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Eurasian Steppe Chariots and Social Complexity During the Bronze Age

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Abstract
This paper aims to examine some societal principles that underlie the development of horse-drawn chariots in Inner Eurasia during the Middle and Late Bronze Age (cal. 2050–1750 BC). Analysis is based on an evaluation and re-examination of the archaeological evidence for horse-drawn chariots, and the social constructs they entail. Chariots were developed in the zone of the Northern Eurasian steppes before c. 2000 BC in the context of complex but stateless societies. Because chariots depend on a set of developed skills, valuable resources, and complicated technologies, which involve several outstanding improvements to previously known solutions, they require specific conditions for their development and maintenance in social life. Most fundamentally, they require a group of people with an interest in this complex technology: a class of military elites characterized by aggrandizing behavior. The competition between collectives of military elites for resources, power and prestige brought into life the earliest chariot complex in the world.

Keywords Chariot · Bronze Age · Eurasia · Sintashta · Social complexity

Introduction

Social complexity in stateless societies takes many different forms, and it is not a simple task to recognize complexity and find its fundamental functional mechanisms (Earle 1997; Drennan et al. 2010). It is essential to investigate multiple lines of evidence through a careful examination of the archaeological record, including

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such variables as collective labor, redistribution and taxation, social integration, and technological complexes. As an essential part of material culture, technology is often well preserved and recognizable in archaeological remains. It entails not only complex skills but social mechanisms. This article examines some societal principles underlying the development of chariots in Inner Eurasia during the Middle and Late Bronze Age (cal. 2050–1650 BC). Specifically, this article concentrates on the materials from the Sintashta, Petrovka and Alakul' archaeological cultures of the Southern Urals, Russia, and Kazakhstan; however, neighboring regions of the Eurasian steppes and forest-steppes are also considered.

Our analysis is based on the evaluation and re-examination of the main evidence for the impressive technology of horse-drawn chariots and the social constructs they entail, discussed previously by Anthony (2009). A chariot is a two-wheeled vehicle drawn by a team of bridled horses, technically consisting of a draft pole and spoked wheels. A chariot requires specific conditions for its development and maintenance in social life, including a set of developed skills and complicated technologies, and valuable natural resources. These factors led Soviet-Russian scholar M. Gorelik to name this social and historical phenomenon the 'chariot complex' (Gorelik 1985). In a social sense, the chariot complex consists of a skilled charioteer, a horse-drawn chariot, and a set of weapons. In the archaeological record, the chariot complex includes the remains of actual vehicles, sacrificed horses, cheekpieces, and weapons. The direct evidence of Bronze Age chariots is known due to a universal tradition of using wheeled vehicles, and the accompanying objects and animals in mortuary practices, and is supported by pictographs on ceramic vessels (Zaharova 2000) and petroglyphs that depict use of chariots (Littauer 1977; Novozhenov 2012).

While the chariot complex has the potential to allow for a better understanding of social complexity in Bronze Age Eurasia, the literature on the topic is burdened with problematic views. At first glance, settlement patterns and life-styles of Bronze Age steppe herders reveal a low level of social stratification. In sharp contrast, analysis of Sintashta mortuary practices suggests well-developed age, gender, and rank differentiation (Anthony 2007; Epimakhov and Berseneva 2012; Berseneva 2013). Often a chariot is associated with an apparently important individual and thus can be interpreted as the classic manifestation of some kind of social inequality. Thus, the most outstanding graves are single burials accompanied by weaponry (projectile weapons and chariots); the insignia of power (stone maceheads); craft tools (adzes, chisels); and a specific set of sacrificed animals (horses, cattle, and dogs). For example, there are two adults buried with chariots, and one with sacrificed horses, among ten burials in six kurgan mounds excavated at the Solntse 2 cemetery in the southern Trans-Urals (Epimakhov 1996).

Even though many scholars suggest that the chariot complex was first developed by Inner Eurasian steppe pastoralists (Diakonov 1950; Moorey 1986; Kuzmina 1994, 2001; Koryakova and Epimakhov 2004; Anthony 2007, 2009; Kocherzhenko and Slonov 2010), this issue is still a matter of debate. Thus, Kozhin (1985, p. 177) and Gorelik (1985, pp. 198–200) both suggest that such complex technology could only be invented and supported under the control of a bureaucratic state, which did not exist prior to the Babylonian Kingdom of Mesopotamia. Later on, Sarianidi suggested that chariots, as well as a domesticated horse, were brought to

Bactria–Margiana by Aryans, who came from the Near East or Mesopotamia (Sarianidi 2007, p. 130). A more skeptical view of the Sintashta and Petrovka material, presented by Littauer and Crouwel (1996, p. 939), suggests that due to the dimensions and measurements of known remains, the chariots were not maneuverable or suitable for use either in warfare or racing. More recently, Jones-Bley (2000, p. 139) agrees with the idea that steppe vehicles were imitations of those found in the Near East, but 'used as transport to the Otherworld'. Vinogradov (2011, pp. 90–91) also supports this notion. Finally, this skeptical view even appeared in English-language textbooks, such as Wiley-Blackwell's *Encyclopedia of Ancient History* (Raulwing and Burmeister 2012, p. 1443). Suggestions that the chariots of the steppe were simple imitations of chariots from the Near East are *'Ex Oriente lux'* arguments that deny the possibility of technological invention, innovation, and improvement beyond the influence of the earliest civilizations. Unfortunately, these critiques rarely consider measurements, archaeological contexts, parallel lines of evidence, or actual steppe landscapes. On the other hand, scholars who argue Sintashta chariots were an integral part of steppe society are mainly interested in placing an Indo-European homeland on the map and tracing the migrations of Indo-European people. These treatments often rely on the mere presence of chariots and a strong association of these vehicles with Indo-Europeans. The position of these scholars is driven more by pre-conceived ideas than by an examination of the evidence.

In reality, analysis of archaeological data supports neither view in the extreme. This article provides a review of the Sintashta and Petrovka chariots, harness elements, horses, and their associations with weapons and individuals. Drawing on analysis of data from 25 known chariots and 100 cheekpieces, this article shows first, that the Sintashta finds do represent the earliest known actual chariots; second, that the chariots were likely developed in the steppe zone of Inner Eurasia among stateless societies; and finally, that the chariot complex highlights established social complexity among the Bronze Age pastoralists.

Historical and Chronological Background

A widespread productive economy, copper and bronze metallurgy, and the migration of culturally similar groups of people (often claimed as speakers of an Indo-European language) into substantial areas within the Eurasian landmass are broadly accepted characteristics of Bronze Age Inner Eurasia. The social and cultural history of this period is known from numerous sets of materials, aptly labeled by Chernykh as the monotonous continuity of the 'steppe belt' of archaeological cultures (Chernykh 2008) (Fig. 1). This monotonous character includes broad similarities in subsistence (namely, multi-source pastoralism with at least some elements of plant cultivation in some regions) and a similar degree of social complexity. Those characteristics are expressed in similar burial patterns, artifact assemblages and settlement systems. Altogether, these developments suggest the cognate nature of interconnected Bronze Age archaeological cultures (Kuzmina 2007, 2010). Here we provide a brief review of the Bronze Age entities from the steppe relevant to our discussion of chariots and the related social constructs. The review starts with the

Fig. 1 Map of cultural developments of the Bronze Age in Northern Eurasia (source of the geographic map: US National Park Service)

Early Bronze Age, when wheeled transport first appears in the steppes, and then covers all periods until the Late Bronze Age. Development of chariots in the steppes took about two millennia, and the tradition persisted after the Bronze Age (Valchak 2009). We do not attempt an exhaustive review of the detailed periodization and local variants of archaeological cultures presented in the regional archaeological literature, but instead focus on a broader, somewhat simplified synthesis. In some cases, there is no agreement among scholars on periodization and labeling of the same set of material culture, and detailed analysis of such debates is outside the scope of this article.

The system of the relative chronology of the Bronze Age was established after typological and chemical analysis of metal artifacts (Chernykh 2008, 1992). According to this system, the Bronze Age can be divided into three sub-phases: the Early, the Middle, and the Late. Each period is characterized by uniform technologies and traditions of copper metallurgy, present across vast areas. The chronological limits of the periods are not necessarily identical in the different regions, but vary according to the spread and adoption of technologies, stagnation processes and so on. The Early and Middle phases of the Bronze Age correspond to the development and diffusion of the so-called Circumpontic Metallurgical Province. This phenomenon involves the technological and morphological standards of metalworking, particular categories and forms of tools and weapons, as well as the use of copper–arsenic alloys. The Late Bronze Age corresponds to the formation and spread of

the Eurasian Metallurgical Province, which differs sharply from the foregoing Circumpontic Metallurgical Province by relying on new sources of metal in Asia (from the eastern Ural Mountains, through Kazakhstan, and up to the western Altai), and large-scale production of tin bronzes. According to this scheme, the Bronze Age cultures fall into the following sequence:

- Early Bronze Age: Pit Grave and Novotitorovskaya cultures
- Middle Bronze Age: Catacomb and Poltavka cultures
- Late Bronze Age: Sintashta–Petrovka phenomenon; Potapovo and Pokrovka types; Alakul' and Srubnuaya (Timber-Grave) cultures
- Late to Final Bronze Age: several archaeological cultures making up the Andronovo phenomenon.

Wheeled transport appeared in the Eurasian steppes during the *Yamnaya* (also known as *Yamna* or *Pit Grave*) and the *Novotitorovskaya* cultures circa cal. 3600–2300 BC (Chernykh 2008). The Pit Grave sites cover a vast region, from the Balkans to the southern Urals, and the majority of them are cemeteries (Merpert 1974; Bogdanov 2004). They consist of kurgan mounds with recognizable burial complexes, after which the Pit Grave set of materials is named. Usually, there are one or two burials of adults covered by a single kurgan mound. Settlements are rare and usually represent seasonal camps of herders, with the exception of the Mikhailovskoye settlement on the Dnieper, which yielded fortifications and evidence of farming (Chernykh 1992; Gei 2000; Ryndina and Degtyareva 2001; Morgunova 2014, etc.). However, the Pit Grave culture is mainly known for the wide distribution of new methods of copper and arsenical bronze metallurgy and a set of bronze objects often called the Circumpontic Metallurgical Province (Chernykh 1992). It seems to be a safe assumption that Yamnaya subsistence strategies varied a lot from region to region, and from period to period. In some regions and periods, people of the Pit Grave culture utilized settled, semi-mobile or mobile pastoralism, as well as hunting and fishing, while in some sites west of the Don River plant cultivation was pronounced (Merpert 1974, pp. 101–105). In those places where the economy relied on animal breeding (including pig), herd composition could vary considerably even from site to site (Kaiser 2010). As an example, analysis of faunal remains from the early Pit Grave settlement of Repin suggests that the horse was a major source of meat (up to 70% of horse bones in the faunal remains). Meanwhile, inhabitants of Mikhailovskoye I settlement practised animal breeding (up to 7% of horse bones in the assemblage), but at the same time some plant cultivation and utilization of wild resources. Intriguingly enough, such differences in presence of horse might suggest utilization of both wild and domestic animals in the subsistence strategies (Korobkova and Shaposhnikova 2005, pp. 245–249). Due to the high variability in the settlement patterns and economy of the Pit Grave culture, it is difficult to describe social structures. Scholars have suggested, though, that some Pit Grave kurgans were devoted to the *post mortem* glorification of local or tribal chiefs (Bogdanov 2004; Korenevskiy 2012), for instance the Bolshoi Kurgan at the Boldyrevo I Cemetery in the southern Urals (Morgunova 2000). Importantly, the Pit Grave burials were the earliest in the steppe accompanied by four-wheeled wagons. It is widely

accepted that these wagons were pulled by bovines and used as a means of transport, and as mobile homes. The issue of horse domestication in both the Pit Grave culture and the preceding period has been widely discussed (see Rassamakin 1994; Levine 1999; Levine et al. 2003; Kohl 2007, pp. 137–144; Outram et al. 2009; Anthony and Brown 2011; Kosintsev and Kuznetsov 2013), though currently we lack direct evidence of use of draft horses at that time.

