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By Who, for Whom? Landscape, Process and Economy in the Bloomery Iron Production AD 400–1000

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ABSTRACT

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Landscape, process and economy in the bloomery iron production during AD 400–1000 are all integrated in this paper initiated by an archaeological excavation of a bloomery site in Motala in Östergötland, southeast Sweden. This site is one among other contemporaneous sites with similar features, such as long-term iron production and a location in the landscape within easy reach of communication routes and, most importantly, access to the vital raw materials ore and wood. The site is placed in a rich region with several high-status features, such as richly furnished graves and settlements. We evaluate the transfer of knowledge and skills in a landscape perspective. Interactions in a complex network involving various entrepreneurs, from producers to consumers, are suggested as central. The major focus is on the importance of the organisation, the economic point of view, as well as quality and trade.

KEYWORDS: Bloomery Iron Production; Scandinavian Iron Age; Heterarchy; Archeometallurgy; Commodity chains; Economy; Landscape Archaeology.

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By Who, for Whom? Landscape, Process and Economy in the Bloomery Iron Production AD 400–1000

Landscape, process and economy in the bloomery iron production during AD 400–1000 are all integrated in this paper initiated by an archaeological excavation of a bloomery site in Motala in Östergötland, south-east Sweden. This site is one among other contemporaneous sites with similar features, such as long-term iron production and a location in the landscape within easy reach of communication routes and, most importantly, access to the vital raw materials ore and wood. The site is placed in a rich region with several high-status features, such as richly furnished graves and settlements. We evaluate the transfer of knowledge and skill in a landscape perspective. Interactions in a complex network involving various entrepreneurs, from producers to consumers, are suggested as central. The major focus is on the importance of the organisation, the economic point of view, as well as quality and trade.

Translation from Swedish by Judith Crawford.

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Introduction

Prehistoric bloomery iron production has attracted much attention from research in Scandinavia since the beginning of the twentieth century. For example, Montelius (1913:87 with references) considered the production of iron to have started in Sweden as early as the eighth century BC. Carl Sahlin was a pioneer when it came to surveying traces of early iron production in Sweden, and he worked in close cooperation with the archaeologist Johan Nihlén (Nihlén 1927, 1932, 1939). Within Jernkontoret, the Swedish steel producers' association, a committee for mining and iron production history was formed in the 1960s; among the initiators was the archaeologist and archaeometallurgist Inga Serning. This resulted in fresh progress for research on prehistoric iron production; several archaeological publications and doctoral dissertations were written on the subject (cf. Englund 2002; Hansson 1989; Hjärthner-Holdar 1993; Hyenstrand 1974, 1977; Magnusson 1986; Serning 1973, 1979, 1984; Strömberg 2008, 2009:75–84; Pettersson Jensen 2012). A comprehensive compilation is recently made about iron- and metal-working, published in the Swedish National Atlas (Sveriges Nationalatlas 2011). In Norway, a survey has been conducted of excavations carried out so far, in order to create a platform for further research on iron production (Larsen 2009).

The research tradition of iron studies roughly follows the same line of development as archaeological research and culture history studies have done in general. Initially, the production was regarded as a predecessor to the industrial power that characterised iron production in Sweden during the nineteenth and twentieth centuries. The focus was to elucidate the size of the production, the geographic frequency and chronology (Lyngstrøm 2008:15–22; Magnusson 2009:7–18). At the same time, attention gradually became more directed towards the technical aspects of iron production and the process of innovation (Hjärthner-Holdar 1993:13–14; Hjärthner-Holdar & Risberg 2009). In later years, in accord with contemporary lines of thought within archaeometallurgical and archaeological research, there has been more interest in holistic approaches taking account of social, economic and technical aspects of metal working (cf. Hjärthner-Holdar 1993:13–14; Strömberg 2008:19–20 with references; Rundberget 2017). In part, this comprehensive perspective also occurs in research on Bronze Age metal production (cf. Melheim 2012; Earle *et al.* 2015). However, such an approach has not yet gained sufficient ground in research on Swedish iron production. For a deeper understanding of prehistoric bloomery iron production, a cosmological perspective was introduced (e.g. Burström 1990:261–271). The perspective attracted immediate and justified criticism (e.g. Englund 1994:281–298), which contributed to nuance this line of thought within archaeometallurgic research. In turn, conceptually oriented approaches came to be applied in a broader meaning. The lack of research output that synthesise perspectives may be due to difficulties, from an archaeological and humanistic point of view, of assessing the impact of technology on societal organisation. On the other hand, from a technological perspective, it is hard to judge the impact of societal organisation on technology and technical knowledge. An interdisciplinary approach is therefore required in order to illuminate the long-term societal significance of historical, social, economic and technical perspectives, in a comprehensive way. With such an approach, this article is an attempt to combine perspectives from humanistic and social sciences with the study of the technical aspects of iron production.

Based on the iron production site that was excavated in Motala in the province of Östergötland, some background information will be presented first, concerning prerequisites and technical aspects of bloomery iron production. Thereafter, iron production at the site in Motala will be presented, set in a landscape perspective; the technical knowledge involved and the economic significance will be evaluated. Further, matters will be discussed appertaining to organisation, economy and trade, as well as the transfer of technical knowledge. This is an attempt to create an understanding for the significance of the site in the local landscape and to interpret it in light of socio-economic and technical aspects.

Background of the bloomery iron production

In Sweden, bloomery iron production started already in the middle Bronze Age, often occurring in the same contexts as small scale bronze casting. Today, approximately 40 Late Bronze Age iron production sites are known (Hjärthner-Holdar 1993). During the latter part of the Late Bronze Age, iron production sites started to appear in locations characterised as outlying areas far away from settlements and burial sites. Examples of such areas can be found in areas like Röda Jorden (the Red Soil) in the province of Västmanland, and in northern Uppland. This was evidently a period for prospecting, when people searched for rich ore in the form of various types of limonite ore, but also places with plenty of fuel (cf. Grandin & Hjärthner-Holdar 2000; Grandin *et al.* 2000; Forenius *et al.* 2014b). The reason for the prospecting may be an increased demand for iron. Subsequently, during the Pre-Roman Iron Age (Table 1), perhaps as early as the eighth century BC, the production of iron had become so prominent that we can no longer speak only of production for self-sufficiency; there would also have been a surplus production.

Pre-Roman Iron Age	500–0 BC
Early Roman Iron Age	AD 0–200
Late Roman Iron Age	AD 200–375
Migration Period	AD 375–550
Vendel Period	AD 550–800
Viking Age	AD 800–1050

Table 1. Iron Age chronology referred to in the text.
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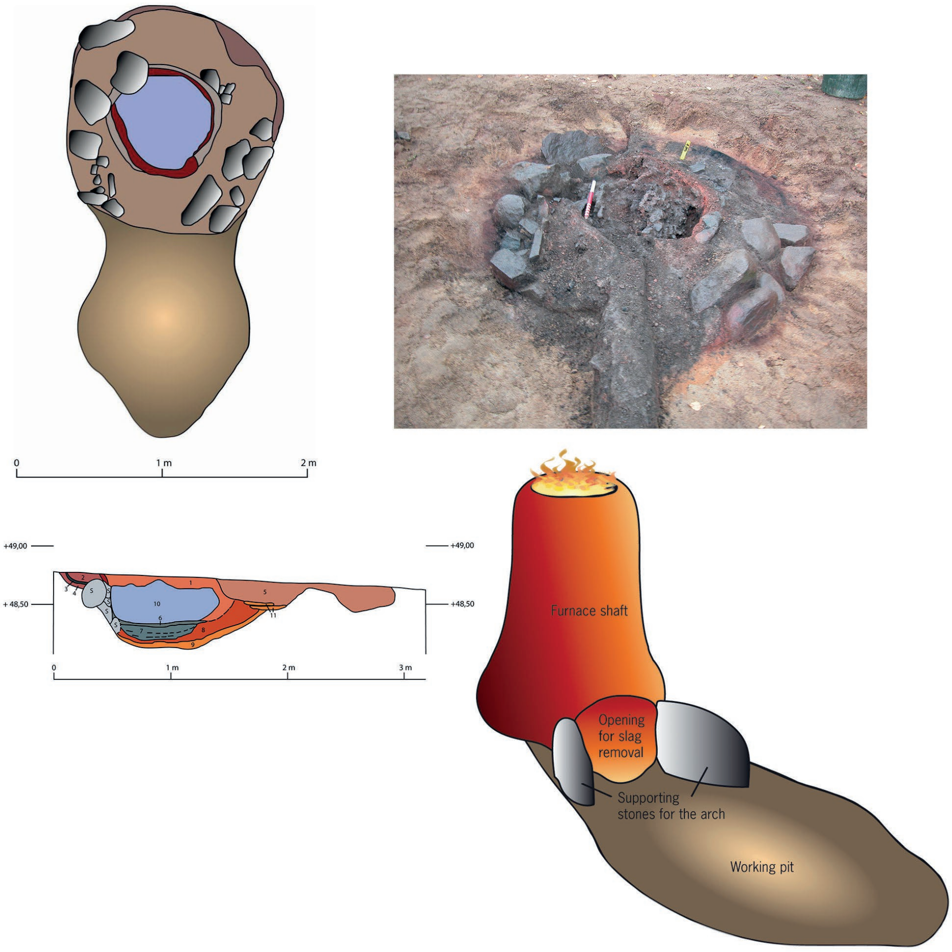

Fig. 1a. Excavated and reconstructed furnace for multiple firings with a slag-pit for the accumulation of slag underneath the shaft. Photo: Geoarchaeological Laboratory. Reconstruction drawing Svante Forenius, The Archaeologists.
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The furnaces

The earliest furnaces were quite small with an inner diameter of 0.3 m. The estimated shaft height would thus be 0.6 m, in order to function satisfactorily. Building material for the furnaces varied; even at an early stage, both stone and clay were used. Generally, non-tempered clay was used, however, occasional tempering with plant material is also known. It is evident that the furnaces were adapted to the material available in the immediate surroundings. The type of furnace was always constructed with a shaft and an underlying pit for the accumulation of slag, even if researchers have given them a variety of local names (cf. Serning 1979; Wedberg 1987, 1988, 1989, 1990:77–81; Englund 2002:242–259, 331, Fig. 181; Grandin & Hjärthner-Holdar 2003:391–424; Hjärthner-Holdar *et al.* 2013:33–35, Fig. 13). Many furnaces were intended for multiple firings (Fig. 1a). During the late Pre-Roman Iron Age and Roman Iron Age, furnaces that were used only once started to appear. Most of these furnaces occurred in western Sweden, mainly in the province of Västergötland, (e.g. Forenius *et al.* 2008) (Fig. 1b). This type of furnace was common in Jutland, Denmark, and across large parts of northern Europe, chiefly during the Early Iron Age.

