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Technical and Social Innovations: A New Field of Research

The grand narrative of cultural developments claims that all technical achievements in prehistory stemmed from urban centers in Mesopotamia and Egypt. But current studies, for instance on the oldest wagons, have opened up space for alternative working hypotheses and models: modern radiocarbon dating of complexes that revealed the cited innovations, e.g. the oldest wagons, functional metal tools, and an advanced copper metallurgy, which predate their first appearance in Mesopotamia, questions the role of this region in the development of technology. Possibly, Mesopotamian cities operated rather as a melting pot of numerous innovations obtained from various areas, which were then re-combined and placed into a different context. The North Caucasus, in particular the Early Bronze Age Maykop culture, is an exemplary candidate for such an interactive process in technical developments. The Maykop culture has been known in research for 120 years, and its genesis is supposed to have originated in Mesopotamia. This is an archaeological narrative meant to explain the high technical state of the Maykop culture. In the light of the new chronology based on a relatively small number of radiocarbon dates, a re-examination and alternative models are necessary. It is obvious that this culture developed a highly innovative potential in metalworking and sheep breeding, and fulfilled an important function as mediator in knowledge transfer between the Eurasian steppe and Upper Mesopotamia. Recent aDNA studies support this view.

Keywords: *Innovations, Early Bronze Age, Caucasus, wagon, composite bow, shaft-hole axe.*

Introduction

The Early Bronze Age of the 4th millennium BC was one of the most vibrant epochs, which was of crucial importance for the cultural development in Europe and Eurasia. A substantial number of technical innovations was developed within only a few centuries' time in the 4th millennium BC (Hansen, 2011). They constitute Eurasia's specific historical development: it was a time of radical changes and transformations.

Technical innovations have always played an outstanding role in prehistory. Indeed, technical, artistic, and social innovations have brought forth fundamental changes in the life of humankind, again and again. One need only recall man' control of fire, the development of communal hunting strategies, and the invention of hand-axe and later blade production. The millennia-long accumulation of knowledge by Palaeolithic gatherers and hunters formed their existence, and had to be nurtured and communicated to the next generations. This knowledge was present not only among smaller populations, but also in larger groups; for instance, among communal winter camps, as well as in transregional networks on a broader basis, and was thus protected from sudden extinction.

Summing up, the basic innovations of the Neolithic include: the domestication of livestock, production of pottery and house building, or the start of copper and gold metallurgy. Yet, in the 4th millennium BC, the density of innovations increased on a hitherto unknown

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scale. Among the most important innovations were the wheel and the wagon (Klimscha, 2017), the breeding of the woolly sheep, the domestication of the donkey (Rossel et al., 2008) and the horse (Warmuth et al., 2011), and the cultivation of olives (Salavert, 2008) and wine (McGovern et al., 1997). By improving metal objects with various alloys the production of prestigious items was transformed into that of common commodities. In the course of time, this was enhanced by innovative techniques, such as casting in the lost-wax form (Hansen, 2014b). Silver was extracted from lead by means of cupellation, and this technology spread throughout the entire Near East and the eastern Mediterranean during the 4th millennium BC (Hansen, Helwing, 2016). Concerning pottery production, the impact of the potter's wheel must be emphasised (Doherty, 2015). The development of seals to manage goods and of writing for recording were innovations of utmost importance (Nissen, Damerow, Englund, 1991). Many of these innovations caused changes in the way of production. Mass production and repetitiveness in work processes already started in the 4th millennium BC (Pollock, 2017).