In the Black Sea region, the Pit Grave period was followed by the *Katakombnaya* (*Catacomb*) culture (cal. 2700–1900 BC (Chernykh 2008)), which continued and improved upon the technological innovations of pre-existing people (Kiyashko 2002), including bronze metallurgy and utilization of four-wheeled wagons. To the east, the Pit Grave gave way to the cemeteries of the *Poltavka* archaeological culture (c. 2700–2100 BC), which occupied the Volga–Ural interfluve (Tkachev 2006; Kiyashko and Sukhorukova 2012). The economy of the Catacomb people was based on animal breeding and some degree of plant cultivation. As with the Pit Grave culture, the name of the development comes from the burial rituals, which included a tradition of building a side chamber for the inhumation of the deceased from the base of the grave pit. The settlements of the Catacomb culture are difficult to find and interpret, and while some scholars suspect sedentism (Kaiser 2010), many of the settlements in the steppes are thought to be seasonal camps of a generally mobile population (Tikhonov and Matveev 1981; Gak et al. 2014). Elaborate burials of the Catacomb culture, especially with wagons and carts, are interpreted as those of high-status people, possibly chiefs and warlords of local communities (Cherednichenko and Pustovalov 1991). At the beginning of this period, the first two-wheeled vehicles in the steppes appeared and were buried in the cemeteries of Tyagunova Mogila (Cherednichenko and Pustovalov 1991; Pustovalov 2008) and Bolshoi Ipatovskyi Kurgan (Korenevskiy et al. 2007), both in the Black Sea region. These carts have small (up to 60 cm diameter), single-piece disk wheels with an integral nave independently rotating on the axle. They can thus be seen as forerunners of an actual chariot, similar to those vehicles known in the Near East at this time. The role of domestic horse in the economy of the Catacomb people is unclear; however, the undoubted presence of horses as ritual offerings in the burials suggests their great importance (Andreeva 2009; Shishlina et al. 2014).

The next period in the East European forest-steppes relates to the *Abashevo* culture (cal. 2100–1700 BC (Kuznetsov 2003; Chernykh 2008)). Year-round unfortified settlements and seasonal camps are situated near rivers and consist of several houses. Kurgan cemeteries usually have several mounds that cover one or two burials, and collective burials are rare (Kuzmina 2000; Tkachev 2007). One of these unusual collective burials was found under the kurgan of Pepkino, belonging to the Middle-Volga Abashevo culture, where 28 violently-killed adult individuals were buried (Khalikov et al. 1966). Seven AMS radiocarbon dates for the Pepkino kurgan yielded a summed calibrated interval between 2130 and 1950 BC (1 sigma) (Kuzminykh and Mimokhod 2016). Analogies of projectile points from the Turbino cemetery also allow it to be dated no earlier than 2100–2000 BC (Kuznetsov 2003), which corresponds well with other dates of the whole Abashevo phenomenon in the Middle Volga region (Chernykh 2008). This makes the Pepkino kurgan one of the earliest mass graves of war victims in Inner Eurasia.

In the Don–Volga interfluve, the latest variant of Abashevo is often referred to as the *Pokrovka* (or *Pokrovskyi*) type, and dates back to c. 2000–1700 BC. The Abashevo culture and the Pokrovka type are often seen as, respectively, the formative and terminal periods of the same cultural complex, which is, in general, the continuation of the *Corded Ware culture* and predecessor of the *Timber-Grave phenomenon* (Kuzmina 2003). However, the relationships between the geographical entities and chronological phases of the whole development are still widely debated (for discussion see Semenova 2000; Pryakhin 2011), as are its relationships with the *Catacomb, Fatyanovo, Balanovo* and other cultures of the Middle Bronze Age. The sites of the Pokrovka type occupy the forest-steppe and steppe zones of the Don–Volga interfluve and stretch farther east to the Samara Valley. Some of the burials are accompanied by weapons, the insignia of power, and gold jewelry, and are conspicuously different from the rest of the graves of the ordinary people. Quite often they are seen as the burials of those who had remarkable social power and prestige (such as the Staroyurievo Cemetery, the Filatovo Kurgan, etc.) (Semenova 2000). Moreover, the same graves provide notable but indirect evidence of wide utilization of wheeled transport. Bones of domesticated horse are found in both burial and domestic contexts, which suggests that the horse was a draft animal (Kosintsev 2010). More direct evidence is provided by the studded elk-antler cheekpieces—the earliest artifacts of this kind in Eastern Europe, dated back to c. 2000–1700 BC (Kuzminykh and Mimokhod 2016, p. 41). More than fifty of these have been found in the wide area between the Don and the Ural, and importantly these cheekpieces have their own recognizable and unique style (Pryakhin and Besedin 1998; Usachuk 2012). In sum, the Pokrovka phenomenon is often seen as an important part of the 'chariot horizon', which represents a rapid extension of the chariot complex to the vast areas of Northern Eurasia.

In the southern Urals, a significant part of the Bronze Age development is the *Sintashta–Petrovka* archaeological phenomenon, which is the focus of this paper. It is situated within the southern Ural Mountains of Russia and the northern part of the Republic of Kazakhstan (Grigoriev 2002; Koryakova and Epimakhov 2007). By the end of the Middle Bronze Age, a minimum of 25 Sintashta settlements occupied the area of the Ural–Tobol interfluve, located near low spots on banks of the small steppe streams. The essential archaeological evidence of the Sintashta and Petrovka prehistoric groups is found in the form of local communities of nucleated and fortified settlements paired with recognizable kurgan cemeteries. These include settlements enclosed with ditches and earth walls, strengthened by wooden and stone constructions. Within settlements, houses are closely packed together in rows or circles in such a way that they share walls (Koryakova and Epimakhov 2007). An important fact is that domestic artifact assemblages do not allow the separation of elites and commoners, even though some degree of social stratification is visible in burial contexts. Chariots are directly represented in the Sintashta burials, as are studded antler cheekpieces, chariot horses, and weapons. In the Petrovka period, which is slightly later (see below), chariots themselves are rare; however, a new tradition of symbolic representation of a vehicle appears. Thus, in the Petrovka cemeteries, such as Kenes (Zdanovich 1988) and Nurtai (Tkachev 1999) in Kazakhstan, sacrificed horses are laid under the kurgans and next to the burials as a symbolic imitation of the chariot.

The chronology of the Sintashta and Petrovka horizons is particularly relevant to the current discussion, due to the previously assumed chronological precedence of the Near Eastern chariots. The absolute chronology of the Bronze Age of Inner Eurasia has only recently been established, due to increased utilization of radiocarbon dating (Chernykh 2008; Hanks et al. 2007). These dates demonstrate that the development of the Sintashta and Petrovka phenomenon occurred over a relatively short period of about 300 years (cal. 2050–1750 BC), consisting of two chronological phases. The earlier Sintashta phase (cal. 2050–1850 BC) is distinguished from the later Petrovka phase (cal. 1850–1750 BC) by minor differences in ceramic styles and some attributes of bronze metallurgy.

The following period (cal. 1750–1450 BC), associated in the Urals with the *Alakul'* culture of the Andronovo horizon, is marked by visible changes in lifestyles. The settlement pattern of this second period is characterized by smaller occupied areas with settlements that are unfortified and less standardized. Changes in mortuary practices include the more simplified rituals and the disappearance of mortuary chariot burials (Koryakova and Epimakhov 2007).

The *Potapovo* cultural type (cal. 1950–1750 BC) represents an intermediate phenomenon in the Middle Volga, with elements of both the Abashevo and Sintashta cultures. There are four published cemeteries, and about a hundred excavated burials of the Potapovo type; however, as today, there are no known settlements. The individuals found in the large central graves, accompanied by rich offerings, probably represent elite burials. Although studded antler cheekpieces are the only visible elements of the chariot complex, the sacrifice of paired horses, symbolically representing the cart, is a well-known feature of Potapovo burial practices (Vasiliev et al. 1994; Kuznetsov and Semenova 2000; Kuznetsov 2006).

The *Srubnaya* or *Timber-Grave* culture is a massive cultural entity of the Late Bronze Age, which covers the area from the Dnieper to the Ural River. This phenomenon was named after the tradition of burying the deceased in cubic wooden crypts under kurgan mounds. In conjunction with the Pit Grave (Early Bronze Age) and Catacomb (Middle Bronze Age) cultures, Srubnaya represents the Late Bronze Age element of Vasiliy Gorodtsov's periodization of the Bronze Age in the western Eurasian Steppe (Gorotsov 1927). Proposed in the early twentieth century, this periodization is still an adequate characterization of the chronology and general development of material culture in this part of the world. The Srubnaya culture is one the largest phenomena of the Late Bronze Age in the East European steppes, and it is still characterized by many features of the preceding times. For instance, the Srubnaya people continued to rely on livestock breeding, hunting, and gathering, with little or no agriculture. On the other hand, the mining of copper ore attained an almost industrial scale in such settlements as Gorny (Chernykh 2002), which is believed to be a specialized metallurgical center, where metal was produced for trade. Chariots themselves are not known in the Srubnaya material, but there are studded cheekpieces and ceramic vessels with images of two-wheeled vehicles on them (Zaharova 2000).

The *Andronovo* horizon is another large and important phenomenon of the Late and Final Bronze Age, covering areas to the east of the Ural Mountains (Kuzmina 1994, 2007). The important characteristic of the lifestyle is year-round unfortified

settlements on river banks. Together with animal breeding, the Andronovo people practised some degree of plant cultivation, as well as mining of copper and tin ores for export. Kuzmina argues that the Andronovo people utilized horses of three breeds: a little horse of 128–136 cm height; a medium horse of 136–152 cm; and a large horse of 152–160 cm. This third breed was a chariot horse, the rare and prestigious possession of social elites, and the predecessor of the Akhal-Teke horse (Kuzmina 2010, p. 66). Similarly, based on his work in the Koksu valley, Frachetti argues that prestige and status were likely attributed to control over domestic animals, and that the ownership of horses was characteristic of distinguished individuals (Frachetti 2008, p. 16). Furthermore, numerous petroglyphs exist depicting chariot technology. These petroglyphs likely cover the period of the Bronze Age and are found across the Russian Altai, Kazakhstan, Mongolia, China, and Pakistan (Novozhenov 2012, p. 35). Nowadays, archaeologists distinguish at least three Bronze Age pictorial traditions on the basis of style, and demonstrate some parallels in the material culture. The earliest is the Yamna–Afanasievo tradition, which is characterized by the symbolic depiction of sun-headed men and animals. Another tradition is a record of the Andronovo people (Kuzmina 1994; Novozhenov 2012), who depicted in it their everyday life and the importance of wheeled transport (Novozhenov 2014a, b). Although petroglyphs on open-air natural rock surfaces are obviously hard to date, the occurrence of similar carvings on stone grave stelae within some Andronovo culture cemeteries (such as the Tamgaly Cemetery and the Samara Cemetery in Sary Arka, Kazakhstan) provide a level of chronological control. Finally, the finds of petroglyphs depicting chariots in the burials of the *Karasuk* culture (c. 1400–800 BC) in southern Siberia and Kazakhstan allow us to distinguish the latest tradition (Novozhenov 2014b).

In summary, Bronze Age individuals who might be described as elites can be distinguished in various ways among the archaeological materials. We now turn to a consideration of the role of the chariot complex.

Chariots in the Archaeological Record of the Sintashta, Petrovka and Alakul' Cultural Complexes

The site of Sintashta in the steppe zone of the Southern Trans-Urals (the eastern side of the Ural Mountains) was excavated in the 1970s and yielded abundant Bronze Age material, including unparalleled evidence of six vehicles buried in graves, each with two spoked wheels accompanied by cheekpieces and sacrificial horses (Gening 1977; Gening et al. 1992). Subsequent archaeological investigations have expanded the area of the chariot complex to the whole Ural–Kazakhstan region (Fig. 2), and probably more broadly to the forest-steppes of the Volga–Don interfluve. Evidence of chariots comes mainly from Sintashta sites (16 finds), Petrovka sites (9 finds), and from two Alakul' sites in the southern Urals and northern Kazakhstan. There are three possible graves of the Abashevo–Pokrovka and Potapovo cultures in the Don–Volga region (Pichaevo kurgan, grave 2; Utevka cemetery, kurgan 6, graves 4 and 6). To date, there are 28 published cases (and at least two known unpublished cases) of chariots in mortuary ritual contexts (Figs. 3, 4, 5, 6; Table 1). Chariot

Fig. 2 Map of distribution of chariot burials in Inner Eurasia (cal. 2050–1750 BC) (source of the geographic map: National Geographic Society, i-cubed, 2013). 1—Berlik II Cemetery; 2—Bestamak Cemetery; 3—Vetlyanka IV Cemetery; 4—Kamennyi Ambar 5 Cemetery; 5—Kenes Cemetery; 6—Krivoe Ozero Cemetery; 7—Nikolayevka II Cemetery; 8—Satan Cemetery; 9—Sintashta Cemetery; 10—Solntse II Cemetery; 11—Ulubai Cemetery; 12—Ozernoye-1 Cemetery

remains from the Middle and Late Bronze Age in the southern Urals are quite abundant compared with early chariot remains from other parts of the world, and allow statistical analysis.

