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18

‘Metal makes the wheel go round’: the development and diffusion of studded-tread wheels in the Ancient Near East and the Old World

Simone Mühl

As emphasized by the image on the cover of Stuart Piggott’s book *Ancient Europe* (1965), the wheel is, perhaps, one of humanity’s greatest inventions. The ingenuity and simplicity of its idea and the forms we know today are the result of a long process that involved several stages of construction, testing and cumulative improvement. Developments in wheel technology were, of course, related to the emergence of different categories of vehicles – including different forms of carts, wagons, or chariots – each representing a response to changing needs in agriculture, elite representation and warfare. One of these modifications was the ‘studded-tread wheel’ and this will form the focus of this paper.

Early Bronze Age

The earliest examples for wheeled transportation in the ancient Near East already provide evidence for the use of the ‘studded-tread wheel’. Painted decoration on certain Scarlet Ware vessels from Khafaje (Smith 1933; Delougaz 1952: 70, pl. 62) and Susa (‘Donjon’ tomb 322; DV côte 9.80 1937/77: see Mecquenem 1943; Carter 1985: 45) shows vehicles with four wheels and ray-like protrusions on their treads. The vessels in question are dated to the beginning of the 3rd millennium BC (Figures 18.1-2). Glyptic remains from Uruk serve as further attestations for the first half of the 3rd millennium BC. Two seal impressions (W 24278, W 24547) belonging to the same seal (Figure 18.3) were found on sherds that had presumably once belonged to a single decorated vessel. They were found on the surface of the site near the city wall (Eb X 2) and in the northern centre of the city (Pe X 5) (Finkbeiner 1983: 29, pl. 1; Boehmer 1985: 104f., pl. 6.7, no. 58; 1991: 135, no. 23, pl. 254; 1992: 175, no. 4). The seal representation shows a procession which includes a drummer and a four-wheeled vehicle, the latter drawn by two equids and driven by a figure holding a staff-like object, most likely an axe of a type known from other depictions of charioteers in contest scenes (e.g., Hansen, 2003: 98f., row 1, fig. 1, row 3, figs. 1, 2, 6). As fragment W 24278 shows, the chariot runs on four wheels with spike-like patterned treads, similar to the representation on the vessels from Khafaje and Susa.

The schematic illustrations of the earliest wheels with profiled treads are matched by archaeological finds of entirely preserved wooden disk wheels. The details of

Figure 18.1. Motif on a Scarlet Ware vessel, Khafaje (after Delougaz 1952: pl. 62).

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Figure 18.2. Motif on a Scarlet Ware vessel, Susa (after Amiet 1966: fig. 106 A).

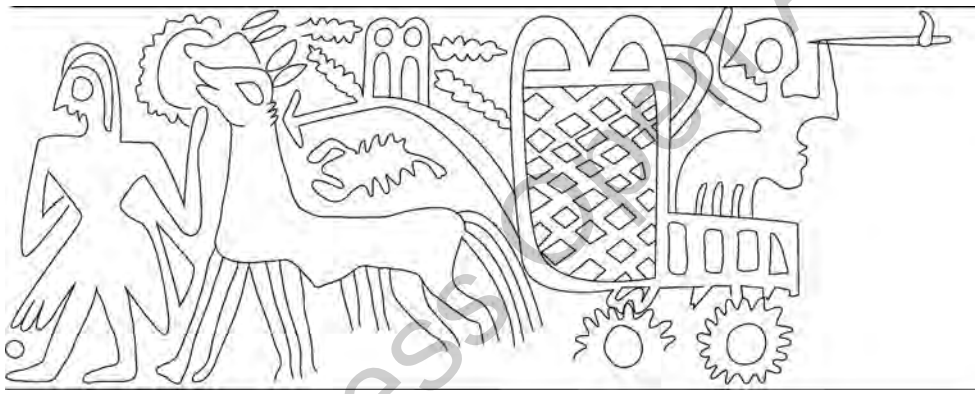

Figure 18.3. Drawing of a sealing from a vessel, Uruk (after Boehmer 1985: 105, no. 58).

these slightly later, mid-3rd millennium BC studded-tread wheel constructions were revealed by the organic remains of well-preserved carts that were uncovered in tombs at Kish and Susa. In the 'Donjon' area of Susa, a 'chariot burial' with four carbonized wooden wheels was excavated (grave no. 280: Mecquenem 1943: 122-24, pl.10 bottom). Unfortunately, the documentation of this discovery is lacking certain details. The only published photograph of the context (Figure 18.4) (Amiet 1966: 143 fig. 103) seems to indicate that the wheels belonged to a partially disassembled vehicle (for discussion of the context, see Carter 1985: 45). There were two differently-sized pairs of wheels: the diameters of the two sets measured 83 cm and 64.4 cm. The two big wheels were pinned with 86 and 91 nails, whereas the two smaller wheels had 64 nails attached to the tread.

In Kish three burials are reported to have contained a varying number of chariots or carts (Langdon and Watelin 1934: 30; Gibson 1972: 83-86; Moorey 1978: 104-10) including both four- and two-wheeled types of vehicles. One grave (Y529) might have held both. Only one four-wheeled example from grave Y354 (Figure 18.5) was discussed in the excavation report by Langdon and Watelin due to its exceptionally good state of preservation (Langdon and Watelin 1934: 13, fig. 3, 30-34). On the basis of this published description we can assume that the four wheels were of equal size, with a diameter of 50 cm. Leather straps on the treads had been fixed in place with the help of 55 protruding nails. This ratio between number of nails to diameter of wheel is comparable to the finds from Susa.

The impression that wheels with nailed treads were a fairly common feature in Early Dynastic Mesopotamia is supported by profiled terracotta discs with an incised or profiled side rail that arguably form part of clay (or in one case even copper) chariot models. Unfortunately, these probable wheels have only occasionally been found together with the model superstructures, but there are no known archaeological contexts and finds that would suggest that these discs could have been used in a different

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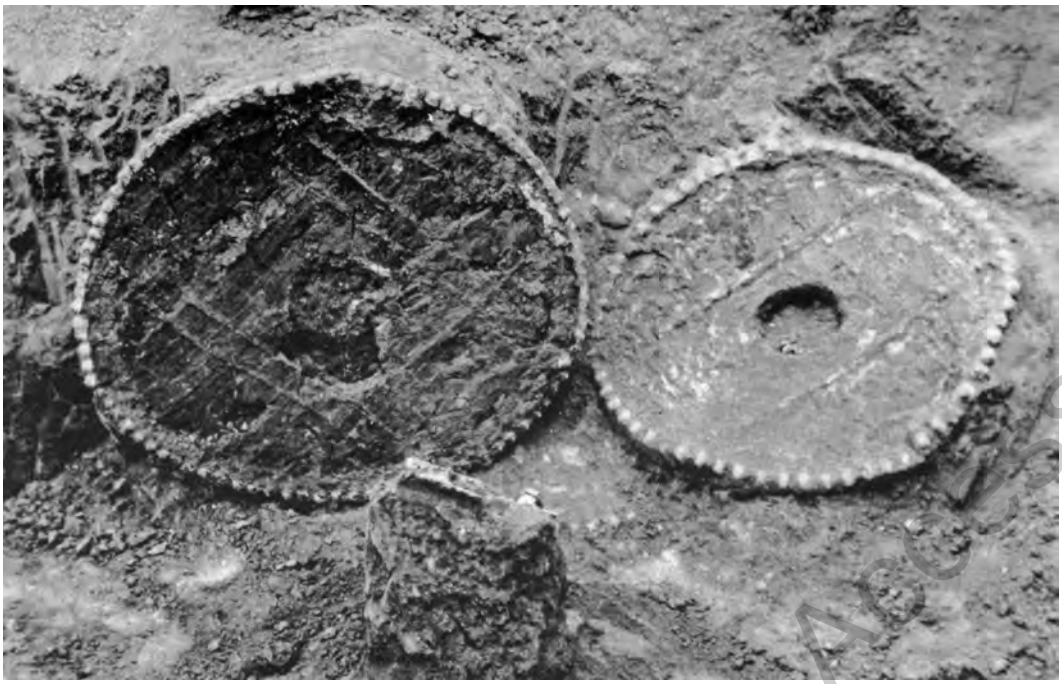

Figure 18.4. Cart burial, Susa (Amiet 1966: 143, fig. 103).

Figure 18.5. Cart burial, Kish (Langdon and Watelin 1934: pl. 23, 1).

way (e.g., as spindle whorls or net sinkers). We can, therefore, assume that these represent models of vehicles with studded-tread wheels.