Each of these innovations brought considerable economic, social, and cultural consequences. Moreover, they shaped the bodies of men and women. People became drivers, horsemen, warriors or writers and readers through intensive training and repetitive practice. The wagon enabled heavy goods, e.g. the harvest, to be transported, and thus indirectly affected the spread of agricultural production. The wagon facilitated the development of a mobile way-of-life of cattle and sheep herders in the vast steppe, which was coining Eurasia well into medieval times. Breeding sheep with long hair enabled the procurement and processing of wool, an achievement that led to a revolution in textile production. It provided steppe dwellers with well isolating fabrics for clothes or mobile tents and yurts. The domestication of the horse allowed control over large herds of cattle and sheep. Even more important was the ability to cover great distances swiftly by riding on horseback; this speed held pace well into the modern era. It was first surpassed by the railway in the early 19th century. The development of various copper alloys led to a decisive improvement in the properties of metals: casting became easier, and the elasticity and hardness of alloyed metals were enhanced considerably as compared to that of pure copper. From a technique primarily meant for prestigious goods emerged an efficient metal industry aimed at basic commodities. Linked with these technical improvements in metallurgy were technical innovations in weaponry: the first swords and spearheads, as well as more effective battle axes, appeared in the Caucasus and eastern Anatolia. A transformation in warfare can be presupposed by these developments, and there is evidence of warlike conflicts and rebellions among the population in northern Mesopotamia during the 4th millennium BC (Reichel, 2006; Bernbeck, 2009; McMahon, 2009). Finally, in the Near East and in Egypt the production of stone statues began, larger than life-size, which represented deities and rulers (Kemp, 2000). Further, large anthropomorphic stone stelae found between the Caucasus mountains and the Atlantic coast can also be seen as an iconographic innovation of the 4th millennium BC (Robb, 2009). They are very appropriately designated "stones of power", because they are illustrative of the concentration of power in a few hands at that time (Vierzig, 2017).

Theoretical background

The modern use of the term "innovation" goes back to J.A. Schumpeter, who recognised at the end of the 1930s that technical innovations were the foundation for the existence of longer economic cycles, which overlie short-term cycles. For Schumpeter, innovations play a decisive role in economic development (1939). He largely built upon an article by N.D. Kondratieff (1926), in which the existence of long term (50 to 60 years) cycles of economic boom followed by depression was postulated. Each of these long cycles was triggered by certain innovations, e.g. the steam engine, railway, chemistry, etc. Adopting this model for archaeology has high heuristic potential. Concentrations of innovations in the Neolithic period and in the 4th millennium BC seem to confirm modern-day observations, that technical innovations did not appear continuously and singly, but were instead discontinuous and materialised in clusters. According to G. Mensch (1975), innovations arose quite likely in times of crisis, and thereby formed the prerequisite for a new long wave of economic prosperity.

Schumpeter also focused on the co-evolution of technology, organizations, and institutions, which is elementary for modern innovation theory (The Oxford Handbook…, 2004). R.R. Nelson and S.G. Winter (1977, 1982) followed Schumpeter's discussion of innovation in detail. They emphasized the Schumpeterian insight that innovation in the economic system is likewise the creation of any sort of novelty in art, science, or practical life, and that it consists to a substantial extent of a recombination of conceptual and physical materials that were previously in existence (Nelson, Winter, 1982). They addressed the importance of the institutional structure for the adaption of innovations: "technological regimes" and "selection environment" (Nelson, Winter, 1977). Technological regimes are the frames of research comparable with L. Flecks "Denkstile" (1993). Selection environments of innovations are the "firms", the consumers, and the regulators (state institutions). In pre-state societies, households, their members, and political and religious authorities are decisive factors.

The importance of the institutional frame is also stressed by F.W. Geels' multi-level perspective including niche-innovations, sociotechnical regimes, and sociotechnical landscape as heuristic concepts (Geels, 2002; Geels, Schot, 2007). Sociotechnical regimes refer to shared cognitive routines in an engineering community, but also to broader communities of social groups. Technological niches are the micro-level, at which radical novelties emerge. These novelties are initially unstable "sociotechnical configurations" with low performance. Niche-innovations are developed by small networks of specialists, often outsiders or fringe actors. Sociotechnical landscapes form exogenous environments beyond the direct influence of niche and regime actors (macro-economics, cultural patterns, macro-political developments). Changes at the landscape level usually take place slowly (over decades or even centuries). According to Geels, all three levels operate with network models. Transfer processes through space, and also the interlinkage of archaeological phenomena networks in the late 4th and 3rd millennia BC were analysed in the case of the Baden culture (Furholt, 2008).

