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The Coming of Iron in a Comparative Perspective

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The Coming of Iron in a Comparative Perspective

The paper deals with the introduction of iron as a new raw material in the transition period between the outgoing Bronze Age and the Early Iron Age. Objective of the paper is to introduce the interdisciplinary research group A5: Iron as a new raw material of the Excellence Cluster *Topoi. The Formation and Transformation of Space and Knowledge in Ancient Civilizations*. After a short overview of the history of the spread of iron technology after the decline of the Hittite empire, the central research categories of the group: space, knowledge, innovation and resource are introduced. The interdisciplinary composition of the group enables the integration of different methodological approaches from the archaeological sciences, ancient oriental studies and physical geography. Furthermore the spatio – temporal potentials and limitations of the single disciplinary methodological approaches are discussed and a brief overview of the regions under investigation is given. The introduction of iron as a new raw material is in detail presented in the light of two case study regions: the Ancient Orient and the Teltow region.

Iron Age; innovation; knowledge transfer; iron smelting.

1 Introduction

Each year, over 1.5 million tons¹ of steel are produced worldwide, making it one of the most important raw materials. Characterized by its hardness, steel can be formed into any shape and – if treated properly – is highly durable. These characteristics make iron an ideal raw material for a diverse range of products. The discovery of iron ore, the development of smelting technology and the establishment, transfer and perception of this innovation through space and time, is of historical significance and has been investigated since November 2012 within the framework of the research group A-5 *Iron as a raw material* of the Excellence Cluster *Topoi. The Formation and Transformation of Space and Knowledge in Ancient Civilizations*.

The five case studies of the group are situated in different regions between the ancient Near East in the south and the Baltic coast in the north (Fig. 1) and are based on a wide range of different sources and materials, starting from the Hittite cuneiform to purely material sources of the Central European Iron Age. The interdisciplinary methodological approach of the group allows the incorporation of different sources and methods. Thus different aspects of the new technology, from detailed information on the development of prices for iron from the ancient Near East to broad insights in the technical process and its improvements, can be taken into account. This comparative research strategy appears to be most promising as it brings similarities and differences in the innovation and diffusion process to light and enables the identification of cultural, social and spatial foundations underlying individual processes in the respective region. Particular attention

is paid to human-environmental interactions related to iron production. Consequently, spatial patterns of production sites and centres are also under investigation as possible impacts of intensive iron smelting on the landscape and metallurgical analysis, enabling a characterization of the quality of the exploited ores and processed iron slags and objects.

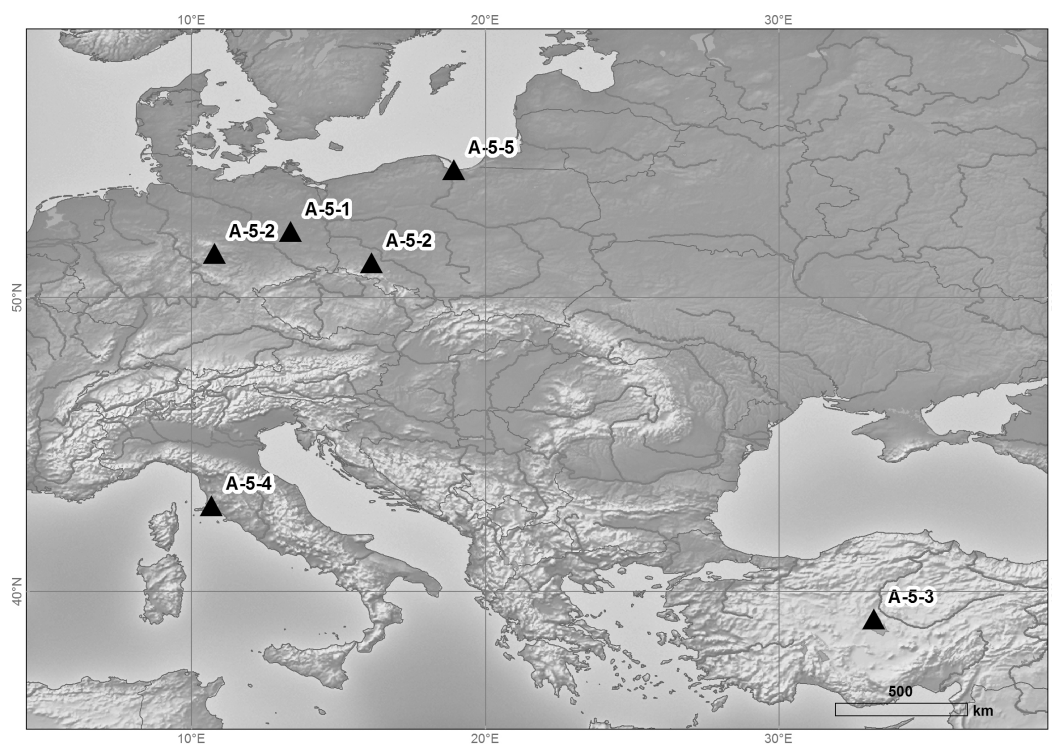


Fig. 1 | Location of the research regions of the research group A-5 *Iron as a raw material*. The triangles mark the centre of the region of interest. Alphanumeric codes identify the research projects as follows A-5-1: Teltow, A-5-2: Silesia and Southern Harz Forelands, A-5-3: Near East, A-5-4: Populonia, A-5-5: Baltic region.

2 The coming of iron – a brief overview of the state of research

The production of malleable iron from terrestrial iron ores was preceded in the Near East by a long period, beginning in the 4th millennium BC, which was characterised by a sporadic use of meteoric iron,² which can in general be distinguished from terrestrial iron by its high nickel content.³ At the same time, there is also evidence that use may have been made of telluric iron, which admittedly occurs only rarely in nature.⁴ The first millennia of iron usage were characterized by the production of various ornamental objects⁵ and dagger blades, which can be regarded as luxury objects and status symbols.⁶

The smelting of terrestrial iron ores in Anatolia dates back to the 2nd millennium BC. Apart from a few iron finds, evidence of these beginnings is found primarily in written sources.⁷ It is highly probable that a decisive role in the discovery and development of

2 Belgia et al. 2013.

3 Lychatz 2012, 13; Pleiner 2000, 7; Yalçın 2000, 308, Tab. 1, Taf. 13.1.

4 Yalçın 2000, 308–309, Taf. 13.2.

5 Koryakova and Epimakhov 2007, 189 fig. 5.1.

6 Pleiner 1996, 284–285; Pleiner 2000, 7–8.

7 Lychatz 2012, 13; Pleiner 1996, 285; Pleiner 2000, 8–9; Yalçın 2000, 309.

this new technology was played by well-established copper-ore smelting.⁸ After a period of apparently insignificant production, iron developed in the second half of the 2nd millennium BC in this region from a prestige product to a commonly utilized raw material for various metal products.⁹ Interestingly enough, there are no known finds of technical installations for iron-ore smelting from this early period of iron production.¹⁰

Towards the end of the 2nd millennium BC, following the collapse of the Hittite Empire, iron objects also begin to emerge in neighbouring regions, indicating an accelerated spread of iron metallurgy.¹¹ In Georgia and the Levante, archaeological findings, in particular furnaces, date the arrival of this new technology to the 10th century BC.¹² The first iron objects reached Europe in the 13th century BC via the Balkan peninsula, the Black Sea and the Caucasus.¹³ For centuries this would remain a matter of individual imports, with iron objects functioning exclusively as luxury items.

The subsequent spread of iron smelting in Europe is currently quite difficult to investigate as a whole, because the state of research varies greatly from region to region. It is relatively certain that knowledge of iron metallurgy began to reach the Iberian and Italian peninsulas from the eastern Mediterranean region in the 10th to 9th century BC.¹⁴ In the 7th to 6th century the Etruscans started to exploit the ore deposits on the island of Elba, a process that would not attain industrial dimensions until the 4th century BC.¹⁵ Possibly very early dates, which are of use in consolidating the picture of the beginnings of iron smelting, are meanwhile to be found in Spain.¹⁶

Whereas the earliest iron objects can clearly be shown to have reached Central Europe via the Balkans,¹⁷ the ways in which knowledge of iron metallurgy reached this region are significantly harder to trace and remain largely hypothetical.¹⁸ Extensive research by G. Gassmann indicates that people from the Latène culture were already smelting iron on a large scale in the northern Black Forest in the 5th century BC;¹⁹ also in France early iron production can be dated back to the Late Hallstatt/Early Latène period.²⁰ Smelting slag and bloomeries from Brandenburg²¹ and Jutland²² also date to this period. Iron production from the 4th to 3rd century BC has been proven for East Yorkshire in north-western England.²³ Iron smelting was therefore already widely distributed throughout the region north of the Alps by the early Latène period.