Terracotta wheels with studded-treads can be divided into two categories: those with a flat hub and those with a convex hub. A convex hub would allow the wheel to turn more smoothly and reduce lateral wobble (cf. the Middle Bronze Ages finds from Lchashen in Avetyan 2003: pls. 45-47; for different nave constructions see Littauer and Crouwel 1979: 18f.). Two models with wider hubs have been discovered at Nippur (Figures 18.6-7). The wheels of the first model were used for a reconstruction of the chariot as a functioning vehicle in the publication of the terracotta objects from Nippur (see Legrain 1930: 30 no. 239; Bollweg 1999: 116 no. VI 06). The second model

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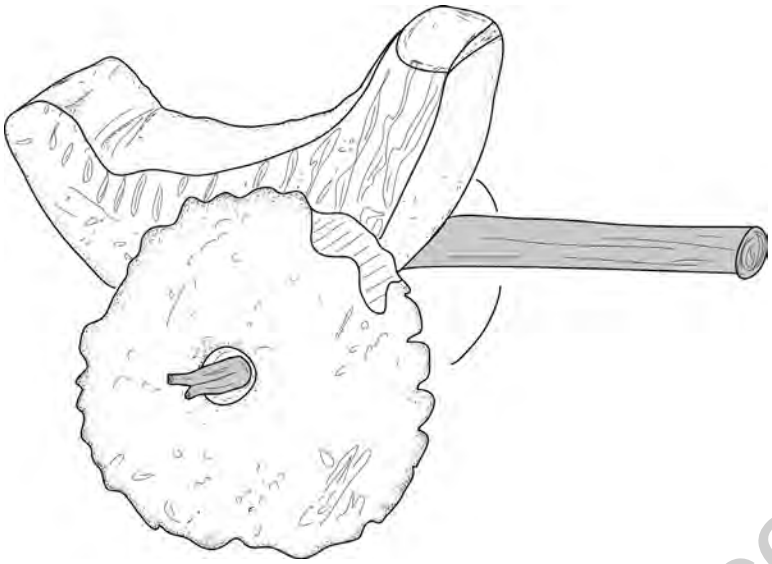

Figure 18.6. Terracotta, Nippur (after Legrain 1930: pl. 45, no. 239).

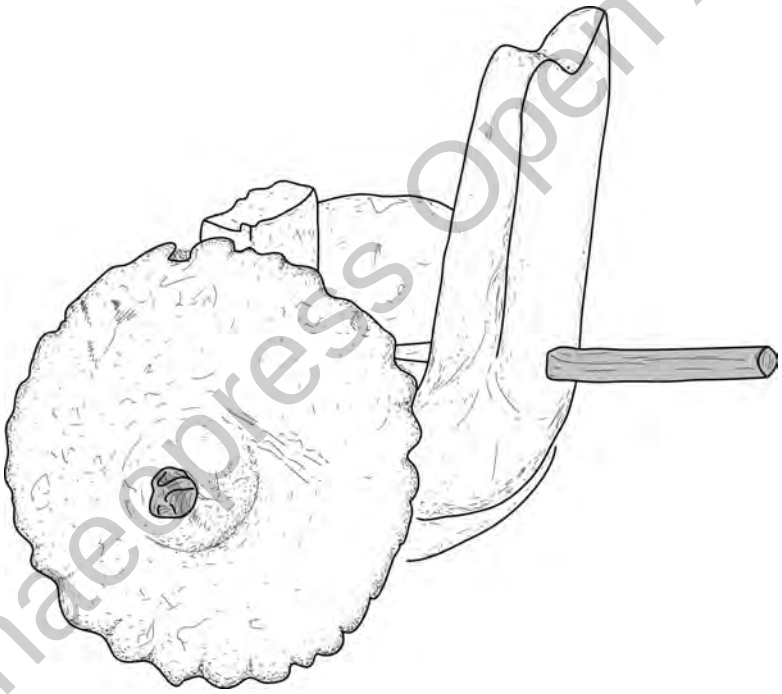

Figure 18.7. Terracotta, Nippur (after Legrain 1930: pl. 46, no. 241).

(Legrain 1930: 30 no. 241) was found together with the studded-tread wheels that had once been attached to it (Figure 18.7, see above). Unfortunately, the exact context of most terracotta-objects was not documented during the old excavations at Nippur with one exception (Legrain 1930: 3). This might be due to the fact that many terracotta wheels from controlled excavations were found in secondary contexts such as street debris, deposit layers and pit fills (cf. Bollweg 1999: 47).

According to Langdon and Watelin (1934: 11), a composite model from Kish (Figure 18.8) consisting of a chariot, two wheels, a male figure as charioteer and seven equids, was found *in situ*. The latter, however, has been challenged by Bollweg in her discussion of Ancient Near Eastern cart models (Bollweg 1999: 116 no. VI 08). The contexts of singular studded-tread wheel models, which were found in several areas at Kish, are unclear (e.g., FMNH 228304 from Ingharra Kish East; FMNH 156531, Ingharra Kish East, Y, 3 m below plain level, Level 3; FMNH 229151-52, Ingharra Kish East, Y, 1 m below plain level; FMNH 229855, 229857, 229985, 228181, 236408, 230985 and 2002.1.213, no provenance; see also the Kish Collection online database, Field Museum, Chicago: http://fm6.

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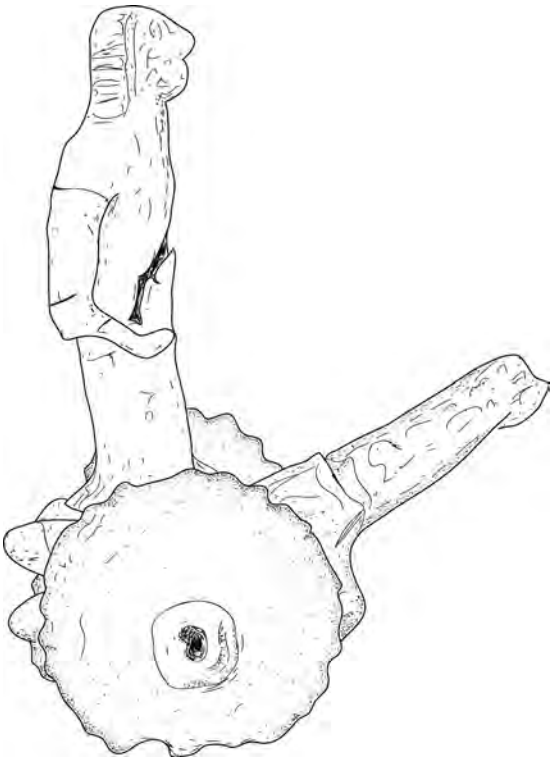

Figure 18.8. Terracotta, Kish (after Langdon and Watelin 1934: pl. 14, 1).

fieldmuseum.org/kish/kishSearch2.aspx [Accessed 13.04.2014]).

The copper model of a 'quadriga' (Ag. 36: 150) was found in room M 14:12 of the Shara temple at Tell Agrab (Delougaz and Lloyd 1942: 257, fig. 200 and 268; Frankfort 1943: 13, pls. 58-60). The two-wheeled vehicle (Figure 18.9) is drawn by four equids and the figure of a charioteer stands on a so-called 'straddle car'. The chariot seems to have been made of thick wooden beams and heavy tripartite wheels with nailed felloes. Nevertheless, it may have been lighter than the vehicles listed above, since there seems to have been no cabin construction. This lighter construction and the number of animals to pull it, suggest that this vehicle was meant to go fast and that it was not necessarily intended for use in combat (Littauer and Crouwel 1979: 34). One can think of the Agrab model as a depiction of a racing vehicle for an equestrian ritual sport or for elite contests.

Due to its geographical provenance, the model of a studded-tread wheel found at Tell Halaf is an exceptional find (Hrouda 1962: 18, 26 no. 210, pl. 22 no. 210). It was recovered from a secondary context within the so-called *Buntkeramikschicht* (the prehistoric deposits), but as Hrouda rightfully argued, it is very likely that it had originated from a Bronze Age layer. Be that as it may, this