Network structures can also be supposed for the diffusion of innovations through space. In the case of the earliest metallurgy, the rapid transfer of knowledge was most likely triggered by existing networks between Iran and the Balkans (Hansen, 2016). Archaeologically, the diffusion of innovations is often visible only in the technical object, e.g. the artefact itself, but not in greater parts of material culture. In whatever ways the transfer of metallurgy may have been sustained, the result was that it helped to preserve the knowledge that had been gained through experimentation. The integration of technical knowledge with different origins in a larger network might have been the operational basis for the Mesopotamian cities to become hubs of complex organised innovative societies. Another way of knowledge transfer is the migration of larger groups of peoples, which is widely attested for prehistoric as well as historical periods. The new results of aDNA have shown possible migration events in the early 3rd millennium BC (Haak et al., 2015).

The micro level in Geels' concept can be approached in archaeology through detailed research of innovations using scientific analyses, which allow e.g. the differentiation of certain recipes in metal alloys or the construction routines of wooden wheels. Developmental changes in the sociotechnical landscape can be described on the macro level. The new research tool "Digital Atlas of Innovations" (https://atlas-innovations.de/en/) allows the illustration of trajectories and periods of increased spread of innovations in dynamic maps. Furthermore, it is possible to quantify innovation density in the *longue durée*. This aids in describing the knowledge of prehistoric societies and in tracing the transfer of knowledge through space and time.

The cradle-of-civilisation-narrative

The ongoing discussion as to whether the introduction of innovations is caused by (consumer) demand or (provider) technology—so-called "pull and push" theories—does not aid in explaining the cases discussed here (Rogers, 1995). A multi-level perspective seems to be more fruitful in describing these innovations. Furthermore, new radiocarbon-based chronology shows that the old model of the development of all technical innovations in the civilisations of Mesopotamia and Egypt is impossible to uphold. New data have now opened room for a different line-of-thought. The hypothesis is: it was not the development of new techniques, but the adaption of techniques from various "peripheries" and their new combination in "centers", which formed the actual basis for the success of Mesopotamian and Egyptian "civilisations". This challenges one of the most influential and still prevailing cultural narratives of Western civilisation, that technical innovations were all developed in centres of "advanced civilisations" and from there diffused to the "peripheries" (Childe, 1958; Sherratt, 1981; Frank, Gills, 1992).

The institutional structure discussed by Nelson and Winter necessitates an understanding of technical innovations in their social dimensions and consequences as well. Hence, the frequent question is whether technological developments induce social change, or social reforms cause technical developments. Ethnographical evidence seems to show that political centralisation triggered chains of innovations (Sigrist, 1979). This is in line with a different but connected phenomenon, the production of surplus. H.W. Pearson (1957) argued in his seminal paper that "There are always and everywhere potential surpluses available. What counts is the institutional means for bringing them to life". In consequence, surplus (as innovation) was enforced by political centralisation in the hand of strong rulers (Hansen, 2018). In this respect, the 4th millennium BC was a "watershed" in Eurasian prehistory, not only because of new key technologies, but also new forms of social domination (Hansen, 2014a). A supra-regional warrior ideology evolved in the Caucasus and reached as far as western Europe (Hansen, 2013; Jeunesse, 2015). This can be understood as a new *dispositif* by which all relations in society were rearranged (Das Spiel…, 2003).

The formation of steep hierarchy did not need the influence of advanced "civilisations". Under certain conditions such hierarchies formed autochthonously, but they also collapsed regularly (Jeunesse, 2014). Early states, too, were always threatened by diseases, revolts, or military conflicts, and they collapsed not only once (Scott, 2017). The course in history of social institutions was less likely in a straight continuous line, but instead marked by breaks and discontinuities (Ur, 2010).

