as the evidence of Roman imports, golden textiles and elaborate furniture, points to the princely status of the deceased buried at the site.

The human remains (LF 251) were found dispersed on the floor of the inner chamber, and were identified as belonging to a male of 20-25 years with a height of c. 1.71 m[202,203]. In contrast to the organic remains of wood, textile and leather, the human remains were not well preserved, and only a few teeth were identified. Nevertheless, due to the importance and uniqueness of the grave, we conducted aDNA and strontium isotope analyses on the teeth.

The grave has been interpreted as being somewhat culturally related to the North Carpathian group, whose settlements can be found in the hilly areas of northern Slovakia, yet the grave of the chieftain represents the only single grave found to date[202]. Additionally, the inventory can be compared with other European elite Germanic chamber graves from the Late Roman Period.

Strontium isotope analyses
In order to investigate the provenance of the man buried at the site, we measured the strontium isotope ratios of two tooth enamel samples taken from the individual buried at the site. Additionally, we conducted strontium isotope analyses of a total of 13 baseline samples from surface waters, soils, wood bark and unspun wool to map the local bioavailable strontium isotopic range of the area of Poprad.

Slovakia is characterized by a complex geology of tectonic events with folding, thrusting and faults in several directions. Furthermore, Slovakia is situated in the Western Carpathian mountain range that originated during two primary tectonic stages, i.e. the Hercynian and the Alpine. The Western Carpathians are generally divided into Outer and Inner zones. The Outer Carpathians are represented by the Flysch Belt and are separated from the Inner Carpathians by the Neo-Alpine structure of the

Klippen Belt, which contains elements of both zones. The Inner Carpathian block comprises a Paleo-Alpine Late Cretaceous nappe system and post-nappe Cenozoic volcanic and sedimentary rocks. Poprad is located in the Inner Western Carpathians in the Poprad Basin of northeastern Slovakia. This area is characterized by a Pre-Palaeogene base, composed mostly of Mesozoic carbonates.

The strontium isotopic ratios of the baseline samples yielded values of $^{87}Sr/^{86}Sr$ from 0.70879 to 0.71003, with an average of $^{87}Sr/^{86}Sr$ = 0.70939 (2σ ± 0.00004). These values are in agreement with the sedimentary profiles of the Poprad basin. As previously mentioned, the human remains where scattered within the inner chamber and exhibited poor preservation. Consequently, it was not always possible to confidently identify all the human remains. Normally, provenance investigations based on strontium isotope analyses aim to sample the tooth enamel of one of the first molars, as the enamel of the first molars act as an indicator of early childhood[204,205]. However, in our case, we could not identify which molars (first, second or third) were sampled. Therefore, we conducted additional analyses on one of the incisors (the same tooth on which aDNA analyses had been conducted). Both samples yielded similar values; the molar yielded $^{87}Sr/^{86}Sr$ = 0.70921 (2σ ± 0.00004) and the incisor yielded $^{87}Sr/^{86}Sr$ = 0.70935 (2σ ± 0.00001). Both ratios lie within the local baseline range, which indicates that the male buried at the site was most probably of local origin (Supplementary Figure 157). However, it should be noted that there are other areas within Europe that have similar baseline ranges, hence a nonlocal origin cannot be ruled out.
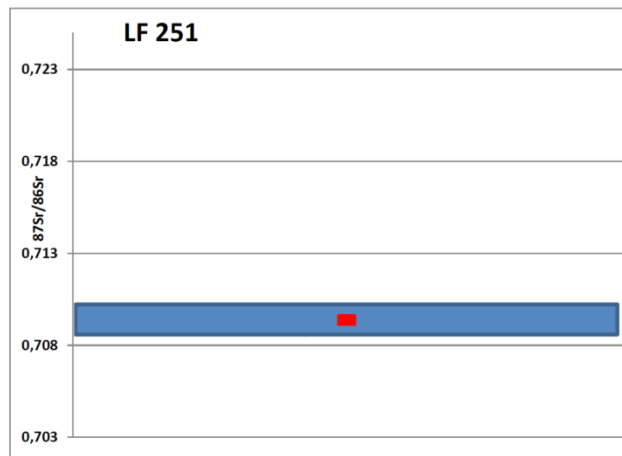
Supplementary Figure 157 - Diagram depicting the local bioavailable strontium isotope range (blue rectangle) and the strontium isotope ratios of the two tooth enamel samples from the individual buried at the site (overlapping red rectangle, errors are incorporated). The individual's strontium isotope analyses reveal that he might have been of local provenance.
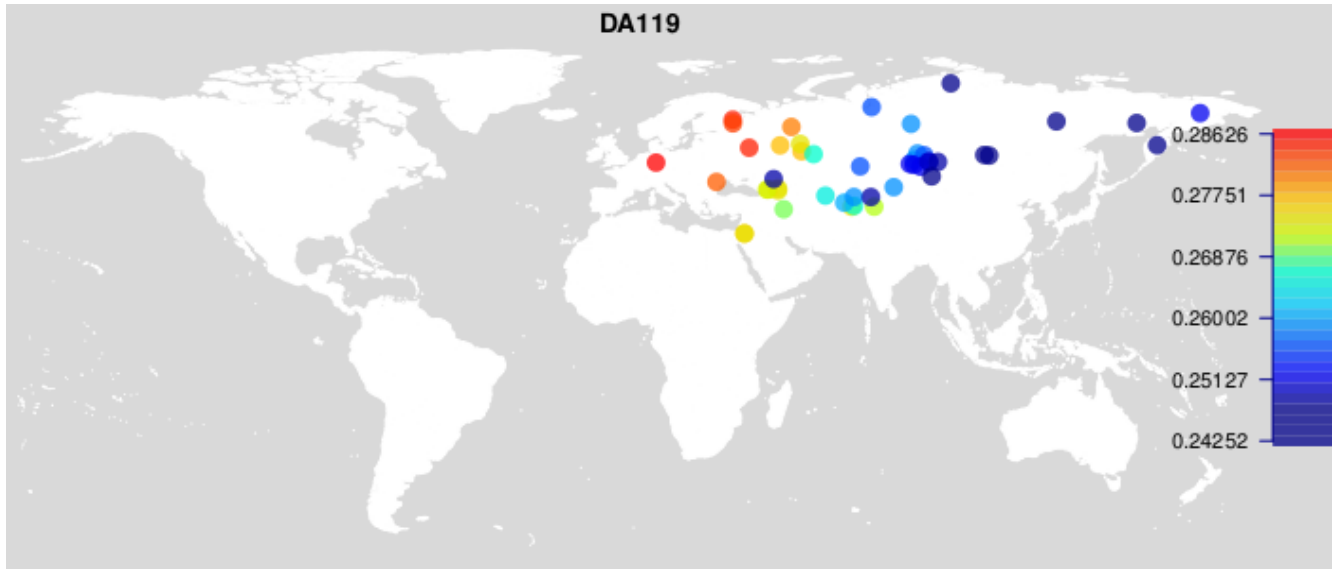
Supplementary Figure 158 - Outgroup-f3 statistics for sample DA119.

DA119 - Region: Central steppe
Period: Migration Period (Hun period)
Population label: Poprad

Section 5: Present-day dataset

By Peter de Barros Damgaard*, Nina Marchi*, Tatyana Hegay, Choduraa Dorzhu, Mikkel Winther, Hakon Hakonarson, Ludovic Orlando, Rasmus Nielsen, Thorfinn Korneliusen, Martin Sikora, Rana Dajani, Evelyne Heyer", Eske Willerslev"
* contributed equally
" contributed equally and corresponding authors

More than just a large geographical area, the Eurasian steppe is currently inhabited by numerous human populations, belonging to several ethnic groups. These ethnic groups have both historically and currently inhabited distinct geographical regions: some are settled in Central Asia, in the central steppe and Uzbek basins (e.g. Tajik, Turkmen, Uzbek), others are present in Northern Asia, in Siberia, in the Altai mountains, and the Mongolian steppe (e.g. Altai-Kizhi, Mogush, Ondar, Telengit, Tubalars, Buryats, Khakas, Shores or Mongolians), while others reside over the whole Eurasian steppe (e.g. Kyrgyz or Kazakh). In most cases, these ethnic groups are present over the limits of eponymous former USSR republics. Culturally, these ethnic groups belong to two main groups: the Indo-Iranian-speaking sphere, *versus* the Turkic- and the Mongolic-speaking spheres. Besides being contrasted by this linguistic criterion[206], these groups are also associated with two different lifestyles (sedentary *versus* semi-nomadic)[207], different matrimonial systems (respectively, in majority endogamous *versus* exogamous), and subsidence modes (agriculturist *versus* herders or fisher-hunters). Some ethnic groups vary a little from this pattern, such as the Uzbeks who have shifted to a sedentary-agriculturist lifestyle since the sixteenth century[208]. As such, the present-day distribution of mostly sedentary Indo-European speaking groups and mostly nomadic Turkic and Mongolic speaking groups reflects the major changes that the populations of the central steppe area underwent during the transition from Iron Age to Medieval times.

This high level of cultural diversity motivates us to investigate the histories of the living ethnic groups, their origins and past population dynamics. In this study, we newly sampled and genotyped 502 individuals from 16 distinct ethnicities (Supplementary Data Table 4) and analyzed them in the context of the ancient genomic dataset, in order to discern patterns of genomic ancestry.

Sampling & Genotyping

During several field expeditions Heyer's lab and collaborators collected DNA from Central and Northern Asian volunteers who provided informed consent and ethno-linguistical informations. Ethnicities were defined based on self-reported spoken native language. Participants were assigned to populations, defined as groups of individuals living in a similar area and belonging to the same ethnic group. DNA was extracted from blood and saliva, then genotyped on an Illumina genotyping array (either Omni1-Quad, or Omni2.5) by "Institut Pasteur – Genopole (Génotypage des Eucaryotes)", in Paris, France. Secondly, samples from populations belonging to the Altaian groups Mogush and Ondar were genotyped on the OmniExpress-Exome v1.2 at Aros Applied Biotechnology A/S, Aarhus, Denmark.

Tjetjen and Circassian diaspora, currently settled in Jordan in the Middle East, were sampled by Rana Dajani's group. All donors provided signed informed consent for the analyses. For these two groups, genomic DNA was isolated from whole blood sample using a phenol-chloroform protocol, and the samples were then SNP genotyped using the GeInfiniumII OMNI-Express BeadChip technology (Illumina), at the Center for Applied Genomics at The Children's Hospital of Philadelphia (CHOP), USA.

After a Quality-Control process performed independently on each array, data was merged into a single

present-day dataset, with all positions flipped to Hg19+. We controlled for call-rates and relatedness by removing individuals with more than 5% missing data, and excluded relatives up to first-degree cousins (included). Relatedness was estimated using all final positions with the software package plink 1.9. The final dataset included 502 individuals. To contextualize this data, we added to the dataset previously published genotypes of populations from Siberia, Central Asia, Caucasus, and Eastern Europe[155] and retained overlapping positions. Thus, the final dataset included 502 new individuals and 612 previously published individuals for a total of 242,406 autosomal SNPs.

Genetic proximities among present-day populations from the Eurasian steppe

A Principal Component Analysis (PCA) was performed on the present-day dataset alone. As the 171 Tjetjen and Circassian genotypes are outliers on the second Principal Component driving most of the variance, we remove them from this analysis (Supplementary Figure 159).
We qualitatively assess four clusters in this PCA (Supplementary Table 5.1). In details, the first Principal Component 1, explaining 3.5 % of the variance, corresponds to a gradient from Caucasus (cluster Y) and Europe (cluster X), to East Asia (at the extreme right of cluster W). Next, on the second Principal Component, that represents 0.5% of the variance, we distinguish European from Caucasian populations (X and Y clusters respectively). This PC also separates the Inner Asian populations in clusters W and Z.
Indeed, three main pools emerge for Inner Asia on the plot: first, cluster Y, the "Indo-Iranian" one, including Yagnobis, Tajiks from Pamir and from Uzbekistan, that are genetically close to populations from Caucasus, such as Azeris and Kumyks.
The second pool (cluster W) englobes variability amongst Turkic and Mongolic-speaking groups (notably Kyrgyz, Telengits, Kazakhs, Mongols, Buryats) from Northern Asia, clustering with populations from East Asia (Even, Evenks, Chukchis).
The third pool (cluster Z) includes some Siberian populations (namely the Shores, Tubalars, Telengits and Khakas), that are traditionally fisher-hunters, and who cluster with the Nenets and Kets, reindeer herders from the Russian Artic Circle. We can note that, despite close neighbouring, Siberian Turkic groups are genetically heterogeneous, being in both cluster W and Z.
Three Turkic-speaking populations from Central Asia are included to this study: the Uzbeks, the Karakalpaks and the Turkmens. While most of the Turkmen samples are included in cluster Y, the other Turkmens, the Uzbeks and the Karakalpaks are found between cluster Y and W, indicating that they are genetically related to both Indo-Iranian and Turkic-speaking populations of Northern Asia. This intermediate genetic component has already been documented for uniparental markers[209] and autosomal STRs[210]; and these populations are documented to have experienced interesting cultural histories: both Turkmens and Uzbeks likely descend from Indo-Iranian speaking tribes assimilated by Turkic-speaking invaders.

Cluster X	**Cluster Y**	**Cluster Z**	**Cluster W**	**Unclustered**
Vepsas	Tajiks_Pamir	Shores	AltaiKizhis	Uzbeks
Karelians	Tajiks	Tubalars	Telengits	Nganassan
Russians	Kumyks	Kets	Kyrgyz	Gagauzes
Germans	Azeris_Daghestan	Nenets	Ondar	Bashkirs
Komis	Yagnobi	Khakas	Buryats	Chukchis
Udmurts	Kabardins	Tuvans	Mongolians	Koryaks
Chuvashes	Azeris_Iran		Kazakhs	Karakalpaks
Tatars	Turkmen		Even	
Yakuts	Balkars		Evenks	
Uygur			Kalmyks	
			Mongush	
			Altaians	

Supplementary Table 5.1: In blue the 10 European populations, in orange the 6 Caucasians, in black the 20 Inner Asians, in purple the 8 Asians from out of Inner Asia (Northern Siberia and East Asia). Tjetjens and Circassians are excluded from the PCA. The number of individuals per population can be found in Supplementary Data Table 4.
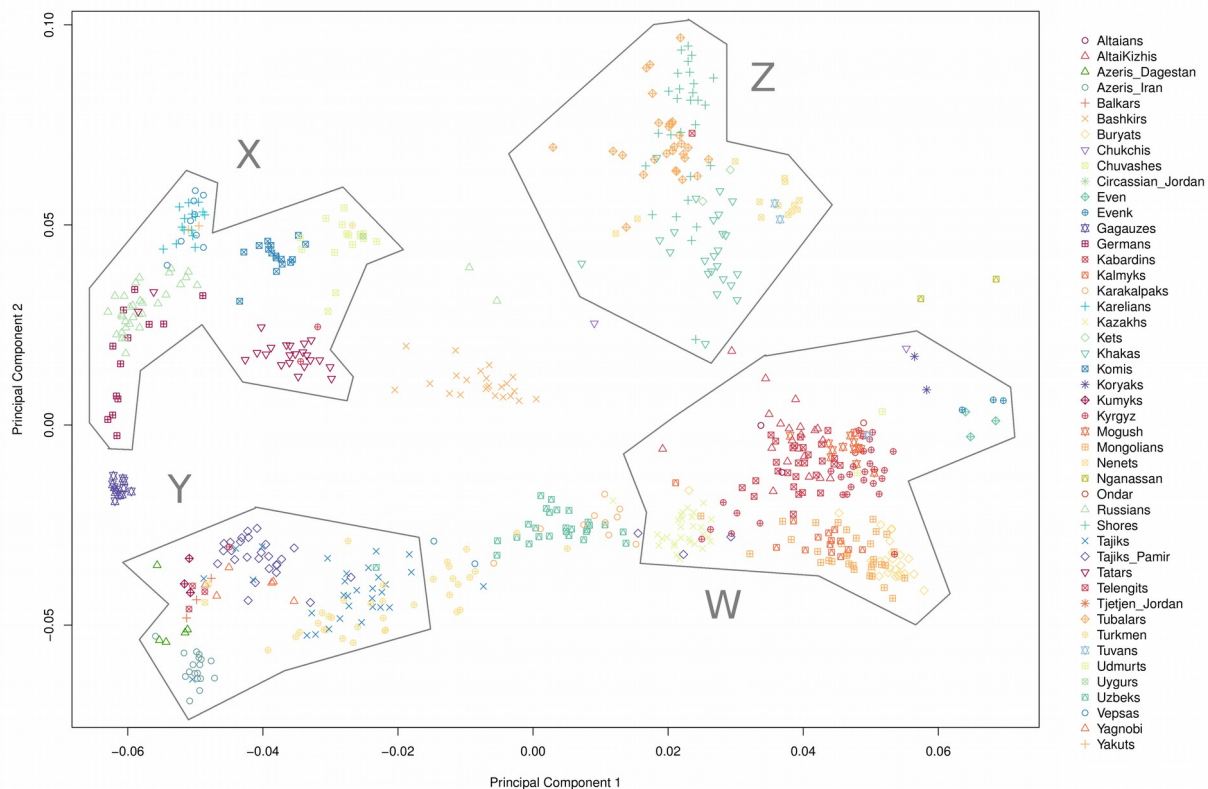
Supplementary Figure 159: Principal Component Analysis of the present-day dataset, excluding

Tjetjens and Circassians. The component were calculated using a final dataset of 385 individuals and 242,406 autosomal SNPs.