In contrast, only two wagons and one sledge were found in the Royal Cemetery of Ur (Woolley 1965), and only ten actual chariots and their parts are known from tombs of the New Kingdom of Egypt (1550–1069 BC) (Littauer and Crouwel 1985; James 1974; Herold 2006), with the rest of the information on the Near Eastern chariots coming in other forms. Two chariots and the wheels of a third were also found in the Lchashen Cemetery in Armenia (Yesayan 1960), dated to 1400–1300 BC (Pogrebova 2003, p. 397), and bronze models of chariots were found in the burial sites of neighboring Transcaucasia (Brileva 2012). Over one hundred chariots have been discovered in Shang period tombs in China, but none dates before 1200 BC (Wu 2013).

Due to the poor preservation of organic materials, much of our knowledge of Bronze Age Eurasian steppe chariots is drawn from the imprints of their two wheels when placed upright in slots or wheel-pits in the grave floor, closer to one of the shorter walls of the burial chambers (Table 2). A similar method of placing chariots in tombs was utilized by the people of the later La Tène culture (Piggott 1983, p. 397). To date, there are just nine cases of wheel impressions with spokes, felloes, and sometimes naves; among these, three are of particular interest. These are: the well-known chariot from Krivoe Ozero, where imprints of an axle and naves are preserved in the soil (Vinogradov 2003); Burial 12 of the Sintashta cemetery,

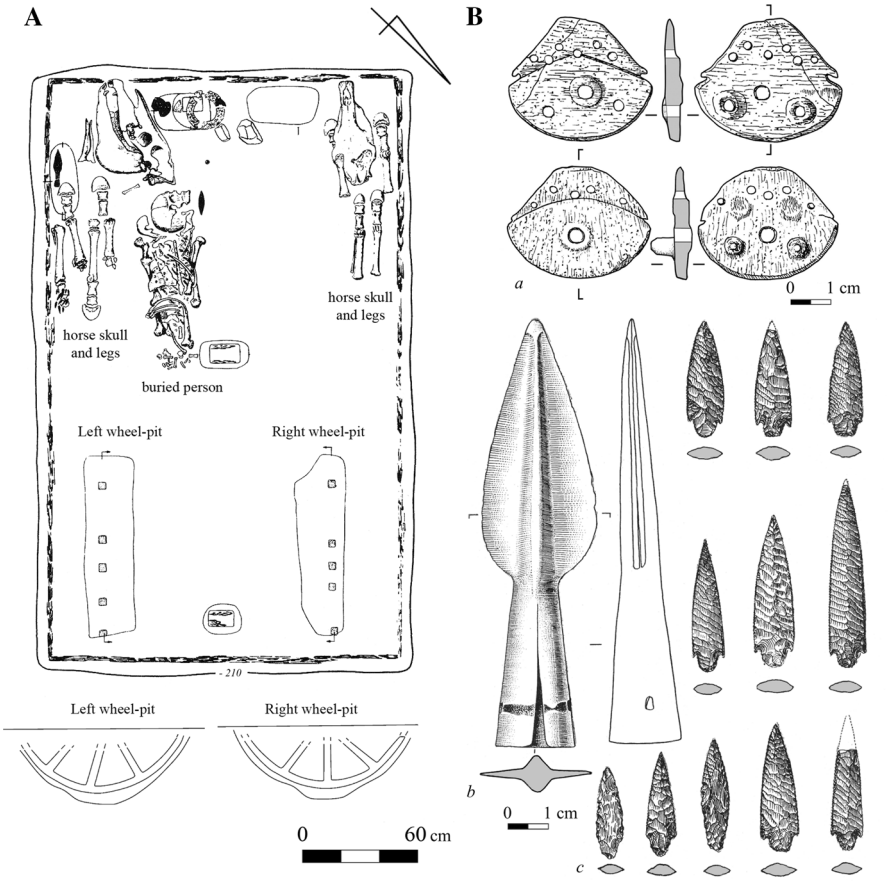

Fig. 3 General plan of Grave 30, the Cemetery of Sintashta, Chelyabinsk region, Russia (redrawn after Gening et al. 1992, pp. 210–213). **a** Plan of the grave with a buried adult individual, two horses and imprints of wheels; **b** the artifact assemblage, including: *a*—cheekpieces, *b*—a spear, *c*—a set of arrowheads

with a possible nave impression; and the remains of a chariot from Satan cemetery, where leather tires were found attached to the wheel rims (Novozhenov 1989, 2012, p. 200). In the remaining cases, such imprints were not found, but pairs of measurable, segment-shaped wheel-pits were discovered, dug into grave floors, possibly to stabilize the vehicles during burial rituals.

Dimensions and Technological Solutions

As previously discussed, Littauer and Crouwel (1996) have drawn upon a very small number of examples to argue that Sintashta chariots were not suitable for warfare or racing, since the dimensions (wheel-track of 120 cm and short nave length) would render the vehicle impractical at speed and limit its maneuverability (Littauer

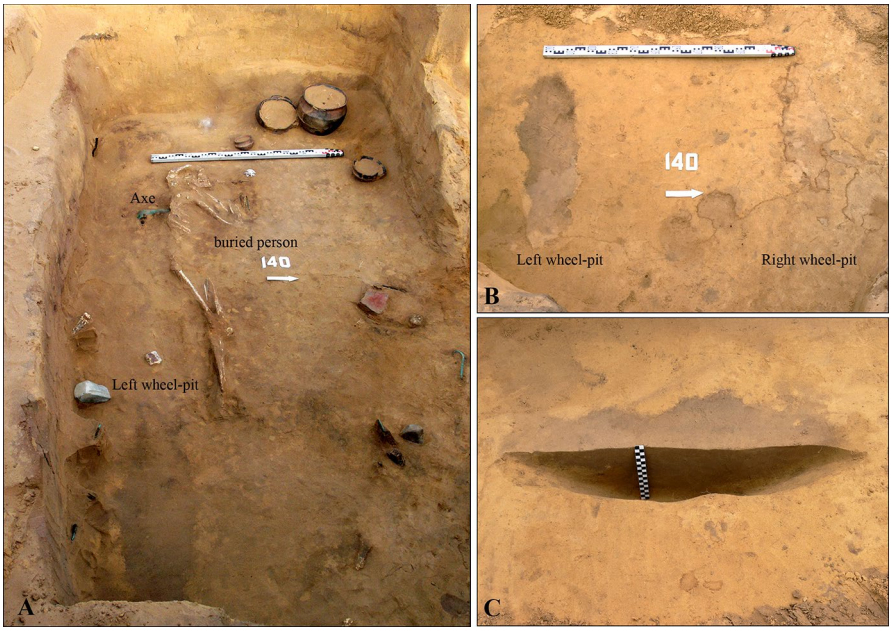

Fig. 4 General plan of Grave 140, the Cemetery of Bestamak, Kostanay region, Kazakhstan (courtesy of Dr. Irina Shevnina). **a** Plan of the grave with a buried adult individual; **b** the imprints of wheels; **c** an excavated wheel-pit

and Crouwel 1996, p. 934). However, Anthony using a similar sample reaches the opposite conclusion and demonstrates the logic we also follow here (Anthony 2009, pp. 58–59). The statistics provided here report mean values and error ranges, which are used to describe a population from a sample. By analyzing the complete set of measurements from all available specimens, however, it can be concluded that Sintashta–Petrovka chariots had similar measurements with little variation (Tables 1, 2, and 3). From our point of view, the observed variability points to a degree of traditional chariot standardization, rather than divergent production. There are some exceptional cases, such as the vehicle from Vetlyanka 6 with the wheel track of 200 cm, but they demonstrate regional variation and are obvious outliers. These measurements correspond well with measurements of ancient chariots from other better-known contexts, in Egypt, the Caucasus, and China (see below). This observation suggests that Sintashta–Petrovka chariots were functional and used for carrying passengers and, probably, for warfare. Otherwise, one would not expect to see consistency in the measurements and technological solutions. Reconstruction of chariot wheels and superstructures based on direct measurement of surviving wheel pits and grave chambers, can be used to establish the dimensions of, and technological restrictions imposed by, elements such as wheels, wheel-tracks, and means of traction (Fig. 7).

(1) The technological solutions used to construct a wheel and its dimensions are derived from the measurements of the ‘wheel pits’. They allow such analysis because some had the actual imprints of felloes and spokes. Thus, the

Fig. 5 General plan of Grave 8, kurgan 2, the Cemetery of Kamennyi Ambar-5, Chelyabinsk region, Russia. **a** Plan of the grave; **b** the artifact assemblage, including: *a*—cheekpieces, *b*—mace heads; **c** general plan of the kurgan; **d** photos of the grave (Epimakhov 2005)

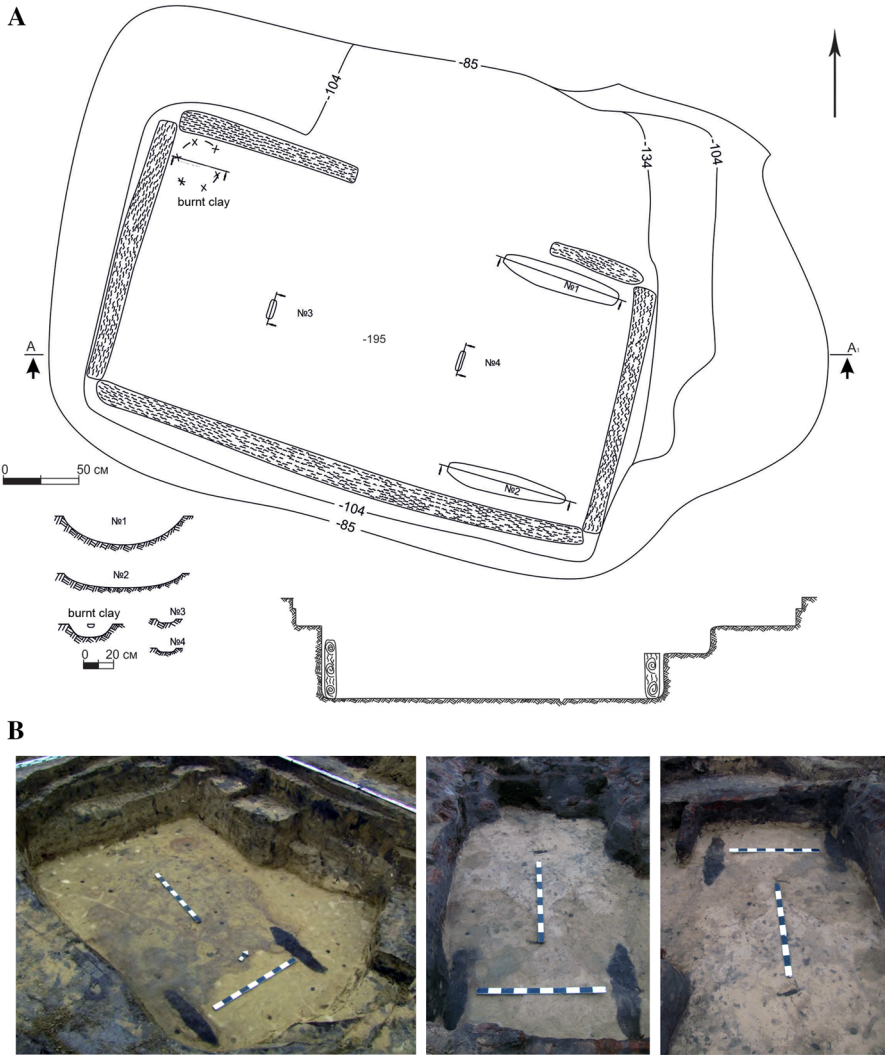

Fig. 6 General plan of Grave 8, kurgan 7, the Cemetery of Ozernoye-1, Kurgan region, Russia. **a** Plan of the grave; **b** photo of the grave (Epimakhov and Novikov 2017)

wheel pit measurements are 78 ± 6 cm (length), 25 ± 4 cm (width) and 22 ± 2 cm (depth), with error ranges at the 95% confidence level. The mean values of chord and height allow calculation of an important dimension, which has been previously ignored: wheel diameter. In eight cases with imprints of felloes, the diameters vary from 74 to 121 cm. At first glance, this appears to show highly variable wheel size. However, the mean wheel diameter is 95 cm with an associated error range of 87–102 cm (95 ± 10 cm at 95% CL), which, given biases resulting from decomposition, excavation and measurement, is not a great variability