The apparent parallelism of the 4th millennium BC innovation clusters and the social rearrangements of this epoch fits with the concept of understanding social and technical innovations as a co-evolutionary process (Alijani, Wintjes, 2017). Theoretical approaches to innovation allow prehistoric, historic, and modern analyses of innovations processes to be connected.

Chronology

The first calibrated radiocarbon datings changed the prehistoric chronology dramatically. This had consequences especially for the 4th and 3rd millennia BC. It became clear that many cultural manifestations, once assumed for only a few centuries' time in the 2nd millennium BC, in reality encompass nearly the entire 3rd millennium BC (Chernykh, Orlovskaya, 2004). The finds from the famous burial in Maykop must even be re-dated more than 1000 years prior to the middle of the 4th millennium BC (Govedarica, 2002; Chernykh, Orlovskaya, 2008; Chernykh, 2008).

The end of the bloc confrontation enabled cooperative research in eastern Europe and Eurasia for the first time since the October Revolution in 1917. With that, the North Pontic and Eurasian steppes and the Caucasus came into view again (Anthony, 2007; Kohl, 2007; Cunliffe, 2015). Yet, ^{14}C-chronology raised considerable doubt about the idea that all innovations were developed in the Near East. Today, it can no longer be stated without any doubt where the wheel and wagon were "invented", because the earliest archaeological evidence is distributed within a very narrow time-window around 3500 BC between the Baltic Sea and Mesopotamia (Klimscha, 2017).

The famous grave mound of Maykop (Piotrovsky, 1998; Bronzovy vek…, 2013), uncovered in 1897 by N.I. Veselovsky, was discussed during the 20th century by eminent scholars like M. Rostovtzeff (1922) and V.G. Childe (1936), among others. With the royal graves in Ur in mind, the strong narrative of the Mesopotamian background of the Maykop grave goods seemed plausible. However, radiocarbon revolution in the last 25 years has made clear that the grave was built between 3700 and 3500 BC, not around 2500 BC. This predates the grave for more than one millennium in time, as was long assumed (Govedarica, 2002).

Regardless of this re-dating, the narrative is still maintained that the Maykop grave and the Maykop culture generally were the result of direct Mesopotamian influence or of larger migrations from the South (Masson, 1997; Izbitser, 2003; Pitskhelauri, 2012).

The monumental kurgan, more than 10 metres in height, was erected above the grave of one important individual and two other persons. The grave chamber contained vessels made of gold, silver, and bronze, which represent the oldest evidence ever of metal vessels. Further, the chamber held bull figurines made of gold and silver, which provide early evidence for casting in the lost-wax technique. The seventy gold appliques in the form of lions that were found had likely been sewn onto a mantle. This interment is the earliest known grave that is associated with the iconography of the lion as the heraldic animal of a ruler (Trifonov, 1998; Hansen, 2017). Additionally, thousands of gold beads, as well as beads of turquoise and carnelian, were found.

Grave mounds were erected already in the 5th millennium BC (Govedarica, 2004; Korenevskiy, 2012). Nonetheless, the monumentality of the mound in Maykop represented something hitherto unknown that signified the new, powerful, social rank of the deceased, a status that was accentuated especially by the persons who were obliged to follow the deceased to the grave (Testart, 2004). This fits with the political landscape of that time. In north Mesopotamian towns, such as Arslantepe (Frangipane, 2016), Tell Brak (Emberling, 2002; Oates et al., 2007; McMahon, 2013), Hamoukar (Reichel, 2006), and Tepe Gawra (Tobler, 1950), the emergence of strong rulers and the first steps towards the state likely occurred during the first half of the 4th millennium BC (Stein, 2012).