Interestingly, we discern a pattern of East Eurasian ancestry (Baikal Hunter-Gather like, from Glazkovo culture) driving PC1 and, Ancient North Eurasian MA1-like ancestry driving PC2. In order to confirm and illustrate that these ancestries are driving the clines representing the two Principal Components, we then calculate D-statistics for each populations of the clusters individually of the following forms: 1) for illustrating gradient of Principal Component 1: D(BHG, Mbuti; Cluster Z, Cluster X); D(BHG, Mbuti; Cluster W, Cluster Z); 2) for illustrating gradient of Principal Component 2: D(MA1, Mbuti; Cluster X, Cluster Y), D(MA1, Mbuti; Cluster Z, Cluster W). All of these D-statistics are highly significant towards the hypothesized value, i.e., reflecting increased shared ancestry between Baikal Hunter-Gatherers and cluster Z and W compared to X and Y respectively, and increased shared ancestry between MA1 and clusters X and Z compared to Y and W respectively (see Supplementary Data Table 4). Interestingly, in this dataset, we include three European populations Vepsas, Udmurts and Komis of Finno-Ugrian origin, and representing a recently described pole in the present-day European genetic diversity[211]. These groups Vepsas and Komis are at the MA1-rich extremity of PC2 indicating some MA1-like gene flow coming in through the arctic corridor of Siberia, independent of Bronze Age steppe impact in Europe, and therefore a population genomic history to be explored in future studies to remedy the absence of relevant ancient genomes.

Formation of the Central Asian gene pool

We identified the ancestral representatives composing the extremities of the first two dimensions on the Principal Component Analysis with the ancient samples (Main Figure 2). They are samples from previously published data (Natufian from the Near East[154], and Eastern Hunter-Gatherers, EHG, from Eastern Europe[1]) and new East Asian hunter-gatherer sequences obtained in this study (Lake Baikal Hunter-Gatherers, BHG). We find that almost all the steppe populations, across both time and space, can be modelled using qpAdm[1] as a mixture of these three ancestral hunter-gatherer groups, while some require additional specific. In particular, broadly across West Eurasia, an additional Mesolithic hunter-gatherer source was required (Western Hunter-Gatherers, WHG, from Europe[212–214]), and finally in the Far-East, Chukchis required Native American ancestries (here Clovis, a Paleoamerican[215]).
In total, we trace back the genetic history of present-day populations by exploring their ancestries relatively to these five hunter-gatherer populations. We infer the proportion of each ancestry with the qpAdm approach[1] (Supplementary Data Table 4). Our results show an increase in Baikal HG ancestry eastwards (on average, 67% in Inner Asia, against 20% in Caucasus and 27% in Europe; Spearman's correlation between longitude and Baikal HG ancestry part: rho=0.82, p-value=1*10^{-15}), while westwards the Natufian and EHG ancestries increase (in total, 80% in Caucasus; 55% in Europe; 35% in Asia; Spearman's correlation between longitude and respective ancestry part: rho=-0.82 and -0.54, p-values=4*10^{-12} and 2*10^{-4}). This confirms two obvious trends: East Asian ancestries increase at the expense of Natufian and EHG ancestries along an East/West geographical cline (Supplementary Figure 160).
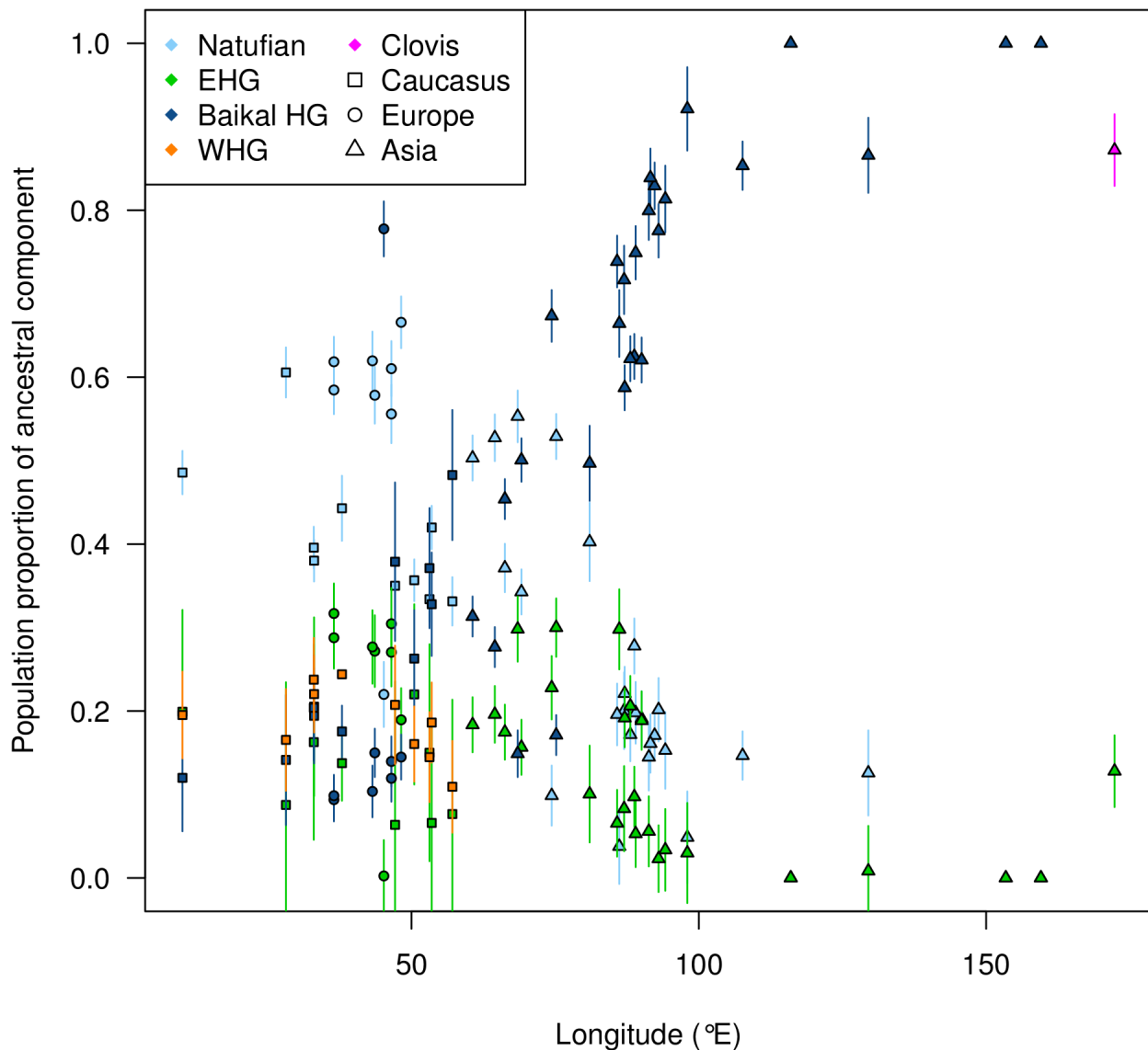
Supplementary Figure 160: Hunter-Gatherer ancestries for each of the 46 populations understudy, as a function of its longitudinal coordinate (°N). Each ancestry is plotted with its standard error x 2, available in Supp. Table. 4.

European and Caucasian present-day populations are differentiated by WHG ancestry in present-day European populations (19%), and an excess of Natufian in Caucasians (56% against 41% in Europeans). We also correlated the Natufian ancestry with latitude, revealing a negative association (Spearman's correlation between latitude and Natufian ancestry part: *rho*=-0.66, p-value=7*10^{-7}), coupled to the requirement of WHG ancestry (Supplementary Figure 161).
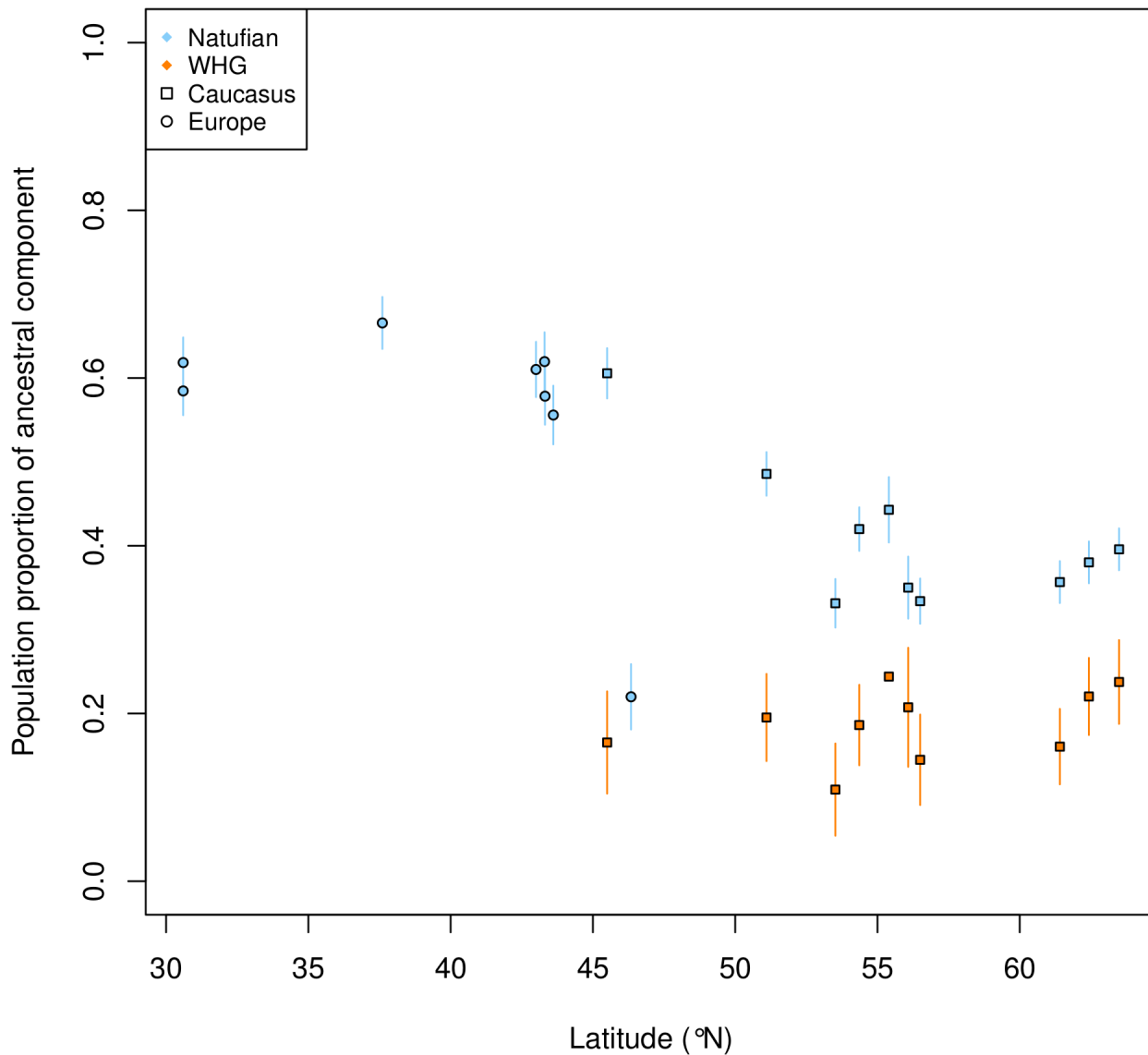
Supplementary Figure 161: Natufian and WHG ancestral proportions in Caucasian (N=8) and European (N=10) populations according to their latitude (°E). Each ancestry is plotted with its standard error x 2, available in Supplementary Data Table 4

All the results are illustrated in Supplementary Figure 162. Importantly, we note that the 'Native American' ancestry in Chuckchis is highly inflated (87%) as Clovis ancestry then replaces East Asian ancestry in the model.
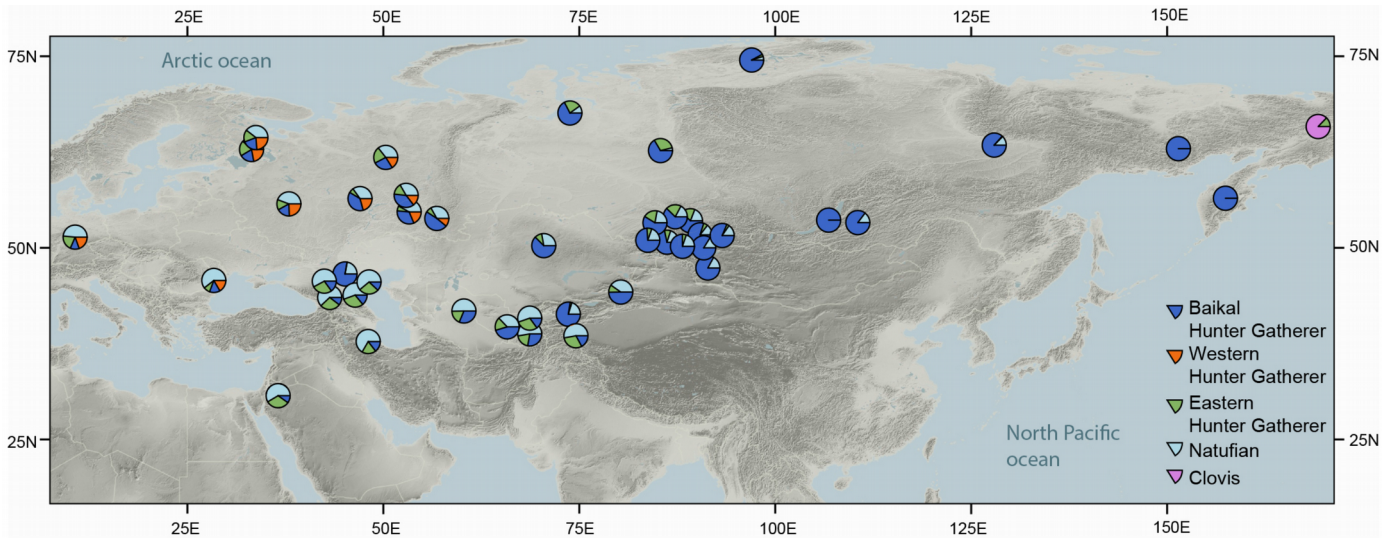
Supplementary Figure 162: A depiction of hunter-gatherer ancestries in present-day populations. The East/West gradient of Baikal and Eastern Hunter-Gatherer ancestry is evident (blue) while the distribution of Natufian ancestry is notable in the Near East (light blue), the southern fringes of the steppe and Europe where Western Hunter-Gatherer ancestry is evident (orange). The Clovis ancestry (pink) is only required for Chuckchis from the extreme east of Asia in these models.