There are exceptions to this method of gathering slag in underlying pits; for example, double furnaces occurring in Småland and Västergötland. In these furnaces, dated to the latter part of the Late Iron Age, the slag is separated from the bloom through tapping (Fig. 1c). However, only a minority of furnaces are constructed in this way. Why is the technology of tapping the slag not adopted everywhere in Sweden, as it is in several places in Norway, for example (Rundberget 2017:121–126, Fig. 3.20)? One plausible explanation is that the composition of the Swedish limonite ore makes it difficult to tap; the slag is viscous and does not flow out of the furnace if tapped. This is evident in double furnaces; the smith sometimes had to hook the slag out of the furnace (Nordman 1994:69–77; Englund 2002:213–215, 322). Thus, perhaps such attempts of tapping the slag should be regarded as an innovation that was probably not considered profitable and therefore not adopted in Swedish bloomery production.

When excavating the furnaces we usually only find the absolute bottom part of the shaft or just the underlying slag-pit. Through scattered parts of shaft material, technical and metallurgical knowledge and know-how of the process and experiments it is possible to reconstruct the furnaces. During the Iron Age, the furnaces varied considerably in size. Usually, traces that are left are 0.3–0.9 m in diameter, mainly measuring 0.5–0.6 m. Even if furnaces over one metre in diameter do occur. Taking technical aspects of the process into account, the height of the shaft above the inlet of air should be twice the diameter of the furnace in order to reduce the Swedish limonite ore into iron efficiently. This means that the height of the bloomery furnaces varied, they would have measured from 0.6 m up to 1.8–2 m in height (Hjärthner-Holdar *et al.* 2013:27–30).

Fuel

Fuel is an important factor in iron production. There is a discussion among researchers whether charcoal and/or wood was used as fuel for the furnaces (Wedberg 1988, 1989, 1990; Englund 2002:206–208; Westin 2003:386). To start with, charcoal has a higher output of energy than wood. Moreover, it is not possible to forge iron on a wood fire; forging requires charcoal as fuel. This means that methods of burning charcoal were known. It does seem, however, that there is a lack of structures indicating charcoal burning, at least dating from the Bronze Age and Early Iron Age. Such structures did not become common until Late Iron Age (Englund 2002:313–315 with references). Nevertheless, smaller structures that have been interpreted as pits for burning charcoal did occur as early as Bronze Age and Early Iron Age (Hjärthner-Holdar 1993:80; Forenius *et al.* 2014a; Biwall & Hjärthner-Holdar in manuscript). Accordingly, it can be strongly suggested that charcoal was readily available and that it was used as fuel in the bloomery process.

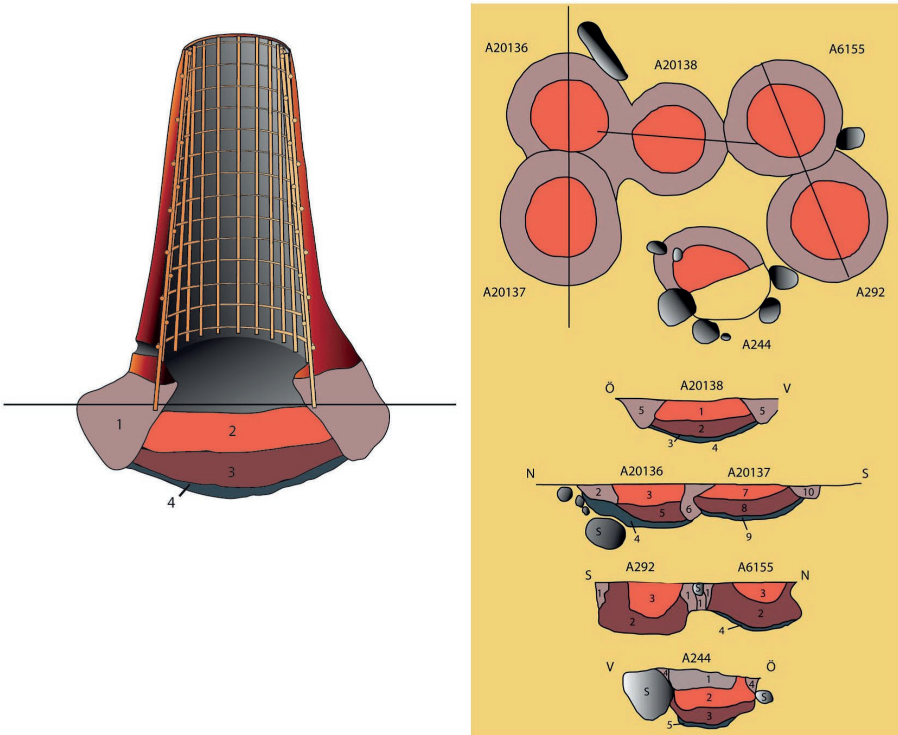

Fig. 1b. Excavated and reconstructed furnace for single use with a slag-pit for the accumulation of slag underneath the shaft. In the burnt clay, in the shaft, there are imprints that clearly demonstrate that the wattle was placed on the inside of the clay shaft, and not covered by clay. Reconstruction drawing Svante Forenius, The Archaeologists.
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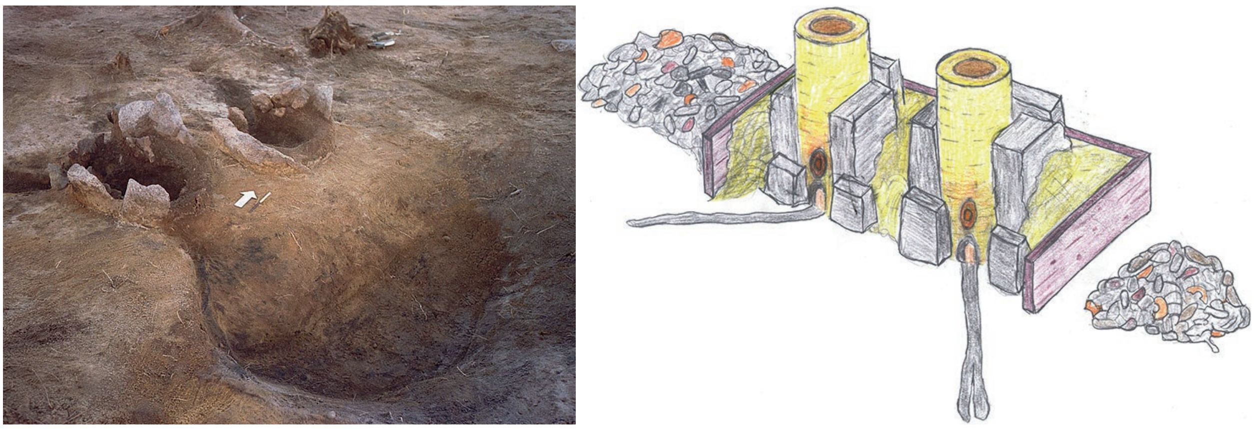

Fig. 1c. Excavated and reconstructed furnace for double blooms and slag tapping. Photo: Geoarchaeological Laboratory. Reconstruction drawing Lars-Erik Englund, The Archaeologists.
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What direct indications are there, that charcoal and not wood was used for fuel? In the bottom slag, there are large imprints, which differ from the smaller imprints that also occur in the slag. The structure of the imprints is revealing in many cases – smaller marks are from charcoal and larger are caused by wood. However, most likely, the larger imprints come from wood that was used for separating slag and iron, resulting in hollow spaces in the slag, and was probably not used as the main source of fuel. Such a procedure made it easier to break up the large lumps of bottom slag when extracting them from the furnace.

The efficiency of the process

The amount of slag found in the slag-pit varies from a few kilos to several hundred kilos. This is the case for furnaces used only once as well as those intended for multiple firings. In central Sweden, furnaces containing up to 350 kilos of bottom slag have been found. Assuming that the Swedish limonite ores yielded as much as one kilo of metallic iron to every kilo of slag in one firing (1:1), each firing would have yielded around 350 kilos of iron (not compacted and cleansed from slag). Naturally, a certain amount of variation in yield occurred; one of our problems is to determine how much iron that was produced (Hjärthner-Holdar *et al.* 2014). Among researchers, there has been a discussion about how much iron was lost in the process of forging leading up to the final product. It has been estimated that the loss was extensive; in the first forging, the primary forging, up to 50% of the original weight was lost. This involves the assumption that the bloom was severely mixed with slag (Englund 2002:288–294 with references). However, blooms that had not been wrought (weighing 25 and 33 kilos, respectively) were discovered on a site in Torsåker in the province of Gästrikland; these convey a different message. These blooms only contain a small amount of slag. However, the blooms (iron) were somewhat porous and would have needed to be compacted before forging into billets or finished items. Nevertheless, the quality was much higher than was previously considered to be the case in iron produced in a bloomery furnace (cf. Hjärthner-Holdar 2009:30, 34, Fig.10).

The resulting product is a sign that a successful method had been established at an early stage. Already in Late Bronze Age, various types of iron of excellent quality were produced, including wrought iron with no carbon and carbon steel of good quality. It was thus possible to produce good material suitable for tools and weapons. It is also noteworthy that the first artefacts to be made of iron in Sweden were not ornaments but items with a cutting edge (Hjärthner-Holdar & Risberg 2001:31; Hjärthner-Holdar & Risberg 2003:84).

Iron – an important commodity in society

Considering the rich occurrence and availability of limonite ore in Sweden combined with the efficient technique for smelting iron that has been recorded, the preconditions were favourable for the Iron Age societies to be able to produce good quality iron. This probably meant that when the extraction of iron was mastered, the dependency of long-distance import of the metal that had been of prime importance for societal development ever since it was introduced, declined. Iron markets evolved, governed by local, regional and inter-regional supply and demand. With the accumulation of experience and better methods, more iron could be produced. Consequently, iron was available for a larger part of the population and new ways of using this easily formed metal emerged. In comparison, iron is superior to bronze for manufacturing tools and weapons requiring strength and sharp edges. Not least, iron ore was obtained much more easily than copper ore. Moreover, copper was an imported commodity during prehistoric times. Domestic copper resources was not utilized until later, possibly as late as at the end of the Viking Age (Willim *et al.* 2011; Hjärthner-Holdar & Grandin 2013; Ling *et al.* 2014).