E. Hjärthner-Holdar postulates that iron smelting began in Sweden in around 1000 BC, i.e. during the Bronze Age.²⁴ However, some researchers take a critical view of this thesis.²⁵ At present, it can only be established with certainty that iron smelting took place

8 Lychatz 2012, 13; Pleiner 1996, 285; Pleiner 2000, 11–13.

9 Lychatz 2012, 13; Pleiner 1996, 285–286; Pleiner 2000, 9–10; Yalçın 2000, 310.

10 Lychatz 2012, 13–14, Abb. 2.1; Yalçın 2000, 309–310, Tab. 1.

11 Lychatz 2012, 13; Pleiner 1996, 286; Pleiner 2000, 14–18; Yalçın 2000, 310.

12 Rehren and Veldhuijzen 2007; Nieling 2009, Eliyahu-Behar et al. 2013.

13 Boroffka 1991; Lychatz 2012, 14; Pleiner 1996, 286–287; Pleiner 2000, 23–28. On the discussion about the dating of the Ganovce Iron object see Benkovsky-Pivovarová 2002.

14 Álvarez-Sanchís, Fernández-Götz, and Ruiz Zapatero 2012a; Lychatz 2012, 14; Pleiner 1996, 287.

15 Lychatz 2012, 16; Mommersteeg 2016, 587–2; Pleiner 1996, 287–288; Pleiner 2000, 28–30.

16 Cf. Montero Ruiz et al. 2013. Caution should be exercised in the detection of polymetallic ores and slags. An intentional iron production need not necessarily be accepted.

17 Pleiner 2000, 31 fig. 8.

18 Álvarez-Sanchís, Fernández-Götz, and Ruiz Zapatero 2012b, 151 fig. 1; Pleiner 2000, 31 fig. 8.

19 Gassmann 2005; Gassmann, Rösch, and Wieland 2006.

20 Leroy and Cabboi 2014.

21 Brumlich, Lychatz, and Meyer 2012; Brumlich 2012a, 149–153, Tab. 1.

22 Matthissen 2011, 119; Olesen 2010.

23 Halkon 2011, 139.

24 Hjärthner-Holdar 1993; Hjärthner-Holdar, Grandin, and Forenius 2013, 26–27.

25 Critique by Pleiner 2000, 25, 32; Zimmermann 1998, 80. We also have to keep in mind that there are sometimes problems of dating charcoal from smelting furnaces or slags (e.g. Schäfer 2010, 86).

in Sweden as early as the 4th century BC. In Eastern Europe, a detailed overview of the situation is, for various reasons, almost impossible.²⁶

From the highly selective nature of this portrait it follows that when conducting a large-scale assessment of the iron-smelting innovation process a strategy of comparative research focusing on individual, thoroughly studied regions is currently preferable to an attempt at devising an overall picture. This also means that up to now it has been difficult to distinguish regions and cultures with a high and low willingness to adopt innovations and new technologies, as the lack of evidence might merely represent the state of research.

3 Central research categories

The analysis of the diffusion of iron smelting technology in the different study areas of the research group is guided and consolidated following four major categories, which can be summarized by the keywords: space, knowledge, innovation and resource. In the following the concepts behind the individual terms will be highlighted more in detail.

3.1 Space

Space in its different scales and dimensions is an important category for analyzing and understanding the introduction of iron production. It is understood as a dynamic entity that integrates human production of space as a result of economic, political, social and cultural circumstances as well as physical space.

Iron production takes place in physical space. Natural resources – iron ore, clay, water and wood – are part of the natural environment and their usage changes the perception of it. Workshops, settlements and production centres are positioned in the landscape, and the landscape potential is used for transporting and exchanging iron. Iron production creates and transforms social space, while iron exchange takes place in economic space. The reconstruction of these spaces and spatial relationships is of major importance for the work of the group. Different scales have to be taken into consideration, from the spatial organization of a small workshop to large distribution areas of production centres, from the development of social and political space on a micro- and meso-scale up to the emergence of interregional spatial systems.

The fact that we are dealing with the human appropriation of natural resources points to the need for a holistic definition of space that allows the integration of natural environmental characteristics, since the world is constituted of hybrid²⁷ elements: consequently, it is not possible to assign them to a definite class called ‘human’ or ‘environment’. Accordingly, the dichotomy between these classes is not able to answer questions concerning humans *and* the environment, in our case the effects of iron utilization on cultural and societal concerns.²⁸ The concept of landscape archaeology, as outlined by Meier²⁹, integrates both aspects since it concentrates on the social construction of space, though it does not disregard the role of natural environmental characteristics in this process.

26 For a general overview: Bidzilya et al. 1983; Koryakova and Epimakhov 2007, 187–202.

27 Latour 1993.

28 Weichhart 2005.

29 Meier 2012.

3.2 Knowledge

The history of the invention, innovation and distribution of the technology used for iron production cannot be understood without investigating the specific knowledge that was generated and transferred in these processes. Much of this knowledge has a clear connection to space: where to find the raw materials, how to lay out a workshop, on which routes to transport and with whom to exchange the iron.

For the specific process of iron smelting, technological knowledge is of high importance. In this regard, a differentiation between explicit and implicit knowledge is not very promising. Even though written sources on the iron production process are lacking for most periods, this does not necessarily mean that this knowledge was not explicit – there are other media available for storing and handing over knowledge. It appears more meaningful to apply the concept of recipes: actual formulas that describe the different steps of a process. Who knew these recipes? Who had access to the knowledge, and by which mechanisms was it transferred to other groups, regions and cultures? Was it necessary to know the whole recipe or was it possible and likely that rudimental knowledge was enough to reproduce the process? How is that connected to the fact that the distribution of iron production often lead to minor innovations in the technique? How did this further development occur? Was it by chance or do we have to assume that structured experiments were conducted in order to improve the technology?

Obviously, in all regions that adopted the technology of iron production, iron objects and also smithing was known before the production was introduced; knowledge transfer clearly occurred as a process, and not as an event.

3.3 Innovation

What's new? The process of innovation and its diffusion has become an important topic in archaeological research, especially since the end of the last century.³⁰

In the following we would like to understand innovation after a definition of Braun-Thürmann, who defined material and symbolic artefacts, which are perceived as novel and experienced as improvement as an innovation.³¹ As far as we know up to now the major innovation, the invention of iron smelting techniques took place in Anatolia and was distributed from there into the Old World. The research group focusses on the specific course of this diffusion process in selected regions. In our point of view this process was accompanied by minor innovations, technical modifications that helped to adopt the *chaîne opératoire* to local conditions. The spread of iron production can only be understood by considering the distribution as well as accompanying minor innovation.

However, which processes trigger an innovation and its diffusion? Different models like the one by E. M. Rogers³² try to answer this question based on the observation of modern day societies for which manifold empirical data can be generated. In contrast to this, our knowledge of ancient societies is quite incomplete and selective, but nevertheless, this model, with its five stages of the adoption process,³³ can also provide possible explanations for archaeologists. For instance Roger's observation of a relatively small early adopter group which stands at the beginning of an innovation process can be correlated with the observation that early iron objects are generally found in an elite context.³⁴

30 E.g. Torrence and Leeuw 1989; Eisenhauer 1999; Müller 2002.

31 Braun-Thürmann 2005, 6.

32 Rogers 1983.

33 1. knowledge; 2. persuasion, 3. decision, 4. implementation, 5. confirmation.

34 Pleiner 2000, 7–11. 18–22; Biel and Rieckhoff 2001, 57. Graves with blacksmiths tools are another source of possible early adopters (Kokowski 1981; Brumlich 2005).

Another question we are focussing on is: why were innovations taken over by different societies? That innovations are not abruptly disseminated and / or are used sparsely is related to the fact that technological progress requires not only the pure will to innovate, but also the appropriate social conditions³⁵ and fundamentally personal communication and / or interaction (cultural contacts)³⁶. Many types of convergence between individuals from different communities and groups – equal technological skills³⁷, the same social position or maybe political consensus³⁸ – seem to be basic conditions for the diffusion of innovations. Thus, the diffusion and / or technological transfer of iron smelting were not necessarily a superordinate process between two archaeological cultures (Fig. 2).

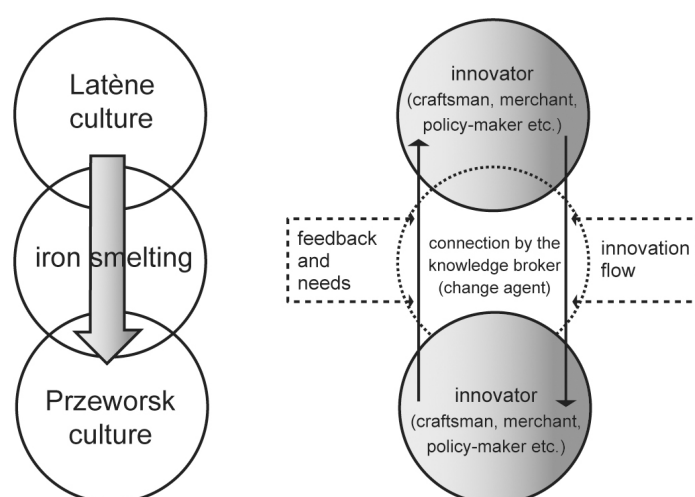


Fig. 2 | Innovation diffusion and technology transfer as intercultural superordinated process (left) and at the personal agent level (right) in the case of the introduction of iron production in the Late Iron Age Przeworsk culture.