Innovations and migrations in the 4th and 3rd millennium BC

Many of the innovations mentioned before are found in the archaeological record all over the western parts of Eurasia and the Near East nearly at the same time. For understanding the transfer of techniques and knowledge during the 4th and 3rd millennia BC, the Caucasus region plays a key role (Munchaev, 1975; Hansen 2014b; Kohl, Trifonov, 2014; Chernykh, 2017; Sagona, 2018). The Maykop phenomenon provides us with a number of early evidence of innovations like wool (Shishlina, Orfinskaya, Golikov, 2003), traction (Reinhold et al., 2017), metal alloys, silver, etc. The Caucasus is one of the richest areas of mineralisation in Eurasia (Iessen, 1935). Copper, gold, and antimony ores were exploited at the latest from the Bronze Age onwards. The oldest gold mine in Sakdrissi, Georgia, dates to the 4th millennium BC (Gambashidze et al., 2010; Stöllner, 2014). Without doubt, these resources were attractive, not least for the evolving urban cultures of Mesopotamia. The North Pontic steppe, northwest of the Caucasus, was likewise interested in metal and an area of important, wide-reaching interactions, which connected the Caucasus to the Carpathians and to Central Europe.

As early as the 4th millennium BC, a network of connections existed between the Caucasus and Central Europe. This can be observed in a multitude of individual elements and is also evident in the plenteous material in later burials of the Maykop and Novosvobodnaya cultures

(Rezepkin, 2000; Kantorovich, Maslov, Petrenko, 2013; Belinskij, Hansen, Reinhold, 2017). One need only recall the shaft-hole axes (Hansen, 2010) or daggers (Korenevskiy, 2011).

Further, the depictions of oxen teams on stones in the Kammenaya Mogila in Ukraine (Fig. 1), in the Alps, and in the megalithic chamber grave at Züschen near Fritzlar in northern Hesse (Fig. 2) are well known. Recognisable are the large horns of both bovids—left and right, whose body is rendered with a simple vertical line. Both draught animals are fastened to the yoke, signified by a horizontal line. Visible between them is the two-wheeled wagon with its long drawbar. This graphic representation (today we would say *iconic*) emphasises the great prestige value of the innovation of the wagon.

Astonishing connections can be noted among the elements in two megalithic burials, one burial located in Novosvobodnaya near Maykop (Fig. 3) in the western foothills of the Caucasus, the other in Göhlitzsch near Leuna in Saxony-Anhalt (Fig. 4). A. Rezepkin has already pointed out these ties (2000, 2012). The equipment of weapons, reflex bows, and quivers in both burials was depicted on one of the stone slabs in the grave chamber. In Göhlitzsch, the slabs of the chamber were covered with a dense geometric ornamentation (zig-zags and triangles). This decoration, unusual in Central Germany, is found in similar form at the same time in stone-slab graves in the northern Black Sea area (Szmyt, 2014). Surprising traces of such grave complexes were identified in the Regnitz River valley in middle Franconia, too (Nadler, 2011).

Thus, it can be stated that connections between the Caucasus and the northern Black Sea can be confirmed; namely, ties that far exceed an occasion exchange of portable goods. Moreover, these contacts also possessed a religious-ideological dimension, in that they also influenced the way in which a burial was designed.

Transfer of knowledge

Technical knowledge spread among societies without script by means of direct contact, personal communication, imitation, and learning (Hansen, 2016). Thus, the transfer of knowledge was linked to the high degree of mobility of peoples in existing networks. The Corded-Ware, Single-Grave, and Yamnaya cultures have long been interpreted as migration phenomenon and identified with the Indo-Europeans (Glob, 1968; Gimbutas, 1994). Since then, there is a growing tendency towards recognising specific, social forms of representation in these cultures (Damm, 1991).

Today, for the first time in the history of archaeological research, the field of palaeogenetics provides unambiguous evidence for immigrations from the Eurasian steppe area in the early 3rd millennium BC (Lazaridis et al.,

Fig. 1. Depictions of oxen teams and wagons. Kamenaya Mogila, Ukraine (after (Gladilin, 1966/1969)).

Fig. 2. Depiction of an oxen team and a two-wheeled wagon on a slab in the chamber of the tomb at Züschen (Hessen, Germany). Photo Museumslandschaft Hessen Kassel.