Finally, we computed ADMIXTURE runs with K=2 to K=20 (Supplementary Figure 163) in a total of 20 replicates per run, with the full dataset containing ancient and present-day data. The results are visualized in three plots: "Previously published ancient genomes", "Present-day SNP data", "New ancient genomes".

K = 2
20/20 runs

K = 3
20/20 runs

K = 4
20/20 runs

K = 5
20/20 runs

K = 6
20/20 runs

K = 7
20/20 runs

K = 8
20/20 runs

K = 9
20/20 runs

K = 10
20/20 runs

K = 11
20/20 runs

K = 12
20/20 runs

K = 13
20/20 runs

K = 14
20/20 runs

K = 15
20/20 runs

K = 16
20/20 runs

K = 17
20/20 runs

K = 18
20/20 runs

K = 19
20/20 runs

K = 20
20/20 runs

Avg. pairwise similarity: 1

K = 2
20/20 runs

K = 3
20/20 runs

K = 4
20/20 runs

K = 5
20/20 runs

K = 6
20/20 runs

K = 7
20/20 runs

K = 8
20/20 runs

K = 9
20/20 runs

K = 10
20/20 runs

K = 11
20/20 runs

K = 12
20/20 runs

K = 13
20/20 runs

K = 14
20/20 runs

K = 15
20/20 runs

K = 16
20/20 runs

K = 17
20/20 runs

K = 18
20/20 runs

K = 19
20/20 runs

K = 20
20/20 runs

Supplementary Figure 163. Model-based clustering ADMIXTURE analyses. Ancetral clusters were fixed from K=2 to K=20 and all models were run with 20 replicates. All present-day and ancient populations were included in the ADMIXTURE runs.

Without surprise, these analyses revealed gradients of ancestry across the Eurasian steppe, explained by archaeological and proto-historical genomes. The historical transect (Figure 4 from main text) portrays the genetic composition of more recent ancient cultures (e.g. Scythians, Sarmatians, Xiongnu, Turkic-speaking Khanates) revealing that these groups can, just like the present-day populations, all be modeled as mixtures of the same five Eurasian hunter-gatherer groups. This illustrates that the vast majority of present-day variation is explained by i) genetic drift occurred in a period of human history characterized by smaller hunter-gatherer populations, and ii) by admixture between groups with varying proportions of these hunter-gatherer ancestries during the last 5,000 years. Thus, the genomic transect of the last 5,000 years of steppe nomads depict a complex history of gradual admixture, in particular between groups with increased genomic ancestries traced back to East Asian hunter-gatherers (here represented by 4 individuals from the early Bronze Age Lake Baikal).

In this study, we pictured the genetic landscape of the whole Eurasian steppe, for a considerable dataset of SNPs. We highlighted genetic differences between geographical and cultural groups, such as Eastern Europe, Caucasus, East and Central Asia, and Siberia. Finally, we found that these differences could largely be explained by increased Near Eastern ancestries in populations living south of the steppe belt, and increased East Asian ancestries in central and eastern steppe nomads, as well as particular Altaian groups.

Section 6: Comparing ancient DNA preservation in the mineral and organic phases of tooth cementum

Peter de Barros Damgaard

Adult tooth cementum is typically classified in two categories, the acellular extrinsic fiber cementum which covers the cervical part of the root and the larger and thicker cellular intrinsic fiber cementum which covers the apical part of the root[216]. Both of these histological substrates have been shown to preserve ancient DNA for thousands of years: surprisingly, ancient DNA has been successfully retrieved from infant teeth where only the cervical part is preserved, despite this substrate being acellular[2]. This outlines that endogenous DNA is deposited, and protected, within extracellular matrix.

Both of these substrates contain densely packed collagenic fibres embedded with a mineralized fraction namely the incremental lines[216]. It has been shown through PCR-based approaches that endogenous DNA is preserved in both mineral matrices and within the organic fibres of long bone[217,218], however, the same is currently unknown for tooth cementum. Tooth cementum is unequivocally categorized amongst the two optimal substrates for ancient DNA next-generation sequencing[138,140] rendering such a comparison of considerable importance. Furthermore, whether either fraction represents an optimal target in terms of retrieval of the highest human DNA proportions is unknown altogether from any substrate. In order to remedy this lack of knowledge, we extracted DNA from the two different phases of the digested tooth. This was undertaken by first applying a demineralization of the tooth cementum in an EDTA buffer for 24 hours, followed by a full enzymatic digestion of the proteinaceous material, according to guidelines outlined in[217].

Results and interpretation

Previous experiments have underlined that during a two-step digestion, environmental contamination is greatly reduced in the second extraction, in the range of 3-fold on average[138,219–222]. For this reason, the data is expected to be highly biased towards an improved organic fraction (post-demineralization), and does for this reason not directly reflect true substrate specific human proportions.

Our results indicate that the mineral phase yielded just as high fractions of human DNA than the paired organic phase (paired t-test: $t = 0.2945$, $df = 13$, p-value $= 0.7731$). We find that this may well suggest better preservation conditions in the mineral phase, since the results counter the expected bias towards a better second extraction. The results are indicative: the mineral matrix could protect human DNA better from exogenous contaminants, and applying a 24 hour demineralization prior to collagen digestion may eventually result in two optimized extracts, compared to one extract obtained through standard approaches; ie. one extraction improved through the optimized target, the mineral phase, and one extraction improved for the in-depth superficial rinse provided by the 24 h demineralization step prior to dissolving the organic phase.

This experiment clearly calls for an additional experiment not carried out here. We encourage the undertaking of an experimental setup in which half the tooth root, preferably from a well-preserved 'homogeneous' tooth, is dissolved through the same conditions as applied here, and the other half is solely subjected to a standard full digestion.

Here we briefly present a comparison of the human proportions in either fractions and report no

significant differences in the human proportions (paired two-tailed t-test t = 0.2945, df = 13, p-value = 0.7731) nor the degree of deamination damage (paired two-tailed t-test t = 0.9716, df = 7.687, p-value = 0.3608).
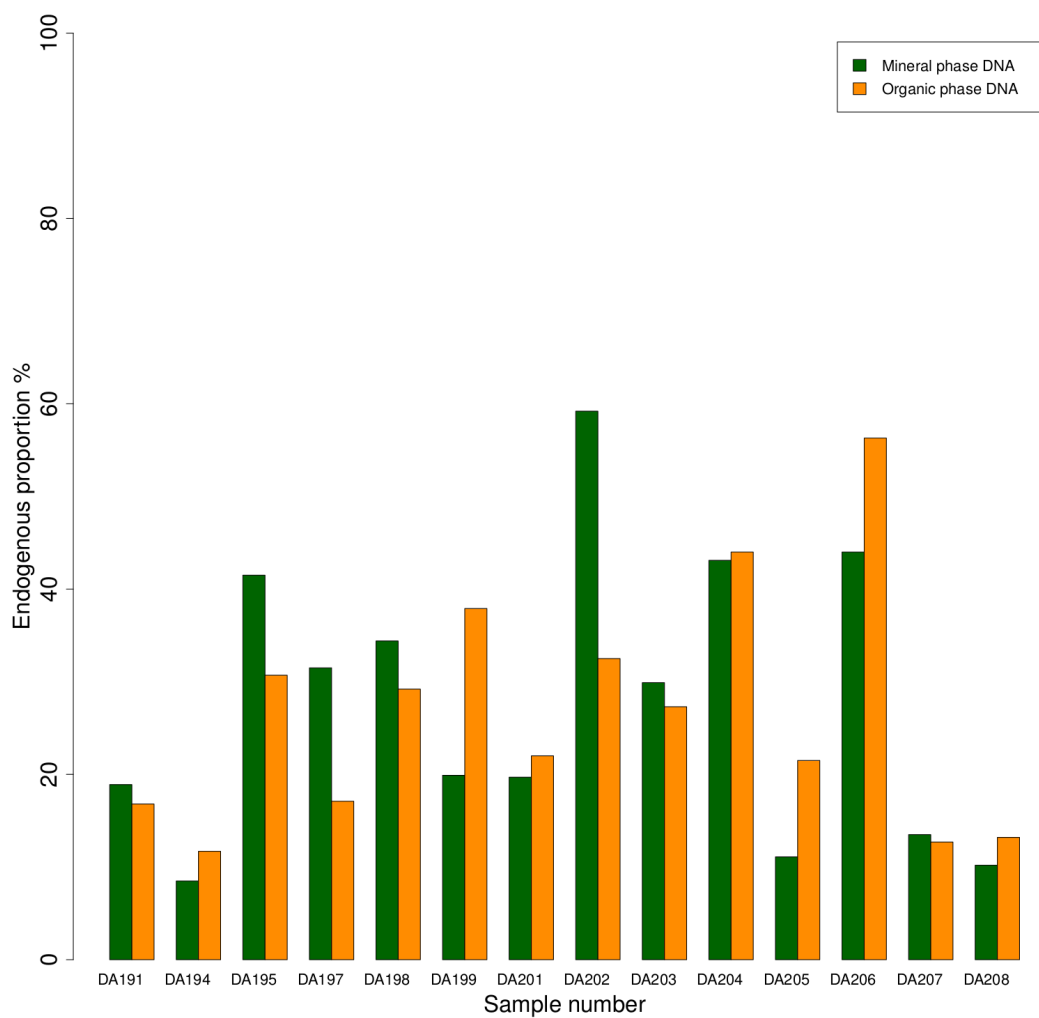
Supplementary Figure 164. Human DNA content in the two substrates in 14 samples.

Section 7: Iron Age plague genome reconstructions

By Simon Rasmussen, Peter de Barros Damgaard, Kasper Nielsen, Anders Gorm Pedersen

Y. pestis genome assembly

We followed the procedures of[31] and screened all trimmed reads for *Y. pestis* by mapping using bwa mem 0.7.10[223] to a collection of *Y. pestis*, *Y. pseudotuberculosis* and *Y. enterocolitica* genomes. All reads with any hit to these genomes were kept and mapped using bwa aln 0.7.10[146] with the seed disabled to both *Y. pestis* CO92 and *Y. pseudotuberculosis* IP32953 reference genomes. Hereafter individual runs were merged to library level using samtools-1.3.1[147] and had duplicates removed using picard-1.127, were merged to sample level, realigned using GATK-3.3.0[148], had baqs calculated and md-tags updated using samtools. Only 2 out of 140 screened samples had at least 10% of the genome covered by at least one read and a depth of >0.1X and were considered candidates for further analysis. All other samples had covered less than 1% of the genome and an average depth less than 0.1X. The two positive samples (DA101 and DA147) had good coverage and depth on both the chromosome and the plasmids and copy numbers for the three plasmids were around 1, 2 and 8-10 for pMT1, pCD1 and pPCP1, respectively (Supplementary Table 7.1 and 7.2). These samples were therefore re-scaled using mapDamage-2.0.6[151] to mask damaged bases.

Y. pestis authentication

We investigated DNA damage patterns of the reads mapping to the *Y. pestis* CO92 genome and found them to have an average fragment length of 53.5 and 45.8 nt, respectively. Additionally, DNA damage patterns mached the expected pattern of ancient DNA with excess of C-T and G-A substitutions on 5' and 3' ends. Furthermore the damage pattern was observed for each of the chromosome and plasmids (Supplementary Figure 165).

We investigated read mapping affinity patterns of the reads mapping to the screening database by comparing edit distances when mapped to *Y. pestis* and *Y. pseudotuberculosis* reference genomes (Supplementary Figure 166). Similarly to Rasmussen et al., 2015 we used known single genome isolate strains from *Y. pestis*, *Y. pseudotuberculosis* and *Y. similis*[224] as representatives for known genomes and found the distribution of DA101 and DA147 to match the distribution of known *Y. pestis* strains.

Genotyping and phylogenetic reconstruction

We hereafter called genotypes for the DA101 genome as described earlier[31]. In short we used the DNA damage-rescaled alignment to *Y. pseudotuberculosis* IP32953 and called genotypes using samtools-1.3.1 and bcftools-1.3.1 using the consensus calling model (bcftools call –c) and filtered by removing heterozygote variants, indels and variants that clustered within 10bp of each other, as well as variants within 10 bp of a gap. Genotypes were filtered for at least 4 high quality base calls per site and full-length consensus sequences were created by adding N basecalls for all missing sites. The gene model of IP32953 were used to call consensus sequences for each gene and genes with high rates of missing bases (20 or more modern *Y. pestis* samples had >10% of the gene missing) were removed.

We only kept the *Y. pestis* strains (142 taxa) and the resulting 3,141 genes were merged to a supermatrix and used for phylogenetic analyses. We partitioned the supermatrix in 3 partitions based on average pairwise distances within each gene across the 142 taxa so that the partitions contained genes with an average pairwise distances of: less than 1E-5; between 1E-5 and 5E-5; and greater than 5E-5 corresponding to 1921, 745 and 470 genes, respectively. The phylogeny was reconstructed using

RAxML-8.1.15[225] with the GTR+G+I substitution model. Bootstraping was performed by generating 100 bootstrap replicates and their corresponding parsimony starting trees using RAxML. Hereafter, a standard Maximum Likelihood inference was run on each bootstrap replicate, and the resulting best trees were merged and drawn on the best ML tree. The resulting tree is illustrated in Extended Figure 9.

Variant comparisons

Single nucleotide variant (SNV) comparison was performed by genotyping rescaled alignments to *Y. pestis* CO92 following the same parameters as above. In total 288 sites were found to be different between 0.ANT4 or 0.ANT5 compared to CO92 and 102 of these were identical in 0.ANT4 and 0.ANT5. Because CO92 is derived compared to the MRCA of the two strains we used strains 620024 (0.PE7 clade) and 42013 (0.ANT1 clade) to identify variants that occurred after the split of 0.ANT4 and 0.ANT5, which we termed ancestral compared to CO92. Of the 102 identical variants 101 were ancestral compared to CO92 and only 1 variant was unique for both 0.ANT4 and 0.ANT5. Of the 186 sites that were different between 0.ANT4 and 0.ANT5, 89 variants had missing data in either 0.ANT4 or 0.ANT5 and were not used for the variant comparison. Of the remaining 97 sites, 92 were unique to 0.ANT4 (Aschheim) and 5 sites unique to 0.ANT5 (Tian Shan).