Table 1 Chariots in graves of the Bronze Age Eurasian Steppe

No.	Site	Region	Culture	Radiocarbon date	Source
1.	Berlik II cemetery, kurgan 10.	Kazakhstan	Petrovka		G. Zdanovich (1988)
2.	Berlik II cemetery, kurgan 2	Kazakhstan	Petrovka		G. Zdanovich (1988)
3.	Bestamak Cemetery, g. 140	Kazakhstan	Sintashta/Petrovka	3260 ± 60 (Ki 13752)	Logvin and Shevnina (2008)
4.	Vetlyanka IV cemetery, kurgan 14, g. 6	S. Urals	Sintashta		Gorbunov et al. (1990)
5.	Kamennyi Ambar 5 cemetery, kurgan 2, g. 6	S. Urals	Sintashta	3572 ± 50 (OxA-12530)	Epimakhov (2005)
6.	Kamennyi Ambar 5 cemetery, kurgan 2, g. 8	S. Urals	Sintashta	3549 ± 29 (OxA-12531)	Epimakhov (2005)
7.	Kamennyi Ambar 5 Cemetery, kurgan 4, g. 9	S. Urals	Sintashta		Epimakhov (2005)
8.	Kenes cemetery, kurgan 5, g. 1	Kazakhstan	Petrovka		G. Zdanovich (1988)
9.	Krivoe Ozero, kurgan 2, g. 1	S. Urals	Petrovka		Vinogradov (2003)
10.	Krivoe Ozero, kurgan 9, g. 1	S. Urals	Sintashta	3580 ± 50 (AA-9874a) 3740 ± 50 (AA-9874b) 3700 ± 60 (AA-9875a) 3525 ± 50 (AA-9875b)	Vinogradov (2003)
11.	Nikolayevka II Cemetery, kurgan 1	S. Urals	Alakul'		Epimakhov (2004)
12.	Ozernoye-1, kurgan 7, g. 8	S. Urals	Petrovka		Epimakhov and Novikov (2017)
13.	Satan Cemetery, kurgan 1	Kazakhstan	Petrovka	3420 ± 160 (LOIA-2320)	Novozhenov (1989)
14.	Sintashta Cemetery, SM, g. 4	S. Urals	Sintashta		Gening et al. (1992)
15.	Sintashta Cemetery, SM, g. 5	S. Urals	Sintashta	3360 ± 70 (Ki-862)	Gening et al. (1992)
16.	Sintashta Cemetery, SM, g. 12	S. Urals	Sintashta		Gening et al. (1992)
17.	Sintashta Cemetery, SM, g. 16	S. Urals	Sintashta		Gening et al. (1992)
18.	Sintashta Cemetery, SM, g. 19	S. Urals	Sintashta	3560 ± 180 (Ki-864)	Gening et al. (1992)
19.	Sintashta Cemetery, SM, g. 28	S. Urals	Sintashta	3760 ± 120 (Ki-864)	Gening et al. (1992)
20.	Sintashta Cemetery, SM, g. 30	S. Urals	Sintashta		Gening et al. (1992)
21.	Sintashta SIII	S. Urals	Sintashta		Stefanov and Epimakhov (2006)

Table 1 (continued)

No.	Site	Region	Culture	Radiocarbon date	Source
22.	Stepnoye VII, kurgan 2, g. 5	S. Urals	Alakul'		Kupriyanpova and Zdanovich (2015)
23.	Stepnoye VII, kurgan 4, g. 18	S. Urals	Petrovka		Kupriyanpova and Zdanovich (2015)
24.	Solntse II Cemetery, kurgan 4, g.1	S. Urals	Sintashta		Epimakhov (1996)
25.	Solntse II Cemetery, kurgan 5., g. 2	S. Urals	Sintashta		Epimakhov (1996)
26.	Solntse II Cemetery, kurgan 11, g. 2	S. Urals	Sintashta		Epimakhov (1996)
27.	Ulubai Cemetery, kurgan 1, g. 1	Kazakhstan	Petrovka		G. Zdanovich (1978)
28.	Ulubai Cemetery, kurgan 4, g. 1	Kazakhstan	Petrovka		G. Zdanovich (1978)
29.	Pichaevo Kurgan, g. 2	Volga–Don	Abashevo–Pokrovka		Moiseev and Efimov 1995
30.	Utevka VI Cemetery, kurgan 6, g. 4	Volga–Don	Potapovo	3760 ± 100 (AA-12568) 3510 ± 80 (OxA-4262)	Kuznetsov (2006)
31.	Utevka VI Cemetery, kurgan 6, g. 4	Volga–Don	Potapovo	3585 ± 80 (OxA-4264) 3470 ± 80 (OxA-4263)	Kuznetsov (2006)

g. = grave

Table 2 Chariot Burial Assemblages and Related Measurements (in cm)

No.	Site	Wheel pits' dimensions (X/Y/Z)—left/right	Diameter of wheels	Spokes (left/right)	Wheel track	Dimensions of the grave pit	Dimensions of the grave chamber (X/Y/Z)	Cheek-pieces	Horses	Projectile points	Melee weapons
1.	Berlik II Cemetery, kurgan 10	L: 20/85/20 R: 15/85/20	L: 110 R: 110	3/3	140	340×250×160	340×250×?	0	4	0	–
2.	Berlik II cemetery, kurgan 2	L: 30/90/20 R: 30/90/20	L: 121 R: 121	0/0	140	360×870×140	360×870×?	3	2	5	–
3.	Bestamak cemetery, g. 140	L: 20/70/20 R: 20/70/20		0/0	115 (?)	344×180×100	–/–/95	0	2	12	Axe, macehead
4.	Vetly-anka IV cemetery, kurgan 14, g. 6	L: 10/43/20 R: 10/43/20		0/0	200	370×390×50	–	0	1	0	–
5.	Kamennyi Ambar 5 cemetery, kurgan 2, g. 6 *(possibly one wheel—a* pars pro toto*?)*	L: 110/60/30 R: 0/0/0		0/0	–	370×215×95	330×180×20–30	1	2	6	–
6.	Kamennyi Ambar 5 cemetery, kurgan 2, g. 8	L: 25/100/35 R: 35/85/30		0/0	120	350×220×70	–/–/35	4	3	1	Two maceheads

Table 2 (continued)

No.	Site	Wheel pits' dimensions (X/Y/Z)—left/right	Diameter of wheels	Spokes (left/right)	Wheel track	Dimensions of the grave pit	Dimensions of the grave chamber (X/Y/Z)	Cheek-pieces	Horses	Projectile points	Melee weapons
7.	Kamennyi Ambar 5 Cemetery, kurgan 4, g. 9	L: 45/95/25 R: 28/-/25		0/0	140	325×400×120	–/–/76	0	1	0	–
8.	Kenes Cemetery, kurgan 5, g. 1	L: 30/70/30 R: 30/70/30		0/0	145	370×220×100	370×220/?	0	0	0	–
9.	Krivoe Ozero, kurgan 2, g. 1	L: 30/100/15 R: 40/100/15		0/0	150	260×390×150	370×240×50–130	1	+	0	Dagger
10.	Krivoe Ozero, kurgan 9, g. 1	L: 4/90/35 R: 4/100/40	L: 96 R: 102	7/7	115	370×230×285	320×160×95	4	5	2	Spear
11.	Nikolayevka II cemetery, kurgan 1	L: 18/48/15 R: 15/35/10		0/0	130	205×310×100	200×305×90	0	0	3	–
12.	Ozernoye-1, kurgan 7, g. 8	L: 15/80/9 R: 15/80/18	L: ? R: 106	0/0	140	520/316/30	331×179/69	0	0	0	–

Table 2 (continued)

No.	Site	Wheel pits' dimensions (X/Y/Z)—left/right	Diameter of wheels	Spokes (left/right)	Wheel track	Dimensions of the grave pit	Dimensions of the grave chamber (X/Y/Z)	Cheek-pieces	Horses	Projectile points	Melee weapons
13.	Satan cemetery, kurgan 1	L: 15/70/25 R: 15/70/25	L: 74 R: 74	0/0	150	390×250	–	1	0	0	–
14.	Sintashta cemetery, SM, g. 4	L: 15/72/20 R: 21/68/20		0/0	140	350×210×210	320×183×30	0	6	12	–
15.	Sintashta cemetery, SM, g. 5	L: 9/37/15 R: 12/42/20		0/0	130	370×250×170	365×300×10	4	8	20	–
16.	Sintashta cemetery, SM, g. 12	L: 30/100/25 R: 40/95/35	L: 92.8 R: 92.8	2/4	125	360×215×332	330×192×190	2	4	8	–
17.	Sintashta cemetery, SM, g. 16	L: 60/100/25 R: 80/100/25		0/0	110	270×185×313	225×150×30–40	0	+	3	–
18.	Sintashta cemetery, SM, g. 19	L: 28/85/24 R: 25/80/20	L: 80 R: 80	2/4	130	340×190×235	330×180×110-125	0	4	0	–
19.	Sintashta cemetery, SM, g. 28	L: 13/105/30 R: 11/100/30	L: 92 R: 92	4/3	140	280×160×230	280×160	0	0	0	–
20.	Sintashta cemetery, SM, g. 30	L: 25/97/34 R: 25/95/34	L: 92 R: 92	3/3	125	322×200×240	307×180×100–110	2	2	12	Spear
21.	Sintashta SIII	L: 30/80/– R: 21/43/15		0/0	95	400×315×300/260	–	0	1	0	Macehead

Table 2 (continued)

No.	Site	Wheel pits' dimensions (X/Y/Z)—left/right	Diameter of wheels	Spokes (left/right)	Wheel track	Dimensions of the grave pit	Dimensions of the grave chamber (X/Y/Z)	Cheek-pieces	Horses	Projectile points	Melee weapons
22.	Stepnoye VII, kurgan 2, g. 5	L: 18/79/13 R: 15/79/13		0/0	100	425×300×230	375×235×230	2	0	0	–
23.	Stepnoye VII, kurgan 4, g. 18 (*two pairs of wheel-pits*)	West: L: 18/65/10 R: 20/85/10 East: L: 12/53/10 R: 72/22/10		0/0	120 125	350×210×130	–	3	0	9	–
24.	Solntse II Cemetery, kurgan 4, g. 1	L: 22/85/25 R: 30/90/25		0/0	140	360×225×115	357×217×70-80	1	2+4	2	–
25.	Solntse II Cemetery, kurgan 5, g. 2	L: 15/55/10 R: 30/63/15		0/0	133	237×360×120	228×318×40	0	–	–	–
26.	Solntse II Cemetery, kurgan 11, g. 2	L: 20/90/15 R: 20/90/15		0/0	130	300×480×140	240×360×30	0	1	0	–

Table 2 (continued)

No.	Site	Wheel pits' dimensions (X/Y/Z)—left/right	Diameter of wheels	Spokes (left/right)	Wheel track	Dimensions of the grave pit	Dimensions of the grave chamber (X/Y/Z)	Cheek-pieces	Horses	Projectile points	Melee weapons
27.	Ulubai Cemetery, kurgan 1, g. 1	L: 40/105/20 R: 55/110/20		0/0	120	250×400×155	–/–/30–45	0	3	0	–
28.	Ulubai Cemetery, kurgan 4, g. 1	L: 40/100/20 R: 40/80/20		0/0	140	400×230×130	–	0	1	0	–
29.	Pichaevo Kurgan, п. 1 *(possibly only one wheel—a* pars pro toto*?)*	–		–	–	360/420×220/280×277	–	5	5	0	–
30.	Utevka VI Cemetery, kurgan 6, g. 4 *(possibly only one wheel—a* pars pro toto*?)*	–		–	–	–	–	4	2	9	Spear Dagger

Table 2 (continued)

No.	Site	Wheel pits' dimensions (X/Y/Z)—left/right	Diameter of wheels	Spokes (left/right)	Wheel track	Dimensions of the grave pit	Dimensions of the grave chamber (X/Y/Z)	Cheek-pieces	Horses	Pro-jectile points	Melee weapons
31.	Utevka VI Cemetery, kurgan 6, g. 4 *(possibly only one wheel—a* pars pro toto*?)*	–		–	–	–	–	3	0	5	Dagger

? = unknown value

Table 3 Summary of statistics at 95% confidence

Dimension	Wheel diameter	Nave length	Wheel track	Draft pole	Max. length	Max. width
n	47	45	28	25	16	16
Estimation	91 ± 8 cm	26 ± 4 cm	131 ± 8 cm	208 ± 20 cm	327 ± 20	205 ± 21

for handicraft industry. Including the cases without imprints does not change this result dramatically, resulting in a mean diameter of 91 cm with an error range of 82–99 cm (91 ± 8 cm at 95% CL). This estimated wheel diameter fits well with other known historical cases of chariots. For example, according to Littauer and Crouwel, Egyptian chariots show wheel diameters in the range 90–100 cm (Littauer et al. 2002, p. 320; Crouwel 2013, p. 82), and the chariots of Lchashen have wheels from 98 to 102 cm in diameter (Yesayan 1960, pp. 146–147). According to Piggott, the great majority of La Tène wheels approach a standard of 90 cm (Piggott 1983, p. 212). This narrow error range demonstrates that measurements of wheel pits can be used as a reliable indication of wheel diameter, and further suggests that Sintashta–Petrovka wheel diameters are similar to those of Egyptian chariots.