Having presented this background, the iron production at Motala will now be set into its contemporary context.

The landscape of bloomery iron production

The iron production site by the side of the river Motala Ström

The excavated iron production site in Motala, today in the middle of the city of Motala (Fig. 2), was situated in a slight slope to the south-west slanting down to the river Motala Ström, just beyond the eastern outlet of Lake Vättern (Gruber & Westermark 2017). It is located at the intersection in the landscape of several different topographic zones, giving it an exceedingly communicative position. Apart from the water routes via Lake Vättern through the present-day provinces of Närke, Västergötland and Småland, there are also routes on land in the form of sunken tracks, northwards towards wooded land and on towards Närke, as well as to the south towards the Vadstena plain and the farmland there. Heading east, towards the region of Linköping and on to the Baltic Sea coast, people probably travelled along Motala Ström and through the lakes. Since there are strong currents, steep rapids and waterfalls between the lakes, the whole journey might not have been attempted by boat. The iron production site is thus situated in a favourable location in the landscape, not only in regard to communication, but also in view of raw materials such as ore and fuel.

In connection with the archaeological excavation, four bloomery furnaces were documented. These were of a type of furnace with a shaft and an underlying slag-pit. In addition to the furnaces, there was also a dump zone with reduction slag on the slope towards the shoreline. Radiocarbon analyses of charcoal from the structures show that production started at the earliest during the Late Roman Iron Age. The smelting of iron continued throughout the Migration Period and into the Vendel Period; there was thus a long continuity of production on the site, between AD 260 and AD 690, around 400 years (Table 2). Slag varying in chemical composition and amount, type

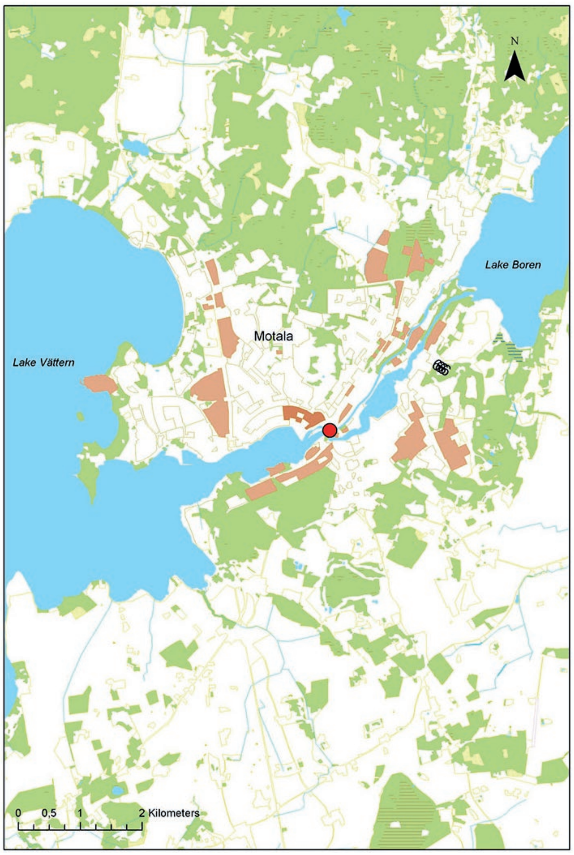

Fig. 2a. Map of Motala, showing Lake Vättern to the west and Lake Boren to the east. The red dot marks the location of the iron production site on the northern shore of Motala Ström. Graphics Katarina Sköld, The Archaeologists.
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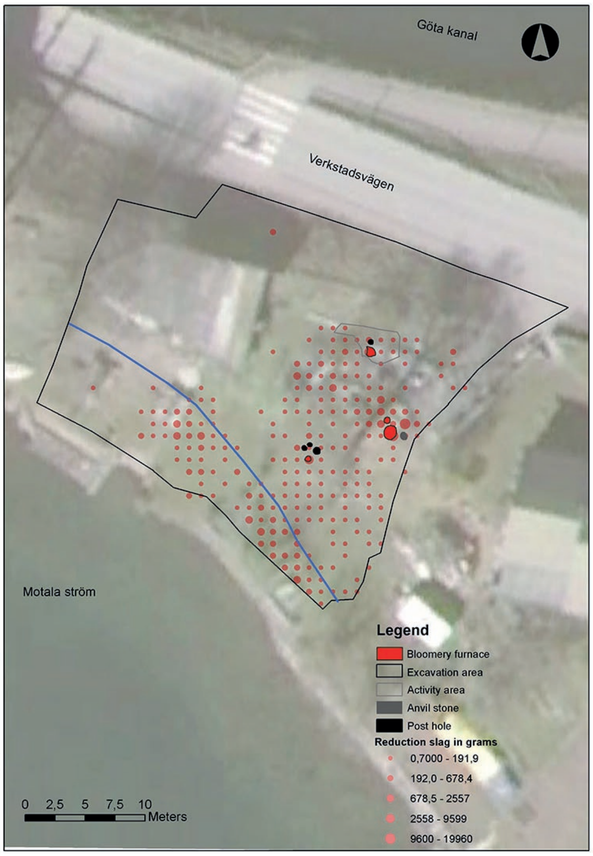

Fig. 2b. The excavated area at Verkstadsvägen in Motala. The picture shows the location of the furnaces, and other archaeological contexts related to the iron production site. The blue line marks the former shoreline and the red dots illustrate the dump zones with reduction slag. Graphics Katarina Sköld, The Archaeologists.
http://files.webb.uu.se/uploader/1338/Fig2b.jpg

Lab-nr.	Archaeological Context	^{14}C age BP	Cal AD, 68.2% prob.	Cal AD, 95.4% prob.	Dated material	Species
Ua-30055	A8453	1649±30	345–430	260–540	Charcoal	Oak (*Quercus*)
Ua-30622	A8533	1370±30	640–670	600–690	Charcoal	Alder (*Alnus*)
Ua-30623	A20501	1600±31	410–540	400–550	Charcoal	Oak (*Quercus*)
Ua-30624	A20501	1489±30	550–605	460–650	Macrofossil	Seed, unspecified

Table 2. Radiocarbon data from the 14C-analysed furnaces at the Motala site. Note that one furnace has two datings from the slag pit, one (Ua-30623) was charcoal from oak and the other (Ua-30624) from unspecified seed. Atmospheric data from Reimer *et al.* (2004); OxCal v. 3.10 Bronk Ramsey (2005);cub r:5 sd:12 prob usp [chron].
http://files.webb.uu.se/uploader/1338/Table2.pdf

of furnace and the fact that the furnaces had been raked out, are signs that they were used several times (Willim *et al.* 2012:27). The amount of recovered slag from the bloomery smelting process, in total around 60 kilos (Svensson 2012:12), is not much, but slag including used charcoal are waste products, which are often spread out or reused on site, or in a different time and place,

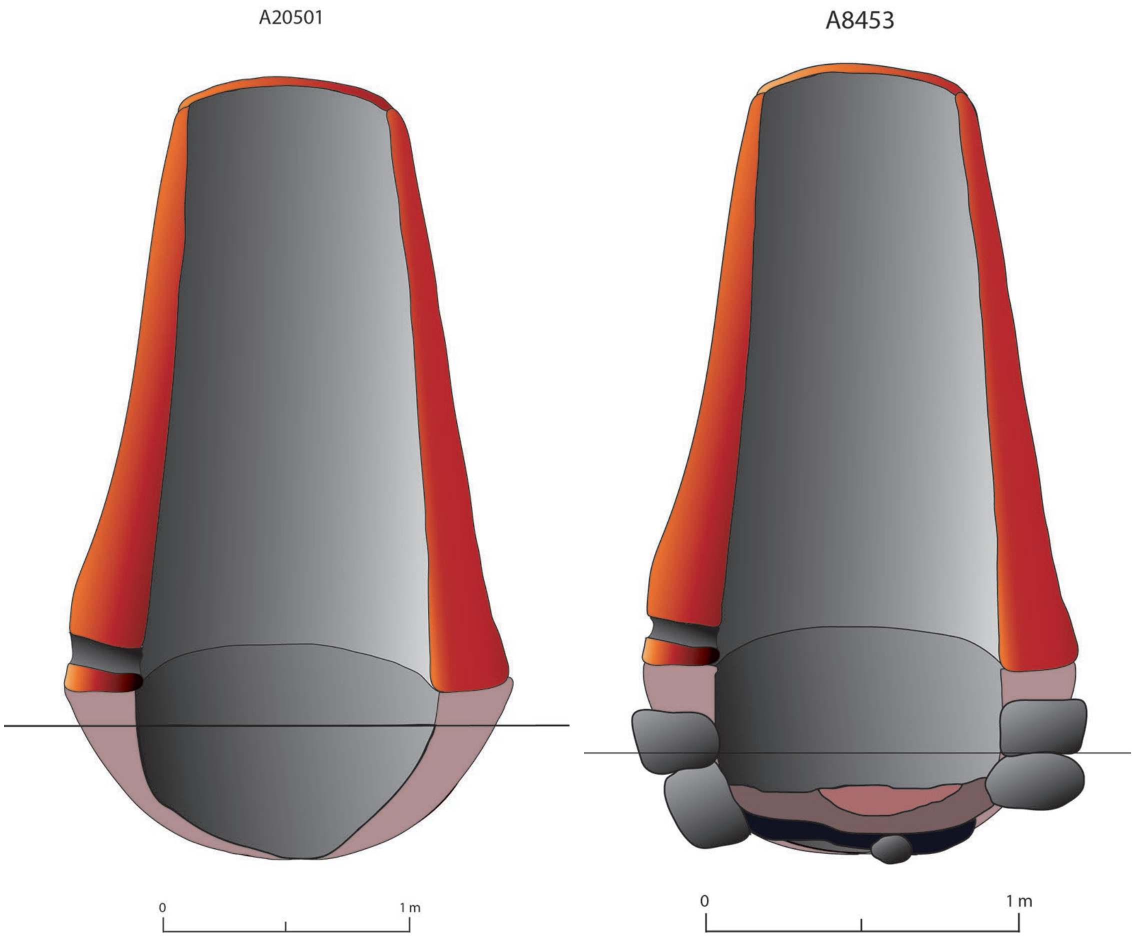

Fig. 3a, b. Reconstruction of the Motala bloomery furnaces. Different sizes and partly also built of different materials. The furnace shafts were of the same construction and were built of wattle and daub; the wattle was placed within the daub and therefore not shown in the reconstruction. Reconstruction drawing Svante Forenius, The Archaeologists.
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http://files.webb.uu.se/uploader/1338/Fig3b.jpg