Variant effect

We investigated variant effect of the five unique SNVs in the 0.ANT5 strains using SnpEff[226] and found four of the variants to be intergenic and one variant to be a missense mutation (pos. 3641873, C>T, Pro164Ser) in a putative methyltransferase gene (*yfiF*). Additionally, to identify the potential for flea transmission we investigated loss of function mutations in pde2[32], pde3[32], *rcsA*[32] and *ureD*[227] and for the presence or absence of *ymt*[228]. Furthermore, we investigated whether the 0.ANT5 strain had the auto-catalytic form of *pla*, enabling *Y. pestis* to cause bubonic plague[229]. Based on the phylogenetic position of 0.ANT5 we expected all of the above genes to have loss of function mutations, *ymt* to be present and *pla* to be present in the autocatalytic form (I259T).

- For *pde2* we investigated for the presence of a 6A>7A frameshift insertion at position 1,560,134 (IP32953). The frameshift mutation was supported by 10 reads when compared to IP32953.
- For *pde3* we investigated for the presence of both the promoter mutation at position 3,944,166 (IP32953) and the nonsense mutation at position 3,944,534 (IP32953). The promoter mutation (C>T) was supported by 3 non-damaged reads and the nonsense mutation (G>A) by 7 non-damaged reads.
- For *rcsA* we performed *de novo* assembly using SPAdes-3.9.0 and aligned the assembly to IP32953 and CO92. We could not identify the 33bp internal duplication in 0.ANT5, however all other strains derived from 0.PE7 had the internal duplication. It is therefore likely that the internal duplication not identified in DA101 could be caused by an assembly error where the duplication is collapsed in the *de bruijn* graph.
- For *ureD* we investigated for the presence of a 6G>7G frameshift insertion at position 3,470,756 (IP32953) and found the insertion to be supported by 4 reads.
- For *pla* we investigated for whether the 0.ANT5 strain had the derived allele (C) or the ancestral non autocatalytic allele (T) at position 7,500 on pPCP1 (CO92 genome). Here we found 72 reads supporting the derived allele and one read supporting the ancestral allele, which may be attributable to DNA damage.

A120 substitution rates

We used 25,000 post-burnin BEAST trees of the *Y. pestis* phylogeny from Rasmussen et al., 2015 to investigate whether the substitution rate on the branch leading to 0.ANT4 (A120/Aschheim) was higher compared to the substitution rates of the entire *Y. pestis* phylogeny. We extracted the estimated branch substitution rates from each node in the trees and for each tree determined the fraction of substitution rates that was smaller compared to that of 0.ANT4 (Supplementary Figure 166). Additionally we determined the number of times that the substitution rate of 0.ANT4 was the highest in a particular tree.

Supplementary Tables

Sample	TotalReads	TrimReads	MappedReads	Duplicates	FinalReads	Duplicates %	CovMore1X	AvgDepth	Avg Fragment Length
DA101	404,608,972	386,988,989	1,089,974	307,813	782,161	28.24	0.95	8.68	53.5
DA147	168,258,736	148,079,111	25,947	985	24,962	3.80	0.20	0.24	45.8

Supplementary Table 7.1. Assembly statistics of the two *Y. pestis* positive samples.

	AvgDepth (X)					Coverage >= 1X				
Sample	CO92	pMT1	pPCP1	pCD1	Total	CO92	pMT1	pPCP1	pCD1	Total
DA101	8.41	9.67	62.85	18.03	8.68	0.95	0.94	0.80	0.93	0.95
DA147	0.23	0.27	2.30	0.64	0.24	0.20	0.24	0.75	0.45	0.20

Supplementary Table 7.2. Coverage and depth separately for the chromosome and plasmids.
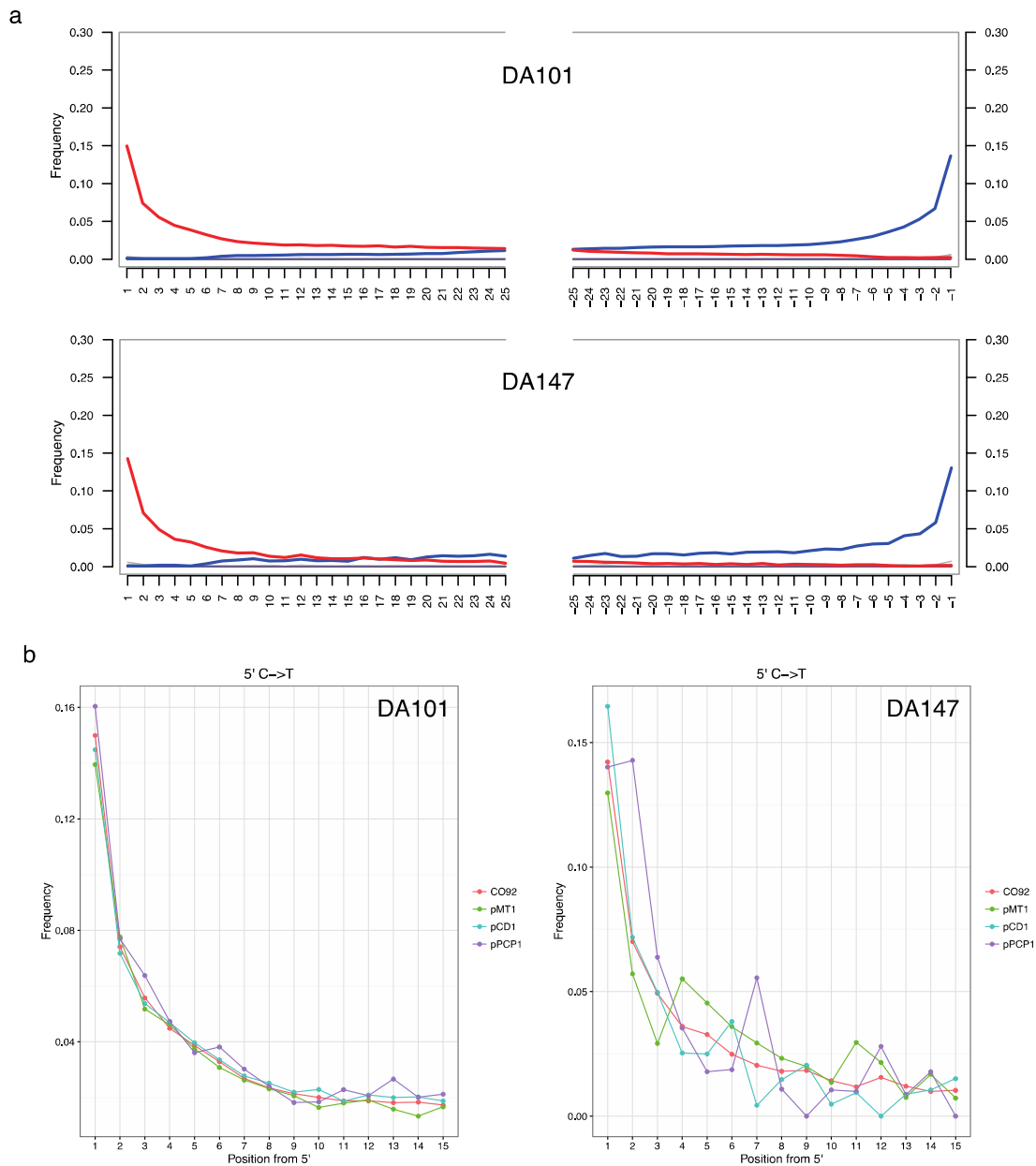
Supplementary Figure 165. (a) DNA damage patterns for DA101 and DA147. The frequencies of all possible mismatches observed between the *Y. pestis* CO92 chromosome and the reads are reported in gray as a function of distance from 5' (left panel, first 25 nucleotides sequenced) and distance to 3' (right panel, last 25 nucleotides). The typical DNA damage mutations C>T (5') and G>A (3') are reported in red and blue, respectively. (b) C-T damage patterns in the 5' of the reads aligned to the CO92 chromosome (red) and the *Y. pestis* associated plasmids pMT1 (green), pCD1 (blue) and pPCP1 (purple).
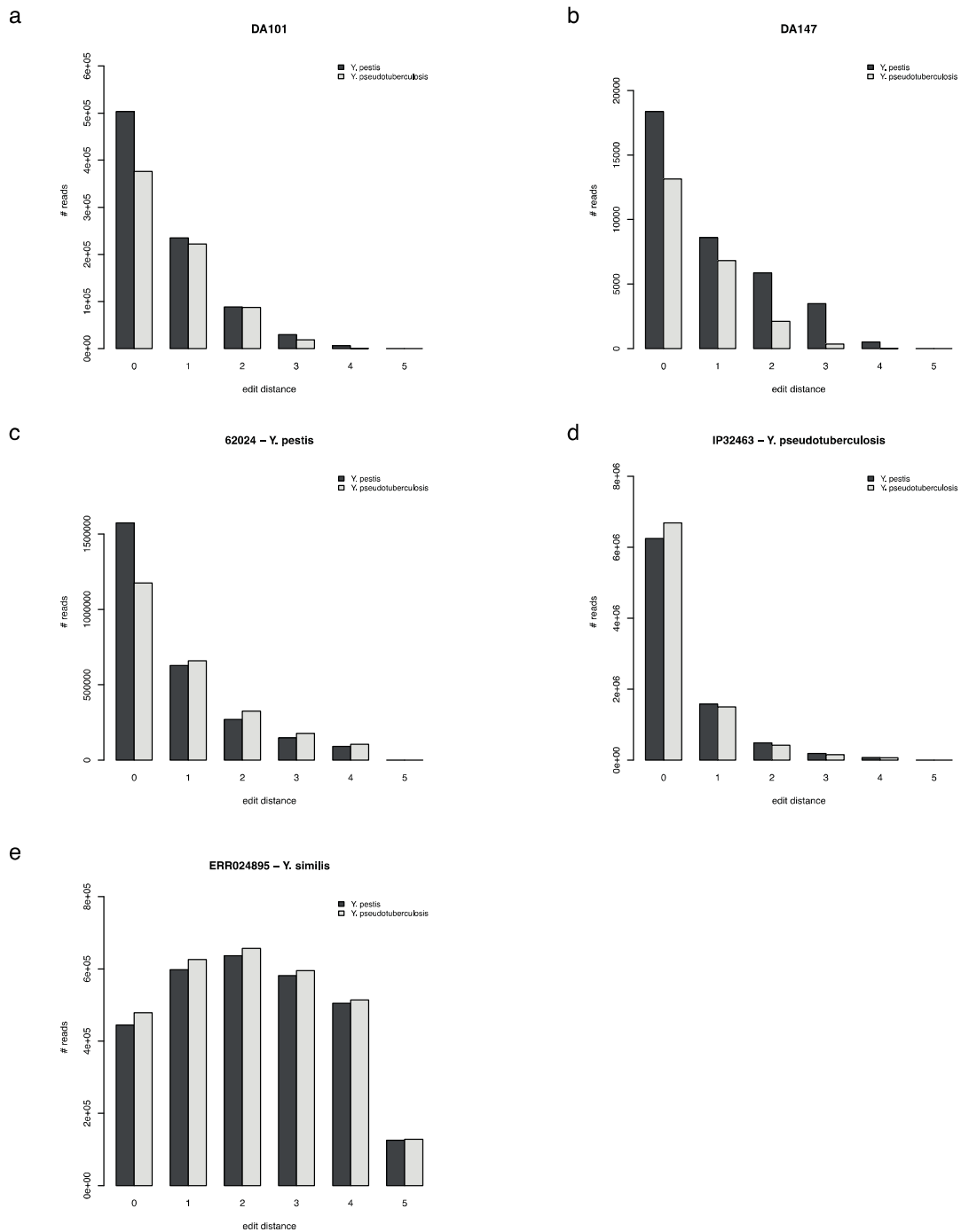
Supplementary Figure 166. Edit distance distributions of high quality reads from DA101 (a) and DA147 (b) as well as reads of known origin (c-e). The investigated, known reads are from *Y. pestis* 620024 (0.PE7), *Y. pseudotuberculosis* (IP32464) and *Y. similis* (ERR024895). The reads from DA101 and DA147 follow the same distribution as the known *Y. pestis* strain 620024 and are therefore likely derived from an actual *Y. pestis* strain.
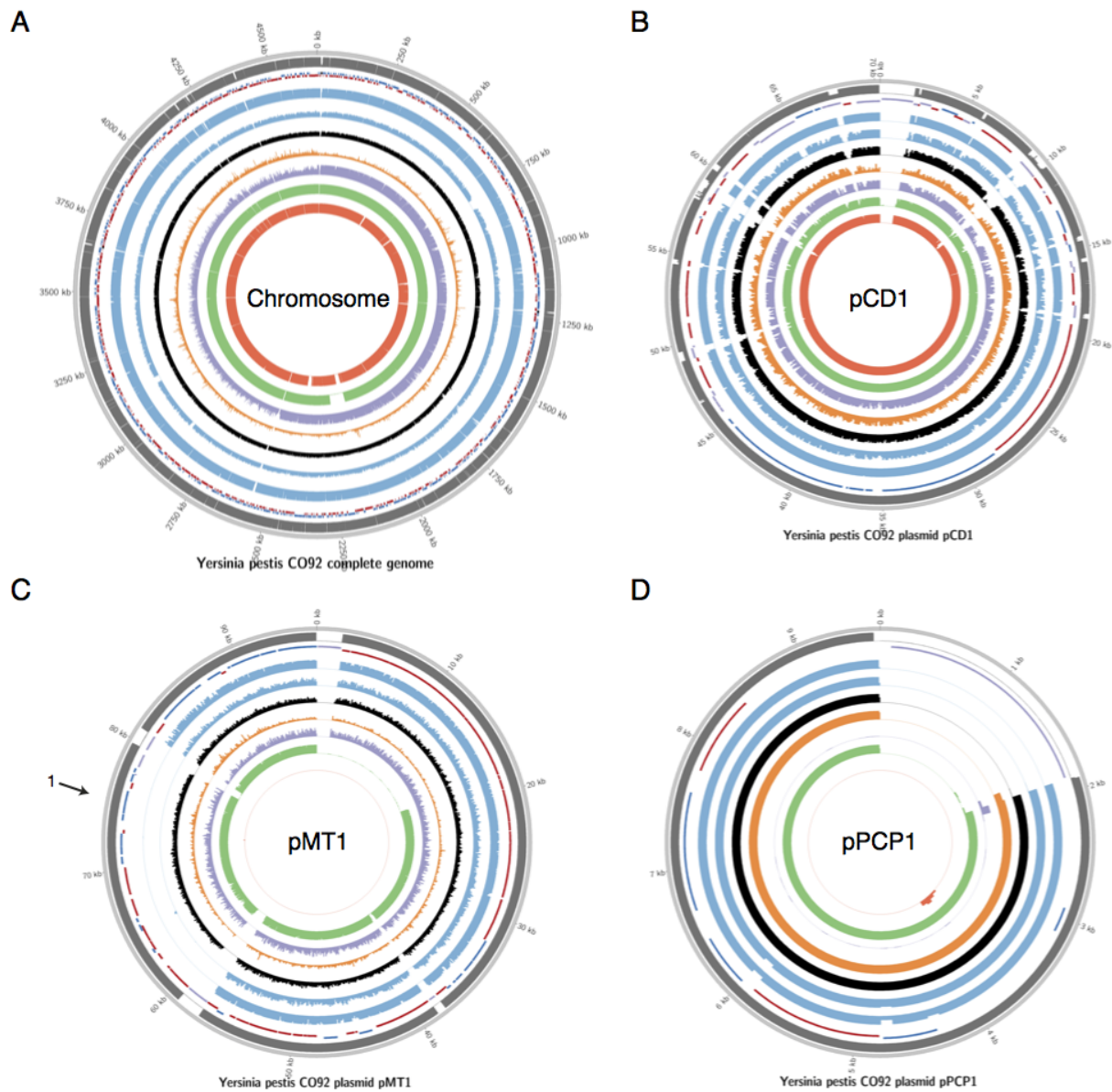
Supplementary Figure 167. (A–D) Depth of coverage plots for (A) CO92 chromosome, (B) pCD1, (C) pMT1, (D) pPCP1. Outer ring: Mappability (gray), genes (RNA: black, transposon: purple, positive strand: blue, negative strand: red), RISE509 (blue), RISE505 (blue), DA101/Tian Shan (black), Justinian /Aschheim plague (orange), Black Death plague (purple), modern *Y. pestis* D1982001 (green), *Y. pseudotuberculosis* IP32881 (red) sample. The modern *Y. pestis* and *Y. pseudotuberculosis* samples are included for reference. The histograms show sequence depth in 1 kb windows for the chromosome and 100 bp windows for the plasmids with a max of 10X depth for each ring. Arrow 1 shows the position of the *ymt* gene and that there is clear coverage in that region for the Tian Shan sample (DA101 - black).
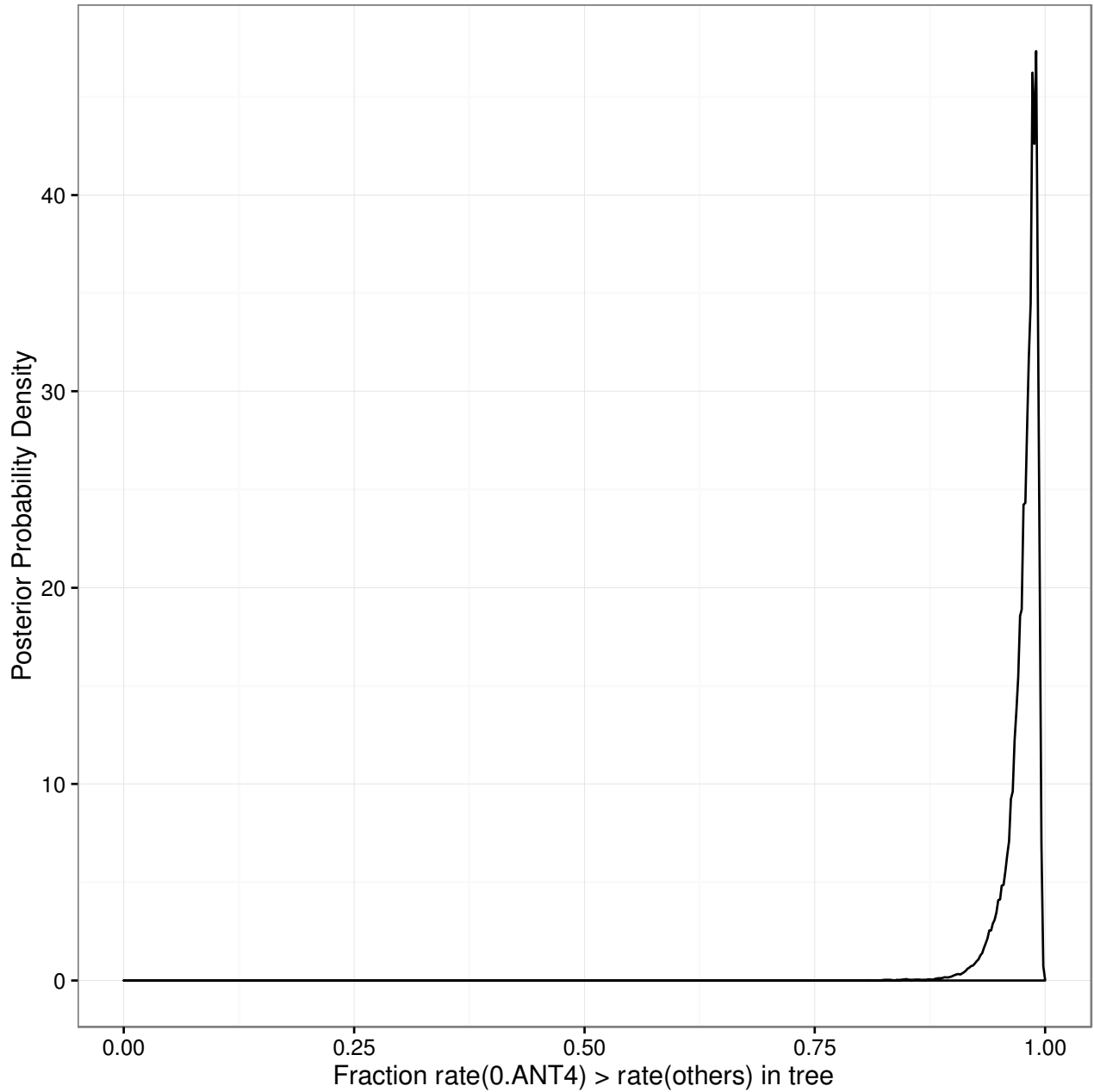
Supplementary Figure 168. The substitution rate on the branch leading to 0.ANT4 is generally higher compared to all other substitution rates in the *Y. pestis* phylogeny. Based on 25,000 post-burnin BEAST trees from Rasmussen et al., 2015 we determined the fraction of branch substitution rates in each tree that were smaller than the 0.ANT4 substitution rate. Posterior mean 0.977, 95% HPD interval 0.94-0.99).