Which innovation will be accepted is also based on selection processes whereby technical and ideological interests play an important part.³⁹ In addition to the resources (e.g. iron ore) of a particular landscape, which form the basic natural conditions, all the above-mentioned socio-cultural factors contribute to a certain degree to the technology transfer (Fig. 2). In some regions, if all these criteria come together, in the best case “innovative milieus”⁴⁰ can emerge. These spaces are characterized by a high degree of dynamic interaction and communication between different actors. However, the temporal existence of such milieus may be relatively short.⁴¹ In a long time perspective, so-called ‘innovation spaces’ and/or ‘advantage landscapes’ might emerge in which knowledge and skills are adopted faster than in other regions.⁴²

35 Damminger 2000, 227.

36 Especially trade networks and migration seem to be principal reasons for the diffusion of iron smelting.

37 It is not a coincidence that there is often a linkage between bronze cast and iron processing in the prehistory which are both pyrotechnics (Waldhauser 1986, 200–202; Rehren and Veldhuijzen 2007, 199; Álvarez-Sanchís, Fernández-Götz, and Ruiz Zapatero 2012b, 160).

38 The transition from one criterion to the next can be fluent. It’s possible that skilled craftsmanship goes hand in hand with political decision-making power.

39 Lüsebrink 2012, 148–149. For example, the technology of glass production and the technique of the potter’s wheel were not adapted during the later pre-Roman Iron Age of the Jastorf and Przeworsk culture.

40 Crevoisier 2001, 71.

41 Cf. Fritsch 2012, 190–191.

42 Messerli, Münger, and Schwinges 2001, 13. We are thinking in prehistoric respects to central locations of various characteristics and regions that are affected by trade routes.

Innovation research differentiates between linear and nonlinear models when explaining socio-technological change. Linear models are formed by two ideal-typical theories. Both “describe the course as a directed cause-effect sequence”.⁴³ The technological boost model assumes that the proposal of a new technology acts as the driving force of social-technological change.⁴⁴ A social demand caused by ‘market signals’ motivates producers to develop innovations. The demand pull model on the other side is predestined to explain improvement innovations.⁴⁵

But none of the models alone can provide a satisfactory explanation for the emergence of innovations. Or as Rogers put it: “Does a need precede knowledge of a new idea, or does knowledge of an innovation create a need for that new idea? Perhaps this is a chicken-or-egg problem”⁴⁶. Thus, there is a necessity for a regeneration of both aspects resulting in a non-linear model which allows a more general and holistic view (Fig. 3).

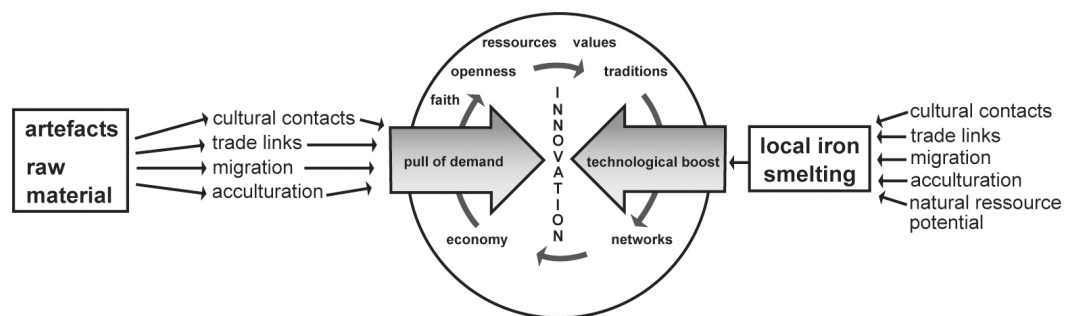


Fig. 3 | Recursive linkage of innovation models and some aspects which can influence the adoption process of an innovation.

Demand pull can occur after coming into contact with iron objects from trade, as presents or maybe in wars. The technological boost is also based on cultural contacts which can entail the introduction of a new technology.

Altogether we are dealing with the adaptation of a new technology and its adjustment to local conditions and tradition. These specific processes become visible in minor innovations – be it in the context of the exploitation of the iron ore, the supply with fuel, the technical outlay of the furnaces or the strategies to process the iron bloom.⁴⁷ The general adaptations of the new technology together with these minor transformations describe the appropriation process of the innovation. It is always socially embedded: a society must be willing to take over a new technology and a new technology must fit to the demands, needs and values of a society. It is of high interest to observe in how far innovation changes society and in how far society is changed by innovation.

3.4 Resources

The earth consists of different biotic and abiotic materials that can be summarized as *total stock*.⁴⁸ Once a part of the total stock is perceived by humans as being valuable in

43 Braun-Thürmann 2005, 30.

44 Braun-Thürmann 2005, 31.

45 Braun-Thürmann 2005, 32–33.

46 Rogers 1983, 167.

47 Pleiner 2000, 141–195. For an impressive ethnographic insight see Celis 1991.

48 Hagget 2001.

order to satisfy needs such as food, shelter, warmth, transportation, tools etc. and / or is in another way of beneficial use, it is defined as *natural resource*. Consequently the term *natural resource* is culturally bound. In the Bronze Age, copper and tin were important minerogenic resources since they were needed to produce bronze, while the meaning of iron deposits was negligible. It was only with a change in the assessment of iron ores as a geological reserve that they became a natural resource of economic significance.⁴⁹

Analyzing the exploitation and processing of natural resources in ancient times in general and in the example of iron ores as the upcoming new raw material of the outgoing Bronze Age in particular helps to enhance our understanding of a) the required knowledge for the identification of iron ore deposits, b) strategies for their exploitation and c) social, cultural and ritual implications of their management.⁵⁰ In general, the following natural resources are required for iron production: a) loam for the reconstruction of furnaces, b) water for cleaning the (bog iron) ores, c) fuel in the form of wood and/or charcoal and d) iron ores. Since the latter two have a special significance for iron smelting, they will be briefly introduced in greater detail below.

3.4.1 Iron ores as a natural resource for iron production

The geochemical composition of the crust of the earth is a result of endogenous and exogenous geological processes. In general, these processes lead to a homogeneous composition of the crust of the earth. Contrastingly, spots with higher concentrations of specific elements are rare and are called deposits when their exploitation under the technological state of the art is profitable. Beside oxygen (46%), silicon (28%) and aluminium (8%), iron (6%) is the fourth most abundant element in the composition of the terrestrial crust.⁵¹

Today, exploitation of iron deposits is profitable when their iron content reaches 50%.⁵² In prehistory, early metallurgists avoided exploiting ores that contained less than 55–60 % iron.⁵³ Iron ores can be differentiated according to their mineralogical composition. Among the nearly 400 iron minerals, only the following are of economic relevance: magnetite (Fe_3O_4), hematite (Fe_2O_3), siderite (FeCO_3), pyrite (FeS_2) and goethite (FeOOH).⁵⁴ Regarding the chemical formula of the minerals, it is obvious that their iron content differs. Magnetite has an iron content of 72%, while the content of pyrite totals approx. 46%.⁵⁵ Pure iron deposits are rare. They develop when volcanic activities affect lignite deposits and iron minerals are reduced to pure iron. Such deposits can be found for instance near the tertiary volcano Bühl (near Kassel, Germany). Iron deposits can be found in magmatic and sedimentary rocks, while more than 3/4 of present day iron deposits are of sedimentary origin. The hematite deposits on the island of Elba are an example of iron deposits of magmatic origin.⁵⁶

One of the youngest iron deposits in geological terms, the so-called ‘bog iron ores’ (Fig. 4), had a special meaning for the early prehistoric iron smelters in northern central Europe, since they occur near the subsurface in a region in which iron gangue minerals from geological rock formations are lacking. Using sounding sticks, these deposits were

49 Cf. Hagget 2001.

50 Aspects which can also be summarised in a broader conception of ‘cultural resources’. See e.g. the definition of the Tübingen SFB 1070 *Ressourcenkulturen*: Informationen zum SFB 1070 esp. 1.2.1.