for example on fields as fertiliser or in constructions (Gruber & Westermark 2017). Furthermore, in this case, some of the slag may have been dumped in the water below the bloomery production site. The furnaces were of the same general type during the whole period, with an underlying slag-pit, intended for multiple firings. In one of the furnaces it was possible to see that twigs and sticks had been applied for the separation of slag and iron (Svensson 2012:8). Imprints of wattle in the wall material of the furnaces show that the shafts were of a wattle-and-daub construction. The slag-pits of the furnaces varied in size between 0.44 and 1.20 m. To ensure an adequate function, this means that the bloomery furnaces would have had a height varying from 0.90 m to over 2 m for the largest (Fig. 3). The largest furnace was dated to the Migration period/ Vendel period (Willim *et al.* 2012; Svensson 2012:8–9; Gruber & Westermark 2017). The iron production site that was excavated in 2010 covered an area of approximately 500 m^2. Presumably the iron production site has covered a more extensive area and may also have been used over a longer period of time.

This is e.g. supported by remains of furnaces with reduction slag occurring a few hundred metres to the north of the excavated site discussed here (Ogenhall 2015). In that case the iron production site would have been up to 5000 m^2. Today, a modern road, Verkstadsvägen, and the canal, Göta kanal, have been constructed in between these iron production areas. Any remains there might have been of iron production would have been destroyed in conjunction with the extensive construction work carried out for the modern infrastructure. In addition, the amount of slag in the dump zone in the water can also be misleading, since Motala Ström has been dredged several times in modern time. Accordingly, the recovered amount of slag is not applicable for plausible estimations of the produced volumes of iron.

The bloomery smiths in Motala mastered the craft of producing iron of varying types and material properties in the form of both soft iron and harder steel. Unfortunately, the small amount of iron left on the site does not allow definite conclusions about the relation between the different excavated furnaces and specific final products (Willim *et al.* 2012:60). During the Iron Age, iron production sites appear to have been placed almost exclusively on sites with close access to the raw materials. (cf. Serning 1979:52; Grandin & Hjärthner-Holdar 2003). There is no reason to believe that this would not have been a relevant circumstance also at the site by the side of Motala Ström. Ore that was used was most likely locally available limonite ore. The nearest registered natural locality of limonite ore is found around ten kilometres to the north-west and north-east of Motala, respectively, at Uttersby, Freberga and at Sjötorp, which in line with corresponding sites in Sweden cannot be regarded as an unreasonable distance. There are, however, no traces of ore in the assemblage of finds. Therefore, the source of iron ore cannot be determined through analysis (Räf 2008; Willim *et al.* 2012:59). Nonetheless, chemical analysis of the slag reveals that ore of different composition was used in the excavated furnaces on the site, for instance concerning the content of manganese (Willim *et al.* 2012:59; Ogenhall 2015). It is possible that different sources of ore were used during the course of time; the iron ore might also have been roasted at the location of the ore source. It should also be pointed out that it is easier to transport iron ore than for instance charcoal; much larger volumes of fuel than ore are needed for the production of iron. Moreover, charcoal tends to be brittle and is easily crushed when transported.

Östergötland in the period between Early and Late Iron Age

Östergötland primarily consists of three types of landscape; woods, plain and coast. Woodlands are widespread in the northern and southern parts; between these woodlands, the fertile plain of Östergötland extends like a wide ribbon across the landscape towards the coast. Östergötland's northern parts consist

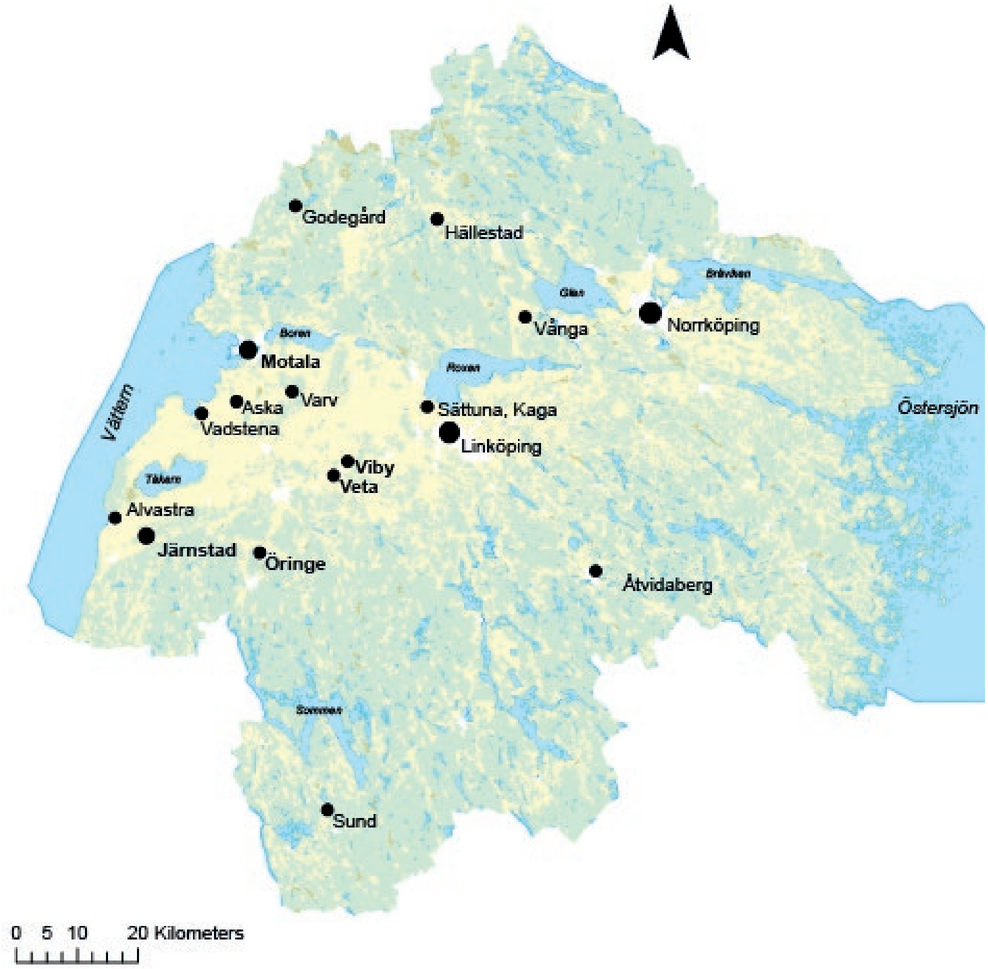

Fig. 4. Map of Östergötland based on Lantmäteriet's General Map. Sites mentioned in the text are marked on the map. Farmland and flat land is marked in yellow; woodland is marked in grey-green. Graphics Katarina Sköld, The Archaeologists.
http://files.webb.uu.se/uploader/1338/Fig4.jpg

of woodlands, with mountains and numerous lakes. A fault in the landscape constitutes a sharp border towards the fertile plain; it extends across the whole province from Motala, from the eastern shores of Vättern in the west, to Norrköping and on to the coast in the east. Parallel to this fault, Motala Ström runs towards the Baltic Sea through the lakes Boren, Roxen and Glan (Fig. 4).

The area in and around Motala has customarily been regarded as a sparsely populated area during prehistory. Few ancient monuments and stray finds have been registered, and consequently, few archaeological excavations were carried out during the twentieth century. Today, we have better instruments for heritage management, such as special archaeological surveys and preliminary archaeological investigations. This makes it possible to detect a greater number of more or less concealed prehistoric sites. Previously, Motala was not regarded to have been a central urban area during the Middle Ages. This situation is considered to have contributed to the poor heritage management surveillance of the town and its surroundings. This was the case even though the town was mentioned in written sources as early as the end of the thirteenth century, and during medieval times, it was one of the largest mill towns in the country (Lindeblad 2008:69–70). However, the perception of the town has been thoroughly revised in later years, when large-scale archaeological excavations between 2000–2003 and 2010–2013 have been conducted due to consequential construction work on the railway between Mjölby and Hallsberg. These excavations revealed traces of human activity virtually throughout prehistory, from the Mesolithic to the Middle Ages (Gruber & Westermark 2017; Molin *et al.* 2014; Carlsson 2007; Sköld & Helander 2017; Lindeblad 2008). Furthermore, the district immediately to the south and east of present-day Motala is a region rich in prehistoric sites.

There are few direct traces of Iron Age settlements in the nearest surrounding area of present day Motala. In order to determine the approximate location of settlements, we must be guided by the position of prehistoric graves and burial sites. Just a hundred metres to the north of the iron production site, there is a burial site dating from the Pre-Roman Iron Age and there are accounts of a stone circle that was removed in the 1940s, a kilometre to the south (Åström 1958:8; Lindeblad 2008:77). Yet another burial site, consisting of graves of a shape indicating a dating to the Late Iron Age, is situated two kilometres to the south-east of the iron production site. Another burial site is located in Fålehagen, two kilometres to the south-west. Otherwise, the prehistoric burials and burial sites in the surroundings of Motala are primarily concentrated to the plain, a couple of kilometres to the south and east. Here, we find richly equipped graves dated to the Migration Period and Vendel Period and even to the Viking Age. Currently, there are no iron production sites in the vicinity of these sites, which further suggests that the bloomery furnaces were positioned near the raw material and communication routes, and not primarily to a settlement.