Section 8: Y-chromosome analyses

Angela Taravella, Melissa Sayres

Data preparation: SNP calling and filtering

A total of 41 present-day and 147 ancient male individuals were included in the analyses of the Y chromosome. Initially, coverage was computed across all samples using GATK (v3.6)'s DepthofCoverage[230]. Coverage on the Y chromosome ranged from 0.00 to 2.42 and 9.15 to 15.9 for the ancient and present-day samples, respectively. Four individuals were removed from downstream analyses due to 0.00 reported coverage. Variants were called separately for the present-day and ancient samples. To account for post mortem DNA damage, three call sets were generated for the ancient samples, one set with trimming reads 5 base pairs on both sides, one with no trimming, and one with rescaled quality scores. Trimming was conducted using the trimBam function of the program bamUtil v1.0.14. Quality scores were down rescaled in areas where post-mortem damage most likely occurred using mapDamage[151]. GVCFs were generated per sample (trimmed, untrimmed, and rescaled) using GATK's HaplotypeCaller and joint genotyped using GATK's GenotypeGVCFs. SNPs were then extracting from each call set; 58149 SNPs were called in the ancient call set without trimming, 37570 SNPs were called in the ancient call set with trimming, 30593 SNPs were called in the ancient rescaled call set, and 73935 SNPs were called in the present-day call set. According to GATK's best practices guidelines, hard filtering parameters were used on the present-day samples leaving 49557 SNPs (hard filter parameters: --filterExpression "QD < 2.0 || FS > 60.0 || MQ < 40.0 || MQRankSum < -12.5 || ReadPosRankSum < -8.0")[148,231]. Additionally, for all sets, sites were restricted to the callable regions as defined in Poznik et al. (2013)[232]; this left 8784 SNPs in the present-day set, 36648 SNPs in the ancient set without trimming, 21663 SNPs in the ancient set with trimming, and 14876 SNPs in the ancient rescaled set. For each ancient set, transitions were removed, leaving 1909 SNPs for the untrimmed set, 1515 SNPs for the trimmed set, and 1957 SNPs for the rescaled set.

Haplogroup analysis

Haplogroup assignment analysis was conducted for all individuals and call sets using YFitter v0.2, a haplogroup assignment program specifically designed for low coverage data[233]. The VCF files were first converted to plink .tped/.tfam files, using plink v1.07[156]. After converting the files, tped2qcall.py, a script provided with the YFitter package, was used to convert plink .tped/.tfam files into qcall files for input into YFitter. The haplogroups are summarized in Supplementary Data Table 4.

Section 9: Sarmatians and Alans

By Peter de Barros Damgaard, Gennady Afanasiev, Martin Sikora, Kristian Kristiansen, Eske Willerslev

The Sarmatians were a large Iranian speaking group occupying the western steppe neighbouring the Hungarian Scythians[234]. They were allies of the Scythian confederation during the second half of the Iron Age and persisted into the first centuries CE. According to Herodotus the Sarmatians descended from intermarriage between Scythian men and Amazon women of which the latter were fighting women, who had been expelled from the Cappadocian area, in present-day Turkey, but sailed to the Scythian territory around today's Azov Sea (Herodotus 4,110-117, mentioned in[58]). When the Huns entered the eastern steppe around 3rd century CE, many of the Sarmatians are argued to have admixed with East Asian newcomers forming the hybrid Hun-Sarmatian culture (revisited in[235]). However, it is also affirmed on both archaeological, historical, and linguistic grounds that in the 2nd-3rd centuries CE, a branch of Sarmatians moved into the northern Caucasus forming the Iranian speaking Alan culture that eventually transformed into the Ossets of today's Caucasus Mountains[112,236,237]. The Sarmatian and Alanic languages are only poorly known, but Ossetic descends from Alanic and Alanic seems to descend from Sarmatian[112] (see Supplementary Section 2). We here address the genetic relationship between Sarmatians and the neighboring Hungarian Scythians and lastly shed light on the disappearance of the Sarmatians from the steppe.

Principal Component Analysis, admixture analysis (Main Figure 2, Supplementary Figure 163), reveal that the Sarmatians of the Late Iron Age are genetically shifted towards present day South Siberian hunter-gatherers and Altaians as compared to the Hungarian Scythians. The relevant D-statistic is D(BHG_BA, Mbuti; Sarmatians, Hungarian Scythians)=0.03; Z= 11.09. Thus, the neighbouring Hungarian Scythians and Sarmatians were clearly genetically distinct. At the same time the Sarmatians harbor less East Asian ancestry than the Inner Asian Sakas, i.e. D(BHG_BA) = -0.05 ; Z = -14.87. This could suggest that these Sarmatians had a western steppe origin and the temporal difference between them and the Hungarian Scythians explains the difference in Inner Asian ancestry.

Two samples were excavated from a region and a time frame assigned to Hun-Sarmatian period, 200BCE-400CE[56]. The first individual in this dataset is an early "Hun-Sarmatian" nomad dating to ~200 BCE while the second dates much later to ~400 CE. Both of these individuals are of East Asian genetic descent and cluster with present-day Evens and Mongolians in the Eurasian PCA (Main Figure 2). The Hun-Sarmatian of 200 BCE from Sjiderty is the oldest example in our dataset of an individual whose ancestry is entirely attributed to the 'East Asian' cluster in the ADMIXTURE analysis, here illustrated at K=7 in Supplementary Figure 163, that was buried in the central steppe zone. Owing to the age of this sample, the results provides evidence that the Xiongnu nomads ventured far west, prior to the emergence of Hunnic culture. The later Hun-Sarmatian being also of clearly East Asian descent agrees with the archaeological models that suggest massive migrations of East Asians into the Sarmatian territory during this period.

In turn, we do not find evidence for substantial genetic contribution of Sarmatians to the 5th century Alans. Instead, we see that these north Caucasian Alans form a clade with the Iron Age Caucasian populations from Armenia with respect to the Sarmatians in a D-statistic. The vast differences between Sarmatians and Alans are illustrated with the D-statistics in Supplementary Figure 170, while there are no significant differences between Alan and Iron Age Armenians to report. Thus, while the Alan and