51 Press and Siever 1995.

52 Pohl 1992.

53 Pleiner 2000, 87.

54 Rothe 2010.

55 Rothe 2010.

56 Pohl 1992, 115.

easy to detect and afterwards to exploit.⁵⁷ Bog iron ores are a terrestrial accumulation of iron minerals, which develop in hydromorphic, structureless gleyic soils of river valleys and fens with continuously high groundwater levels.⁵⁸ Precondition for the formation of these deposits is an inflow of ferrous groundwater. The soluted iron is transported by capillary ascent to the groundwater fluctuation zone where it precipitates.⁵⁹

During early prehistory, the demand for iron ore was mainly satisfied on the base of a surface near exploitation of iron deposits.⁶⁰

3.4.2 Fuel as a natural resource for iron production

Since coke was unknown in prehistory, charcoal was predominantly used to operate the furnaces. On the base of smelting experiments and archaeological finds and findings a fuel to bloom ratio of 1:8, respectively 1:10 has been calculated.⁶¹ Thus, in order to produce one kilogram of iron, 8–10 kilograms of charcoal were needed.⁶² The importance of fuel is illustrated by one of the early prehistoric centres of iron industry in the Mediterranean, Populonia, as it is assumed that iron production shifted from Elba to the Italian west coast after the island has been almost entirely deforested.⁶³



Fig. 4 | Bog iron ore excavated in the Malxe lowlands near Heinersbrück (Spree-Neisse region). Below the field horizon, the bog iron ore banks were still 20 cm thick.

4 Projects, methodological approaches and materials

All case studies focus on the first incidence of iron smelting in the respective study areas: the ancient Near East (project A-5-3), the northern Tyrrhenian Sea with the islands Sardinia, Elba and Populonia (project A-5-4), present-day Silesia (project A-5-2), the region of the Teltow to the south of Berlin (project A-5-1), and the eastern Baltic region (project A-5-5) (Fig. 1). In doing so, the prevailing societal framework during the introduction of the innovation of iron smelting, its effects on social and economic structures and on the

57 Ernst 1966, 11–12; Hücke 1922, 9; Grabig 1937, 9.

58 Banning 2008.

59 Kaczorek, Brümmer, and Sommer 2005.

60 Pleiner 2000.

61 Pleiner 2000.

62 Pleiner 2000; Spazier 2005/2006.

63 Saredo Parodi 2013.

environment are taken into account, as are technological processes of the *chaîne opératoire* and their advancement.

For each case study, the spatiotemporal availability of sources determines the range of possible given evidence for the introduction of iron smelting. We perceive these regional differences as a challenge, which helps us to expand the spectrum of research questions for the research group as a whole and to develop a corporate analysis framework. On the basis of this comparative approach, central development trajectories are identified and discussed against the background of the respective cultural conditions of the case study area and are afterwards compared on a cross-regional scale.

4.1 Projects

The most north-easterly study area is located on the coast of the Baltic region (project A-5-5). During the entire Iron Age this area was characterised by the occurrence of weapons, tools and objects made out of iron.⁶⁴ However, little research has so far been conducted on the question of whether these objects derived from local raw materials, or whether the raw materials were imports from other regions around the Baltic coast. While focussing on this research desideratum, the project carries out fundamental research on the reconstruction of the development of a local iron production in the Baltic region.

The early knowledge of iron smelting in the Przeworsk culture is investigated by applying a comparative approach in their primary population area of present-day Silesia and the southern foreland of the Harz Mountains, to which people from the Przeworsk culture migrated in the 2nd and early 1st century BC, with a focus on innovation, migration and cultural transformation (project A-5-2). The project aims to answer questions like: How is the mining and smelting of iron organized? What exact technologies are used? From a landscape archaeological perspective, the resource potential is analysed with a focus on an assessment of the quality of the smelted iron ore. Furthermore effects of iron smelting on the landscape are investigated.

The postulated dislocation of the iron smelting sites in the Northern Tyrrhenian Sea is investigated with a special focus on the impacts of iron production on the environment (forest clearing, air pollution). Thus, project A-5-4 focuses on one of the important ancient industrial centres of iron production of the Mediterranean: the islands of Elba and Sardinia as well as the ancient city of Populonia, located on the Italian mainland.

The remaining two case study regions are located in the former first Hittite empire (A-5-3) and from the Teltow region south of Berlin and will be introduced more in detail in chapter 5.

The integration of different methodological approaches from archaeology, ancient oriental studies and physical geography enables the research group to incorporate different materials: archaeological finds and findings (e.g. slags, furnaces, iron objects etc.), ancient sources, sedimentological and/or environmental proxy data as well as metallurgical analysis. Anyway, the availability of materials is highly dependent on the location of study areas and the period under investigation. While in the Mediterranean, literary sources of relevance date back to the 2nd millennium BC, visual or written records that could offer insights into the structure of iron metallurgy are lacking in Central Europe for the respective period. Sources of this kind do not emerge until the Early Middle Ages in the region north of the Alps, meaning that research on the preceding period of over a thousand years is reliant upon the interpretation of material remains.

64 Nowakowski 1994.

Nevertheless, the methodological approaches differ from study region to study region, and the interdisciplinary composition of the group has proven to be tremendously valuable for the development of a corporate analysis framework and of research questions.

Below, the methodological approaches and materials of the individual disciplines and their specific chances and challenges analyzing the introduction of iron smelting to an area are presented.

4.2 Methodology and materials

4.2.1 Central Europe

In Central Europe, research on the introduction of the innovation of iron smelting is based on the interpretation of material remains. Foremost among these are the finished iron products. The earliest iron finds do not only indicate knowledge of the new metal; in some cases their typology can indicate their provenance. Besides traditional metallurgical analysis,⁶⁵ the newly applied method of Osmium isotope analysis⁶⁶ opens up new potential for the identification of the distribution patterns of iron objects. Conclusions can also be drawn from the iron objects regarding forging techniques and, in some cases, regional production. The latter can be seen as an indicator of the growing implementation of the innovation of iron.⁶⁷

Evidence of iron trade and iron imports that may have preceded independent iron production is for instance provided by finds of bar iron. These, too, can help to clarify questions concerning the provenience of early iron, and make it possible to identify trade systems and economic spaces.

With regard to iron smelting, the greatest potential is offered by production waste such as slag and the remains of production installations, especially bloomeries. These provide not only unambiguous evidence of the existence of local iron production, but also information on numerous details such as which raw materials were used and what course the process followed. Furthermore, slag quantities also allow inferences to be drawn regarding production capacities. In this context, it is essential that researchers apply a combination of archaeological and natural science methods.⁶⁸

Inferences regarding whether organization of iron production was centralized or decentralized can be drawn from the location of production facilities in relation to settlements and the number and distribution of iron smelting sites within a region. Both forms of organization are closely connected with the respective economic and social structures and are based on different approaches in using available resources.

Grave finds constitute another important type of source in connection with early iron metallurgy. For example, iron slag and chunks of bog iron ore from Early Iron Age graves in northern Germany can be evaluated as evidence of early knowledge of the raw material used in iron production and of corresponding usage of that material. In addition, later graves from this region contain blacksmith tools of which hardly any other evidence has survived. Certain methodological reservations notwithstanding, these so-called 'blacksmith graves' enable inferences to be drawn regarding the social status of metallurgy.⁶⁹

65 See, e.g., Janke and Lychatz 2000, 303, Tab. 14.

66 Brauns et al. 2013.

67 See also chapter 3.3 *Innovation*.

68 In Topoi cooperation with B. Lychatz of the TU Bergakademie Freiberg (Institut für Eisen- und Stahltechnologie).

69 Brumlich 2005.

Knowledge of the social position of blacksmiths and of how iron smelting and processing were organized can also be obtained by means of ethnological parallels. Especially with regard to the spread of a new technology, it is of great importance to determine how the acquisition and mediation of knowledge and skills took place. Knowledge obtained by means of experimental archaeology can also make valuable contributions to the research; the results of bloomery experiments are of great help for the interpretation of archaeological finds and findings.

4.2.2 Ancient Mediterranean

The ancient Mediterranean presents a slightly different picture compared to northern Europe (*supra*), since texts and iconographical sources can be added to the archaeological contexts for dealing with the manufacture and use of iron and products made of iron, at least from the 8th century BC onwards⁷⁰. For previous periods, the situation is comparable to the one in central and northern Europe. For instance, already during the Mycenaean period, and more specifically between the 16th and 13th centuries BC, small objects made of iron or containing iron parts have been found in Greece⁷¹. For various reasons, a connection with Anatolia seems plausible (*cf. supra*), but no explicit textual sources can help to strengthen this assumption for this period. The first finds of iron slag and ingots have been observed for the transitional period from the late Bronze Age to the Iron Age, namely within the later 11th century BC, indicating metallurgical activity during the so-called ‘dark ages’. Interestingly, iron is also present in the two main examples of early Greek poetry and literature, the *Iliad* and the *Odyssey* respectively. While in the *Iliad*, an iron disc is given as a sports tool and as a winner’s prize during games organized by Achilles (*Il.* 23, 825ff.), in the *Odyssey* the technique of hardening iron in water is mentioned when comparing the penetration of the wooden beam into Polyphemus’ eye with a red-hot iron tool held in water (*Od.* 9, 391–394). Since it is commonly assumed that the *Iliad* is slightly earlier than the *Odyssey*, one could interpret the two passages as an evolution from imported iron objects that had a special value due to the “strange” and rare material towards smelting and the production of iron objects in Greece. However, the problem with a more precise statement consists in the construction of the *Iliad* and the *Odyssey*, i.e. the assumption that both texts contain earlier elements that may go back to the late Bronze Age and the transitional period (‘dark ages’), and were preserved over generations in the form of ‘oral poetry’ until they were written down (probably) during the 8th century BC⁷². In any case, the techniques of smelting and working iron can be assumed for the geometric period (ca. 900–700 BC), as has been confirmed, besides archaeological finds, by a passage in Hesiod’s *Theogony* (862 et seqq.), where the smelting of iron by Hephaistos’ force (= fire) is given as a metaphor. From the archaic period (ca. 700–490/80), we also know of some depictions of blacksmiths and their workshops, mainly from Athenian painted pottery.⁷³

4.2.3 Anatolia

For a reconstruction of the role of iron in Anatolia during the 2nd millennium BC, both archaeological and literary sources are available, a fortunate situation that allows us to compare different types of data.