Due to the imprints of spokes and felloes left in the soil, it is clear that the Bronze Age people knew of and utilized the spoked wheel. To date, six recorded cases of spokes and eight recorded cases of felloe impressions have been recovered. The remaining cases do not provide such information, due to taphonomic processes or looting of the burial. However, these few recorded cases of spoked

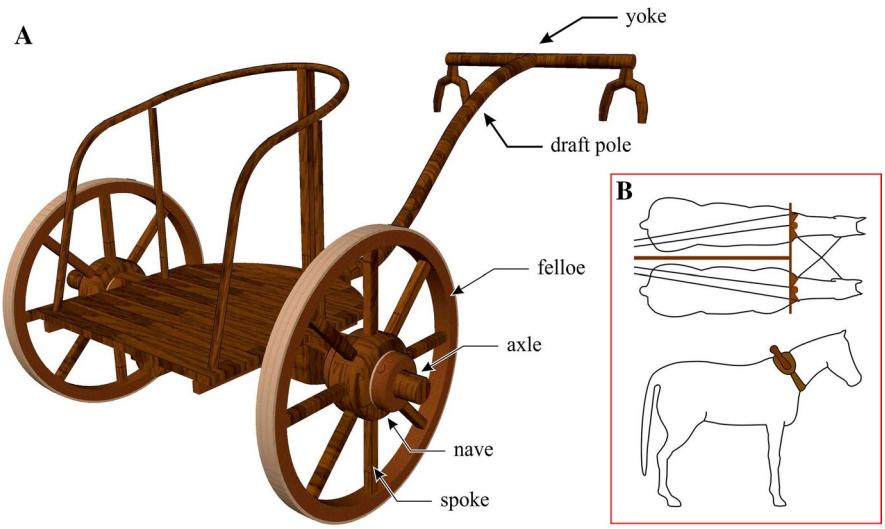

Fig. 7 **a** Principal elements of a chariot (original artwork); **b** neck-yoke system (redrawn after Spruytte 1983, pp. 14, 20)

wheels strongly suggest that spoked wheels were typical of Sintashta–Petrovka chariots. According to the imprints, the wheels consisted of 6–12 spokes, but statistical evaluation of these numbers is difficult. The reason is that wheel impressions usually represent no more than one-fourth to one-third of the wheel, so the actual number of spokes is not known, but rather estimated.

The nave (or hub) is the cylindrical element of a wheel, in which the inner ends of the spokes are secured, and through which the axle passes (Littauer et al. 2002, p. xviii). The nave is the most complex technology, and, unfortunately, we have very little actual knowledge about naves of Sintashta–Petrovka chariots. The only known, well-preserved case is from a vehicle recovered from the Krivoe Ozero cemetery. The dimensions of the nave are as follows: the inner diameter is 30 cm, the diameter of the hole is 20 cm, and the maximum length of the nave is 22 cm. The spatial dimension of burial chambers can also be used to calculate average nave length. The average length of the nave can be calculated as the distance between wheel pits and the closest wall of the burial chambers. Using this distance as a proxy for nave length for all burials with wheel pits indicates that mean nave length is 26 ± 4 cm at 95% CL.

Littauer and Crouwel used the nave length of the Krivoe Ozero vehicle to criticize the suitability of Sintashta and Petrovka two-wheeled chariots either for warfare or for racing. The main point of their critique is that a longer nave is necessary to reduce the wobbling of a wooden nave on wooden axles. Their argument is not supported by any actual observations or experimentation but is instead based on a perception that the 'great majority' of ancient naves are 40–45 cm (Littauer and Crouwel 1996, p. 938). However, Spruytte, in his experiments with a reproduction of a Central Saharan chariot, demonstrated that even simpler wooden wheels with naves as short as the thickness of the wheel itself could be driven successfully (Spruytte 1983, pp. 80–84). Obviously, the Sintashta chariots are the earliest experiments with this kind of fast vehicle and reflect the first steps in understanding chariot mechanics and establishing a general design. For this reason, the Sintashta chariots should be considered as a means of transport suited for the particular goals of an early complex society and the environmental conditions of the steppes.

(2) Wheel track is the distance between the centerlines of two wheels on an axle. It can be estimated on the basis of the distance between the central axes of all known wheel pits, in addition to direct measurement of the eight known cases of wheel imprints. When combined, these measurements indicate the width of wheel tracks to be 131 ± 8 cm at 95% CL. However, if we evaluate only those findings where actual imprints of wheels are present ($n = 6$), the width of the wheel track can be estimated as 136 ± 12 cm at 95% CL. This error range demonstrates that the Sintashta and Petrovka two-wheeled chariots were of similar size. Importantly, the estimated width of these wheel-tracks falls within the range of wheel-tracks found in other regions. For example, the Lchashen chariot N1 has a distance between the wheels of about 114 cm (Yesayan 1960, p. 146), and standard Late Bronze Age Egyptian chariots have an average distance between wheels of 160 cm (Littauer et al. 2002, p. 55; Crouwel 2013, p. 82).

Thus, the majority of findings with a mean wheel track of 136 ± 12 cm might represent either a single-driver chariot or a vehicle with two passengers who accessed

the vehicle from the rear, since one extreme of this wheel-track provides enough space for a standing person, while another is suitable for a driver and passenger. The outliers might stand for other types of the two-wheeled carts. For instance, we might think about having carts for a seated passenger or a pure mortuary cart not designed for everyday driving.

(3) The means of traction is the element that connects the vehicle to the yoke of the draft animals (Littauer et al. 2002, p. xvii). It is needed for a vehicle to be pulled by harnessed animals and is constructed as a central draft pole located between the animals, or shafts located on the external sides of the animals, called thills. The length of the means of traction depends on the size of the animal, and should allow enough space in front of the vehicle for the animal's pace. However, due to the lack of preserved examples in the archaeological record, it is necessary to draw on indirect evidence to characterize the means of traction. For the Sintashta–Petrovka chariots, the maximum possible length of the means of traction can be calculated as the distance between the front edge of the wheel pits and the far wall of the burial chamber. The mean maximum means of traction length is 208 ± 20 cm (95% CL), providing an upper limit that corresponds reasonably well with other known examples. For instance, one of Tutankhamun's chariots has a pole between the rail buttresses and forward end that measures 165 cm in length (Spruytte 1983, p. 31); in the N2 Lchashen chariot this dimension is 162 cm (Yesayan 1960, p. 147); and the Shang chariot from the entry ramp of tomb M1 at Qiaobei has a draft pole of about 180 cm (Wu 2013, p. 4). Moreover, the estimated length of the means of traction is adequate for small ancient horses, which were around 136–144 cm tall (Kosintsev 2010, p. 62), since the average length of their bodies would not have exceeded 140–160 cm.

The harness is another important part of the whole traction system because it transfers an animal's pulling effort to a vehicle. As Spruytte points out, there are only two basic types of harness for equids: those with and without a yoke. Yoke harnesses may be further subdivided into neck yokes and dorsal yokes (Spruytte 1983, p. 13). The burial records do not allow us to determine which type of harness was utilized with the earliest chariots, but petroglyphs from eastern Eurasia do. The majority of petroglyphs featuring traction systems are found in the Altai, the Pamirs, Kazakhstan, and Mongolia and date to the 1st–2nd millennia BC (Novozhenov 2012, pp. 37–44). Depictions of chariots usually show horses harnessed in pairs pulling a vehicle with a draft pole (Fig. 8). The only possible interpretation of a bar perpendicular to the pole, depicted in almost every single image, is a yoke. This perpendicular bar usually crosses the necks of the horses, suggesting a neck-yoke system (Fig. 7b). The same type is demonstrated on the Lchashen bronze models (Brileva 2012, pp. 314–315). However, some petroglyphs show that a bar might cross the heads of the horses, which would be consistent with Spruytte's 'traction-and-support bar' system of the harness. The latter is a very unusual harness system, although known from images in the Sahara and tested experimentally (Spruytte 1983, pp. 75–95). Even though the fuller interpretation of the harness systems depicted in the eastern Eurasia petroglyphs is uncertain, they clearly represent the means of traction of the real chariots.

Since the remains of chariots are often found in the context of wooden rectangular chambers with wheel pits located at one end of the chamber, the dimensions

Fig. 8 Depictions of a chariot on the petroglyphs, the Koksu River valley, Kazakhstan (redrawn after Novozhenov 2012, p. 45 with the author's permission)

of the chambers can be used to estimate the overall dimensions of the chariot, including the means of traction. Using burial chamber size as a proxy, chariots had a maximum estimated length of 327 ± 20 cm, and a maximum estimated width of 205 ± 21 cm. These dimensions suggest a great similarity to six chariots of Tutankhamun that have maximum dimensions of 260×236 cm (Crouwel 2013).

In sum, previous critiques of the suitability of Sintashta–Petrovka chariots for racing were concentrated on very few two-wheelers and excluded several important variables. The current state of knowledge about Sintashta and Petrovka chariots (Table 3) highlights their similarity to the measurements of the chariots the Near East. Statistical analysis of the dimensions of these chariots shows small error ranges, indicating a remarkably high degree of similarity between all known Sintashta–Petrovka chariots. This fact allows us to suggest that Sintashta and Petrovka chariot builders shared highly developed woodworking skills, including woodcarving and bending, and that they built their chariots with respect to a standard

model. Interestingly, the variation visible among La Tène chariots led Piggott to suggest that a uniform and standard 'Celtic chariot' did not exist in the La Tène culture area (Piggott 1983, p. 206).

Before proceeding further, it is important to note that while the dimensions of the burial chamber offer some clues about the dimensions of the chariot superstructure, they also present an obstacle to these estimates. It is well known that Bronze Age burial chambers have a horizontal covering. In eight of 27 cases, the height of the burial chamber from floor to ceiling is less than 50 cm. Thus, the inner space would not have accommodated a fully assembled vehicle. Not surprisingly, the wheel pits in these burials do not have imprints of spokes or of felloes. Nevertheless, the wheel-pits correspond in dimension to those with the imprints of spokes and rims. We argue that, while in some cases chariots remained in the graves, in others they were placed in burials only during mortuary rituals, after which they were replaced by other symbols of chariotry, such as cheekpieces or sacrificed horses. Similar observations were made after studying the chariots and their bronze models from Lchashen (Yesayan 1960, p. 148). This practice appears especially plausible in view of the complexity and value of chariots, and it underscores the high cost of creating and maintaining them. Nevertheless, the importance of chariots throughout life meant that a chariot or its parts accompanied people post mortem.