Osset cultures likely did receive their Iranian language from the Sarmatians, their genetic ancestry was already indistinguishable from the neighboring Caucasian populations by the 5th-6th Century CE. Finally, the evidence for a multi-ethnic Alanic alliance as suggested through the differences in East Asian ancestry of these individuals finds support in evidence of multi-linguism with indications of Turkic languages and Northeast Caucasian languages being used[238].
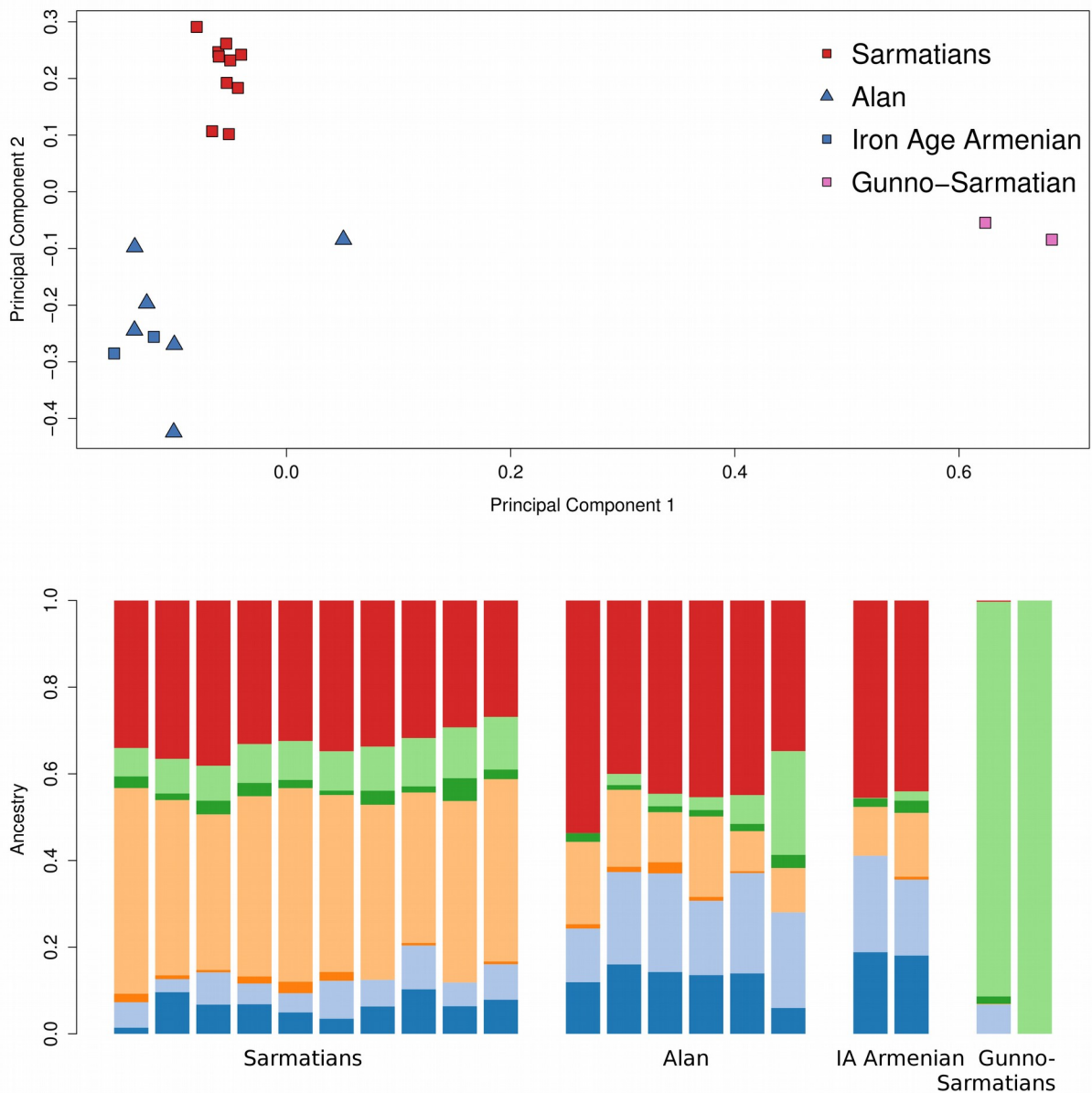
Supplementary Figure 169. Top: PC Analysis including only Sarmatians, Alans, Iron Age Armenians and the Gunno-Sarmatian nomads – ie. using 20 individuals and at 242,406 autosomal SNP positions. Bottom: Admixture analysis at K=7 presented in Section 4 displaying only relevant populations.
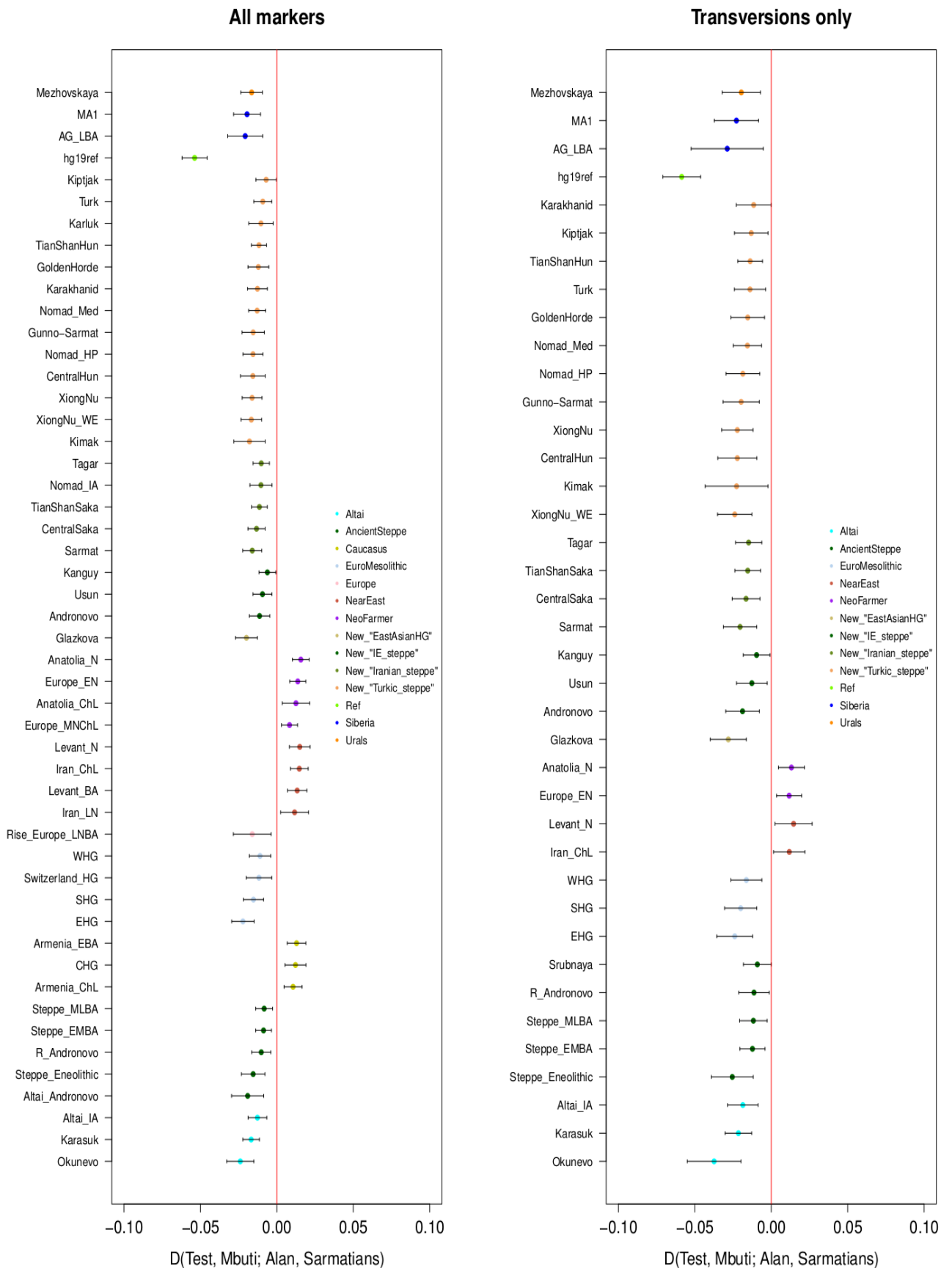
Supplementary Figure 170. All D-statistics of the form D(Test, Mbuti; Alan, Sarmatian). If the D-

score is positive this indicates increased shared ancestry between Alans and Test population, while the opposite is true for negative D-scores. The reported numbers are the D-statistics and the error bars represent 3 standard errors.

Section 10: Mitogenomes

By Gabriel Renaud & Peter de Barros Damgaard

Endogenous consensus call and contamination estimates

A Bayesian maximum a posteriori algorithm[144] was used in order to simultaneously infer the endogenous consensus as well as estimating the levels of present day human contamination. this algorithm is designed to mitigate the impact of ancient DNA damage as well as the potential present-day human contamination. The resulting endogenous consensus was further filtered using a PHRED score of 50 (chance of error: 1/100,000). Sequences for which more than 99% of the bases the mitochondrial genome had been resolved (i.e. not previously filtered or unsequenced) were retained for downstream analyses. To avoid redundancy, sequences for which we knew the family relationship were removed as well as sequences from the same individual but different extracts. A total of 138 sequences stemming from this study as well as 83 from the study[2] were aligned using PRANK v.150803. The resulting multiple sequence alignment was used as input for BEASTv1.8.2[239] to compute Coalescent Bayesian Skyline tree. A total of 100M Markov Chain Monte Carlo chains with the first 10M used as burn-in. Calibrated radiocarbon dates when they exist, or age estimates if else, for each sample were provided to BEAST. The HKY model using gamma plus invariant sites as well as a strict lock with a prior of 2.2E-8 for the mean and 8E-9 for the standard deviation.

Supplementary Figure 171 shows the resulting tree with the distribution of the different haplogroup families highlighted as subtrees. The overwhelming majority of mitogenomes belong to macro haplogroup N but 44 out of 221 pertain to M. Within the macro-haplogroup N, the majority of mitogenomes belong to either the H or U haplogroup (see Supplementary Figure 172 and 173). Among the mitogenomes that were identified as pertaining to the macro-haplogroup M (see Supplementary Figure 174), the Turkic steppes were overrepresented compared to the mitogenomes identified as belonging to the N. When looking at H and U haplogroups, a significant number stemmed from either Europe or the Iron Age 'Iranian-speaking' steppe compared to the ones from the M. In the N macro-haplogroup, among the most under-represented clades were I+N1 (see Supplementary Figure 175), W+X (see Supplementary Figure 176) and F (see Supplementary Figure 177). At an intermediated representation were the J+T(see Supplementary Figure 178) and A+N9 (see Supplementary Figure 179).
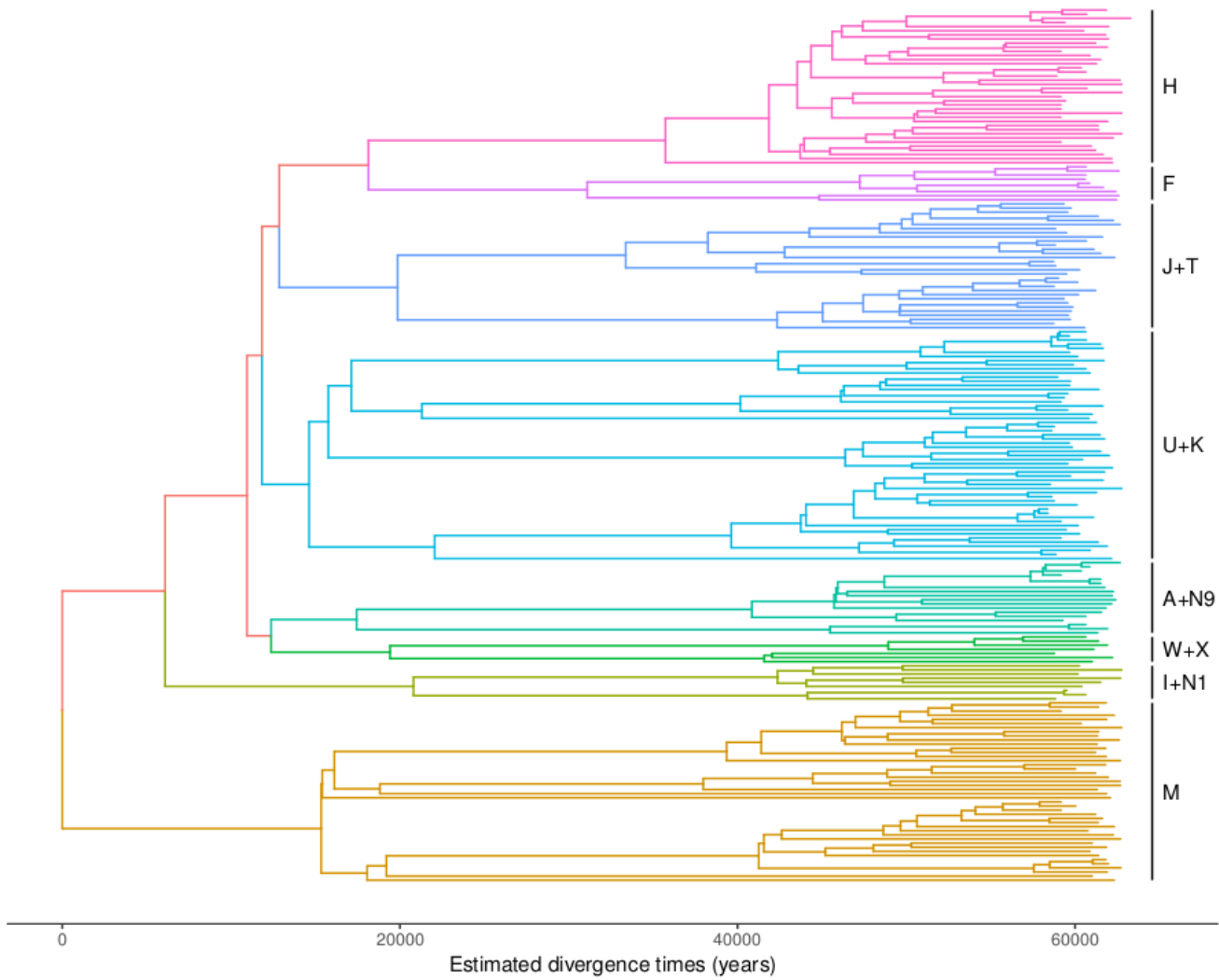
Supplementary Figure 171. Phylogenetic tree of 221 ancient mitogenomes with haplogroup families highlighted.