70 Most written sources are easily accessible in Humphrey, Olsson, and Sherwood 1998.

71 Varoufakis 1981; Varoufakis 1982.

72 Deger-Jalkotzy 2008.

73 Lewis 2011; Zimmer 1982.

The literary sources consist of clay tablets written in cuneiform writing and different languages: Akkadian, Hittite, Hurrian, and Hattian. The places where they were found include Anatolia, with most documents coming from the Hittite capital Hattuşa/Boğazköy, Syria (in particular the archives of Ugarit, Emar, Qatna, and Mari), and Egypt (the Tell el Amarna archive). Iron appears in texts of different typologies: for the Old Assyrian Period (ca. 1950–1700 BC), documents written for commercial purposes are mainly preserved, while for the Hittite Period (ca. 1650–1200 BC), iron is mentioned in a wide range of texts, primarily rituals, festival texts, cult inventories and inventories of goods.

The archaeological finds consist of iron objects and fragments recovered from many Anatolian and Syrian sites, whose number increases considerably with the beginning of the Iron Age.⁷⁴ The recovery of iron slag, when associated with remains of buildings, is useful for identifying the existence of metal workshops.

A significant discrepancy between archaeological and written evidence has to be noted, as both the amount and the typologies of the objects mentioned by the texts do in many aspects not match with those that were actually recovered.⁷⁵ Such a situation is at least partially due to the habit of recycling metals in antiquity that prevented the survival of many objects (for instance, statuettes of persons and animals), whose existence is conversely attested by the written documents.

4.2.4 Landscape archaeology

The earliest example of global atmospheric pollution is related to copper production in the Bronze Age, as increases in lead concentrations in the inland ice of Greenland show.⁷⁶ Contrastingly, the smelting and processing of iron and other non-ferrous metals contribute only to a minor degree to an increased release of lead and other heavy metals into the atmosphere.⁷⁷ Nevertheless, (semi)terrestrial archives such as bogs, soils, colluvial and alluvial sediments in the areas around iron smelting sites are suitable for tracing environmental pollution as a result of early iron metallurgy.⁷⁸ Analysing such archives applying methods from geoscience may allow deriving additional information on the timing and scale of iron mining and smelting in the past.⁷⁹

Ancient smelting and processing locations can also be regarded as abandoned, potentially polluted sites. From this perspective, an identification and quantification of the pollutants in the shallow subsurface in the areas around these locations is of interest. This kind of analysis also helps to enhance our understanding of the long-term reaction of heavy metals in the subsurface. The derived information is also of relevance for the present day management of polluted sites.

The analysis of the resource potential of a region is also of relevance from a landscape archaeological perspective. This aspect comprises the development of geostatistical approaches in order to detect suitable areas for the formation of bog iron ores, and the geochemical characterization of ores and slags in order to identify source areas of the ores and to derive information about technological implications of the smelting process and the quality of the smelted ores.

Landscape archaeological research also contributes to a better understanding of the site formation processes. By mapping and quantifying sediment dynamics, the influence

74 Jean 2001; Patrier 2014.

75 Siegelová and Tsumoto 2011, 296–297.

76 Hong et al. 1996.

77 Hong et al. 1996; Nriagu and Pacyna 1988.

78 Killick and Fenn 2012.

79 Killick and Fenn 2012.

of erosion on the conservation of settlements and smelting sites can be determined in order to support the interpretation of archaeological evidence.

5 Iron as a raw material in the light of two case studies under investigation

To give a closer insight in the work of the group, two case studies will now be presented in greater detail.

5.1 Towards the Iron Age: a case study on the cultural history meaning of iron in the Ancient Orient

The project focuses on the cultural, economic and social role of iron in the Ancient Near East during the Late Bronze Age and the first centuries of the Iron Age, with particular attention paid to the evidence coming from the Hittite Anatolia.

The choice of Anatolia as area of investigation is primarily due to its richness in iron deposits, which are distributed over the entire territory.⁸⁰ Such richness, combined with the numerous mentions of iron objects in the Hittite texts, often led scholars to assume that the Hittites' military successes, which allowed them to ascend to the status of a great power in the Ancient Near East, were due to privileged access to iron deposits and to a distinctive mastery of iron-working technologies. Additionally, the famous letter KBo 1.14, where the Hittite king Ḫattušili III refuses to ship some "good iron" to his Assyrian counterpart,⁸¹ has been interpreted as a piece of evidence for a sort of monopoly exercised by the Hittites over the production of this precious metal.

Although such views are no longer taken for granted,⁸² it cannot be denied that iron objects are often mentioned in texts composed during the Hittite period, i.e. *before* the beginning of the Iron Age. The project aims to reappraise the evidence about iron in Anatolia during the 2nd millennium according to a diachronic perspective, with the dual goal of establishing how the role of this metal changed and determining the circumstances that led to a sudden development of the iron industry from the end of the 13th century, when the Hittite Empire collapsed, onwards.

5.1.1 Methodology and previous studies

As already mentioned, both archaeological and written evidence is taken into account in this project in order to gain a more complete overview on the topic, compared with the previous studies that basically focused on one single kind of source. The investigation is not limited to the Hittite period, but also includes the previous historical phase, the Old Assyrian Colony Period, during which central Anatolia was divided into small kingdoms and had not yet reached a political unity; it has in fact to be observed that many aspects concerning the use and role of iron, especially during the first centuries of Hittite history, can be better understood in light of the attestations from the Old Assyrian texts.

The research perspective has also been geographically broadened and takes account of data from Syria and Egypt, two areas that maintained commercial and political relationships with the Hittite kingdom for long time. Iron finds in these regions do not necessarily

80 See the map in Muhly et al. 1985, 72.

81 See lastly Mora and Giorgieri 2004, 57–75.

82 See Košak 1986, 134: "Any notion of a Hittite supremacy based on their technological superiority, may therefore be relegated to the status of fiction"; see also Zaccagnini 1970.

have to be interpreted as local products,⁸³ since the practice of exchanging gifts between royal courts characterized the whole Late Bronze Age and is well testified by the textual sources.⁸⁴

As far as the analysis of the written documents is concerned, two important works should be mentioned: “Gewinnung und Verarbeitung von Eisen im Hethitischen Reich im 2. Jahrtausend v. u. Z.” by J. Siegelová⁸⁵ and “The Gospel of Iron” by S. Košak.⁸⁶ The latter provides a list of all incidents of the use of the word ‘iron’ in the Hittite texts, which are organized according to their typologies and divided into four groups: ‘iron’, ‘black iron’, ‘good iron’, and ‘white iron (?)’. The investigations by J. Siegelová span from the Old Assyrian Period to the end of the Hittite empire, following the basic lines of the development of the role of iron and its progressive loss of an exclusive connection with the idea and symbols of kingship.

Both studies date back to the 1980s and are based on systematic lexical research that needs now to be updated with new published texts, some of which provide important references to the role of iron.⁸⁷

Within this project, all lexical occurrences have been re-examined, updated and organized in two separated catalogues collecting attestations from the Old Assyrian texts recovered in Anatolia and from the Hittite texts respectively. Such a distinction is justified by the difference between the two groups of documents. The Old Assyrian texts were compiled by the Assyrian traders based in Anatolia during the first centuries of the 2nd millennium BC, and refer almost exclusively to their commercial activity there. Iron, which played an important role in this business, was mostly traded as a raw material (iron objects are only rarely mentioned) and its weight (expressed in shekels or minas) and price (in silver or gold) are often reported in the texts. These pieces of information are useful for reconstructing the mechanisms of the Assyrian trades and indirectly also cast light on the status of iron at the Anatolian courts before the beginning of the Hittite period, since the local rulers were the main addressees of the Assyrian commercial activity.⁸⁸ Conversely, the Hittite texts were directly produced by the royal chancellery (no private documents are preserved) and cover a wider range of typologies spanning from religion to administration; therefore, when they mention iron, they provide us with first-hand information on its use and role by the Hittites. Compared with the Old Assyrian evidence, in the Hittite texts iron mostly appears in the form of finished objects, which are mainly used for religious purposes; additionally, it is also mentioned in metaphors or symbolic sentences, which are very informative about its status and relation to the idea of kingship.