In this context, it is also of significance to consider stray finds. In Motala, a gold bracteate with runes of the early runic alphabet, dating from the Migration Period, has been found (SHM, inv nr 12762). The spot where it was discovered is unknown, although there are accounts that it was encountered at the '*from Motala northward bound railway line*'. A gold bracteate with the same stamp was recovered in Vadstena (Montelius 1906:148) (Fig. 5). Such bracteates with identical stamps have been used to determine the outline of political alliances and groups (Andrén 1991:252; Lindeblad 2008:77). In the archaeological database of the Swedish National Historical Museum, 15 bracteates are recorded from Östergötland. Two of these are from Vadstena and eight from Vånga. The bracteate from Motala is indeed a stray find, but it still indicates the presence of an upper social level, clearly with connections towards the south-west.

Furthermore, the name Motala is an indication that it was a place of importance. Among researchers, it has been debated what the name stands for, one meaning might be *the shrine where the roads meet*, a combination of the word 'mot', junction, and 'ala' meaning *shrine or temple*. A similar interpretation is that the older meaning of the word for shrine, temple, might

Fig.5. Gold bracteate from Vadstena. A bracteate produced from the same stamp was recovered in Motala. Photo: Ulf Bruxe SHM, bild-id 12931.
http://files.webb.uu.se/uploader/1338/Fig5.jpg

instead be shelter. Stefan Brink's hypothesis is that in Scandinavia the word al meant noble house (Franzén 1982:73; Brink 1992:116; Lindeblad 2008:70).

In Östergötland, the settlements of the elite of society were concentrated to the rich farmland on the central plain during both the Migration period and the Vendel period (Rundkvist 2011:49). Several sites have been discovered in Östergötland in the central settled areas of the Vendel Period and Viking Age, which can be interpreted as large farms for influential families. A site that has been emphasised as one of the most prominent centres of power during the Late Iron Age, with continuity of settlement from the Migration Period until the Viking Age, is located in Sättuna, Kaga, on the western side of Lake Roxen in the surroundings of Linköping. Varv, Vadstena and Alvastra are other places where influential aristocratic families resided. Another major central place during the Viking Age was Aska, ten kilometres to the south of Motala. This is the place for the Aska barrow, which was thought to be a large grave barrow, but prospection with ground penetration radar has indicated that it was more likely a large building, a hall (Rundkvist 2011:47ff; Rundqvist & Viberg 2014). Several burial sites, containing richly equipped graves are located near the Aska site. One grave contained a sword from the late ninth century and a smith's hammer (Fig. 6). An interpretation of this might be that the blacksmiths had a particular significance and a high standing in society. The same distinct message is conveyed in the boatgraves at Valsgärde and Vendel, as well as the so-called graves of the kings at Birka in Uppland. Here, tokens such as smiths' tools and iron billets accompanied the burials; these were presumably insignias of

Fig. 6. A blacksmith's hammer from the burial in Aska RAÄ 36. Photo: Helena Rosengren, SHM.
http://files.webb.uu.se/uploader/1338/Fig6.jpg

ownership, knowledge and skill (Arbman 1943; Arwidsson 1942, 1956, 1977; Hjärthner-Holdar *et al.* 2007:739).

In the light of studies of settlement sites, burials and burial sites in Östergötland, we can discern several phases of rapid change. The most radical transformation phase took place at the beginning of the Late Iron Age. Östergötland is not unique in this respect; extensive change occurred in society all over Scandinavia at this time. In Östergötland, a major part of the locations of the Early Iron Age settlements and burial sites were abandoned. At the same time, new settlements and new burial sites were established in completely different locations in the landscape; usually this was on or near the later sites of historically known villages. There was a discontinuation of the hierarchic society of the Early Iron Age, with small subordinate farms. A hypothesis that might explain these circumstances in part is that there was a change in the organisation of farming practices. Wealthy head farms of the elite were no longer farmed with the help of subordinate smallholdings; instead, the workforce was moved to the actual head farm itself. The cause of this course of events has been debated (Petersson 2014:49). Here, it is an interesting point that the iron production sites appear to continue in the same locations as in the Late Roman Iron Age, which means that these sites were relatively unaffected by the overall transformations that took place. This strengthens the impression that the bloomery sites were primarily placed close to the raw materials.

Transformations occurring around AD 500 are not only seen in settlement patterns and grave gifts, but also in a decline of the tradition of making sacrifices in certain settings in the natural landscape, most notably in wetlands.

At this time, ritual depositions also started to occur on the farms themselves. Several researchers have considered these changes to reflect a shift in ideology related to the rearrangement of the contemporaneous society, which became gradually more individualised. The wealthy elite and the growing aristocracy moved the religious practice and worship from the open and public wetlands to the farms, or to more arranged places. In this way, a new element of power was created (Browall 2003:114; Fabech 1991; Näsman 1994; Falk 2008:62). In a traditional view of archaeological research, it was considered that Late Iron Age society was based on alliances, exchange of gifts and alternately changing relationships of dependence between different persons and groups. It is considered likely that there were several wealthy families, who shifted their alliances with each other and against one another (Browall 2003:114). A range of further explanations have been suggested, such as a deterioration in the climate, changes in farming practices, but also war or an outbreak of plague (cf. Widgren 1983; Hedeager 1988; Näsman & Lund 1988; Göransson 1989; Berglund 1991; Lagerås 1996; Pedersen & Widgren 1998). During this period, there is also an increase in the number of hill-forts constructed in Östergötland. This would indicate times of unrest; hill-forts are usually interpreted as having a defensive function, although they may have been used as a centre of power for the elite (cf. Browall 2003:113). Recent research, however, takes a foothold in social and ideological conditions (Schmidt Sabo 2001, 2005; Mogren 2005). Probably, since this was such a far-reaching transformation, it was due to a combination of various factors (Petersson 2014:33). It is difficult to know what set the restructuring process in motion, since utilisation of the landscape, for instance meadows for grazing and iron production sites, were more or less unaffected (Petersson 2006). Could the iron production have been a factor in the economy and a driving force? The iron production at the investigated sites shows that it is highly plausible that iron was produced for sale. Could this production have created a new economic situation, which in turn generated new power structures? Times of change and the breaking down of old hierarchies often provide greater scope for adopting and developing new techniques and technologies. There is also a tendency for these to catch on rapidly, which has been demonstrated in studies comprising Greek as well as Swedish contexts (Hjärthner-Holdar & Risberg 2003:83–86, 2009:983–984).

Bloomery iron production in Östergötland – state of research

Mining and iron production in historic times in Östergötland is well documented and was a considerable industry in the northern and southern parts of the province. In the north, iron mining and production occurred in Hällestad, Vånga and Godegård, in the south there was Åtvidaberg's copper mining district as well as Sund in Ydre (cf. Räf 2014:8 with references). Prior to a recent research project, *Östergötlands äldre järnframställning* [Östergötland's early iron production], initiated by Räf (2008; 2014) hardly any research had been conducted on bloomery iron production, apart from a few smaller studies of very early iron production sites in Östergötland (cf. Hjärthner-Holdar 1993:51–54).

The study conducted in 2008 also contained a survey and evaluation of previous excavations; this provided an overview in which finds of ascertained prehistoric iron production were distinguished. These finds correlate with the right geological conditions for sources of raw material occurring in the western and southern parts of the province. In the rest of the province, mainly in the farming areas, there is evidence of primary and secondary forging, but not of the production of iron. Bloomery iron production is suggested from seven further sites located in the Kinda district in the southern part of Östergötland. No archaeological excavation has taken place, and no furnaces have been identified, but radiocarbon dating of slag present an interesting spread out in time covering Early Iron Age, Migration period, Viking Age as well as the Middle Ages (Räf 2008:9; 45).

However, the iron production site in Motala excavated in 2010 is situated in the north-western region of Östergötland. Within these parts of Östergötland, archaeological excavations have been conducted only at five sites, located in Järnstad, Öringe, Veta, Viby Bosgård and Motala (Grandin *et al.* 2002; Eklund & Larsson 2002; Räf & Norr 2009; Stenvall 2009; Willim *et al.* 2012; Gruber & Westermark 2017). Järnstad and Öringe, Veta and Viby are all situated on the western side of the plain, in a zone bordering on the woodlands in the southern part of Östergötland. The site at Motala is located in a similar way in the northern part of the province, in the border zone between the plain and the rougher topography of the woodlands.

The largest contiguous area containing remains of prehistoric iron production has been identified in Järnstad, Åby parish, near Ödeshög. At least 17 furnaces were excavated here, all of the type with a shaft and an underlying slag-pit. Dated to the Roman Iron Age and continuing into the Vendel Period, the area of furnaces was placed adjacent to a settlement site (Räf & Norr 2009). Interestingly, despite the similar construction of the furnaces throughout the entire period of use, the great variation in the composition of the slag indicates that several ores had been used. This comprises ore with a low content of manganese in furnaces of an early date, and extremely manganese rich ore in some of the later furnaces. The production of iron continued during the sixth and seventh centuries, despite the fact that the settlement ceased in the Roman Iron Age. The placement of the iron production sites was thus not dependent on the location of the settlement, instead, it was governed by the availability of raw material; in other words, the bog iron in the adjacent wetland. This is a further indication that the location of iron production was primarily dependent on sources of raw materials.

On a Roman Iron Age settlement site at Öringe in the district of Boxholm, signs of iron smelting were identified; the production was chiefly assessed through the recovered slag. Despite the rather limited amount of slag, about 3 kilos, the analysis showed tendencies equivalent to the site at Järnstad, the use of several types of ore with extreme differences in the content of manganese (Grandin *et al.* 2002). In the waste material, metal was present, consisting of iron, although a distinct part of this was steel – a circumstance we will return to in the discussion about the products.

In Östergötland, limonite ores are mainly found in the southern and northern woodlands where the landscape is dominated by lakes. No occurrences of iron ore are registered in the Archaeological Sites and Monuments Database for the plain of Östergötland with its calcareous and clayey soil, where many settlement sites and burial sites are listed (Räf 2008:49). Thus, it appears that in the transition from the Early Iron Age to the Late Iron Age, people supplemented the farming economy with activities in the woodland areas, such as iron smelting, hunting, fishing and cattle herding.

In the Linköping area, many settlement sites from this period have been archaeologically excavated. Among these there are several localities with evidence of primary and secondary smithing, but no signs of iron production. Consequently, the iron must have been produced somewhere else and transported to the area (Räf 2008:36). One suggestion is that the producers themselves brought the iron back to their own farm and performed the forging of billets and/or artefacts there. Another possibility is that there was a de facto surplus production in one area, which was sold in another area. This would involve management of the iron production, which was not limited to the producer's (bloomery smith's) own sphere, but also encompassed external, or semi-external organisers for the distribution of the products (Räf 2008:54).