Associated Individuals

Association of chariots with people is complicated because nine of the chariot burials with skeletal remains are collective tombs, with a composition of mixed sex and age, and it is unclear if there are principal individuals in those burials (Table 4). On current evidence, it is not possible to confidently connect chariots with male individuals, mainly because qualified determinations of sex and age have been made in only a few of the cases of burials with chariots. Moreover, in seven of the 28 cases studied, human skeletal remains were not found. Individual burials occurred in nine cases, suggesting an association of chariots with specific persons, but only three individuals were identified as adult males who might be interpreted as charioteers and warriors (cemeteries of Bestamak, Krivoe Ozero, and Pichaevo). To illustrate this, there is a burial of a 34–40 year-old man in grave 140 of the Bestamak cemetery in northern Kazakhstan (Logvin and Shevnina 2008; Fig. 4). Even though the chariot was placed in the tomb only during the ceremony, and then removed before the grave was sealed at a height of 50 cm, the artifact assemblage is revealing. Included in the rich offering are a bronze axe, a stone macehead, and 12 projectile points, along with a set of 'peaceful' artifacts suggesting a craft specialist—probably a carpenter and metalworker (pestles, grinding plates and chisels)—as well as tools for subsistence pursuits (sickles and a fishing hook). Finally, two complete corpses of horses were placed over the grave cover. The authors suggest that this person was a chief, and that the burial context illustrates his significance in the social life of the local community (Logvin and Shevnina 2008, p. 193). However, it also suggests the diverse role of the Sintashta–Petrovka elites, who were likely engaged in

Table 4 Associated individuals

No.	Site	Number of individuals	Sex and age
1.	Berlik II Cemetery, kurgan 10	1	Unidentified adult
2.	Berlik II Cemetery, kurgan 2	–	–
3.	Bestamak Cemetery, g. 140	1	Male, 30–40 y.o.
4.	Vetlyanka IV Cemetery, kurgan 14, g. 6	–	–
5.	Kamennyi Ambar 5 Cemetery, kurgan 2, g. 6	8	Male, 30–35 y. o. Male, 13–16 y. o. Adolescent, 8–12 y. o. Adolescent, 9–13 y. o. Child, less than 10 y. o. Child, 1–2 y. o. Child, 1–2 y. o. Newborn
6.	Kamennyi Ambar 5 Cemetery, kurgan 2, g. 8	5	Male, 25–30 y. o. Female, 12–14 y. o. Child, 5 y. o. Child, 6 y. o. Child, 8 y. o.
7.	Kamennyi Ambar 5 Cemetery, kurgan 4, g. 9	2	Adult male Adult female
8.	Kenes Cemetery, kurgan 5, g. 1	–	–
9.	Krivoe Ozero, kurgan 2, g. 1	1	Unidentified adult
10.	Krivoe Ozero, kurgan 9, g. 1	1	Male, 50–55 y. o.
11.	Nikolayevka II Cemetery, kurgan 1	–	–
12.	Ozernoye-1, kurgan 7, g. 8	–	–
13.	Satan Cemetery, kurgan 1	–	–
14.	Sintashta Cemetery, SM, g. 4	2	Unidentified adult Unidentified child
15.	Sintashta Cemetery, SM, g. 5	5	Unidentified adults
16.	Sintashta Cemetery, SM, g. 12	1	Unidentified adult
17.	Sintashta Cemetery, SM, g. 16	1	Unidentified adult
18.	Sintashta Cemetery, SM, g. 19	1	Unidentified adult
19.	Sintashta Cemetery, SM, g. 28	2	Unidentified adults
20.	Sintashta Cemetery, SM, g. 30	1	Unidentified adult
21.	Sintashta SIII	5	Unidentified adults
22.	Stepnoye VII, kurgan 2, g. 5	1	Male, 30–40 y. o.
23.	Stepnoye VII, kurgan 4, g. 18	4	Male, 18–22 y. o. Female, 15–17 y. o. Child, 10–12 y. o. Child, 9–10 y. o.
24.	Solntse II Cemetery, kurgan 4, g. 1	1	Unidentified adult
25.	Solntse II Cemetery, kurgan 5., g. 2.	–	–
26.	Solntse II Cemetery, kurgan 11, g. 2	–	–
27.	Ulubai Cemetery, kurgan 1, g. 1	1	Unidentified adult
28.	Ulubai Cemetery, kurgan 4, g. 1	1	Unidentified adult
29.	Pichaevo Kurgan, g. 1	1	Adult male (?)

Table 4 (continued)

No.	Site	Number of individuals	Sex and age
30.	Utevka VI Cemetery, kurgan 6, g. 4	2	Unidentified adult Unidentified adult
31.	Utevka VI Cemetery, kurgan 6, g. 6	1	Unidentified adult

a number of different activities, such as warfare, craft production, food production, and a broad social life.

While there is no significant correlation between the burial of an adult male and the presence of a chariot in a tomb, the collective tomb 8 under kurgan 2 of the Kamennyi Ambar cemetery tells an interesting story. The tomb contains four persons, presumably buried simultaneously; three children of five, six and eight years old, and an adult man of 22–26 (Epimakhov 2005, pp. 32–41; Fig. 5). The male adult and the eight-year-old were laid facing and hugging each other, probably symbolizing a ritual(?) marriage. Intriguingly, a similar composition of age and sex of buried persons was found in burial 18, in burial complex 4 of the Stepnoye VII Cemetery (Kupriyanpova and Zdanovich 2015, pp. 45–53). In our example, the artifact assemblage consists of two maceheads, four cheekpieces, and one arrowhead, as well as four ceramic vessels and some metal artifacts. There is a sacrifice of two horses, two cows, three sheep, and two pigs. In our view, a chariot was placed in the tomb only for the mortuary rituals, or even just symbolized with the wheel pits since the closed sealing did not allow placement of a full vehicle. This evidence leads to the conclusion that the male was an important individual, and, probably, had an inherited elite status which allowed him to be buried together with a possible wife (a human sacrifice?), and glorified with a symbolic chariot and insignia of power.

While the evaluation of sex is not relevant to the problem of chariot reconstruction, it is important for the understanding of the nature of complexity. As suggested by Wright and some other archaeologists, not all warriors were necessary males (Wright 2008), so the nature of a social group characterized by chariots might not have been strongly related to male individuals, and both sexes could have used chariots throughout life, or at least have been glorified in funerals. However, this remains an unknown variable, since determinations of sex are not always available, although there is a tendency towards male individuals, or male individuals accompanied by female individuals (Table 4).

Weapons

The occurrence of chariots with different types of weapons is of considerable interest. To characterize this relationship, we draw a sample of 220 out of 251 excavated Sintashta (excluding Petrovka) burials with particular types of weapons, including 16 graves with chariots (Table 5).

There are 6 out of 16 burial chambers without any weapons, but all of them were robbed, or disturbed by animal burrows. Consequently, the results are biased towards

Table 5 Numbers of chariot and non-chariot Sintashta graves in which four kinds of weapons were also found

	All burials sampled	Chariot burials	Non-chariot burials
Projectile weapons	52/220	10/16 (62%)	42/204 (21%)
Maceheads	11/220	3/16 (18.7%)	8/204 (4%)
Spears	8/220	2/16 (12.5%)	6/204 (3%)
Axes	6/220	1/16 (6.25%)	5/204 (2%)

a lower ratio of co-incidence of weapons with chariots. Projectile weapons, including arrowheads and elements of a composite bow (Bersenev et al. 2011) were found in 42 out of 204 non-chariot Sintashta burials, as well as 10 out of 16 chariot burials. This kind of weapon predominates in the chariot burials. Stone maceheads are interpreted as symbols of power rather than weapons. There are 8 out of 204 cases in total, and 3 of them are within the same context as the chariots, showing an association between these two categories of artifacts. Spears and axes are rare weapon categories, but they have been also found together with chariots. In one case two maceheads were found along with cheekpieces, horses, and an imitation of a chariot (wheel pits with no imprints) (Kammenyi Ambar-5, kurgan. 2, g. 1). In sum, while weapons are not universally present with chariots, they are present much more often than in non-chariot burials: more than 50% of the chariot burials are accompanied by weapons, with a clear predominance of projectile arms.

Cheekpieces and Horses

Horses provide speed and maneuverability and are therefore essential features of the chariot complex. By the end of the third millennium BC horses were already a part of the subsistence system of steppe herders of the Pit Grave–Catacomb cultures, an important element of their ritual practices and, possibly, a means of transportation (for discussion see Kohl 2007, pp. 137–144; Anthony 2007). In the Sintashta–Petrovka period, more than 115 sacrificed horses occur in funerary contexts in the Ural-Kazakhstan region, which made horse the third most abundant animal used in funerary rituals after cattle and sheep (Zdanovich 2005). The analysis of horse burials of this period allowed Cherlenok (2006) to formulate three basic criteria that help to distinguish chariot horses from those offered for feasts. According to Cherlenok, these criteria are: (1) the remains of two horses in the same context; (2) such a pair forms a spatially isolated group; and (3) horses should be associated with remains of a chariot and cheekpieces. Cherlenok demonstrates forty-two burials of the Bronze Age across the steppes of the Volga–Tobol interfluve that meet these criteria (Cherlenok 2006, pp. 174–175). Importantly, there is a little difference between the number of chariots (28) and the number of cases where chariot horses are found in the burials (at least 42) (and they are coincident in the same context in 11 cases). This suggests that if the chariot horses symbolize and replace the actual chariots in the graves, the difference between observed chariots and missed is not large.

Of particular interest are cases of sacrificed horses in the Petrovka burial complexes. At ground level under the Petrovka kurgans, the pairs of sacrificed horses are located outside the graves (which symbolize vehicles), imitating harnessed teams pulling chariots (Zdanovich 1988). Coupled with several cases of two horses buried in conjunction with four cheekpieces within a single grave, these facts suggest the predominance of harnessed teams with two or more horses in horse-drawn two-wheel chariots. Significantly, this shows that Sintashta–Petrovka chariots utilized draft poles with a yoke as the means of traction. Taken together, these facts demonstrate a spread of horse-drawn chariots in Eurasia and their importance in funerary rituals.

The introduction of two-wheeled horse-drawn vehicles necessitated new means of animal control, and, as a result, bits with cheekpieces were invented (Ditz 1992). In other words, their relevance for the discussion of chariots is that cheekpieces are necessary elements for the control of a harnessed horse at speed versus a mounted horse, as demonstrated by Brownrigg in a series of experiments (Brownrigg 2006) and supported by our own study (Chechushkov et al. 2018). Cheekpieces are widely known across Eurasia, and nowadays there are more than 260 specimens associated with a variety of the Bronze Age cultures. Studded cheekpieces of bone and antler provide convincing evidence that chariots were used extensively in the Sintashta culture and were not just ceremonial objects. For this reason, it is worth looking at the frequency with which chariots, cheekpieces and horse remains appear together in the same archaeological contexts. As of 2012, among 251 Sintashta burials, 6% have direct evidence for chariots, 9% have cheekpieces and 10% contain horse bones (Epimakhov and Berseneva 2012). The ratios of these elements are similar and overall are not high, which possibly suggests a high ceremonial value for the chariot complex.

As for co-occurrence of the objects, Sintashta–Petrovka sites have yielded about a hundred cheekpieces, from both burial and domestic contexts. Cheekpieces are present in only 36% of chariot burials (9 out of 25), but the incidence of cheekpieces in chariot burials is still notably higher than in Sintashta burials as a whole, where it is at 9%. In addition, 9 of the 25 chariot burials were looted and may have contained cheekpieces originally. Moreover, chariots are clearly associated with sacrificed horses: 80% of chariot burials (20 out of 25) also contained horse bones, even though horse bones are only present in 10% of the 251 total Sintashta burials excavated. Thus, there is a relationship between the occurrence of wheel pits, cheekpieces and horse remains. They might represent the principle *pars pro toto*, in which a whole complex is represented by a part, which Piggott (1983) also proposed for at least some La Tène chariots. If it is true, then we can assume that burials of the Don–Volga Pokrovka–Abashevo culture and Potapovo culture of the same chronological horizon, with horses and cheekpieces, also contained chariots, at least during the burial rituals, as has been proposed by Cherlenok (2006).

Cheekpieces provide important insights into the use of the chariot as a transport vehicle, not just as a ritual object. As mentioned above, bits with cheekpieces are a requirement of harnessed horses—a mounted horse can be controlled by simpler means. For example, a Cook's bitless bridle comprises 'an elongated strap which includes a center piece at the poll, and two crossover

straps at the sides, attachable to a pair of reins providing a direct link between the centerpiece and the reins. The crossover feature of the bitless bridle provides for persuasive, but non-painful, pressure to be applied to the whole of the opposite side of the head of the horse, from poll to chin or for rapid alternate pressure to be applied to both sides of the head' (Cook 2003).