On such bases, the Old Assyrian and the Hittite catalogues offer different pieces of evidence and are therefore organized according to different criteria: the former mainly focuses on the economic aspects of trade of iron as a raw material and provides data about its weight, price, place of sale, and circulation; in the latter, more attention is paid to the typologies of iron objects, to their use and to the contexts in which they are mentioned.

As far as the archaeological part of the project is concerned, iron objects and fragments, as well as iron slags, have been collected in a separate catalogue, which brings together the data from the excavation reports of many Anatolian and Syrian sites of the

83 See for instance the dagger with iron blade from the tomb of Tutankhamun, about which C. Lilyquist notes that “metalwork is another technology that might indicate the Near Eastern origin of some Tutankhamun objects” (Cochavi-Rainey and Lilyquist 1999, 211).

84 On this topic see Zaccagnini 1973.

85 Siegelová 1984.

86 Košak 1986.

87 See for instance the mention of iron in the letter of Tikunani, published by Salvini 1994.

88 On this topic see recently Cordani 2016.

2nd millennium BC. As previous works have already shown,⁸⁹ the study of the metal finds in the Ancient Near East is based on very limited evidence, since “the normal fate of a metal object (...) was the crucible to be recycled”.⁹⁰ The archaeological context of many iron fragments (especially those recovered during the early excavations) is unknown and the pieces cannot be dated; furthermore, very few fragments have been analyzed in order to ascertain whether they are actually made of iron, and in many cases, new analyses contradicted the older results.

The catalogue brings together a large quantity of information on iron finds that were otherwise scattered in many single publications, and updates them with the results of recent excavations.⁹¹ The archaeological data, such as weight, measures, and contexts of the finding, is integrated with the results of chemical analysis (when they are available) and historical studies, with the goal of establishing when iron objects were produced, by whom, and for which purpose. Since, as already noted, the catalogue collects objects within a wide geographical and chronological frame, it aims to provide an overview of the diachronic development of the iron industry in Anatolia during the 2nd millennium BC and, especially, during the crucial phase of passage from the Late Bronze to the Iron Age. We are particularly interested in how object typologies changed over this long period, since the textual evidence seems to suggest that the use of iron in ritual and cultic contexts was progressively abandoned in favour of more practical uses (tools and weapons). Furthermore, we aim to ascertain whether iron finds from those areas that maintained commercial and diplomatic contacts with Anatolia were local or, conversely, imported products, i.e. the result of an exchange of goods, whose existence is attested in the international correspondence on clay tablets. The archaeological catalogue is therefore useful by itself, but at the same time it represents the ideal complement to the attestations provided by the textual sources.

5.1.2 Terminology

In both the Old Assyrian and Hittite texts many terms appear whose meaning is related with iron. Some of them seem to refer to different qualities of iron, while others might indicate the results of different phases in its smelting. Less frequently, references to the places and ways in which iron was smelted and turned into objects have been attested.

In most cases, the analysis of the contexts in which such terms are mentioned is not sufficient in order to determine their meaning with certainty, but some hypothesis might at least be formulated and compared, when possible, with the archaeological data.

In the Old Assyrian tablets, which were compiled in Akkadian language, four words are attested that might mean ‘iron’: KÙ.AN, *amūtum*, *ašī’um*, and *parzillum*. Among the published texts where such words appear (approximately 120) *amūtum* is the more attested (more than 80% of the cases), followed by KÙ.AN and *ašī’um* (approximately 20% each), and *parzillum* (only 4 cases). Their meaning is still a matter for debate,⁹² but on the basis of some passages in which KÙ.AN and *amūtum* seem to be used as synonyms, it has been proposed that the former represents the logographic form of the latter.⁹³ This identification is supported by the fact that for both of them, at least two different qualities are attested, the higher and more expensive of which is generally labelled as SIG₅ ‘good’

89 See especially Waldbaum 1978 and Waldbaum 1980; Muhly et al. 1985 and the studies of Ü. Yalçın (Yalçın 1999 and Yalçın 2005). See also Jean 2001 and Patrier 2014 for a recent overview.

90 Thus Siegelová and Tsumoto 2011, 283.

91 See for instance the updated reports on the excavations in Kaman-Kalehöyük, published in the journal *Anatolian Archaeological Studies*; for Boğazköy see now Schachner 2014.

92 For a summary of the interpretations see Reiter 1997, 379–392.

93 See Dercksen 1992, 796 and Dercksen 2005, 27.

iron. R. Maxwell-Hyslop noted also that, compared with KÙ.AN and *amūtum*, in the case of *āšī'um* no indications of price or weight are reported. She therefore proposed for this latter the translation “iron ore”,⁹⁴ and for KÙ.AN and *amūtum* a double meaning: in their cheaper form they would designate the “bloom-iron”, i.e. the spongy mass rich in slags that was achieved after the first phase of the ironworking (the smelting); with the additional label SIG₅ they would stay for the results of the following phase, the hammering, through which the bloom-iron was purified. However, while the identification of KÙ.AN and *amūtum* with bloom-iron and purified iron has been accepted by many scholars,⁹⁵ the meaning of *āšī'um* remains more contested, also because in some texts it seems itself to be used as a synonym of *amūtum*.⁹⁶

For the word *parzillum*, which appears only rarely in the Old Assyrian documents, M. Valério and I. Yakubovich have recently suggested a Luwian origin from an hypothetical word **parza-* ‘iron ore’,⁹⁷ but an alternative explanation is equally plausible, according to which *parzillum* would be the result of a linguistic influence from the area of Mari; in the texts produced during the reigns of Yasmaḥ-Addu and Zimrî-Lîm the term is in fact well attested, both in syllabic (*pa-ar-zi-lim*, *pár-zi-lim*) and pseudo-syllabic (*bar-zil*) writings.⁹⁸

Quite interestingly, in the Hittite texts a completely different terminology is attested.⁹⁹ Iron is usually indicated with the logogram AN.BAR, in documents compiled both in the Hittite and Akkadian languages. When used in Akkadian context, the logogram is never accompanied by a phonetic complement; it is therefore hard to guess which Akkadian word it hides. Some scholars proposed an equivalence with Akk. *parzillum*, which however appears rarely in the Hittite texts written in the Akkadian language.¹⁰⁰

In a Hurro-Akkadian inventory of gifts belonging to the Egyptian archive of Tell el Amarna and sent to the pharaoh by the king of Mittani (EA 22), the logogram AN.BAR alternates with the Hurr.-Akk. word *ḥapalkinnu*. A similar word (*ḥapalki-*) appears in texts in Hittite language, in complete syllabic writing or partially hidden under the logogram AN.BAR (often with phonetic complements); cf. also the form *ḥapalkiyaan* appearing in the Hattian section of the bilingual foundation ritual KBo 37.1, and corresponding to AN.BAR in the Hittite part of the text.¹⁰¹

In some cases, iron is further qualified as ‘black’ (AN.BAR GE₆). Since in the foundation ritual KBo 4.1 the sentence “they brought black iron of the sky from the sky” is reported,¹⁰² it has been proposed that AN.BAR GE₆ should be translated as ‘meteoric iron’. However, there is still no agreement among scholars on the use of meteoric iron in Anatolia during the 2nd millennium:¹⁰³ Unfortunately, the comparison with the archaeological finds is not very helpful, since only a modest number of them has been analyzed

94 Maxwell-Hyslop 1972.

95 See for instance Muhly 1980, 35. Differently Reiter 1997, 392 who suggested to identify KÙ.AN with antimony or an antimony-zinc-alloy. See also Dercksen 2005, 28 for some criticisms.

96 Landsberger 1950, 331, n. 14.

97 Valério and Yakubovich 2010, 108–109.

98 On iron in Mari see lastly Arkhipov 2012, 12–14.

99 For an overview see recently Vanséveren 2012. See also Kammenhuber 1996.

100 Cf. the Tikunani letter (AN.BAR-zi-lu-ù), which however does not seem to be a product of the Hittite scribal school (Weeden 2009, 70–75), as well as one text recovered in Boğazköy but displaying a Middle Babylonian ductus, the anti-witchcraft ritual *ana pišerti kišpi* KUB 37.44+.

101 Another possible term for iron (Anat. **kel/iklu-*) has been identified by Melchert 1983, 139–141, but cf. Vanséveren 2012, 206–208.