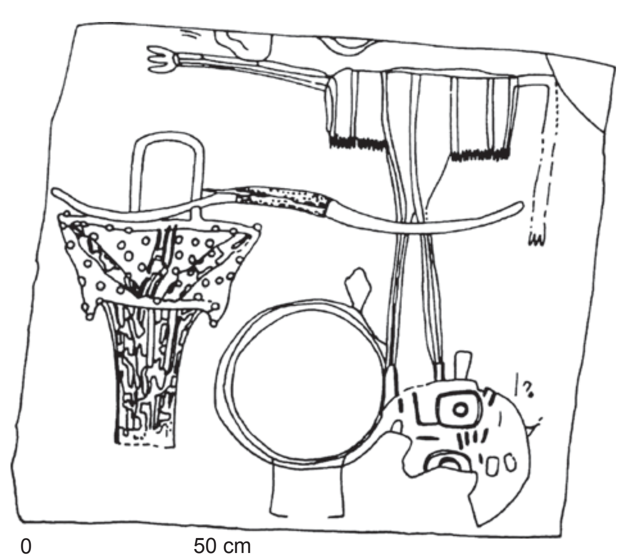

Fig. 3. Depiction of bow and quiver. Novosvobodnaya, Adygeia, Russia (after (Rezepkin, 2000)).

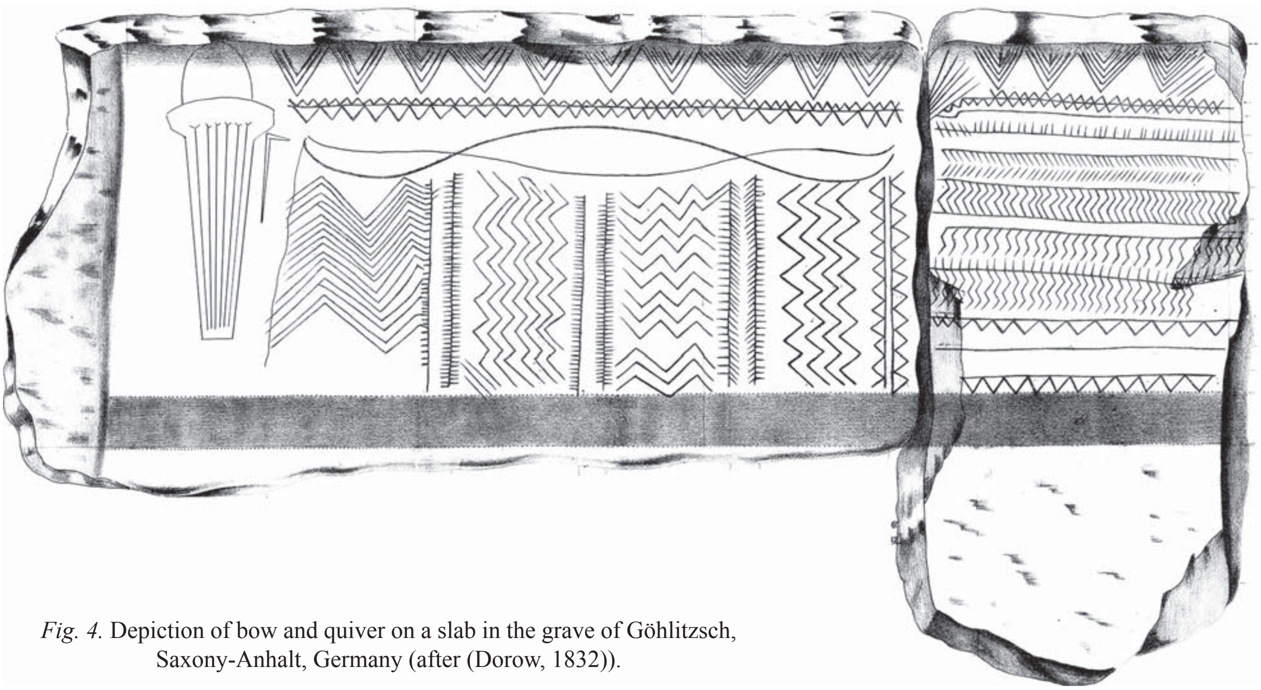

Fig. 4. Depiction of bow and quiver on a slab in the grave of Göhlitzsch, Saxony-Anhalt, Germany (after (Dorow, 1832)).