Late Iron Age bloomery sites – a geographical overview

It has been mentioned previously that the iron production site at Motala was highly intentionally placed, from a landscape perspective. Central factors influencing the placement of the site included availability of necessary raw materials in the form of iron ore and wood for charcoal, as well as the strategic communicative location.

In order to pursue the hypothesis about the intentional placement of the bloomery site by the side of Motala Ström, concerning raw material and communication, a comparison with other such areas (Fig. 7) from the same period is necessary. An important point is also the question whether differences and similarities in the technology are reflected in the localisation of the sites.

To the south

The region south of Lake Vättern is an interconnected area with access to wood and iron ore. This is exemplified by the long-term occupation of the

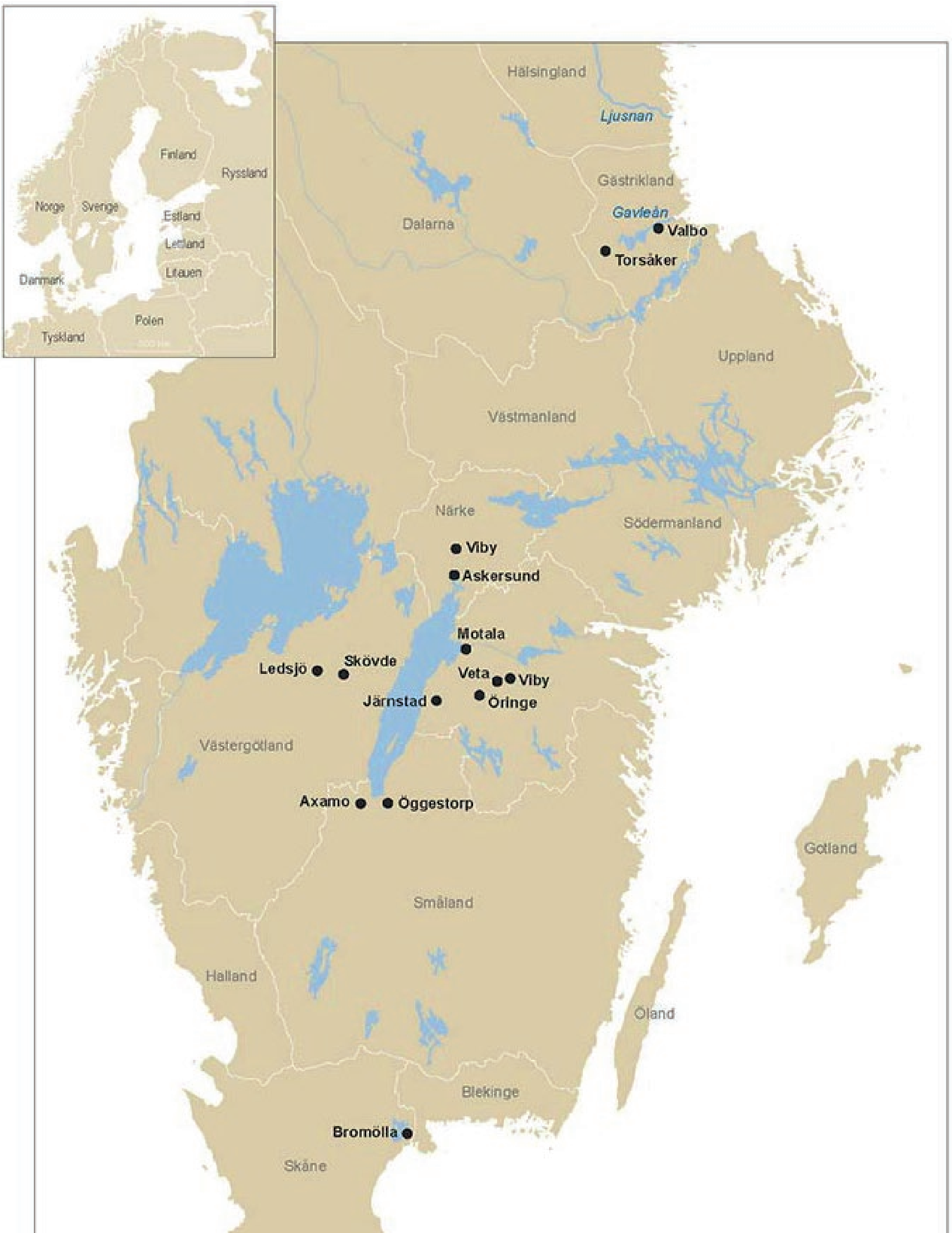

Fig 7. Map showing half of Sweden. The province borders are marked along with bloomery iron production sites mentioned in the text. Graphics Henrik Pihl, The Archaeologists. http://files.webb.uu.se/uploader/1338/Fig7.jpg

area ranging from the Early Iron Age to the High Middle Ages when the Taberg region constituted a regular 'bergslag', a well organised mining/iron production district, even if the production was still based on sources of bog ore (Rubensson 2000:272–275). A typical feature in this context is that the sites where iron was smelted in bloomery furnaces were clustered within a limited area of around 30 square kilometres. The sites at Öggestorp and Axamo (Fig. 7) constitute local intensive areas consisting of sites in between which differences as well as similarities can be observed. The whole area is characterised by lakes and smaller wetlands, where numerous small iron production sites were located. There are also signs that primary smithing has been performed near the production (Kristensson 2007:271–276). According to the current state of knowledge, this region could be described as having had a decentralised production with a greater number of small production units, rather than large units, which would have been the result of a centralised organisation. The question is whether it could be concluded that this was a case of a fully organised management of iron production, a 'bergslag', as early as the Iron Age.

The iron production site at Öggestorp is situated about 15 kilometres south-east of the town of Jönköping at the southern point of Vättern. This site is placed on the southern side of Lake Stensjön, which has an outlet flowing into Vättern, in a landscape abundant in lakes. Iron production occurred on the site during the course of a long period, from the latest part of the Bronze Age throughout the Iron Age, although the most intensive activity occurred from Roman Iron Age to the Migration period (Kristensson 2007:279–282). The bloomery furnaces were placed near the settlement site, dating from the Pre-Roman Iron Age and onwards. However, no traces of settlement dating from the latest part of the Bronze Age have been documented, when the first signs of iron production on the site appear (Häggström 2007:159–162). A plausible conclusion is that the main factors in the establishment of iron production in the area were access to raw materials and communication routes, and not nearness to settlement. Iron smelting took place in shaft furnaces with an underlying slag-pit for the accumulation of slag. Even if the technology was the same in the furnaces within the area, chemical analysis shows that ores of varying composition occurred, for example, the content of manganese varied. The signature of trace elements nevertheless indicates that the ores originated from the same source (Grandin & Willim 2004).

At Axamo, seven kilometres south-west of the southern point of Vättern, a large-scale iron production site situated in outlying land was recorded. The production was dated to the Viking Age and the Early Middle Ages (Nordman 1994:71; Lorentzon 2012:33–34). There are no indications of contemporary settlement in the immediate vicinity (Kristensson 2007:276; Lorentzon 2012:11). The distinct and recurrent characteristic arrangement of the iron production sites of the area has been discussed among several scholars (e.g. Varenius 1987, 1990; Nordman 1994; Björck 1991, 1996; Rubensson 2000; Lorentzon 2008; Grandin 2009a). An important detail, typical of the bloomery furnaces in the Axamo area, is that slag was tapped out of the furnace during the course of the process. The furnaces in this area are defined as double furnaces; these are further treated by Englund (2002). Ore smelted in these furnaces largely came from red earth, which occurs in the area. According to the results from the analysis of some of the slag (Englund & Grandin 2002; Grandin 2009a), the composition of the ore only varied within a limited range, having a reasonably constant content of manganese, one or a few per cent by weight. The method of tapping slag and the somewhat later date distinguishes this area from many others. Even so, the same kind of properties of the landscape appears to have motivated the choice of site for the iron production, including the communicative location and access to raw material (Lorentzon 2012:11).

This kind of clustering of smelting sites can be seen in many other places in the south Swedish woodlands. A clear example of this is the shrubby heaths and forest areas extending from eastern Blekinge, through the north of Skåne and across south-western Småland and Halland (Strömberg 2008; Björk 2009; Grandin 2009b). Within this region, several different furnace types and processes were used throughout this long interval of time. A particularly intensive area should be mentioned in this context, near Bromölla in north-eastern Skåne, where shaft furnaces with underlying slag-pits occur. Owing to the small amount of slag recovered during the archaeological excavation and the short chronological interval demonstrated by around ten radiocarbon dates, covering the Roman Iron Age, the iron smelting has been interpreted as related to a self-sufficient farm (Björk 2010:13). An interesting point in this context is that the iron ore is considered to have originated from the neighbouring Lake Ivösjön (Englund & Larsson 1997; Grandin & Willim 2005). Again, the same type of properties in the landscape appear to have influenced the placement, access to raw material and a favourable spot in view of communication.

To the west

In the province of Västergötland, iron smelting in bloomery furnaces has a long tradition in a geographically widespread area (Forenius *et al.* 2008). Iron production sites are often situated in the border zone between woodland and farmland (Magnusson & Millberg 1981:267). As early as the 1920s, the prehistoric iron production was noticed by J. Nihlén, who excavated a furnace at Essunga together with K.E. Sahlström (Nihlén 1932:56). Through the private survey conducted by E. and M. Key, 140 sites have been encountered; the dating indicated a concentration of the iron production to Viking Age – Early Middle Ages (Magnusson 1986:196–202; Jonsson *et al.* 2001:5–8).

Many archaeological excavations have taken place owing to considerable development work carried out in the region in recent years. The results have broadened our knowledge of Early Iron Age iron smelting, illuminating the relation of production sites to the general settlement pattern. In Ledsjö parish, 75 bloomery furnaces were documented within the limited area of planned development work. The chronology of these was mainly set in the Roman Iron Age, but a few later dates occurred, from the Vendel Period and possibly the early Viking Age. The furnaces were of a type with a clay shaft and an underlying slag-pit; these furnaces were probably only used once (Forenius *et al.* 2008). The iron production site in Ledsjö could be compared with the site in Ryd (near Skövde), dated to a somewhat earlier period, where a larger number of remains of iron production of a similar type were found (Särlvik 1975a and 1975b).