102 Obv. 39.

103 See Maxwell-Hyslop 1972, 161: “in an area so rich in minerals there would have been no need to use meteoric iron (a material extremely difficult to work) instead of smelted metal”; Yalçın 1999, 184; Siegelová and Tsumoto 2011, 296–297.

and the presence of high percentages of nickel, despite being distinctive of meteorites, does not seem to completely exclude a terrestrial origin of some of the iron used.¹⁰⁴

5.2 Iron smelting in the Teltow

In project A-5-1, *Iron Smelting in the Teltow*, the focus is the early phase of iron smelting in a region in northern central Europe, for which – unlike other project regions – no written records are available, so that the analyses are of necessity based solely on archaeological material. The Teltow was selected as a research area because here, there has been knowledge of a large number of slag sites since the 1980s¹⁰⁵, and in a DFG project immediately prior to this one, the first important discoveries could be made on the beginnings of iron production.¹⁰⁶ According to the research findings to date, regional iron smelting begins as early as the late Hallstatt period, although at the latest during the earliest Latène period (5th century BC). Indications for this are provided on the one hand by a radiocarbon dated find of iron smelting slag from a settlement at the Waltersdorf 11 site (Dahme-Spreewald region), and on the other by the state of development of iron smelting in the extensively studied settlement on the Glienick 14 site (Teltow-Fläming region). In the latter settlement, iron was produced from the early 4th century BC onwards in re-usable bloomeries of the ‘Glienick’ type, which clearly were to a certain degree the standard form used in the region during the entire pre-Roman Iron Age (Fig. 5). Due to the amount of work required to operate a bloomery of such a type,¹⁰⁷ iron smelting was apparently organised in such a way that it was conducted by an association of several small settlement communities, and took place cyclically in one of these settlements. The production, which was part of the Iron Age subsistence economy, was largely aimed at covering the settlements’ own needs.

The iron that was produced was further processed directly in the settlements, as an almost systematic coexistence of iron smelting and smithing waste materials on the Iron Age sites of the Teltow shows. It can be assumed that small-scale mobile smithies were used in the region alongside those that operated on a fixed site, which worked to fulfil orders and which certainly also played a key role in the organisation and implementation of iron smelting. In the settlement excavated near Glienick, proof was also found of activity by polymetallurgists, who processed bronze and iron in the same workshop.

The strategy of researching early iron metallurgy in the region of the Teltow is to work at three different levels.¹⁰⁸ The first level is the microlevel, in which a selected settlement with existing evidence of iron smelting and processing is investigated in detail using archaeological and geophysical prospections and large-area excavations in order to reach conclusions, on the basis of examples, regarding the technology and capacity of iron production. Here, further issues are the spatial relationship between the generation and further processing of the raw material and the incorporation of the iron production into the settlement structure. Additionally, obtaining material for the chronological classification of iron smelting is of importance. The archaeological investigations at the microlevel, which are accompanied by analyses from the field of the natural sciences (radiocarbon

104 On this problem see especially Photos 1989.

105 Seyer 1982, 35–37.

106 The ME1251/4 DFG project, *Iron Smelting in the Pre-Roman Iron Age of Northern Central Europe: The Teltow as a Case Study*, was conducted under the leadership of Prof. Dr. Michael Meyer from 2009–2013. A detailed preliminary report on this project was published in the *Prähistorische Zeitschrift* (Brumlich, Lychatz, and Meyer 2012).

107 In this regard, it has been possible to obtain new key information in recent years through our own experiments with the ‘Glienick’ furnace type.

108 See also the similar research strategy of the Bochum Siegerland project (Stöllner 2010, 104–106, fig. 2).



Fig. 5 | 'Glienicke' type bloomery in the excavation findings (below) and in the experiment (above).

dating, archaeobotany, archaeozoology, archaeometallurgy) have been conducted within the framework of the DFG project at the above-mentioned site at Glienicke, and have to a large extent been completed.

The mesolevel comprises prospections and sondage excavations at a selection of Iron Age settlement sites that include surface finds of iron slag, and which are distributed in a type of network over a larger territory. Archaeological field surveys with individual find measurements and geomagnetic prospections make it possible to gain insights into the extent and structure of these settlements. Targeted excavations of geomagnetic anomalies, which can be interpreted as residues of bloomeries or as deposits of smelting waste products, are intended on the one hand to provide information on the technology of iron smelting, while on the other offering additional find and sample material for the purpose of dating. With these methods, and in comparison with the results gained at the microlevel, the nature of the metallurgical iron activities in these settlements can be determined, and development tendencies envisaged over a larger geographical area. The

work at the mesolevel has already begun as part of the DFG project, and is currently being continued in Topoi.

Project A5-1 is dedicated to the analysis of the macrolevel, which consists of a record of all Iron Age sites of the Teltow. Here, the main aim is to examine the material available in the archives and to create an overview-style catalogue of the sites, which includes information on the metallurgical finds. Alongside the archival work, field surveys should as far as possible be made of all settlement sites in order to uncover finds that provide information about the date on the one hand, and on the other to uncover iron slag that gives an insight into the character of the metallurgical activities within the individual settlements. In this context, on the basis of certain features of the smelting slags, a possible classification of these slags as being of the 'Glienick' bloomery type is to be checked. The radiocarbon method is applied in turn in for the direct dating of the iron smelting waste products. This method is particularly important, since the sites involved are predominantly sites only with surface finds, which in some cases comprise multi-phase settlements.

The final product will, among other things, be a map of the sites, which illustrates the Iron Age settlement pattern of the Teltow. It is of great interest to discover the extent to which there was a dependence between the settlement and the conditions provided by the natural space; this is one of the interfaces between archaeological and geographical research. In connection with iron smelting, the question naturally arises above all as to what extent the selection of settlement sites was oriented to the presence of bog iron ore, which formed the basis for regional iron production. It has emerged that it is problematic when clarifying this issue that almost nothing is known of the former and recent bog iron ore deposits. Currently, the only sources available are the geological maps produced by the Prussian land inventory and several historical reports, which provide only very patchy or narrowly focussed information. Precisely for the area of the Teltow, with the most dense Iron Age settlement and numerous pieces of evidence of iron smelting, almost no information is available regarding iron ore deposits, which certainly does not mean that these did not exist, or are not still present in places. The attempt to produce a new map does not necessarily have to fail due to the amount of work involved, but also because of significant methodological problems, which arise from the destruction of the bog iron ore close to the surface and a disruption of the conditions in which it was created through amelioration measures and agriculture. For these reasons, we aim to produce a potential map, in which those areas are reconstructed in which according to certain geomorphological features, the theoretical conditions for the formation of bog iron ore have been fulfilled.

Other natural resources apart from the ore are of fundamental importance for iron smelting. First comes a sufficiently large forested area, which provides wood for producing the charcoal needed as fuel for iron smelting and processing. The mixed forests of pine and deciduous trees of the ground moraine plateaus of the Teltow were clearly suited to this purpose. According to investigations at the microlevel, which include detailed calculations of the wood consumption used in iron smelting near Glienick, metallurgy had no severe impact on the forests. This conclusion is also confirmed by the pollen analyses at a core, which was obtained from the biogenic sediments of the *Rangsdorfer See* lake.¹⁰⁹

A fireproof building material was needed to construct the bloomeries. In the Teltow, the clay present on the ground moraine was suitable for this purpose. It can already be determined from the current state of research that the Iron Age settlement was very recognisably oriented to the presence of clay, since there is no evidence of settlement from the southern section of the Teltow, which is characterised by large areas of sand.¹¹⁰ This

109 Palynological analyses by P. de Klerk (Karlsruhe).

110 Clay was also needed e.g. for the construction of lime furnaces, which appear from the early pre-Roman Iron Age onwards. In contrast to that of the Iron Age, the Bronze Age settlement extended throughout

is an interesting aspect, since numerous ore deposits are known to exist precisely in the Baruth Urstromtal valley that adjoins the area to the south. Furthermore, large stones were used as building materials specifically for the ‘Glienick’ bloomery type, with which the slag pits were constructed. Stones of this type are present in the ground moraines in the form of glazed rubble.¹¹¹

A fundamental factor for the situation of settlements is the availability of water, which was needed not only for consumption, but also for various handcrafts. In the context of iron smelting, water was used to wash the ore and to process the clay for the furnaces. Furthermore, water¹¹² needed to be ready for use at all times while the bloomeries and smithies were in operation. This is underlined by the fact that in the settlement excavated near Glienick, there are immediately two cases of bloomeries and the smithies that were used with them being located just a few meters away from wells.¹¹³ The Iron Age settlements were always situated on the edges of damp lowlands, since here, a constant supply of water could be guaranteed by building wells.¹¹⁴ At the same time, the settlements including the iron production facilities enjoyed a favourable position between the ground moraine with the presence of clay and stone, and with extensive forests on the one side and the lowlands with the iron ore deposits on the other.