Haplogroup(s): H

Altai
Caucasus
Europe
IE steppe
Iranian steppe
New "Iranian steppe"
Turkic steppe
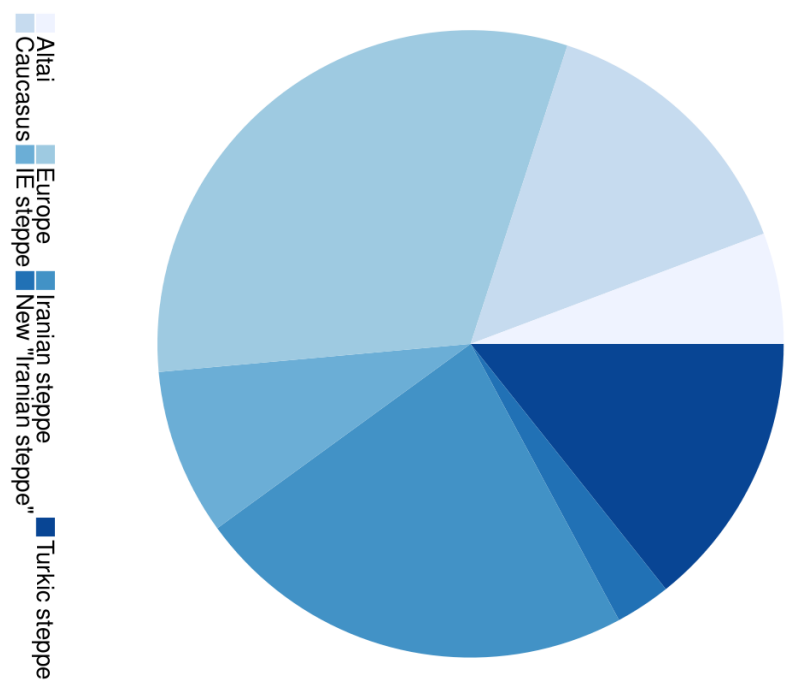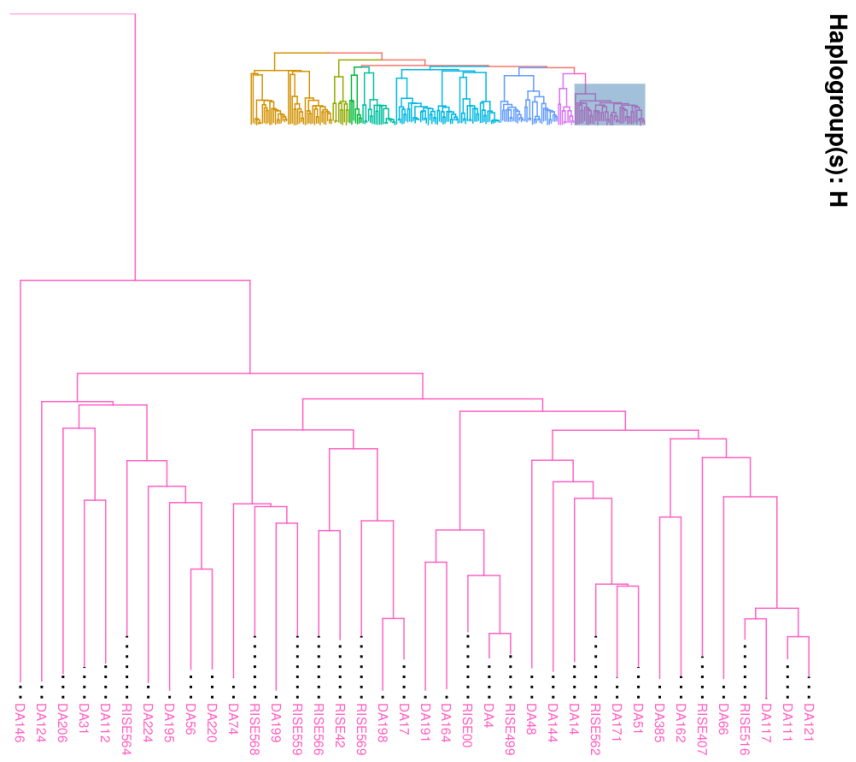
Supplementary Figure 172. Distribution of haplogroup H mitogenomes
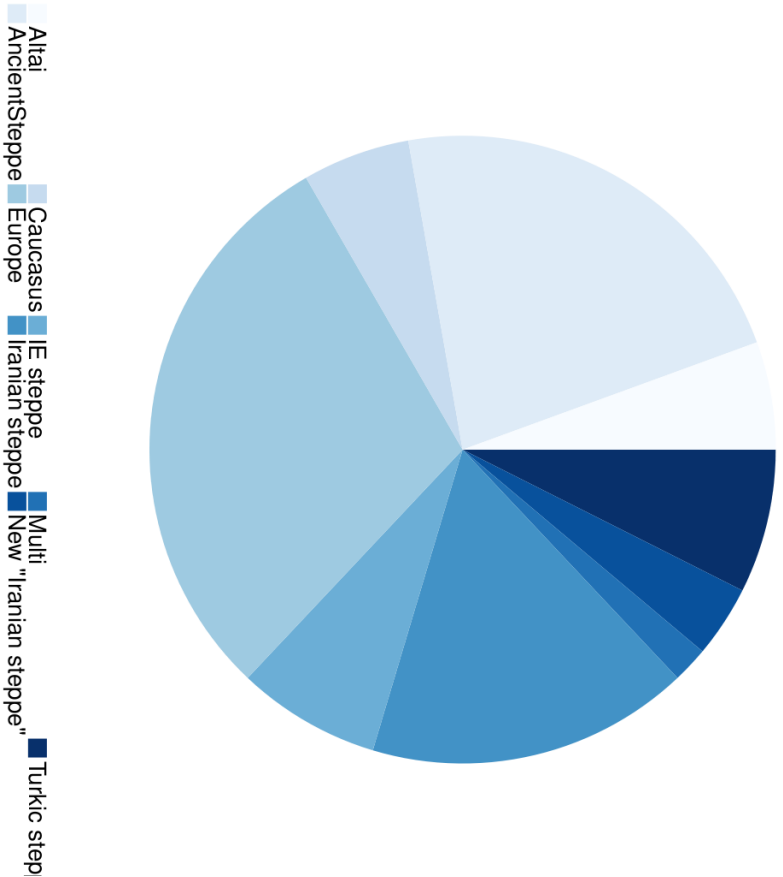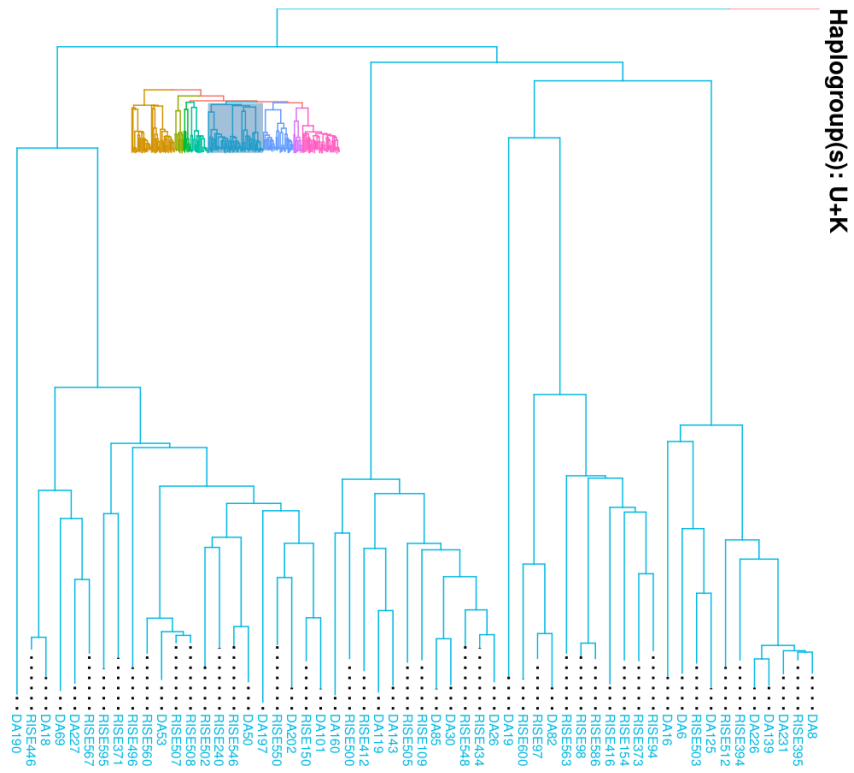
Supplementary Figure 173. Distribution of haplogroup U+K mitogenomes
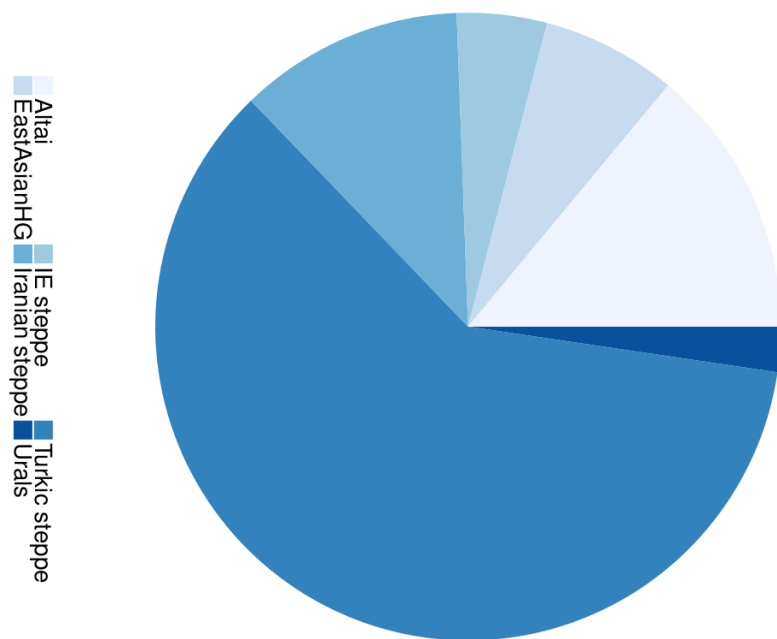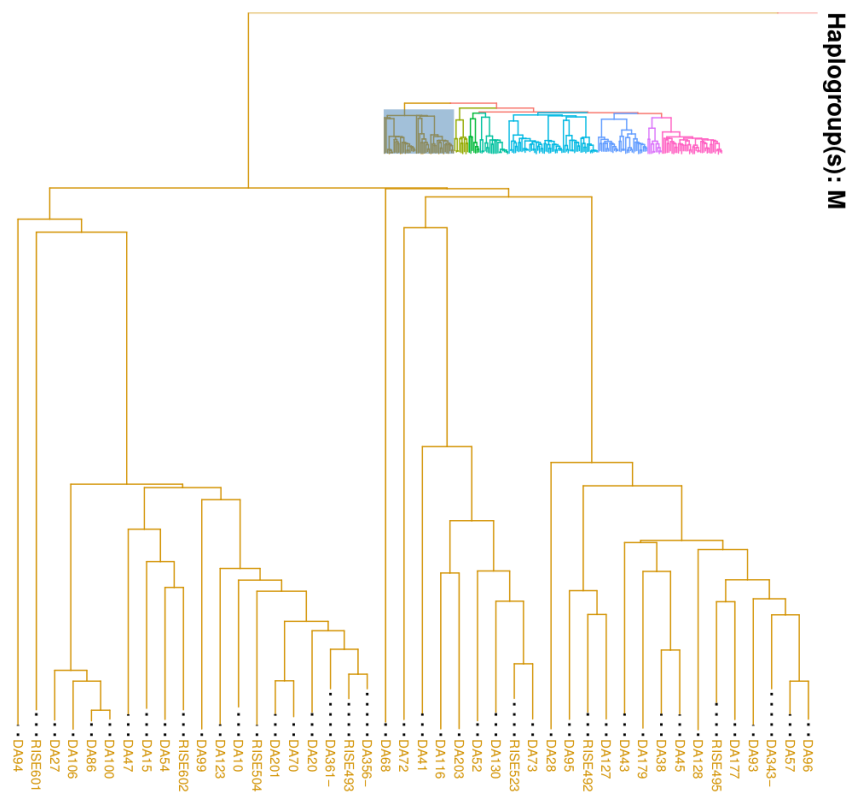
Supplementary Figure 174. Distribution of macro-haplogroup M mitogenomes
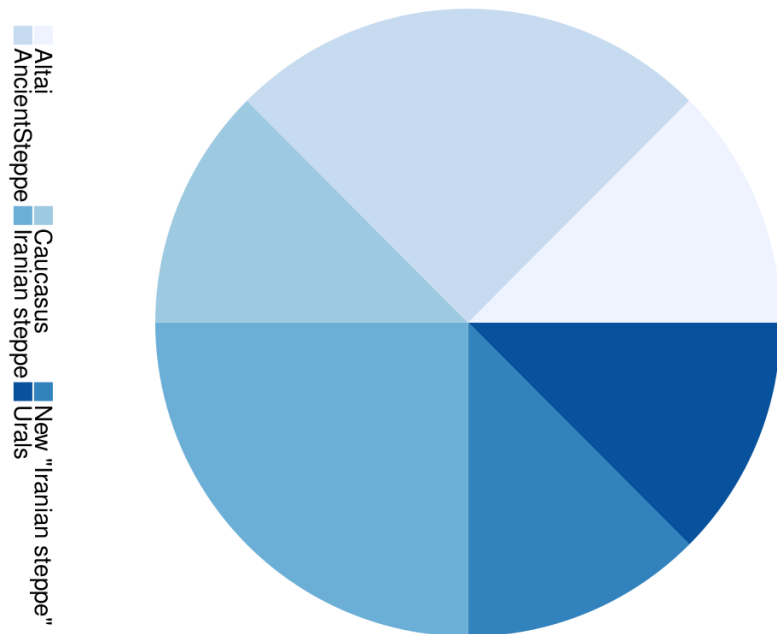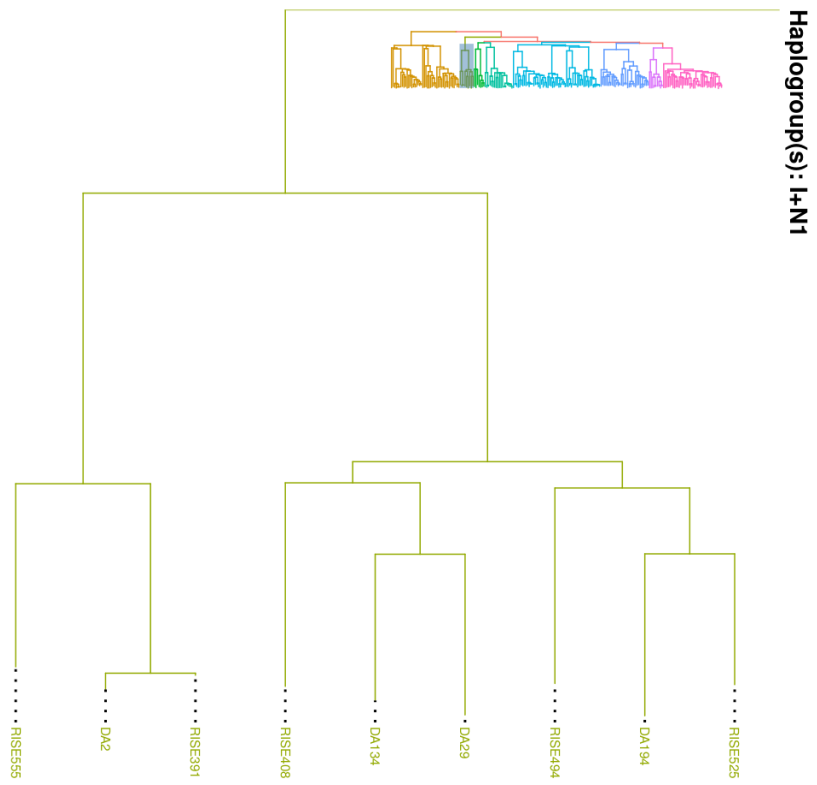
Supplementary Figure 175. Distribution of haplogroup I+N1 mitogenomes
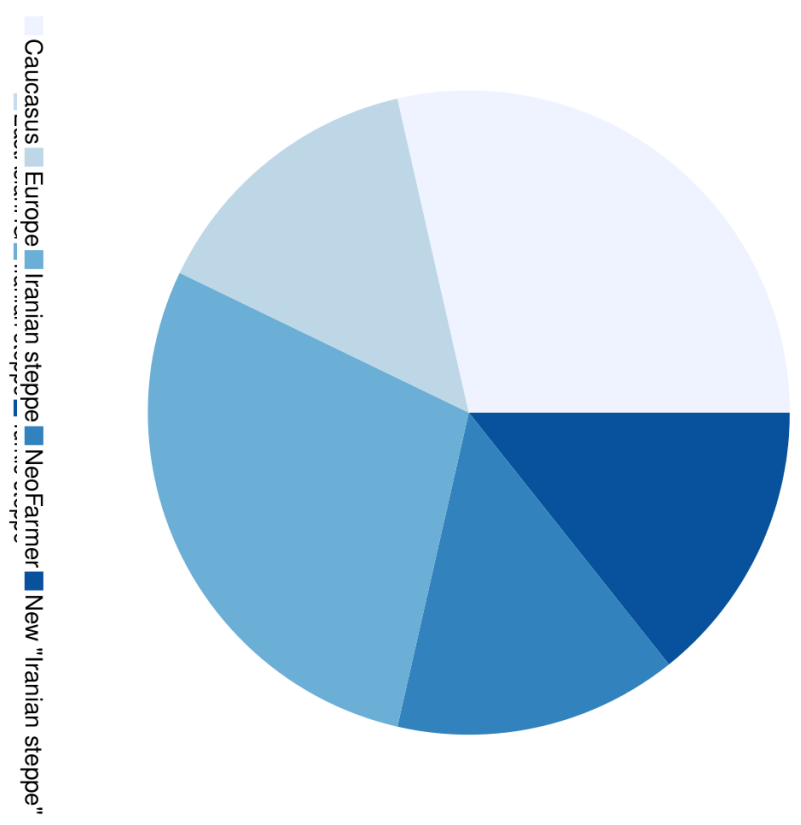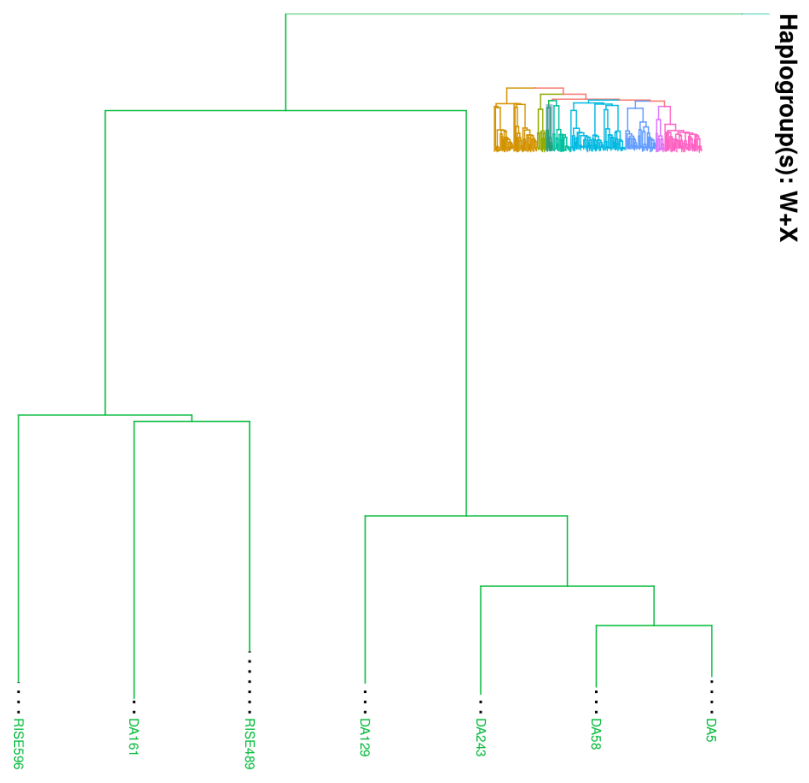
Supplementary Figure 176. Distribution of haplogroup W+X mitogenomes
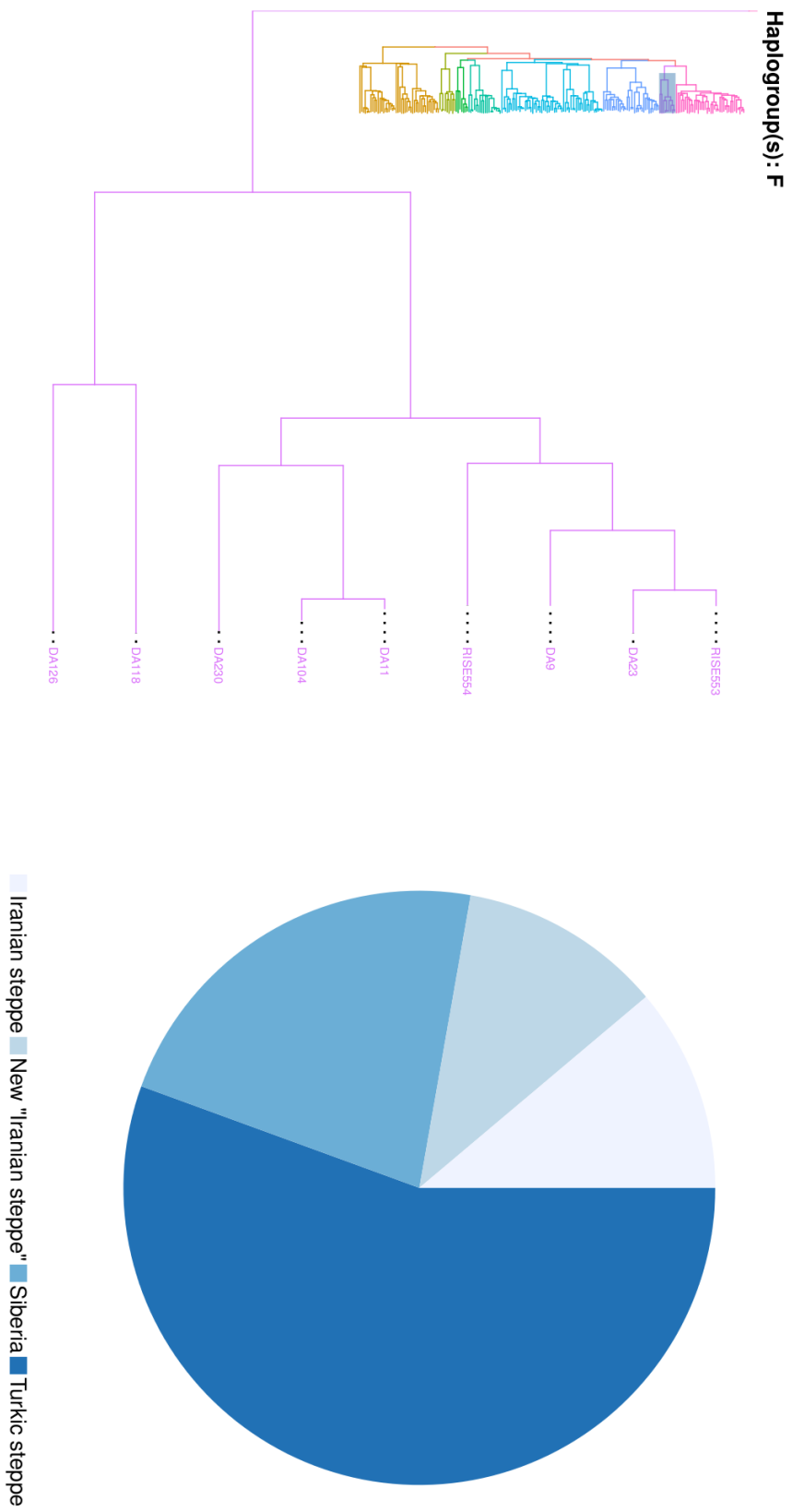
Supplementary Figure 177. Distribution of haplogroup F mitogenomes
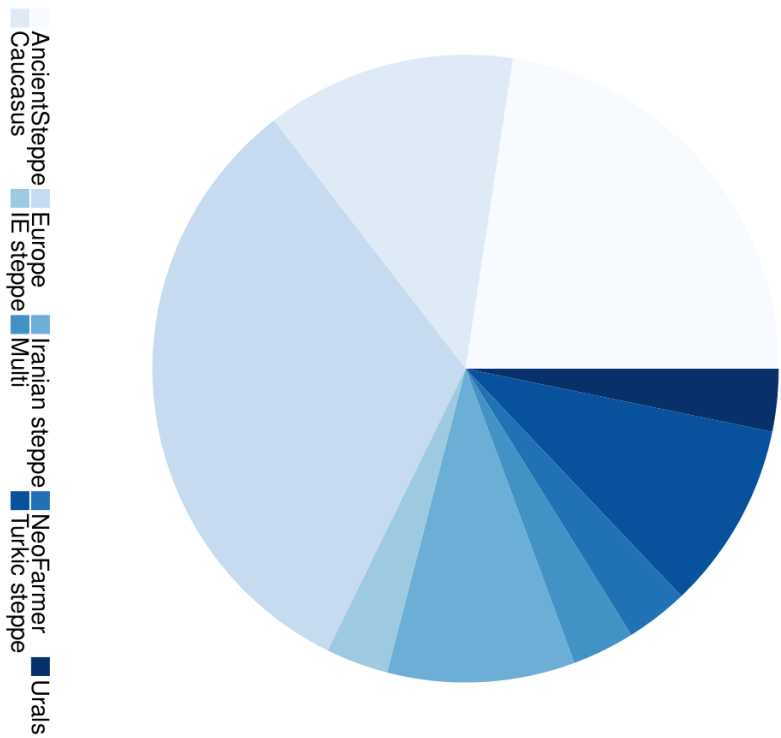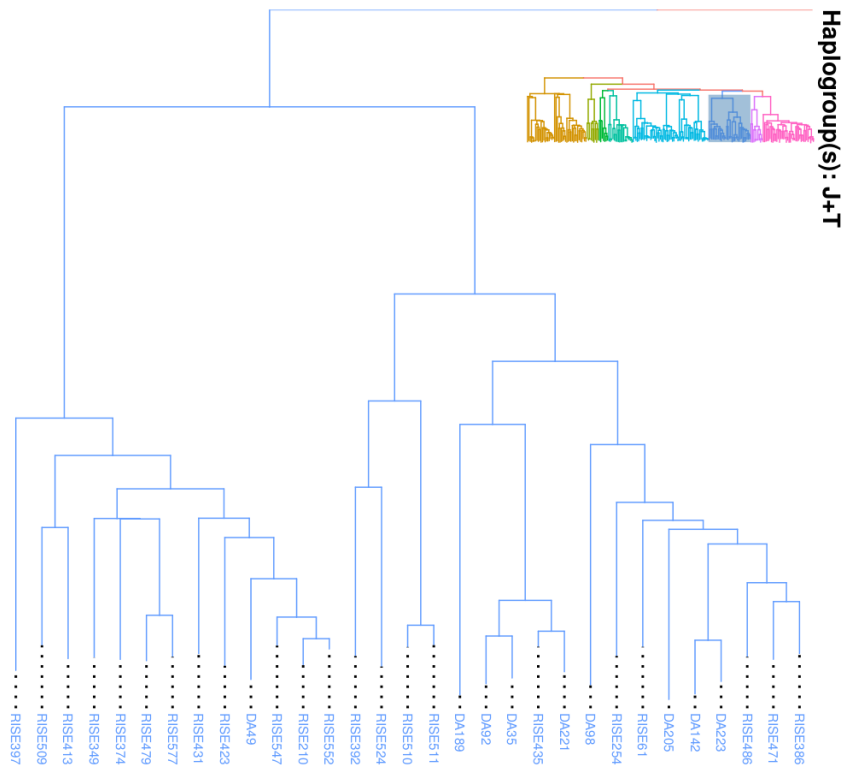
Supplementary Figure 178. Distribution of haplogroup F mitogenomes
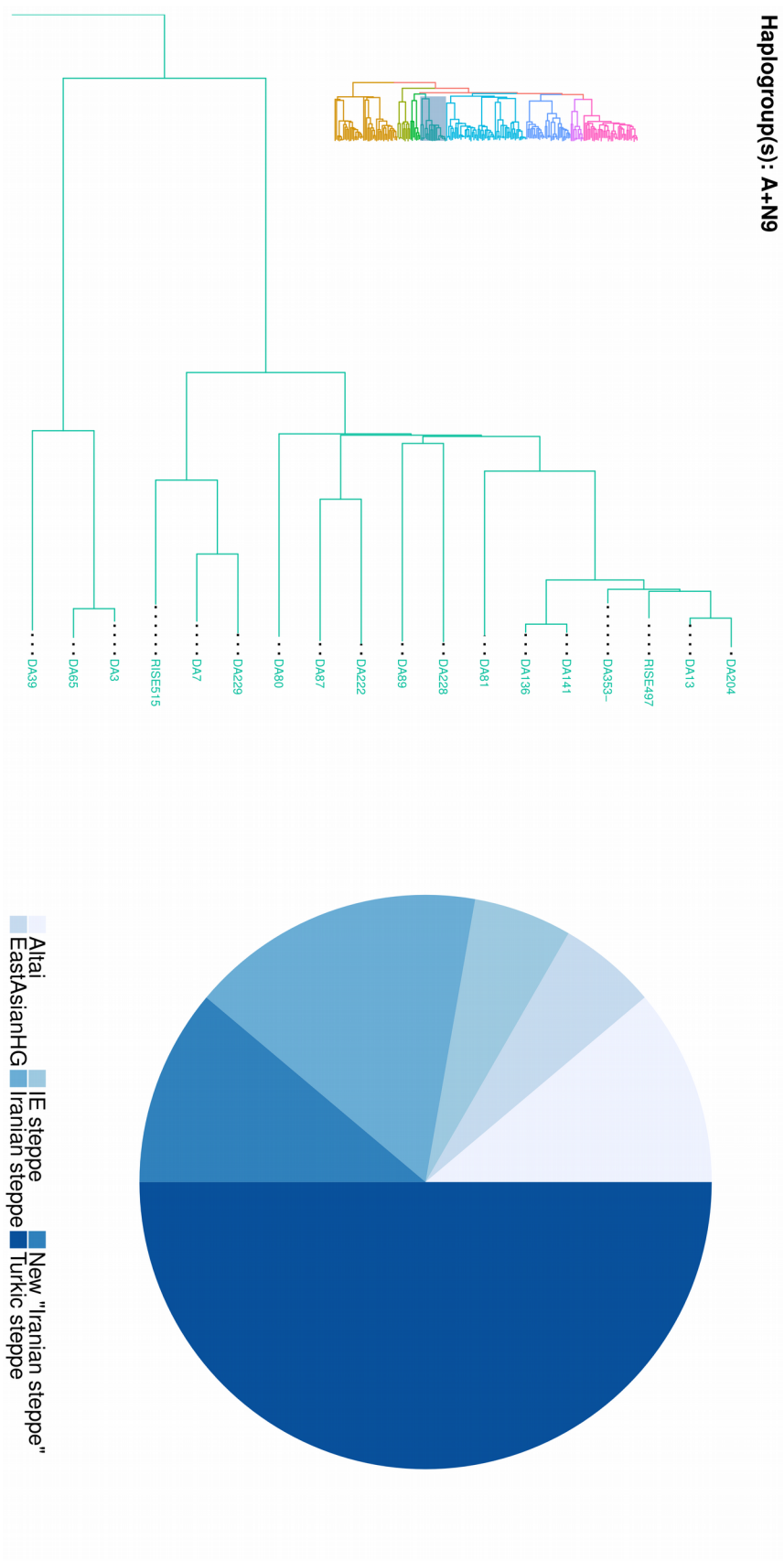
Supplementary Figure 179. Distribution of haplogroup A+N9 mitogenomes