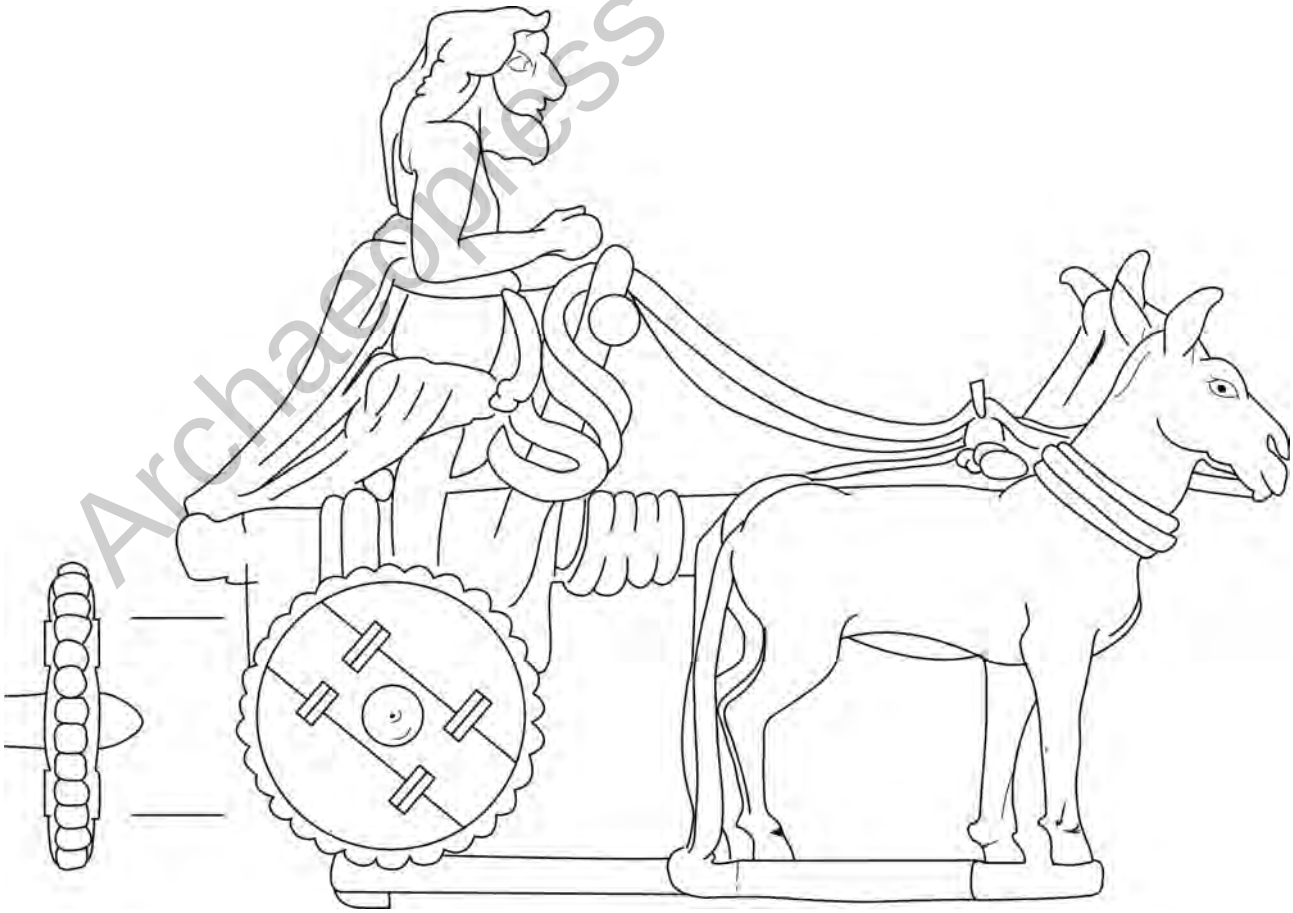

Figure 18.9. Copper model, Tell Agrab (after Frankfort 1943: pl. 60).

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artefact is of considerable significance for this paper as it is the only example of such a studded-tread terracotta wheel discovered in northern Mesopotamia. A variety of reasons may be responsible for the scarcity of representations of this kind of wheel in the north: the Halaf-wheel might have been imported from Babylonia as part of a model; but it is equally possible that the use of studded-tread wheels was so restricted in northern Mesopotamia at that time, that models and images of them were rarely produced.

The same type of wheel is also depicted in diverse scenes on fragmentary late 3rd millennium BC stelas. Only the studded-tread wheel and the hind legs of a draught animal are preserved on a small fragment of a relief found at Tello (Cros excavations, 1905: AO. 4586; Börker-Klähn 1982: cat. no. 61, with further bibliography, pl. F). The scene must have originally shown a chariot as part of a processional, war or religious scene. Larger fragments of a stela which is assumed to have been discovered at Tello (acquired by the Berliner Vorderasiatisches Museum in 1897: VA. 2902-2904 and other parts in the Istanbul Museum without inventory number) show a cult chariot, probably belonging to a war chariot of the god *Ningirsu*, that has a studded-tread wheel with schematized fringe-shaped nails (Börker-Klähn 1982: cat. no. 45a; Nagel and Strommenger 2001: 352-59).

Indirect hints at the spread of the studded-tread wheel as an aspect of vehicle technology or at least of its addition to the iconography of the region of Jiroft can be derived from two fragments of a chlorite vessel from Khafaje (Figure 18.10). One of the fragments was acquired in London or Chicago and eventually was joined to another fragment, found in room Q 43:11 of Sin temple IX at Khafaje (Frankfort 1935: 48, 52f., fig. 55; Delougaz and Lloyd 1942: 69 fig. 63). The fragmented vessel shows several contest scenes with monsters, lions, bulls, and a bird of prey catching caprids. Another scene on this vessel depicts a single-axle chariot driven by a charioteer who is holding a short spear or club. The right wheel of the chariot is shown with a studded-tread in the same fashion as the iconographic examples discussed above.

Figure 18.10. Motif on a chlorite vessel fragment, Khafaje (after Frankfort 1935: 48, fig. 55).

Beyond representations and evidence for presence across a wide area, the extant corpus also allows us to discuss some practical and technological issues: the type of wheel under examination cannot be attributed to a certain kind of vehicle. For instance, on the basis of depictions or recovered objects, studded felloes are associated with both two- and four-wheeled vehicles. We may also conclude that the entire vehicles with their full disk or compartment wheels must have been quite heavy. Even though some efforts were made to reduce the weight, and therefore increase the speed of certain vehicles for specific purposes, the light chariots of the Early Bronze Age were still rather heavy compared to examples from the 2nd millennium BC. This is evidenced by the use of massive disk wheels, thick axle wood and a superstructure consisting of thick wooden parts. It is likely that the wheels were affected by a high level of 'rolling resistance'.[1] Due to the great weight of the Early Bronze Age construction and the large friction-surface of a stiffly-attached axle that had to be lubricated repeatedly, it is very likely that the wheel had trouble turning on a slippery surface or in mud. This must have been a major problem especially after longer periods of rainfall. Adding thick headed protruding nails to the tread of the wheel was therefore a solution to avoid this particular problem. The same principle can still be found today in special car tires for wet and cold seasons with deep lateral grooves on the tread.

Iron Age

Although there are numerous Middle and Late Bronze Age attestations for wagons and chariots (cf. Littauer and Crouwel 1979: 48-98; Piggott 1983), not a single known example points to the use of studded-tread wheels.[2] The 2nd millennium BC is characterised by the spread of the light chariot, fitted out with wheels made of bent wood pieces as opposed to older solid disc wheels (which consisted of one or more planks of wood). As vehicles became lighter, their potential for use in warfare changed. During the Early Bronze Age, the standard crew of a war-chariot seems to have consisted of the charioteer and a warrior wielding an axe and/or a set of short spears. At that time, the charioteers might hunt down single enemies at the periphery of fights or in the aftermath of a battle. In contrast, the 2nd millennium BC fast chariot is manned

[1] 'Rolling resistance' is defined as the power that opposes the movement of a wheel. It explains, for example, why thin wheels have difficulties when moving on sandy ground (they sink deeper, thereby exposing a larger surface of the wheel to friction) or why it takes more power to move rubber tires that are low on air pressure. Several factors are involved, such as the diameter of the rolling object, the size of the surface that is in direct contact with the ground, the firmness of the ground and the tire, the lubricity of the wheel-axle connection. The calculation of the 'rolling resistance' coefficient offers a physical description of this phenomenon (Seireg 1998).

[2] A single image depicted on a cylinder seal of uncertain provenance (BM 89774) was acquired by the British Museum in 1825 and might represent the only 2nd millennium BC attestation of a vehicle with studded-tread wheels. It is dated to the Old Assyrian period and shows a double-axle wagon with front shield that is drawn by four animals (Curtis and Tallis 2012: 85 no. 4). However, the uncertain provenance of the object, its singularity as well as its unclear iconographic details do not permit us to consider this seal as 'secure evidence' for the existence of Middle Bronze Age studded-tread wheels.