At Esketorp, in the outskirts of the town of Skövde, iron production from two chronological horizons has been excavated (Berglund *et al.* 2005). The older smelting site, dated to the first centuries BC/AD, was situated close to a settlement site. However, no relation to any settlement site could be identified at the later site, dated to the later part of the fifth century and onwards. A further two sites in Skövde parish have been investigated in Horsås. Seven furnaces were recorded at one site (Hjulström 2010), dating from 200 BC to AD 350. Yet another 20 furnaces were discovered at the neighbouring settlement site (Ängeby & Forenius 2012). At this site, three generations of iron smelting could be identified, dated to a period between the Roman Iron Age and the Migration Period. The site with the latest date was situated adjacent to the contemporaneous settlement site. When the iron production ceased, so did the farm. The furnaces were all shaft furnaces, with an underlying slag-pit for the accumulation of slag.

To a certain degree, the production to the west is characterised by iron production sites situated near settlements. At the same time, there appears to exist several large production units in the region with a great number of furnaces. Here, the common method involved furnaces intended for just one firing, although there were furnaces intended for multiple firings as well. However, the bloomery furnaces were placed either in smaller groups constituting a unit or separately. In part, just as has been demonstrated for other regions, the placement of bloomery production sites in Västergötland is dependent on the location of the raw materials, since limonite ore in the form of red earth occurs in the surroundings of the sites.

To the north

The nearest area of iron production sites north of Motala can be found just south of the town Askersund in Närke (Fig. 7).This area, consisting of up to some twenty iron production sites extends 5-10 kilometres northwards from the northern point of Vättern (Holm 2012:9–10, Fig.7). One of the sites of this area, Öna in Askersund parish, has recently been excavated (Karlenby 2016) and an analysis of metal waste material was conducted (Grandin & Willim 2014). Iron production was performed in at least two bloomery furnaces with underlying slag-pits. The furnaces are dated to two distinct periods, the Early Roman Iron Age and the Vendel Period-Viking Age. There are no signs of iron production in the period in between these dates. The slag differs chemically (such as the content of manganese) and morphologically, which indicates the use of different kinds of ore, as well as diverging technical procedures. Iron precipitate from the site, not ore however, implies chemical similarities with slag of a later date with a low content of manganese (Grandin & Willim 2014). It is thus plausible that the placement of the iron production was dependent on the raw material. Hence, in an overall perspective of the landscape, we recognise almost all the characteristics in the area south of Askersund in Närke in a comparison with our previous examples. The iron production site is situated in an environment dominated by lakes and wetlands, with the communicative benefits of Lake Vättern nearby.

In addition to the iron production mentioned above, there are clusters of iron production sites in several parts of Närke near settlement sites and in outlying land. An example of such a formation is the group of bloomery sites in Viby parish; the earliest of these dates from Late Bronze Age. However, the majority of the sites are of Iron Age date, from the Roman Iron Age to the Viking Age. Furnaces are constructed with a shaft and an underlying slag-pit for the accumulation of slag, and are intended for multiple firings. The sizes of the furnaces varied between diameters measuring 0.5 m to 0.9 m. Limonite ores of various compositions were used for producing different kinds of iron, ranging from soft pure iron containing no carbon, to carbon-steel and phosphoric iron. Concentrations of bloomery furnaces imply relatively large-scale production, probably with market ambitions. Significant for most of the iron production sites in Närke is their placement near supplies of raw materials and with access to communication routes (Hansson 1989:78–81, Fig. 28, 29; Grandin & Hjärthner-Holdar 2003).

The Gävleborg region also emerges as a major area for bloomery iron production, with similar landscape properties (Englund 1986). There are plenty of iron production sites dating from Roman Iron Age and Late Iron Age; distinct aggregations of sites can be seen along the larger rivers Gavleån and Ljusnan (Fig. 7). Two areas in the province of Gästrikland, the parishes Valbo and Torsåker, exhibit concentrations of production sites dating from Roman Iron Age to Viking Age. Some have been excavated, others have only been radiocarbon dated. The placement of the bloomery sites is evidently intentional, focusing on a communicative strategy involving waterways and access to raw materials (Hjärthner-Holdar *et al.* 2014 with references).

The bloomery iron production in Gästrikland was on a grand scale, most likely with market ambitions (Hjärthner-Holdar *et al.* 2014:272–274). At each site, there were several large furnaces. The placing of iron smelting sites in peripheral areas indicates intentional localisation to places with rich resources and access to communication routes. It was not far to the plain; contact with the main settlement area would have been a matter of course, since the iron producers probably were based there (Hjärthner-Holdar *et al.* 2014:264). In general, iron production sites in Gästrikland were not as clustered to certain areas as the south Swedish examples were. This probably reflects a more even distribution of sources of raw materials, both of iron ore and wood for charcoal.

Economy and process

The socio-economic framework of bloomery iron production

Iron as a merchandise is often considered, for good reasons, to have a central role in the socio-economic setting of the Iron Age. Traditionally, the later periods of the Iron Age are considered as a transitional phase when the production definitely transformed from self-sufficiency, and/or a supplementary occupation, to production with market ambitions, at least on a regional level (Strömberg 2008:38; Räf 2014:17, Fig. 2). However, even at an early stage, soon after the establishment of iron technology, tendencies can be seen in several different areas that the placement of the production was dependent on the location of raw materials, for example at bloomery sites in the provinces of Närke (Karlsson 2003; Westin 2003), Västmanland (Grandin & Hjärthner-Holdar 2000; Englund 2002:310) and Gästrikland (Hjärthner-Holdar *et al.* 2014). Consequently, by the time of the Late Iron Age, the alteration from self-sufficiency to a market-based production was already an established tradition, going back 1000 years in time. Hence, we consider that iron production and the socio-economic development that surrounded it must be regarded as diversified; above all, there was a substantial regional variation. Our postulation is thus that iron production in the discussed periods, in a general perspective, was a market-based arena.

Economic models have long been frequently used in archaeological interpretational work, and various dominant approaches have succeeded one another throughout time. Without a doubt, neoclassical theories and historical materialist/Marxist/substantivist interpretative models have hitherto been the most influential (cf. Gustin 2004:26 among others). In comparison, the latter of these has often been seen as the most attractive. This is largely due to their implicit anthropological perspective, which could be applied directly onto archaeological models and materials (cf. Sahlins 1972, Hodges 1982 among others). Moreover, neoclassical approaches have often been described as contemporary analogies and nothing else, providing unduly simplified interpretations (cf. Gustin 2004:27–28 among others). The criticism is justified, although historical materialist and substantivist models should also be included, to a certain degree. Many times, in the eagerness to distantiate interpretations from the shortcomings of contemporary society, a too radically different past has been sketched (for example Sahlins 1972). In a way similar to the neo-classicist approach of creating a too one-sided picture of socio-economic conditions of the past, the substantivist models deprive the people operating in the past their ability to act. The actors are hemmed into a wider system governed by normalising rules and they are given no scope for their own actions. The polarisation of neo-classicist theory and Marxist interpretations of society has thus created difficulties in producing nuanced archaeological interpretations. A socio-economical model should therefore take both dynamics and scope into account if it is to be useful for interpreting iron production during the Late Iron Age in Scandinavia.

The term we have chosen to ascribe the Late Iron Age iron production – market-based arena – is intentionally inclusive, comprising a number of economic, social and political interpretative models concerning circumstances in Iron Age society. In the discussion concerning the economic conditions of iron production, the important point is not to calculate as accurately as possible the balance and/or maximation of profit. Instead, we use simplified economic models to illuminate our interpretations of the socio-economic framework of the iron production. As mentioned, this point of view has a long tradition within Scandinavian Iron Age archaeology (see Gustin 2004:25–44, among others, for an overview). Recently, it has been shown that the use of concepts from modern political economy can be a fruitful approach to reach increased understanding of prehistoric processes. However, these ideas should not be directly translated from the one discipline to the other (e.g. Earle *et al.* 2015).

The iron production in bloomery furnaces, as mentioned above, if set in relation to the calculated size of the population, the extent of the production and the distribution of produced iron within the area of present day Sweden, is perceived to have been conducted on a grand scale during virtually the whole Iron Age. The picture is clear in Östergötland (Räf 2008, 2014), but it can also be seen in other parts of Sweden, for example in Skåne (Björk 2009), Halland (Strömberg 2008), Småland (Kristensson 2007), Närke (Hansson 1989; Karlsson 2003), Västergötland (for example Forenius *et al.* 2008), Västmanland, Dalarna and in Gästrikland (Serning 1973; Hyenstrand 1974, 1977; Englund 1986:87–94; Forenius *et al.* 2007; Hjärthner-Holdar *et al.* 2014).

In the southern regions, a chronological pattern is distinctly discernible; large-scale production occurred during the Roman Iron Age; from the Migration Period until the Viking Age there was a decline in production, after which there was a rise to large-scale production again. However, this pattern cannot be said to represent the production in Östergötland. As discussed above, there appears to have been a strong continuity in the production right up until the Late Iron Age. In principle, this is equivalent to the pattern of production in Svealand (the eastern central region of Sweden) and southern Norrland (the northern region of Sweden).

The bloomery sites in Motala and Järnstad in the district of Ödeshög is evidence of production in Östergötland, which is located near the raw materials; this implies a well-established flow of communication between farmland on the plain and sources of raw material on the western edge of the plain. Iron production sites in Öringe in the district of Boxholm are also located in a similarly communicative spot along the valley of river Svartån (Grandin *et al.* 2002; Räf & Norr 2009:59; Eklund & Larsson 2002:31–32; Willim *et al.* 2012; Ogenhall 2015; Gruber & Westmark 2017). The fact that the iron production in Järnstad is located near a large settlement site (Räf & Norr 2009) does not particularly complicate this interpretation. Large-scale iron production requires a considerable input of work even if it is a subsidiary occupation. The main aspect to bear in mind is that the site of the iron production was chosen because it was close to sources of raw materials, that is to say fuel, iron ore and material for constructing the furnaces.