For the Teltow, it can be ascertained that the use of space during the pre-Roman Iron Age was clearly oriented to the natural resources that were available. At a regional level, the choice of location was however not – as can otherwise certainly be assumed – determined by the deposits of bog iron ore. Due to the fact that iron was smelted directly in the settlements, the selection of the locations at the local level was also not only made with metallurgical factors in mind. It must have emerged as being advantageous that resources such as clay, wood and water played an equally important role in iron metallurgy as in other areas of life, and the bog iron ore was found in the damp lowlands, the edges of which were preferred locations for settlements. For Iron Age settlement and early iron smelting, the ground moraine landscape of the Teltow offered ideal environmental conditions.

As well as the natural resources, the social and cultural, ‘immaterial’ resources are also of importance for iron smelting and processing. The cultural resources include knowledge, which in the metallurgical context means the relevant technological skill. In relation to iron smelting in particular, detailed knowledge of the natural environment is an important requirement alongside purely technological skill, since without this, the prospecting and procurement of the raw materials hidden under the surface would hardly have been possible. The social resources include personal relationships and networks, which played a decisive role in the organisation of iron smelting and the conveyance of technological skill. In the above-mentioned model of the association as an organisational structure used in iron smelting, which is connected to the way in which the “Glienick” bloomery type was operated, stable social networks are of paramount importance.

The resources situation probably also played an important role in the dissemination of iron smelting as an innovation. The potential of landscapes with particularly favourable natural environments was certainly soon recognised and exploited after the new technology became known. As has already been described above, the Teltow had such potential

the entire Teltow. The change in settlement structure can at least partially be traced back to the new iron smelting and lime burning technologies.

111 Due to the scattering of stones on the surface of the ground moraine, the stones were easy to access.

112 As well as providing a certain degree of safety, water was used above all to cool tools and workpieces, and if necessary, to also harden steel products.

113 Brumlich 2012b, 64–65, fig. 63; Brumlich, Lychatz, and Meyer 2012, 461, fig. 8.

114 A further important factor in the selection of the settlement site was e.g. the soil conditions. However, these were of no consequence in terms of iron smelting, which is the focus of our research. As a result, they are not described in greater detail here.

and the numerous smelting sites from the Pre-Roman Iron Age indicate that this potential was used extensively. This leads to the important question as to when precisely this use began in the region. The notion of an autochthonic emergence of the technology of iron smelting as presented some time ago by F. Nikulka for the north-west German region¹¹⁵ cannot be assumed to have been the case, since the necessary fundamental elements required for this, e.g. in the form of preceding copper smelting, do not exist. As a result, it can be assumed that the technology was transferred from a region where iron smelting was already developed. According to the current state of research, the dating of the oldest pieces of evidence for smelting to date and the state of development of iron production during the early Latène period indicate that the introduction of the new technology occurred either in the late Hallstatt or earliest Latène period.

In this regard, it is interesting that the Teltow, following dense late Bronze Age settlement by the Lausitz culture in the subsequent stages Ha C–D1 was only sparsely settled by the older Billendorf Group or a population that stood within their cultural arc of influence, and in Ha D2 was almost uninhabited.¹¹⁶ The fact that it is not a methodological problem of recognising the early Iron Age settlement in the archaeological material that is at issue, as might otherwise be assumed, is now confirmed by the pollen profile from the Rangsdorfer See lake¹¹⁷, which for the period between 800/750 and around 500 BC shows a low level of the type of pollen that indicated the presence of a settlement. For the first half of the 5th century BC, by contrast, a significant rise in the settlement indicators can be recorded, and there is an increase in charcoal particles in the lake sediment. The Teltow was at that time resettled from the north-west by the Jastorf culture.¹¹⁸ In the adjacent northern part of the region, there is also a slight degree of influence from the Görzitz Group, although in the findings, no contacts can be detected to the younger Billendorf Group.¹¹⁹ However, this does not necessarily mean that there was no contact at all with the Billendorf Group, since during the course of the 5th century BC, the Jastorf culture and the Billendorf Group met in the Luckau-Calau basin, which is located just a short distance away, to the south-east of the Teltow.¹²⁰

It is thus highly likely that there is a direct connection between the start of iron smelting in the Teltow and the arrival of the Jastorf people in the region. However, it remains unclear whether the new technology was brought from the place of origin of the Jastorf culture, or whether it was only adopted from another region after the Teltow was settled. Due to the fact that evidence has only recently been found of very early lokal iron smelting in the Luckau-Calau basin – this is also dated as being in the late Hallstatt to early Latène period (Ha D/Lt A) – it is possible that the technical knowledge was conveyed by the Billendorf Group that lived there. However, the finds of small slag blocks that bear the marks of the ‘Glienicke’ bloomery type come from settlements with find material from the Billendorf Group and the Jastorf culture, making it almost impossible currently to make any clear cultural assignment of the early smelting activities. Accordingly, the technology used for iron smelting could conversely have been brought by the expanding Jastorf culture from the Teltow to the south-east. Here, it should be noted that there is otherwise no evidence of iron production in the area settled by the Billendorf Group. The same applies to the Görzitz Group, and it must therefore be assumed that the decisive role

115 Nikulka 2000, 89–90.

116 Buck 1979, 145, fig. 104, 105, Appendix 1.

117 Pollen analyses by P. de Klerk (Karlsruhe).

118 Buck 1979, 145–146, fig. 106.

119 Bräunig 2006, 6, map 2; 2010, 42; Buck 1979, 145, Abb. 106; Schwarzländer 2012, 65–67; Seyer 1982, 70–72, fig. 25.

120 Seyer 1982, 72.

in the establishment of the innovation of iron smelting in the region between the Elbe and Oder rivers was after all played by the Jastorf culture.

On the basis of the early dating from the Teltow and the Luckau-Calau basin, the transfer of technology to the area north of the uplands zone probably still took place during the late Hallstatt period. Until now, it has not been possible to know for certain from which region iron smelting found its way to the north, and in what manner. One possible area of origin of the technology could probably be the eastern Alpine Hallstatt region. Among other things, the manner of constructing and operating the 'Glienicke' bloomery type points in this direction, since there are certain similarities with copper smelting bloomeries as found in large numbers in the eastern Alpine area in particular. These facilities for copper smelting could have served as early models in the development of early Furnace types, although to date, almost nothing is known about iron smelting in the Hallstatt area, and there is a lack of comparative finds. By contrast, there is certainly evidence available of intensive contacts between the early Jastorf culture and the Billendorf Group on the one hand, and with the Hallstatt culture on the other.¹²¹ These north-south connections are generally abandoned during the earliest Latène period (Lt A)¹²², making it unlikely that technology was transferred during this time period.

There are no indications of an experimental phase in the Teltow; the technology used for iron smelting was clearly introduced in its fully developed state. The extent to which the innovation was subsequently established is reflected in the numerous settlements with smelting slags in the region. From the Glienicke plateau and the area immediately surrounding it alone, 42 settlements from the Pre-Roman Iron Age are known, for example, and in as many as two-thirds of these settlement sites, smelting slags have been found¹²³. Unfortunately, problems with the fine chronological dating of the sites have meant that no new information has been obtained regarding the speed with which the innovation spread in the Teltow landscape. Probably, the process of establishment of the new technology was completed within just a few decades, however – a period of time that is almost impossible to measure using archaeological means – since the need for iron was there, and the regional resources provided an opportunity for producing the metal on site and thus for people to sufficiently cover their own needs. In contrast to the Bronze Age, people were therefore no longer dependent on the importation of metals, which was certainly one of the most important factors in the successful establishment of the innovation.

In passing on the technological knowledge in the region, a decisive factor was certainly the manner in which iron smelting was organised. If – as it can probably be assumed – the inhabitants of several settlements regularly met in order to produce iron in a bloomery of the 'Glienicke' type, the learning process took place through repeated observation of the work stages and active participation in them. If fully developed technology was available, it would have been relatively easy to reproduce. The iron was further processed by blacksmiths, who were possibly in charge of the iron smelting procedure. At least partially mobile activity by the smiths could have contributed towards the dissemination of the new technology.

While in the Teltow, it is not possible to ascertain the first phases of the innovation of direct iron production, as is the case in Anatolia, but instead only the further dissemination of the process through a transfer of technology, details can be found in the way in which the technology was implemented which indicate that the Iron Age inhabitants of northern Central Europe would also have contributed their own innovations. Here,

121 Buck 1979, 150–151; Derrix 2001, 25–27, 166–171; Seyer 1982, 60–65.

122 Seyer 1982, 64–65.

123 For some of the other sites of this sub-region, it can be assumed that iron was smelted, although to date, this has not been possible to verify.

the 'Glienic' bloomery type should be mentioned in particular, which appears to have been a modification specific to the region that succeeded in establishing itself over several centuries.

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1 Map: Wiebke Bebermeier et al., using GMTED2010 of Earth Explorer/USGS.
 2 Modified according to Rogers and Shoemaker 1971, 228 Fig. 7-1; according to Enrico Lehnhardt.
 3 Enrico Lehnhardt.
 4 Photo: Markolf Brumlich.
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