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with a driver and an archer (Littauer and Crouwel 1979: 91, 98, 138; Moorey 1986: 203f., 206-10). With such a crew, it might have been possible to drive along the enemies' flanks and shoot arrows not only at the adversaries' first line, but also at soldiers that were positioned further back, thereby inflicting more damage. Apart from the military aspects, representations from Mycenaean Greece hint at the Bronze Age origin of chariot racing (LH IIIB final and LH IIIC early vase paintings from Tiryns and Mycenae: e.g., Crouwel 1981: 145, pl. 66 [V51]; Güntner 2000: 21f., Wagen 16 and 17, 194f., 196, pls. 3 no. 7; 5 nos. 1a and 1b), which only became possible through the reduction of vehicle weight and the introduction of horses as fast draught animals. It is believed that chariots reached their climax of technological development at the end of the Late Bronze Age:

> Wirkliche Steigerungen und eine Verbesserung des Kosten-Nutzenverhältnisses waren nicht zu erreichen. Im Gegenteil: Was folgte, waren im wesentlichen nur mißglückte Versuche, die Beweglichkeit zu erhalten und den Schutz der Lenker und Schützen zu verbessern – die militärische Effizienz blieb dabei weitgehend auf der Strecke. (Mayer 1995: 448)

In the 1st millennium BC, iconographic evidence suggests that chariots became heavier again. The need to improve the crew's protection might have been one cause for this development, but it could have also been connected to an increased number of soldiers/people riding in the vehicle. During the 9th century BC, Assyrian alterations in chariot design seem to have been related to the addition of a third person to the chariot crew. A shield bearer was introduced to enhance the protection of both the driver and the archer (although the latter acted sometimes as javelin thrower instead). A fourth crew-member is first depicted on reliefs dating to the 8th century BC (Littauer and Crouwel 1979: 104). By then, the party on the chariot seems to have usually consisted of a driver, an archer and two shield bearers, but the latter could also fight as javelin throwers. By the time of Ashurbanipal, the chariot cabins seem to have become large, solid, and firmly constructed platforms. The royal chariot had larger wheels with spokes. Compartment elements gave additional strength to it to carry the, by now, even heavier superstructure. The larger crew (sometimes with a cargo of hunted, dead lions) and the improved armour of the vehicle, contributed to the weight pressing down on the wheels. It is at this time that the studded-tread wheel can once again be seen on depictions of chariots. The earliest examples from this age can be found on the palatial reliefs of Ashurbanipal, discovered in Sennacherib's Southwest Palace and Ashurbanipal's North Palace at Nineveh (Table 18.1), but they are also represented on the wall paintings of the palace at Til Barsip which are also dated to Ashurbanipal's reign (Parrot 1961: 270 fig. 345; Figure 18.11). All chariots with the studded-tread wheel depicted in Late Assyrian monumental art are royal chariots. During the period of Ashurbanipal only one royal chariot is depicted with non-profiled treads (Barnett 1976: 54f., pl. 60).

For Late Assyrian art the question remains if the representations of protruding nails on the tread of the royal chariot should emphasize a precious material for nails that were used to fix perhaps metal treads to the wheels; or if their shape resembles the actual appearance of a studded-tread. The second possibility can be seen in the find of

ID	Building	Date (King)	Room	Slab	Reference
1.1	Southwest Palace	Ashurbanipal's refurbishment	room XXXIII (BB)	slab 386c (s6)	Barnett *et al.* 1998: 29, 97, pl. 309
1.2	Southwest Palace	Ashurbanipal's refurbishment	courtyard XIX (U)	slabs 282b and 273a (s21)	Barnett *et al.* 1998: 81f., pls. 191, 205-207
2.1	North Palace	Ashurbanipal	Room C	slabs 5 and 9	Barnett 1976: 37, pls. 5, 6; Börker-Klähn 1982: 218, no. 229
2.1	North Palace	Ashurbanipal	Room C	slabs 14, 24 and 20	Barnett 1976: 37f., pls. 8, 10-12
2.2	North Palace	Ashurbanipal	Room F	slabs 2 and 15, fragment C (Louvre AO 2254, formerly 27368)	Barnett 1976: 39f., pls. 16, 21
2.3	North Palace	Ashurbanipal	Courtyard J	slab 9	Barnett 1976: 44, pl. 28
2.4	North Palace	Ashurbanipal	Room M ('Babylonian Room')	slab 13	Barnett 1976: 46f., pl. 35
2.5	North Palace	Ashurbanipal	Room S[1]	slab A	Barnett 1976: 53, pl. 56

Table 18.1. Catalogue of Nineveh reliefs by room.

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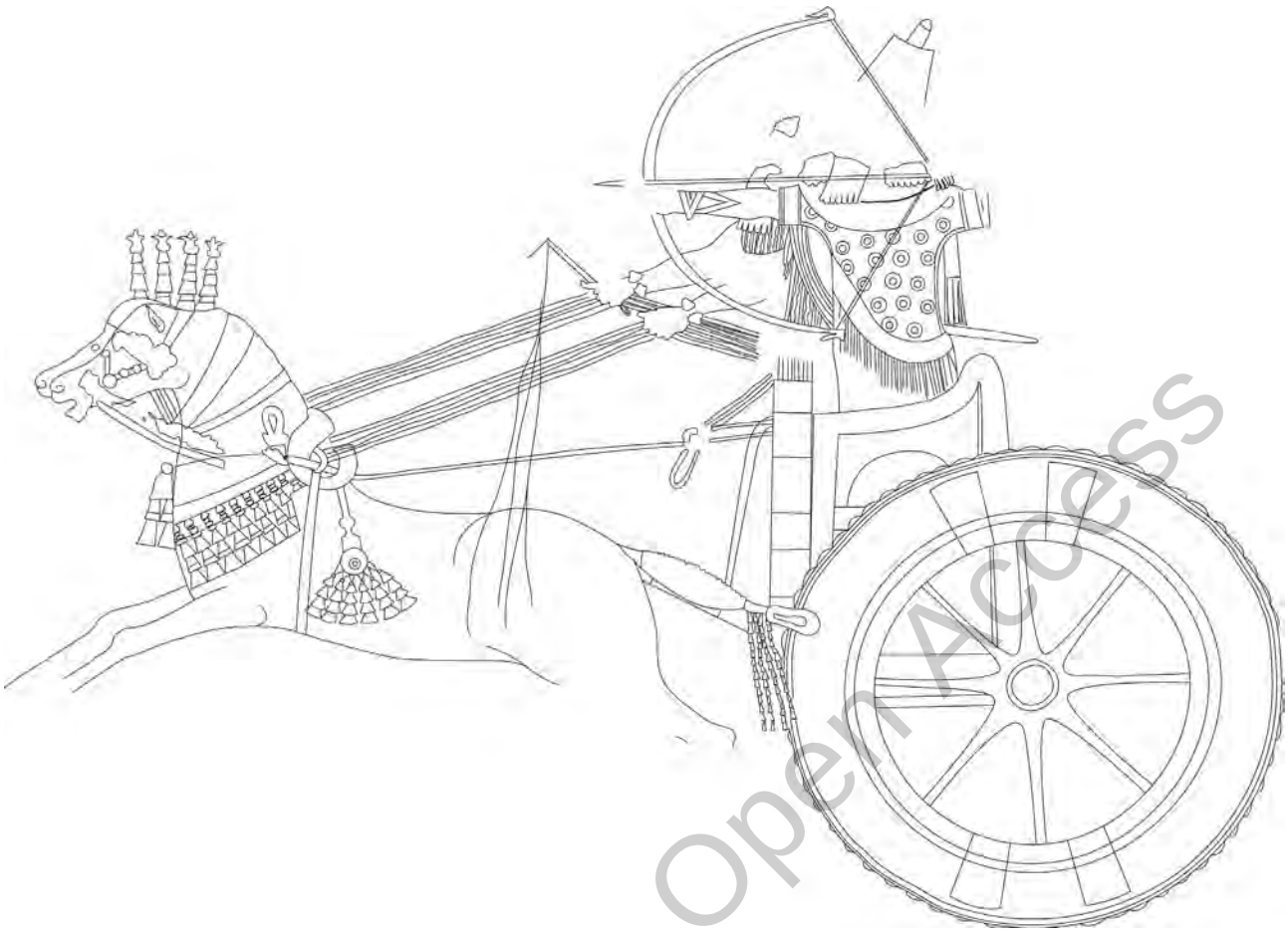

Figure 18.11. Chariot scene, Til Barsip (after Parrot 1961: 270, fig. 345).

wheel parts preserved within a 7th century BC tomb in Balıkesir-Üçpinar (Kökten Ersoy 1998a: 132 fig. 1, 145 fig. 13; 1998b: 115 fig. 5). The wheel can be reconstructed with twelve spokes. The compartment pieces were attached with the help of long nails and clamps. Similar to the known Early Bronze Age wheels, a tread, in this case made of iron, was nailed over the whole surface.

In the 1st millennium BC, however, the studded-tread wheel was also used outside Mesopotamia. A prime example comes from the Urartian necropolis at Lori Berd in Armenia. There, a silver beaker (Figure 18.12) was found in grave 56 (7th-6th century BC), which is also known as the 'royal grave' (Kalantaryan 2007: 74; Debedjyan 2010: 79-81). The beaker, which is distantly reminiscent of late 8th century BC Assyrian Palace Ware (cf. Hausleiter 2010: 308-10, pls. 86-87), is decorated with an incised scene around the middle of its body. It shows a two-wheeled chariot carrying a driver and a person holding a long spear and a round shield. The image of a palm tree separates the chariot from a row of horsemen. When taking a closer look at the right wheel of the vehicle, one can observe a number of small lines cross the external boundary of the five-spoke wheel thus implying that they penetrate its frame. These lines seem to be a schematic representation of felloe nails.