This demonstrates the principle, while archaeology sheds light on the process by which such means appeared. Analyzing horse-headed knobs, Kovalevskaya demonstrates the evolution of horse tack from a simple muzzle to a bridle with bits during the 5th and 4th millennia BC (Kovalevskaya 2014). Her analysis correlates well with a study of pathologies in horse teeth conducted by Brown and Anthony, who suggest the appearance of bits and horseback riding at Botai and Tersek (Anthony et al. 2006). Cheekpieces became the next necessary and logical step in the evolution of means of horse control. Their appearance together with the wheeled vehicles is not a coincidence, but the development of preceding tools. After the year 2000 BC, cheekpieces often occur together with sacrificed horses—13 out of 15 Sintashta burials with cheekpieces also contain horse bones (Epimakhov and Berseneva 2012)—showing evolution in the role of horses. Here it is worth noting that there is just one case of a bridled horse from the Srubnaya culture cemetery of Komarovka (Alikhova 1955). However, the well-known case of a horse's skull with cheekpieces from the Sintashta cemetery (Gening et al. 1992, Figure 22; Kohl 2007, p. 151) is an accidental misrepresentation that arose when an excavator was demonstrating the principles of horse breeding to students, and a photograph of the juxtaposed elements was later published in error (Vinogradov, personal communication 2008).

In her experiments, Brownrigg demonstrated that cheekpieces are an effective means of control, but she did not attempt to determine whether they prove the usability of chariots (Brownrigg 2006). However, a use-wear analysis of cheekpieces, undertaken by Usachuk, shows significant traces of intensive utilization (Usachuk 2012).

How long does it take to leave such traces in a pair of cheekpieces? In order to answer this question, a series of experiments was undertaken using a harnessed horse under control of an organic bit with cheekpieces (Chechushkov 2007; Chechushkov et al. 2018). We manufactured ten full-scale replicas of antler cheekpieces, typical for Sintashta–Petrovka and Abashevo–Pokrovka cultures, mounted them on leather mouthpieces, and then rode and drove horses with them. In the archaeological pieces, use-wear consists of traces of bit wear around the center hole of the artifact and in many cases is simply visible to the naked eye. The experiments show that after an average of 10–15 h of riding, barely visible use-wear appears on the surface of the cheekpiece, identical to that known from the ancient ones (Fig. 9). As such, the intensive use-wear found on the ancient artifacts likely corresponds to hundreds of hours of cheekpiece utilization in actual chariot driving situations. This conclusion strongly supports the idea that the Eurasian chariots were utilized for transportation needs and involved in activities that required intensive use, possibly even for racing or warfare.

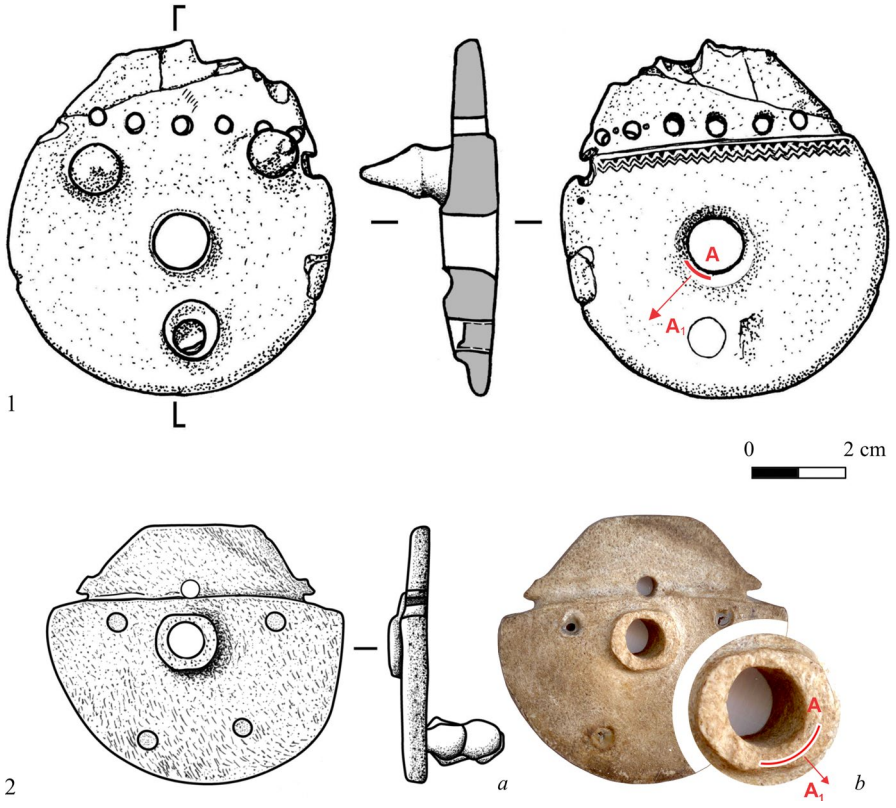

Fig. 9 Use-wear of cheekpieces. **1** The ancient cheekpiece from the Cemetery of Kammenyi Ambar-5, kurgan 2, burial 8 (A—the use-wear; A1—the vector of force). **2** the experimental piece (A—the use-wear; A1—the vector of force)

Chaîne Opératoire Analysis of Chariots

The abovementioned facts suggest that chariot technology is complex and expensive, and requires rare resources, skilled craftsmen, and an extensive production infrastructure. Evaluating the entire chain of material, labor, and skill that goes into their manufacture and use illuminates the social complexity involved in the chariot complex. This can be achieved through Leroi-Gourhan's *chaîne opératoire* analysis, which allows reconstruction of the organization of a technological system (Sellet 1993, p. 106). This can be based on the suggested standardization of some kind in the production of chariots, which allows us to present a generalized view of the utilization of the whole complex.

Manufacture and Complex Formation

Material Gathering

Chariots are built entirely out of organic materials and therefore require wood of specific quality for both durability and rider safety. Unfortunately, we do not have complete information about the different kinds of wood used to make the known prehistoric chariots, but hardwoods such as oak, ash, and beech are critically necessary for making suitable axles and naves. To approach the problem of material we conducted ethnoarchaeological research in the area of interest. We collected information about the construction and dimensions of ten spoked wagon and cart wheels, dating from the nineteenth and twentieth centuries AD. In each case the felloe element (circumference) of the wheel was constructed using bent wood, either from a single piece bent wholly round on itself, or from two or three bent felloe elements joined together (Fig. 10). We took samples of wood from two of these wheels for the further determination of tree species. The analysis was conducted by Dr. Stanislav Arefyev of the Institute of the Problems of Northern Development, Russian Academy of Science. According to Dr. Arefyev, these wheels were made out of common juniper (*Juniperus communis L.*) and pedunculate oak (*Quercus robur L.*). Neither species is local to the southern Urals, and material for these wheels was imported from either West Siberia or Eastern Europe. An archaeological illustration of the same issue is the wheels of an earlier two-wheeled cart from Ipatovsky Kurgan in the Don River region. They were constructed of non-local oak imported from a neighboring region of the northern Caucasus (Korenevskiy et al. 2007, p. 109). Similarly, Sintashta craftsmen had to search for the same kinds of wood in order to have flexible but hard material to make rims. Modern paleoecological studies suggest that around the year 2000 BC a remarkable rise of oak and other broad-leaved deciduous trees in the area of the Sintashta–Petrovka complexes (Stobbe 2013, p. 321) would have made the region East of the Urals a good source of raw materials. Furthermore, the steppes of the Trans-Urals and Kazakhstan were populated by wild horse, which is supported by finds of horse depictions in petroglyphs. One of the latest examples is a stone sculpture of a horse found near the city of Magnitogorsk in the southern Urals (Fig. 11). It clearly depicts a wild animal, which is interpreted as a Przewalski's horse (*Equus ferus przewalskii)* (Botalov and Vasina 2014). The latest studies of the Botai horses in Kazakhstan have also produced evidence of horse domestication in the area of study (Outram et al. 2009). Thus, the southern Urals and Kazakhstan, or the zone from where we know Sintashta and Petrovka, is the area of resources crucial for creating the chariot complex. Crafting of horse harness and bridles requires materials such as fine leather or cord, animal bones, and moose antler. All of these materials were available locally to Sintashta–Petrovka peoples, but processing demanded specialized skills and suggests some degree of craft specialization.

Bringing Together Specialists and Crafting

Due to its technical complexity, chariot production requires a number of specialists. Although Spruytte has shown that stone tools are sufficient to build a simple

Fig. 10 Wooden wheels dated to the nineteenth and twentieth centuries AD. The wheels are stored in the Museum-Reserve 'Arkaim'

vehicle (Spruytte 1983, p. 80), a skilled woodworker is necessary for woodcarving and bending, and also needs metal tools for these difficult tasks. Thus, a specialist in production of such tools is required. A leatherworker must be well acquainted with both tanning and horse physiology to produce proper harness elements. Finally, a bone carver creates cheekpieces, many of which are true masterpieces. While one person could have several specialties, this would require them to dedicate all of their

Fig. 11 Horse figurine found near the City of Magnitogorsk in the southern Urals (source, Botalov and Vasina 2014, with the authors' permission)

professional time to manufacturing chariots. Hence, it is unlikely that a single individual could master all the disparate tasks involved in chariot manufacture, or manage the time required to create a chariot single-handed.

Charioteer and Horse Training

Even a single horse needed to be trained properly to obey orders, and a team of paired horses required a more nuanced and complicated training. The well-known 'Kikkuli text' on chariot horse training, dating to around 1400 BC, highlights the importance and difficulty of this process (Raulwing 2009). Charioteers need special skills as well, since a fast horse-drawn vehicle is not easy to control. Moreover, if the warrior actually fights from a chariot, this entails further skills of shooting and stabbing from a moving platform. It would be necessary for a charioteer who trained horses and was practised in military affairs to combine these tasks.

Equipping the Charioteer

Finally, military tasks require specialized equipment for battle, namely, arrows, a bow, a spear, a mace, as well as armor or other protective gear. Production of all

this equipment at the Sintashta level demands separate specialists, including metal-workers.

Utilization and Discard

Battle

A few points can be made about chariot use in battle on the basis of its depiction in petroglyphs (Fig. 8). First, such events took place, even though we do not know the scale and type of prehistoric warfare during the Bronze Age. Second, projectile weapons played an important role in both warfare and hunting from chariots. Anthony has suggested that there is no need for a team of two for the operation of the chariot, and that a single driver-warrior could shoot a bow and drive a chariot at the same time, by wrapping the reins around his hips as the Egyptian pharaohs did (Anthony 2009, pp. 58–59). In general, we agree with this idea, but our personal experience suggests that wrapping the reins around the body serves mainly to avoid losing them while riding in the vehicle, but would not have been a means of actually controlling the horses: it is impossible to manipulate the horse bits precisely enough to actually steer, etc., solely relying on the relatively imprecise alteration of rein length and tension afforded by such a set up.

Consideration of the abundance of chariots produced in Sintashta times can provide insight into the nature of their use. With the current state of knowledge about this cultural material we can make some very approximate estimates, which should be taken as a minimum possible number. First, five fully excavated cemeteries in five Sintashta supra-local communities had a total of 21 kurgans or 4.2 ± 1.0 (80% CL) kurgans per cemetery. Since Sintashta cemeteries are usually associated with fortified settlements, we will assume that there are 25 cemeteries altogether, with a grand total of between 80 and 130 kurgans (80% CL). The 21 completely excavated kurgans yielded the remains of a total of 15 chariots, or 0.7 chariots per kurgan on average. At this rate, we would be fairly confident that the total number of chariots placed in all Sintashta kurgans was between about 56 and 91. Sintashta chariot remains have never been found except in kurgan burial contexts, but it is possible that some chariots were disassembled for parts or abandoned away from settlements, somewhat increasing this number.

Cheekpieces provide another way to estimate and a line of evidence since they directly represent chariots and sometimes occur in burial contexts, apparently as stand-ins for complete chariots. Four cheekpieces are needed to drive a team of paired horses, so in this sense, four cheekpieces are equivalent to one chariot. The 21 fully excavated kurgans yielded 36 cheekpieces, or 1.7 cheekpieces per kurgan on average. Thus, the grand total of the Sintashta cheekpieces buried in all kurgans is likely to be between 136 and 221, corresponding to between 34 and 55 vehicles. Some of these cheekpieces were found with actual chariot remains and so represent the same chariots as the previous estimate, but broken cheekpieces are also occasionally found in habitation contexts (at least another 15 pieces). This last fact allows us to say, that even if some kind of bias is introduced into the data, it is not a

critical point since the cheekpieces from the settlement are a random sample. Thus, we can assume, that the majority of cheekpieces were buried in the cemeteries and were not discarded at the dumps near the settlements.