Section 11: Radiocarbon dating

By Karl-Göran Sjögren

For this project, 83 new direct datings on human bone samples were performed at Chrono Centre, Queens University, Belfast. Details of the datings are given in Supplementary Data Table 2. ^{14}C values were calibrated to 1 sigma intervals at the Belfast laboratory using the Calib software and the Intcal13 calibration curve. These intervals were used to calculate an estimated age (BP cal), using the midpoint of the calibrated range. δ^{13}C and δ^{15}N isotopes were measured on all samples, as well as C/N ratio. C/N for all samples was within the accepted range for good collagen quality, i.e. between 2.9 and 3.6. We abstain from a paleodietary reconstruction because different sample substrates were used (different teeth positions and petrous bone) and the total sample numbers per population were collected only to comply with the possibilities of ancient DNA analyses, and not assess diet at population level. Further, local isotopic baselines are lacking for many of these environmentally and climatically variable regions, making detailed interpretations of the isotope values difficult. The elevated values for δ^{13}C and δ^{15}N in some samples may have several explanations, such as consumption of C4 plants (high δ^{13}C), freshwater fish consumption, dry climate, or high elevation (high δ^{15}N), or any combination of such factors. To distinguish between these possibilities, we need more detailed knowledge of isotope values through the local foodwebs. This also means that the possibility of a freshwater reservoir effect on some of the datings cannot be excluded.

Collagen was extracted from cleaned, crushed bone samples with an acid-base-acid treatment followed by gelatinization and ultrafiltration[240] using a Vivaspin® filter cleaning method introduced by[163]. The collagen was then freeze-dried.

The dried samples were weighed into pre-combusted quartz tubes with an excess of copper oxide (CuO), sealed under vacuum and combusted to carbon dioxide (CO_2). The CO_2 was converted to graphite on an iron catalyst using the zinc reduction method[241]. The ^{14}C/^{12}C and ^{13}C/^{12}C ratios were measured by accelerator mass spectrometry (AMS) at the ^{14}CHRONO Centre for Climate, the Environment and Chronology (Queen's University Belfast). The sample ^{14}C/^{12}C ratio was background corrected and normalised to the HOXII standard (SRM 4990C; National Institute of Standards and Technology). The radiocarbon ages were corrected for isotope fractionation using the AMS measured δ^{13}C which accounts for both natural and machine fractionation. The radiocarbon age and one standard deviation were calculated using the Libby half-life of 5568 years following the methods of[242].

Bone collagen stable carbon and nitrogen isotopes were measured in duplicate on a Thermo Delta V Isotope Ratio Mass Spectrometer (IRMS) coupled to a Thermo Flash 1112 Elemental Analyzer (EA) peripheral. The measurement uncertainty (1sd) of δ^{13}C, δ^{15}N, and atomic C:N (C:N$_{at}$) based on 6-10 replicates of seven archaeological bone collagen samples was 0.22‰, 0.15‰, and 0.2, respectively. Results are reported using the delta convention relative to international standards: VPDB for δ^{13}C and AIR for δ^{15}N.

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