Further evidence suggests that this particular type of wheel had a wide distribution in the 1st millennium BC and its use was no longer restricted to Near Eastern contexts. The remains of actual chariot wheels were preserved in at least five Etruscan chariot burials, excavated along the west coast of central Italy (Table 18.2). The chariot from Castel di Decima (Figure 18.13) is dated to the 8th century BC, whereas vehicles found in Vetulonia, Populonia and Vulci are slightly younger and are approximately contemporary to Ashurbanipal's palace reliefs. The context of an example discovered at Cerveteri might be even earlier in date.

Whereas all of the Etruscan examples were found in funerary contexts, no Assyrian grave yielded any evidence of complete or disassembled vehicles or draught animals.[3] This raises the possibility of a difference between Assyria and Italy concerning the way chariots were embedded into the respective systems of material culture expression.

[3] The horses mentioned in the royal funerary text K. 7856+K. 6323+K. 14241+80-7-19, 122 (Mofidi Nasrabadi 1999: 25-31, with further references) were not 'broken', as clearly stated by the used term '*la rakbutu*', Akkadian for 'not ridden/not mounted' (Mofidi Nasrabadi 1999: 28 col. III l. 17; akk. **rakābum* – to ride, to mount, CAD 14: 83-91).

Figure 18.12. Silver beaker, Lori Berd (after Kalantaryan 2007: pl. 74).

ID	Place	Context	Comment	Date	Reference	Illustration in this volume
1	Cerveteri	Sorbo cemetery, Tomba Regolini-Galassi, tomb 8 (formerly LXI)		6th-5th c. BC	Crouwel 2012: 199, pl. 116a	Figure 18.14
2	Vetulonia	Costiaccia Bambagini-Lippi cemetery, Tomba del Tridente		7th c. BC	Cygielman and Pagnini 2006; Crouwel 2012: 144, pl. 4	
3	Populonia	San Cerbone cemetery, Tumulo dei Carri	related to Vulci and the older Castel di Decima chariot	7th c. BC	Emiliozzi 1997: 164-67, figs. 2, 4, 5; Crouwel 2012: 143, pl. 3	
4	Vulci	Osteria cemetery, Tomba del Carro	to Populonia and the older Castel di Decima chariot	7th c. BC	Emiliozzi 1997: 149f., figs. 13, 15, 16; Crouwel 2012: 142, pl. 2	
5	Castel di Decima	Via Pontina cemetery, tomb 15	related to the younger Populonia and Vulci chariots	late 8th c. BC	Emiliozzi 1997, 96, fig. 1; Crouwel 2012, 141, pl. 1a	

Table 18.2. Catalogue of Etruscan burials with studded-tread wheel chariots.

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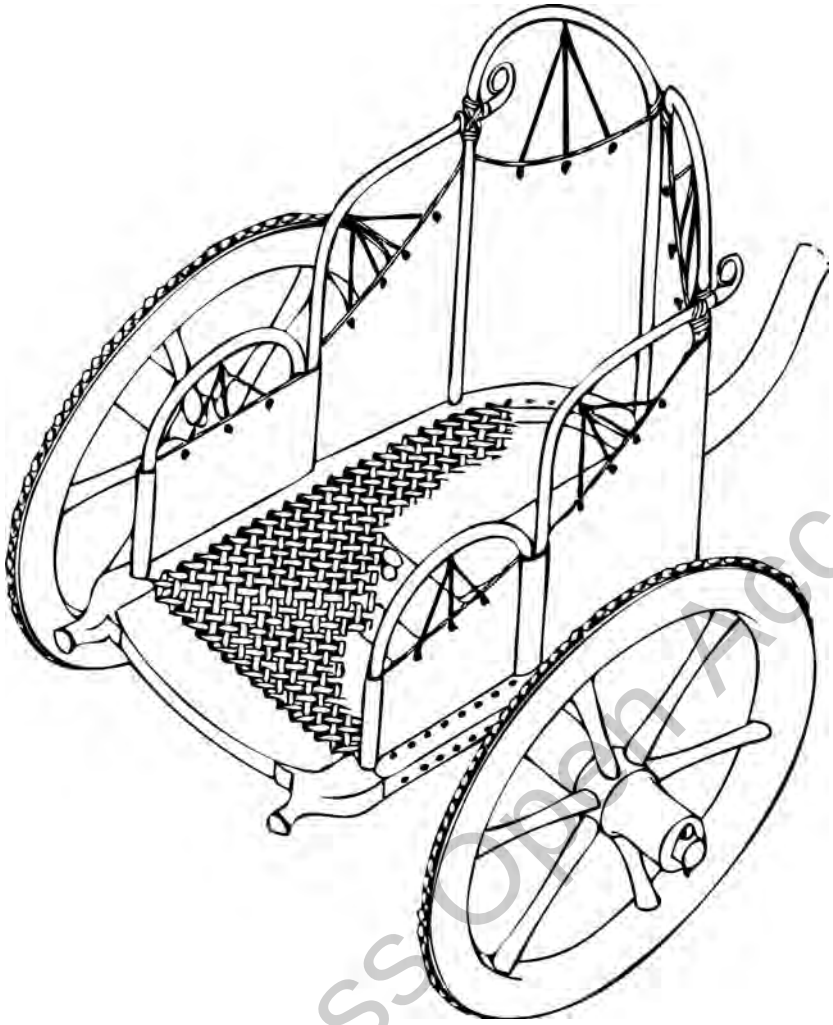

Figure 18.13. Chariot, Castel di Decima, Via Pontina cemetery, tomb 15 (after Crouwel 2012: 141, pl. 1a).

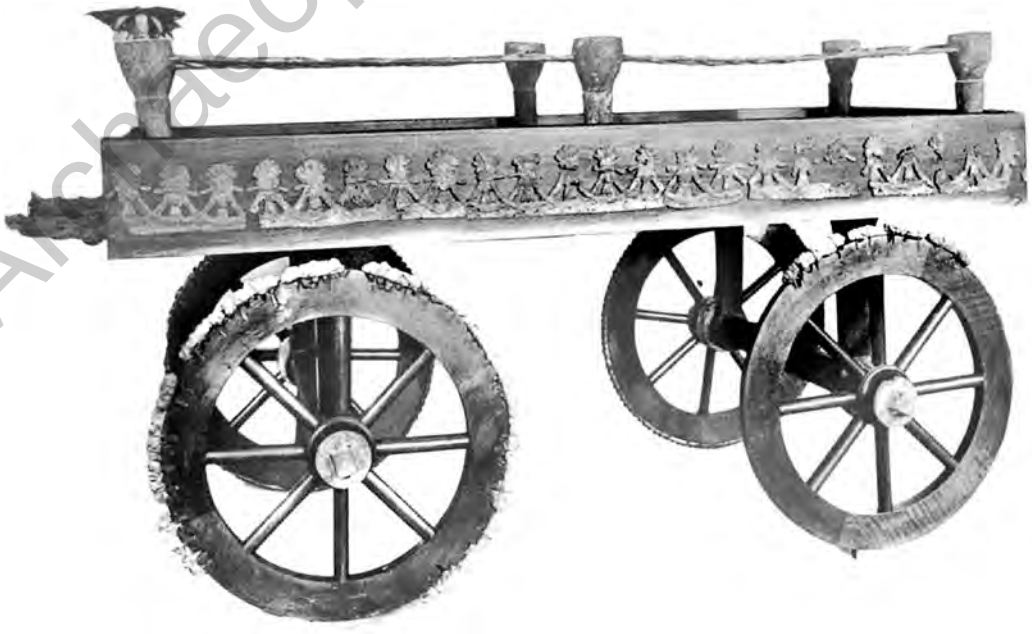

Figure 18.14. Cerveteri, Sorbo cemetery, tomb 8 (after Crouwel 2012: 199, pl. 116a).

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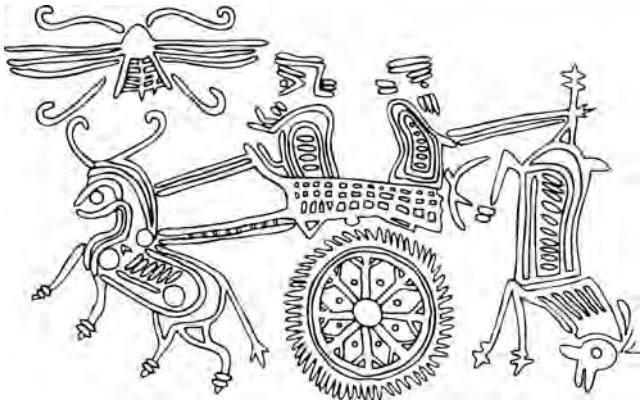

Figure 18.15. Drawing of a sealing, 7287/SS199, Gordion (after Dusinberre 2005: fig. 44, cat. no. 34).