We could add the number of chariots estimated from actual remains to the number estimated from cheekpieces to produce the most generous possible approximation of 90–146 chariots in total for all Sintashta supra-local communities through the entire 200-year period. The maximum estimate of 146 chariots equates to production of one chariot every 35 years in each community. The conclusion that chariots were rare and highly valuable objects is inescapable. Clearly, this number of chariots would not sustain massive chariot battles, but their use by charioteers as military leaders in localized conflicts would be possible. Moreover, the rarity of chariots in burials (only 6% of known burials) suggests chariots were an elite possession and therefore an elite aspect of warfare. In this case, a chariot was a means of transport to the battlefield, and might also have been used as a platform for shooting, and a symbol of the prestige and power of a war-leader.

Hunting

It is likely that once it was possible to travel faster than a man on foot, the hunter would take advantage of this swift form of transport. Even though wild taxa are a minor component of faunal assemblages in this area at this time, hunting scenes appear in petroglyphs (Novozhenov 2012, pp. 48–49). The functioning of the chariots is not entirely clear; however, Bronze Age hunting should not be envisaged as a chase like modern foxhunting, or the American Indian buffalo hunt. The chariot should be regarded as a means of transport to the chosen location, while the ridden horse would be more suitable as a top-speed all-terrain carrier.

Racing

Despite the suggestion that they would have been relatively unstable when driven at speed over rough ground or making sharp turns (Littauer and Crouwel 1996), it could be argued that anybody in possession of a means of swift personal transport would probably want to prove that his team was best by challenging others to a contest. Finds made subsequently to their study of the Sintashta and Krivoe Ozero vehicles have shown that several vehicles had a wider wheel track (see Tables 2 and 3), and would thus have been more stable. Furthermore, the use of studs on the cheekpieces is evidence of a preoccupation with control at speed, since they would not be necessary at slow paces. This is not, of course, not any indication of organized racing, nor of the kind of ritual races in the Indo-European tradition proposed by Jones-Bley (2000). It is unlikely that this would have been the primary use of the Sintashta–Petrovka chariots.

Use in a Ritual Context

It appears that ritual is the primary context for disposing of chariots, where they served as a symbol of the social status of a warrior (Gening 1977, pp. 68–69) and/

or as a as a mode of conveyance for the deceased to the Other World (Cherlenok 2006). However, the known imitations lead us to believe that other people (perhaps descendants) continued to use the chariot after the death of the previous user. Abandonment, disassembling for parts, or other means of destruction are also possible.

Discussion

As discussed above, some previous investigators have argued that these Bronze Age vehicles were not intended for extensive use (Boroffka 1999; Vinogradov 2011, pp. 90–91) and that they were instead imitations of Near Eastern originals, since the Eurasian Bronze Age societies were not sufficiently complex to have developed them independently (Kozhin 2007, p. 155; Kozhin 2015). Littauer and Crouwel (1996) suggested that they would have fewer advantages than ridden horses in the steppes and that their narrow gauge, short nave, and the presumed central position of the axle would have affected their stability, thereby limiting their maneuverability and making them impractical at speed. They argued that in the Near East there was a need for swift personal transport, whereas a horse-drawn vehicle developed in an area presumed to have practical experience of horseback riding must have been intended primarily for prestige and ritual. Moreover, since their study was published before radiocarbon dating was available for these vehicles (Kuznetsov 2006; Hanks et al. 2007), there was a presumption that the finds were contemporary with iconographic evidence for chariots in Anatolia and Mesopotamia dating to the 2nd millennium BC. During our experimental work briefly mentioned above, we utilized a 130 cm wide two-wheeled cart, and found no major difficulties, such as stability, in riding a vehicle without any suspension in such landscapes, even at a gallop. However, standing on a two-wheeled cart during a ride requires a lot of training and experience, and should be considered a special skill.

The evidence presented and analyzed here shows that horse-drawn chariots were a development of the Eurasian Steppe, they were functional and heavily used, and they indicate significant social complexity. Such important aspects of the chariot complex as horses and cheekpieces have been analyzed here in detail for the first time and add relevant insight to this discussion. The argument that Sintashta–Petrovka chariots had a very restricted function and were used only as a transport to the Otherworld (Jones-Bley 2000, p. 139) is not persuasive, since it is based on only limited early evidence and has not taken into account these aspects of the chariot complex. Anthony stated that chariots were invented in the southern Ural steppes (Anthony 2009, p. 62); however, it is important to underline the fact that the Sintashta–Petrovka two-wheelers represent already-developed technology, and do not have known local prototypes. Even the earliest types of shield-shaped cheekpieces have very developed attributes and demonstrate long-term preceding evolution. Since the whole Sintashta phenomenon was likely developed not in the Urals, but elsewhere (Vinogradov 2011), chariot technology also likely developed before the year 2000 BC in the Sintashta homeland, which is the Don–Volga interfluve. The reference point might be two-wheeled carts from the Catacomb culture, the Sintashta predecessor, dated to cal. 2400–2200 BC (Korenevskiy et al. 2007, p. 111;

Pustovalov 2008). These might be the prototypes for the later Sintashta–Petrovka chariot complex.

Discussing the idea of the Sintashta chariots as reminiscent of those found in Near Eastern cultures (Littauer and Crouwel 1996, p. 938), it should be noted that, for the Near East, the main way that chariot forms are dated is by deploying elaborate and complex relative-chronology arguments, and scholars are not in agreement about which version of the chronology is correct (Hasel 2004). There have been two attempts to build a radiocarbon chronology of Mesopotamia, but neither of them is recent (Mellaart 1979; Hassan and Robinson 1987), and a satisfactory solution has not been found (Reade 2001, p. 14). However, the periods contemporaneous with the Catacomb horizon and the early phases of Sintashta are the Early Dynastic III, where the Royal Tomb yielded four-wheeled wagons, and the Third Dynasty of Ur (Woolley 1934; Anthony 2009). The summed probability of six radiocarbon samples attributed to the Early Dynastic III period is cal. 2620–2200 BC (1 sigma) and five dates for the Third Dynasty of Ur sum up to cal. 2440–2030 BC (1 sigma) (Hassan and Robinson 1987). The absence of evidence for chariots in the Near East at this time (Izbitser 2013) contrasts with ample archaeological evidence of actual chariots in Sintashta–Petrovka sites. Hence, the Sintashta findings cannot be reminiscent of those from the Near East, as was suggested by Jones-Bley (2000, p. 139), and Genz (2013), since the chariot complex—evidenced by representations of equid-drawn vehicles with two spoked wheels (Littauer and Crouwel 1979, 1996)—was not known there until the early second millennium BC (Fig. 12). The classic chariot complex, or a true battle chariot drawn by horses, did not appear in the Near East until the Hittite Empire and the Kingdom of Mitanni, c. 1600–1200 BC (Oppenheim and Reiner 1977, p. 14; Novák 2007), even though 'The Kikkuli text' indicates previous extensive use and knowledge of chariots (Raulwing 2009).

Thus, the chariot complex is a complicated set of technologies, skills, and resources that first emerged in the zone of the Northern Eurasian steppes before

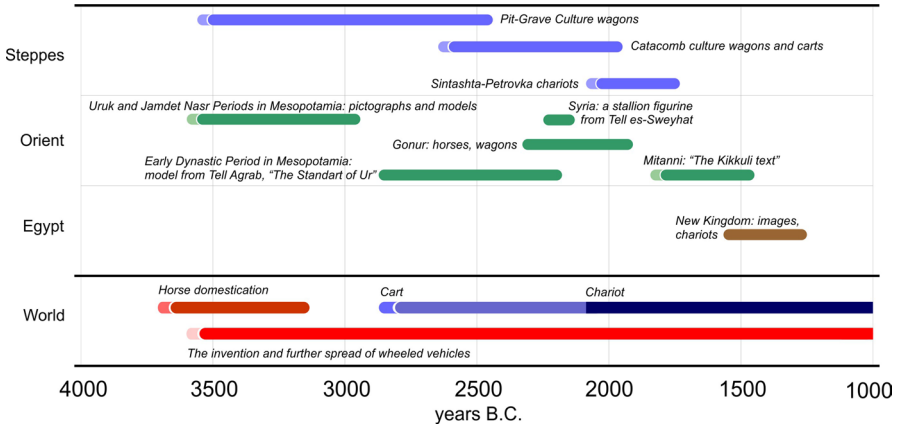

Fig. 12 Hypothetical scenario of the development of wheeled transport in the Old World in the 4th to 2nd millennia BC. Bars show the timeframe when development might have occurred, and text plots main finds in chronological order

2000 BC in the context of complex but stateless societies. Initially, chariots may have been used in local conflicts between competitive groups of people, as well as during the complicated and rapid expansion to the new regions, such as the migration of the pre-Sintashta groups from the steppes of the Don and the Volga to the Urals. The creation, utilization, and maintenance of the chariots would have required a number of important skills, and some degree of standardization in manufacturing chariots might be related to a very small number of chariot makers. This means that the Sintashta–Petrovka craftsmen were 'attached specialists' and made their products following the orders and desires of those who were interested in the competitive use of chariots. Hence, the social group interested in producing and maintaining chariots sponsored all of those processes. While the nature of this social group is unclear, it is reasonable to hypothesize that it could be a group of military elites characterized by aggrandizing behavior. These people shared military identities and values, but also belonged to bigger collectives, presumably diverse kin groups. The competition between these collectives for resources, power, and prestige created the chariot complex.

As a hypothetical scenario, these elites can be seen as those who kept their identity and manifested it through military-related activities and mortuary rituals. However, the abundance of the technology and the high cost of status maintenance did not allow elites to preserve it too long, since stateless societies could not accumulate enough resources. As a result, in the succeeding Alakul' period, when social structures had changed, chariots nearly vanish from the ritual sphere, even though they could still be used for transportation in everyday life. Thus, warfare played an important role during the mass migration of steppe pastoralists to new territories, and elites kept their privileges only due to a high level of conflict and competition between groups. This epoch can be metaphorically called 'The Age of Heroes', since people, involved in military-related activities, took the responsibility of keeping societal bonds and resolving conflicting issues. Once this competition and level of conflict decreased, the necessity of military elites also dissolved and they could no longer maintain their status. Possibly, more peaceful and ritual-related activities, as well as economy, became more important in social life, so in the following epochs elites gradually took other roles. However, the invention of the chariot complex and development of mounted warfare led to the global historical importance of the Sintashta case study and guarantee it a unique place in human history.

Conclusion

In conclusion, evidence provided by the study of the development of Bronze Age vehicles allows us to state that chariots were invented in Northern Eurasia before 2000 BC. The Sintashta–Petrovka finds represent the earliest known spoke-wheeled chariots, whose forerunners are found in the burials of the Catacomb culture. Thus, they were invented in the context of the pre-Sintashta cultures and fully developed during the Sintashta period. The connection with the Near East is not quite clear as yet; however, the chariot complex as a chariot with two spoked wheels drawn by a pair of bitted horses did not appear there until the early second millennium BC,

apparently associated with speakers of Indo-European languages (Raulwing 2009). We have no doubt that these chariots were actively used, and experiments with studded cheekpieces provide strong support for this conclusion (Brownrigg 2006; Chechushkov 2007). It is quite clear that the chariot complex played an enormous role in the social life of Bronze Age people. The Sintashta and Petrovka two-wheeled chariots were similar in construction and size, showing some degree of standardization and complexity. They were intensively used for personal transport, though the actual number of chariots was probably not great, due to the high cost of the vehicle with draft animals and a charioteer. Most fundamentally, their creation and maintenance required a group of people interested in this complex technology: a class of military elites characterized by aggrandizing behavior. Because of the great role played by horse chariots in the social and historical processes of the Middle and Late Bronze Age, the Sintashta–Petrovka chariot complex became a highly important feature of mortuary practices. The competition between collectives of military elites for resources, power and prestige brought to life the earliest horse-drawn chariots in the world.

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Compliance with Ethical Standards

Conflict of interest The authors declare that they have no conflict of interest.

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