2013; Allentoft et al., 2015; Haak et al., 2015). Basing on evidence of the plague bacterium *Yersinia pestis* in skeletons from various European sites (Rasmussen et al., 2015), this pathogen could also be identified in the remains of the deceased person in grave 11, mound 21 in necropolis Rasshevatsky-1, region of Stavropol (Andrades Valtueña et al., 2017). The mound measured 85 × 110 m and was 6.2 m high. Its period of use for funerary practices extended from the time of the Maykop and the Yamnaya culture until the Novotitorovka culture. According to ^{14}C-datings, the mound was used for more than 600 years. Grave 11 is a Yamnaya burial in supine position. The interred individual was dated directly, likely buried between 2875 and 2699 cal BC (4171 ± 22 uncal BP; MAMS-29816). Thus, at present, this case and another with the skeletal remains of a person ascribed to the Afanasievo culture (the Altai Mountains) are the oldest known individuals in which the pathogen *Yersinia pestis* has been confirmed. It is indeed noteworthy that these cases belong to a time span during which ever more extensive migrations to Central Europa are purported to have taken place. The relationship of the plague pathogen from the Late Neolithic and the Early Bronze Age suggest that around 2800 BC *Yersinia pestis* was introduced to Central Europe from the Pontic steppe.

Whether or not humans were carriers of the bacterium, in their flight from areas of the plague, or whether the levels of resistance against this disease varied, is still unclear. Nonetheless, the effects of BC *Yersinia pestis* might explain why the "Neolithic" population in Central Europe was genetically reduced within such a short time. Whatever the causal agent was, evidence of the plague pathogen at that early time, long before the well-known epidemics in Antiquity (e.g. the Justinian plague), is of great significance. For until now widespread epidemics have not played any role in archaeological discourse. Yet, at the same time, it is becoming all the more obvious how little is known about the backgrounds, causal relationships, and consequences of migrations.

Massive population shifts in the 3rd millennium BC, in connection with the expansion of the groups from the steppe who were part of the Yamnaya culture, have long been associated with the transfer of significant technological innovations from Mesopotamia to Europe (Harrison, Heyd, 2007; Kristiansen et al., 2017; Reich, 2018: 108–109). But it is apparent that the results of aDNA-analyses should be studied in combination with the archaeological material in a more complex and nuanced way (Furholt, 2018; Wang et al., 2019).

The spread of early wagons, metal axes or compound bows was embedded in an exchange network between Europe, the Caucasus, and Mesopotamia much earlier, already in the 4th millennium BC. However, can evidence of these technological exchanges also be provided by genetic interactions? The genomes of some Yamnaya individuals from the steppe bordering the Caucasus show subtle genetic traces that are also characteristic of the neighbouring farming populations in southeastern Europe. Detailed analysis now shows that this subtle gene flow cannot be linked to the Maykop population, but that it could have come from the West (Wang et al., 2019). These subtle genetic traces from the West are indeed remarkable and suggest contact between peoples in the steppes and western groups, such as the Globular

Amphora culture, between the late 4th and the early 3rd millennium BC. The Globular Amphora culture connected the Carpathian Mountains with the Baltic Sea. The world of the 4th millennium BC was well-connected long before the migrations of steppe pastoralists. In this wide-ranging network of contacts, people not only spread and exchanged goods and knowledge, but occasionally they also exchanged genes, and not only in one direction.

In the present state of research, the dissemination of innovations cannot be ascribed solely to migrations. Furthermore, the understanding of the Maykop culture must seek a much more complex explanation rather than simply "migration(s) from the South". This is recognisable not only in archaeological findings, but now in genetic contexts as well (Ibid.).

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