A third group, represented by finds of single wheels and hubs from ceremonial wagons, was discovered in a variety of contexts that can all be attributed to the central European Late Bronze Age Urnfield culture, dating approximately to the 8th century BC. Wheels with nailed treads found in Stade in northern Germany and on the northern bank of Lac de Neuchâtel, Switzerland, have been categorized as 'Coulon Type' (Pare 1987: 49 nos. 1, 7, 51f.; Höneisen 1989: 24, 27, fig. 4). They were made of bronze with wooden compartments fixed to the metal parts by bronze nails, and they bore the marks of heavy usage. The diameters of the wheels ranged from 58 to 68 cm, and their construction style and size made them heavier than wheels of older Urnfield types (Pare 1987: 52).

The latest, but richest complex of ancient Near Eastern examples of the studded-tread wheel is provided by Achaemenid and contemporary contexts. Seals and sealings from Daskyleion (Kaptan 2002: 91-96, 198, no. 205 [DS 68], 105f. 206, no. 253 [DS 85]) and Gordion (Figure 18.15) (Dusinberre 2005: fig. 44, cat. no. 34 [7287/SS199]), as well as the royal seal of Darius (presumably the first of this name) with an uncertain provenance from Lower Egypt (BM 89132, acquired in 1835 by the British Museum; Merrillees 2005: 52, 106, fig. 10i, pl. 7, no. 16; see also BM 123292 on pl. 6, no. 15, for a cut-style example), indicate the wide distribution of this particular feature of ancient transportation technology. Furthermore, two grave stelas (Figure 18.16) with depictions of heavy burial carts with studded-tread wheels were discovered at Daskyleion (Borchhardt 1968: 192-94, 196-99, pls. 40, no. 1, 41, no. 2; 47, no. 2, 50, no. 1: Istanbul Museum inv. nos. 5763-64).

The Persepolis reliefs offer further, more-or-less contemporary, representations of such wheels. On the Apadana stairway there are representations of several delegations bringing chariots equipped with studded-tread wheels as tribute gifts to the Persian king (Schmidt 1953: pls. 32 and 48). A closer look reveals that the Persian king's

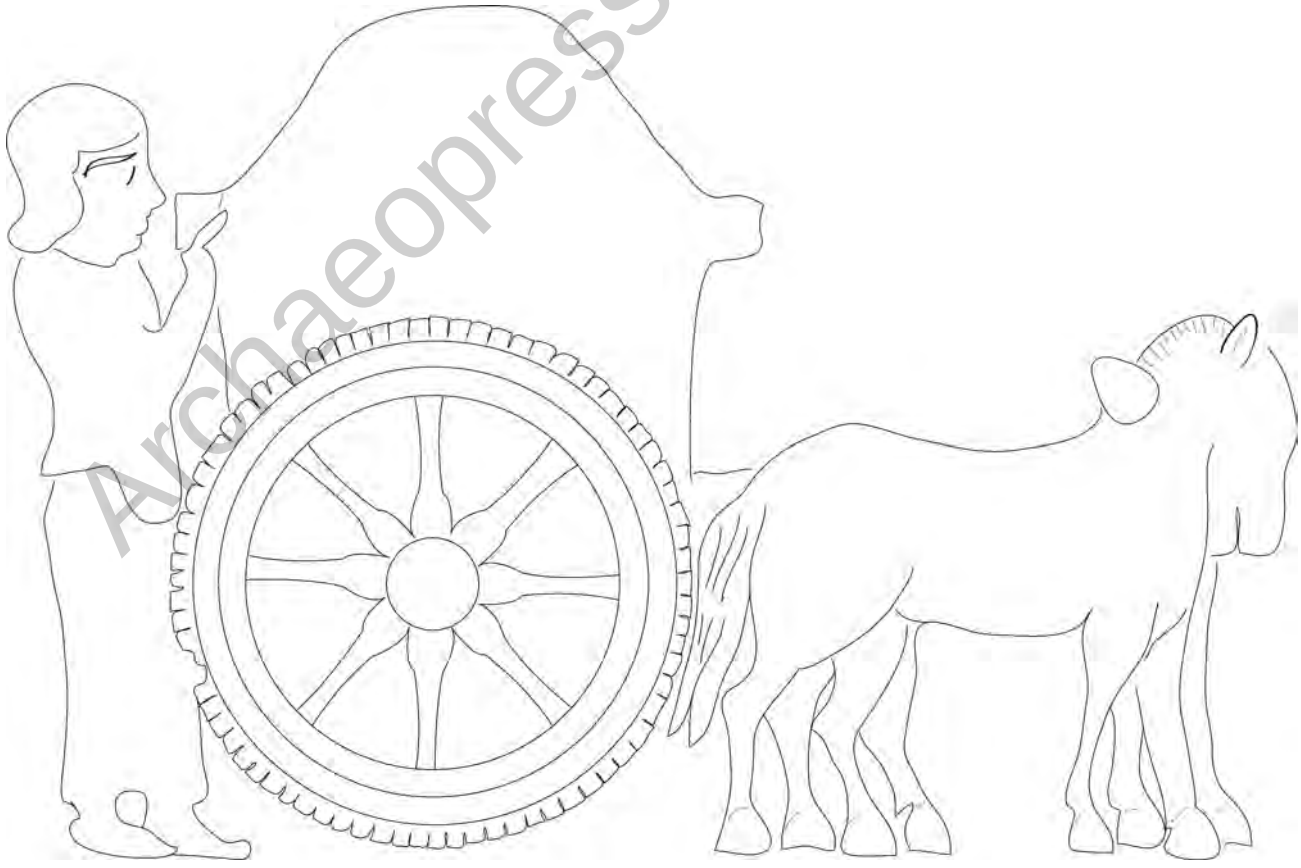

Figure 18.16. Grave stele, Daskyleion, Istanbul Museum inv. no. 5763 (after Borchhardt 1968: pl. 50, 1).

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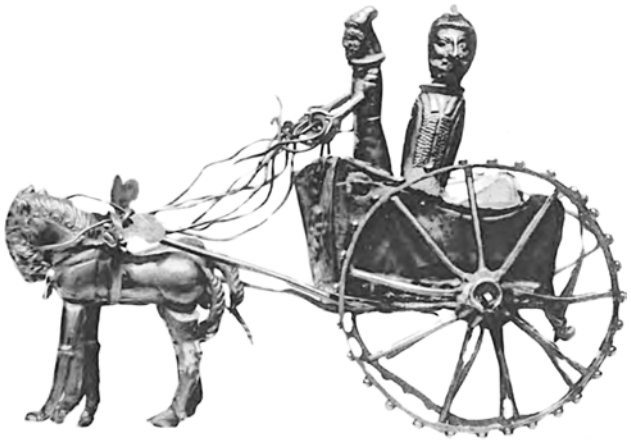

Figure 18.17. Golden chariot model, 'Oxus' (Dalton 1905: pl. 4, 7).

chariot is also equipped with this kind of wheel (Schmidt 1953: pl. 52). This detail survived even into Roman times, as the famous Alexander mosaic from Pompeii shows. It depicts the battle at Issus (333 BC) or Gaugamela (331 BC) that was fought between the armies of Alexander the Great and Dareios III. It is assumed that the mosaic is a copy of a late 4th-century BC wall painting (Stähler 1999). The chariot carrying the fleeing Persian king is partly overlapped by overthrown and dispersed fighters. Nevertheless, the royal chariot is clearly distinguishable through the elaborately worked figure of Dareios and the enormous size of the wheels that are shown to have been as high as a man. Additionally, of course, the detailed representation of the wheels of the king's chariot show nails protruding from the felloe construction. Achaemenid chariot models appear to reveal this technological detail as well, as demonstrated by the famous example of a golden chariot of the Oxus treasure (Figure 18.17) (BM 123908; Dalton *et al*. 1905: 78f., no. 7; Mongiatti *et al*. 2010; Curtis 2012: 138f.).

In the 1st millennium BC, evidence from Near Eastern art is supplemented by excavated remains of wheels for the first time since the 3rd millennium BC. Wheels comparable to the iconographic representations listed above were found in the funerary context of tumulus 89 at Bin Tepeler near Sardis (Figure 18.18) (Kökten Ersoy 1998b: 117-26, figs. 11-12). The nails (Figure 18.19) used on the Bin Tepeler wheel show similar attributes to those discovered in the Early Dynastic burials at Susa (see above). The hollow, but firm, nail-heads protruded from the wheel tread by at least 2 cm, while other nail-heads, used for fixing the

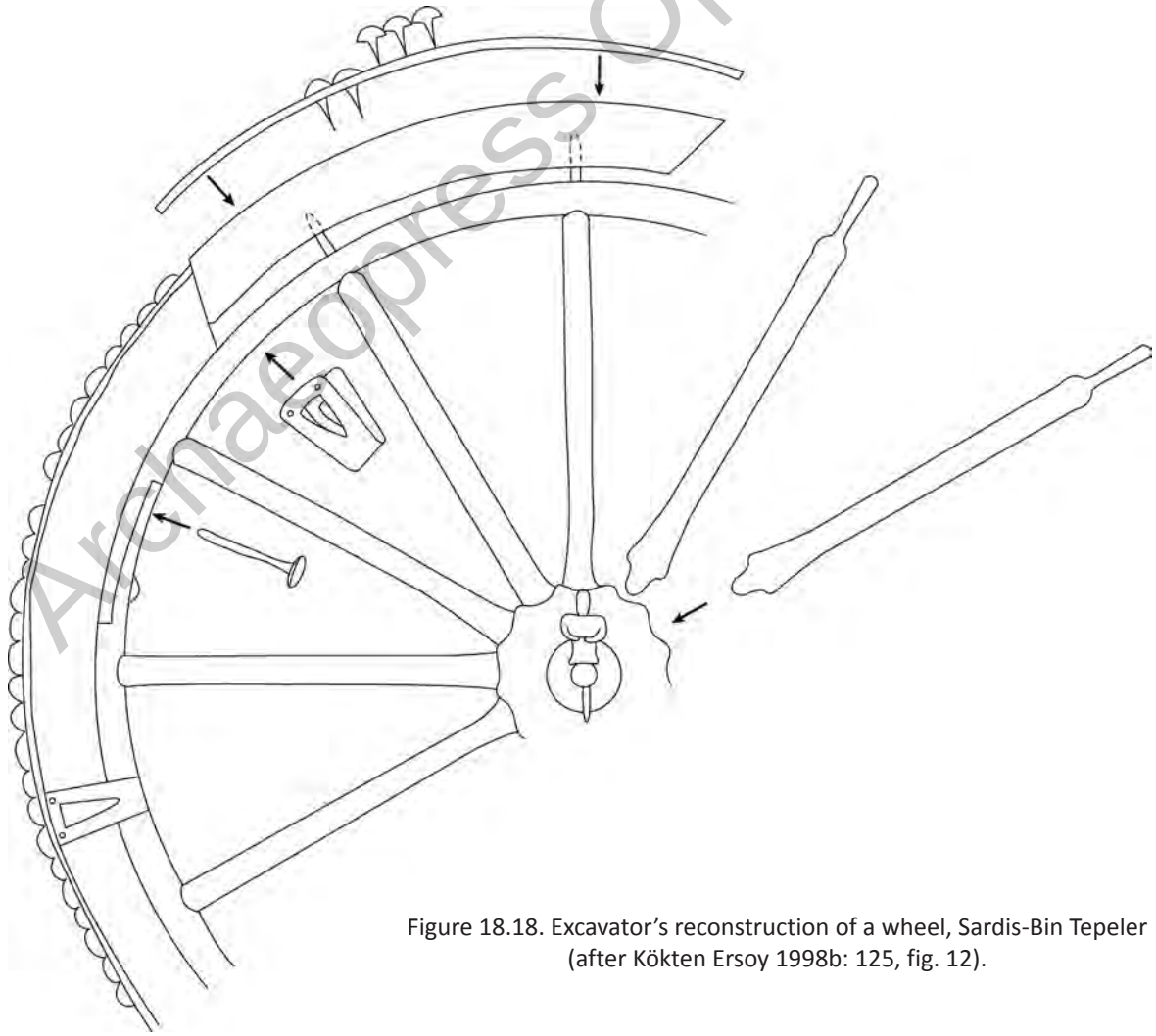

Figure 18.18. Excavator's reconstruction of a wheel, Sardis-Bin Tepeler (after Kökten Ersoy 1998b: 125, fig. 12).

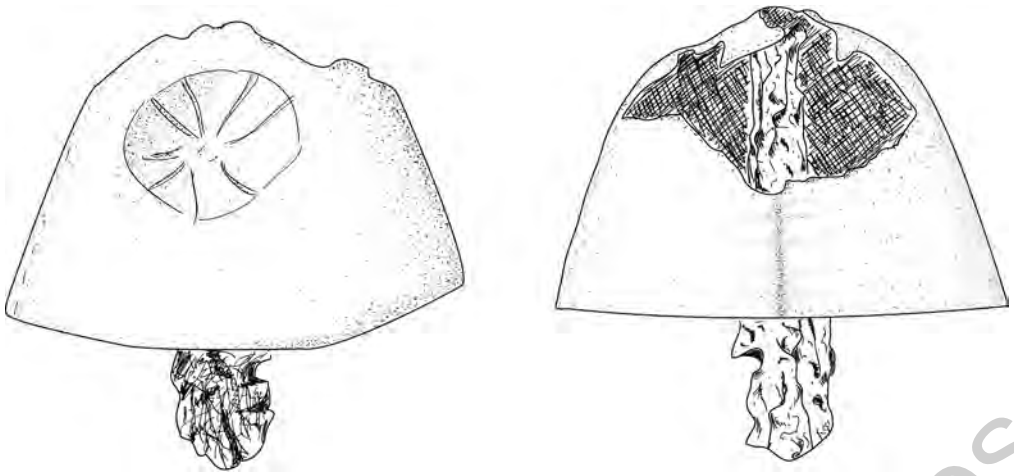

Figure 18.19. Drawing of single tread nails, Sardis-Bin Tepeler (after Kökten Ersoy 1998b: 119, fig. 7).

metal-bands on the tread, were found sunken into the frame of the wheel (cf. Kökten Ersoy 1998a: 115 fig. 5). This arrangement shows that the protruding nails clearly had another function separate to the need to fix the metal tread. The technical aspects of this wheel, protruding large headed strake nails and sectional tyres, resemble the so called 'strake wheels' of the 18th century AD (see Peloubet 1996: 171-74).

Nails and Roads

'Hollow ways' are considered to be visible testimonies of ancient traffic. These features are present in many landscapes of Europe, the Near East and even in the New World. In the Near East their formation is connected to the local/regional and supra-regional level of movement of animals and humans between sites and fields (Wilkinson 1993: 26-28). Dating such features, however, remains difficult, because major sites that were important nodes within the network of roads were usually inhabited over long periods of time, often spanning multiple centuries or even millennia. While some roads might have been in use from the very beginning until the abandonment of the respective sites, others might have been used only during certain periods (cf. Mühl 2013: 23, fig. 20). Discontinuous use like this might have not only depended on political and economic circumstances, but naturally also on the traffic-connections to other sites with differing periods of occupation and abandonment.

The tendency to attribute specific dates for hollow ways is closely linked to the early history of the investigation of such features and to the beginnings of the use of aerial photography in Near Eastern archaeology (Crawford 1931; 1954: 58; Poidebard 1934). The connection of radial arrangements of paths leading to Bronze Age sites was already recognized during the first systematic examination of hollow ways (Van Lierre and Lauffray 1954-55). Later on, combined analysis of survey data and satellite imagery led to the realisation that the physical appearance of the hollows themselves (e.g., their width) can be taken into account as well. The results of these studies suggested that wide hollows tend to be of Early Bronze Age date, whereas narrow ones seem usually to have originated in Hellenistic and Islamic times (Wilkinson and Tucker 1995: 25f.). Nevertheless, since it was also observed that local traffic related to agricultural activities in the surroundings of settlements played a greater role in the formation of hollow lanes than inter-site and inter-regional movements of people and animals, the major impact of agriculture has to be considered when talking about the formation and preservation of hollow ways.

Agricultural developments and the formation of hollow ways are tightly linked to each other not only in the Near East, but also in other regions of the world. In Germany during the 12th century AD, the introduction of intensive crop-based agriculture is related to the formation of these landscape features. Various factors played a role in this process of intensification. The growth of population increased the need for agricultural production and ultimately provided the incentive to clear forests as a means to extend the area of arable land. Eventually this led to further population pressure, soil erosion, famine and demographic shifts (Simms 1976, with further literature; Rösener 1985: 40-45), processes that can be observed several times throughout history in many regions of the world. The expansion of crop-cultivated areas was more significant for the formation of hollow ways than the earlier Roman road system and the traffic connected to it had ever been (for reasons see Glaser 1993: 20f.).

Everyday traffic for the regular maintenance of the fields increased and thus contributed to the increase in pathways. But technological innovations in agricultural engineering played an equally important role. New technologies, such as the mould-board plough, came into wider use from the beginning of the 11th century AD onwards (Steensberg 1980). Horses subsequently were used to pull the plough and to transport heavy loads between fields and settlements.

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Figure 18.20. German road sign for animal pulled carts (after Hassler and Hassler 1993: 71, figs. 6-4).

Over time this led to the intensification of crop-cultivation, especially of oats (Rösener 1985: 124). Technological improvements to the vehicles, such as the introduction of the swing-steering axle, made it more efficient and consequently also more attractive to use carts and wagons for agricultural purposes. Such carts and wagons often had to deal with very poor ground conditions, since paved roads were rare. The wheels and the feet of the draught animals continually ground and loosened the soil. As a result, no vegetation grew on the paths, which in turn promoted fast soil erosion.

A problematic condition for the movement of carts was damp soil, especially after rain: wheels would not turn, because the friction on the axle was too great and the rolling resistance was too little, which would cause the wheels to slide instead of turn. If the wood of the wheel became soft, its surface would wear down unevenly, eventually damaging it beyond repair. Frequently, iron fittings were used to avoid this problem. However, vehicles could easily still get stuck in the mud or slide down a slope. Wheel shoes were a popular countermeasure for the first problem (Figure 18.20), and the second problem was met by attaching iron chains to the wheels, similar to modern snow chains for car tires (Hassler and Hassler 1993: 72).

The metal studded surface of Early Bronze and Iron Age wheel treads in Mesopotamia might well have served the same purpose. We may speculate as to whether this technological feature may have even been responsible for the formation of Near Eastern hollow ways at least in their later history. Vehicle use was still restricted in Mesopotamian Early Bronze Age societies to only a very small part of society, and the formation of 3rd millennium BC hollow ways is more a result of the long span of time – about 1000 years – than with intensity of agricultural and vehicle transportation.

The movement of herds and flocks as well as people commuting between field and settlement are generally

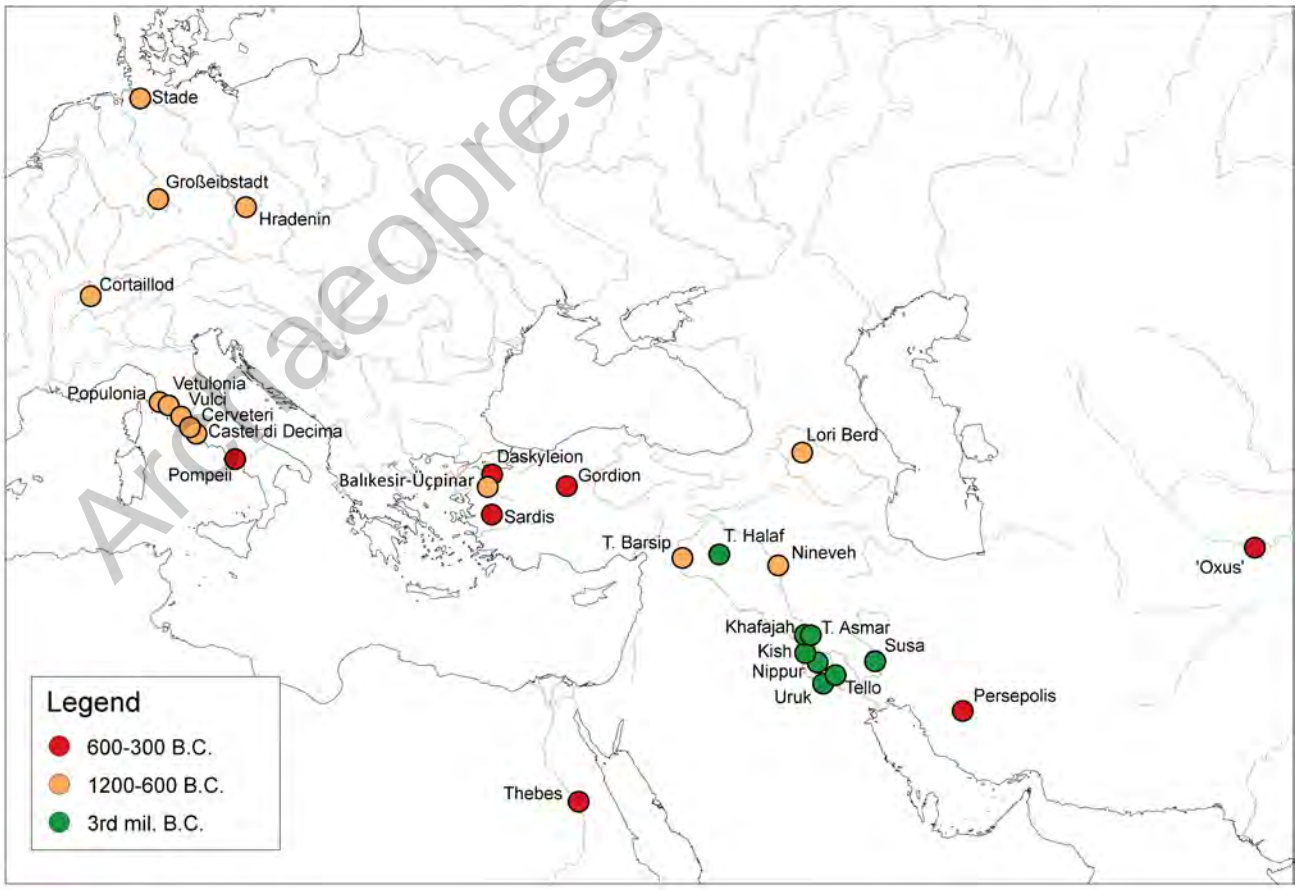

Figure 18.21. Map showing distribution of studded-tread wheel finds in the 3rd and 1st millennia BC.

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believed to have been the major factors for the formation of hollow ways in the 3rd millennium BC. This factor, however, does not automatically apply to Mesopotamia in the 1st millennium BC, during which widespread use of studded-tread wheels seems to have returned. In this respect, the environmental conditions of Iron Age upper Mesopotamia should be taken into account: namely, similar to Medieval Europe. In both cases, agricultural production was intensified on a large scale, which led to significant changes in settlement patterns, demography and technology.

In large parts of Iron Age Mesopotamia the use of animal-drawn vehicles appears to be no longer restricted to upper class society members. Depictions of everyday wagons in deportation scenes as part of Assyrian iconography can be found in the palace reliefs from the time of Sennacherib and Ashurbanipal (e.g., Elamite and Chaldean types of carts in Place 1867: pl. 60 no. 2; Barnett 1976: pls. 19, 29 and 30; Barnett *et al.* 1998: pl. 78 for Assyrian types). Depicted are vehicles carrying either tools for the transport of the colossal stone figures to the Assyrian palace, or deported families together with their properties. It is highly unlikely that the Assyrian army provided the deported families with 'state-owned' vehicles. Instead, it has to be assumed that the defeated brought along all of their personal possessions, their draught animals (equids as well as bovids) and carts.

The phase of expansion of cultivated land and the increasing number of sites in regions not settled in preceding periods started at the beginning of the Late Bronze Age in the heartland of Assyria and reached its climax in the Late Assyrian period (Mühl 2012: 89f.; 2013: 36, fig. 17, 38-43, 198, 211 and 220). In the region of Ashur, it is possible to draw a connection between the deep cut hollow ways and sites dated to the 1st millennium BC. While Early Bronze Age sites and traffic were connected to the major trans-regional routes along the piedmont and navigation on the Tigris, the Iron Age and post-Iron Age systems of settlements and roads show significant differences. Of course, many of the remains of ancient roads connected the Assyrian capitals, which each fulfilled a function as regional as well as trans-regional traffic-hubs (Altaweel 2008: 115-17). But the shift within regional settlement patterns during the 1st millennium BC also brought a change in local road systems, which became more dispersed.

During the Bronze Age, the Trans-Tigridian area had been covered by a network of roads arranged in a linear pattern, but in the Iron Age, the pattern of traffic routes is more reminiscent of a densely knotted web (Mühl 2013: 55-57, pl. 10). The visible remnants of this network allow us to draw some conclusions about the direct use of land in the immediate vicinity of settled sites. Movement between fields and settlement as well as transportation of agricultural products to markets and state granaries (Faist and Llop 2012) was simplified and became more efficient with the, by then, common use of cart vehicles that promoted linear soil erosion.

Summary

The chronological distribution of the evidence for the use of studded-tread wheels strongly suggests that this technological feature was popular during two main phases (Figure 18.21):

The older phase, dating to the 3rd millennium BC, is represented by solid studded-tread wheels with a geographical distribution largely centred on southern and central Mesopotamia. Although many cart, wagon and chariot models have been recovered from sites across northern Mesopotamia (cf. publications of terracotta figurines from Tell Bi'a: Strommenger *et al.* 2010; the Amuq valley: Pruß 2010; Tell Mozan: Bianchi *et al.* 2009; Ashur: Klengel-Brandt 1970; 1978), no Bronze Age representations of studded-tread wheels can be found in the respective excavation reports with the single exception of that from Tell Halaf.

The younger phase may be associated with the technological innovations of the Iron Age, but this time, it seems to have spread over larger parts of the Near East and beyond. In particular, Late Assyrian and Achaemenid material culture and iconography have produced many examples for these wheels.

The mismatch between the distribution of physical remains of the 3rd and 1st millennia BC can probably be attributed to the poor preservation of organic material and iron in general, as well as a change in burial practices. The lack of studded-tread wheels during the 2nd millennium BC seems to be connected to the introduction and use of the light chariot with wheels made of bent wood. Since these constructions were considerably lighter, they did not necessarily rely on studded-tread wheels to secure traction on unfavourable surfaces. When chariots reached the next phase of development, they were harnessed, which made them heavier again, thus leading to the re-introduction of the studded-tread wheel. The climax of this innovation was the famous Persian scythed war chariot (Nefiodkin 2004).

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