Iron production was a governing factor in trading networks; the landmarks of these were resource-rich areas in the woodlands and the high yielding farmland on the plain. The decentralisation of metal crafts and the economic conditions are considered to have been a dramatic consequence of the establishment of iron technology during the Late Bronze Age and earliest Iron Age (Hjärthner-Holdar *et al.* 2007:736–738). This circumstance however retained very little space in the socio-economic climate of the Late Iron Age. The transformation from decentralised utilisation of resources, and partly self-sufficient production, plausibly started almost immediately and would have constituted a fully functioning market-based arena, at the latest, in the Late Roman Iron Age.

Both the introduction and the establishing phase of iron technology are thought to have constituted a rapid and intensive period of innovation. New social structures were created during this phase and partly new conditions for production and sales evolved, although this was quickly adapted to a strictly hierarchic economic system with a certain amount of market control. However, knowledge of the raw materials used in iron production was widely spread. Therefore, there was also ample space for small-scale producers, who should be regarded as entrepreneurs on this market-based socio-economic arena.

Iron trading in the Late Iron Age – a model

With regards to this picture of a full-scale market-based arena of the Late Iron Age iron production, a number of questions arise in relation to the archaeological sources. These questions should be based in the following fundamental premises:

- Who produced the iron?
- Who was it produced for, or for which markets was it adapted?
- Who were the controlling powers?
- Within which stages of the production could control be maintained?
- Was there space for entrepreneurs in the bloomery iron production?

These are central questions that have been emphasised in current research (Björk 2009:33), and should be duly considered when a model concerning iron production and trade is created. To start with, if we assume a market model that is based on a relationship of dependence between the basic components in an economic system (Costin 1991:1), producer – distributor – consumer, a summary of this could be designed as shown in Fig. 8: What kind of a market do we then consider the iron production of the Late Iron Age to reflect? Is it reasonable to presume that circumstances of perfect competition ensued where no outer limits influenced the operators of the market to any great degree? Or, should we assume that the market was controlled? If this is the case, can the controlling factors be explained by using the market definitions of modern economics, such as market monopoly, monopolistic market and oligopoly (Bade & Parkin 2007:324)?

Concerning Norwegian conditions, Christophersen regards the increasing volume of the iron production during Late Iron Age as a sign of a strongly controlled redistributive system governed by the local elite or by chieftains (Christophersen 1989:126 with reference to Stenvik). Primarily, such a controlled market could be described as governed by oligopoly, that is to say,

	Producer	Distributor	Consumer
Pre-conditions	Raw materials Competence - metallurgy (Networks)	Networks Economy	(Networks) Economy
Remits	Bloomery production Trade - semi-manufacture	Trade - semi-manufacture Competence – semi-manufacture Manufacture Trade-Manufacture	(Manufacture) Trade-Manufacture
Metallurgical processes	Bloomery production Primary smithing	(Primary smithing) Secondary smithing	Secondary smithing
Market positions	Supply Local	Supply Demand Regional Inter-regional	Demand Local Competence - finished product

Fig. 8. Simplified market model of the operator/commodity chain of bloomery iron production.
http://files.webb.uu.se/uploader/1338/Fig8.jpg

with a few prominent operators and with set barriers hindering new operators to enter the market (Bade & Parkin 2007:402–403). It is worth noting that this interpretation presumes that all market control is exercised in what is described as the distributor level in the model shown in Fig. 8. Nevertheless, Christophersen opens up for the possibility that the farms situated close to sources of bog ore could benefit from this and may have cooperated in the production (Christophersen 1989:126). The assumption is, however, that this gain primarily involved a supply of iron to augment the livelihood of the farm. Iron intended for sale is thought to be entirely reserved for the elite (the distributor level). Rundberget has further developed the discussion on socio-economic conditions of the Norwegian bloomery iron production of the Late Iron Age and Middle Ages (Rundberget 2015, 2017). With a starting point in the analysis of bloomery iron production in Hedmark in south-eastern Norway and results from excavations in the Gråfjell area, Rundberget arrives at a socio-economic model, which is based in a relation of dependence between the different operators of the iron trade, similar to the model presented in Fig. 8 (Rundberget 2015:284 and Fig.16.5). Rundberget's model acknowledges that the iron management has distinct signs of adaption to a market, but it also leaves space for a certain amount of flexibility in all levels of the supply chain of the iron management. On the other hand, unlike the model above, this understanding assumes that the overall economic framework in which the iron trade was conducted was strictly redistributive, and that almost absolute control was enforced by the level of operators who managed the distribution and networks of contact (Rundberget 2017:363–365).

These Norwegian examples illustrate the general view of the iron trade in Scandinavian Late Iron Age, which is largely based on assumptions about the control exerted by the distributor level (the elite) and the subservience of the producers and consumers. The model presented her (Fig. 8) challenges these assumptions by deconstructing the market models into a simplified basic model in which each component makes it possible to visualise the socio-economic nature of the different levels of operators. Likewise, in this context it is significant to point out that the division into producer-distributor-consumer does not necessarily reflect different groups and/or individuals in the supply chain of the iron management. Instead, they should be regarded as links in the chain, or levels of operators.

The model is only partially applicable to production for self-sufficiency. Production for self-sufficiency has probably continued parallel to iron production with market ambitions throughout the Iron Age and longer. Within the bloomery iron production, it is likely that the level of ambition concerning economic gain or surplus varied, even within the same delimited area of production. In this discussion, we will however mainly focus on production – on a greater or smaller scale – which in some way or other aimed at surplus production for sale.

In the model, we can see the relationship of the different levels of operators by considering the prerequisites necessary for the work, but also the operators' fields of responsibility, or remits, and their market position. The model shows that these factors coincide and overlap between the different levels of operators. In a concrete way, this shows that as a supply chain, the bloomery iron production was based on interdependence between the levels of operators. However, certain distinguishing characteristics can be seen. If these factors are regarded in terms of comparative advantages (Bade & Parkin 2007:81), this model could be useful for a detailed analysis of relationships of dependence within the management of iron production.

For example, what were the prospects for the various levels of operators to take control by gaining from comparative advantages? The model shows that the producers themselves controlled the raw material, production and the metallurgical knowledge necessary for production. Only the distributors could obtain a general view in a regional and inter-regional perspective and would therefore have had the most powerful role in controlling and maintaining the networks of contact. A functioning network is an important prerequisite. The distributors would have had a regional or possibly inter-regional role, while the producers and consumers would have acted locally. Distributors can be seen to be steering in the matter of supply and demand, since control of these parameters requires a regional range of view. Control exercised by consumers in this chain of dependency comprises knowledge about the final product, its value and quality.

A simple analysis of the comparative advantages for the different levels of operators thus shows that the chain of interdependent relationships should not be understood as linear; none of the outlined levels of operators can exert singlehanded control. In order to function, this chain of management needed empowerment from producers, distributors and consumers alike. The interdependence of these forces created a dynamic system in which the control over the iron production and its market was managed among several levels of operators. Moreover, those concerned in the iron production could shift between different positions in the chain of management. All these aspects created a market-based arena, which cannot entirely be translated to any of the market systems that we know from historical or modern times (Bade & Parkin 2007:324). Nevertheless, they could very well be analysed, discussed and interpreted in relation to a deeper understanding of these recent systems and their characteristics.

The economic value of iron

In order to consider the significance and scale of the iron production, it is also important to estimate the amount of iron produced in relation to the supply needed. Not only the amount of iron but also the quality, and thus its economic significance as a trade commodity, would have determined the input of work, time and investments the production unit was prepared to make (Forenius *et al.* 2007). The producer's own use for iron might hypothetically range from next to nothing to it being of vital importance. The reason for producing iron, no matter if this was done of the producer's free will or if it involved enforced work, would thus have depended on the market value; that is to say, there would have been a demand. A production, which might in modern terms be considered a small quantity, may have been of great economic significance if the price of iron was high, or even extremely high. The 'price' depends on the demand; a small production in great demand generates a high price and vice versa. Furthermore, different types of quality affect the 'price'. In fact, we know very little about the market value of iron throughout time. A question that is hardly ever discussed, which moreover is almost impossible to answer, is how much a certain amount of iron was worth, for example during the Roman Iron Age compared with the Viking Age or Middle Ages. Furthermore, there are even difficulties in defining the value of single medieval products. This is exemplified by Crew (2015), who discussed the issue of the well-known Osmund, which was semi-manufactured iron in standardised form. Crew (2015:151–189) has demonstrated that there were contradictory accounts of weights, quality and prices concerning the British market, which complicates the picture of the value of iron.

Increase in size, efficiency and capacity – or development and adaption

Frequently when discussing technology and change, it is assumed that development occurs not only to make something better and more efficient, but will also result in a larger production and greater quantity. Changes in technology are thus associated with both quantity and quality. This aspect is often applied on iron production too, in this case bloomery iron production. Is this reasonable? Alternatively, we might discuss alterations in what kind of items that were produced, or even a change from production for sales to production for household supplies.

Blooms formed in the furnace can be of iron and/or of steel, or of iron with a content of phosphorus, all with different properties; they are thereby suitable for different purposes. In other words, all these products might be in demand. Since we seldom find the iron produced and are able to determine its function, we look for the answers in the usually fragmented furnaces and in the waste products, for instance in the slag. By characterising these in detail, scholars have sought to systemise raw materials, constructions and products, often in relation to chronology, in order to confirm the expected technological development – or improvement.

Did these observed differences, or similarities, occur because of an exchange of technical innovations governed by organisational aspects? Or is it a result of technical knowledge; fundamental physical parameters for how iron production should function and could be adapted locally by skilled crafts persons to suit surrounding conditions concerning iron ore, fuel and construction material?

Such questions have been illuminated on several occasions. Recently, this has become topical again in a Nordic cooperation project studying bloomery iron production (Rundberget *et al.* 2013). From a Swedish point of view, a series of examples illustrates the matter (Hjärthner-Holdar *et al.* 2013 with references). The examples problematise questions about systematisation and terminology, highlighting the complexity of possible ways of constructing the furnaces with respect to function, design and choice of material. It is considered that the furnaces are not easily fitted into the systematisation that researchers would like to draw up, but if this were possible, there would be a linear correlation with the chronology. It is stated that the furnaces, as expected, were built according to the same fundamental technical idea. Variations that occur depend on available types of iron ore and the supply of construction material, but also on crafts traditions occurring in the region. In addition, another important aspect that emerges is that the outcome was not necessarily only determined by technical issues concerning the process – social perspectives such as demand for the product and organisation might also have been significant (Hjärthner-Holdar *et al.* 2013).

As an example, Hjärthner-Holdar *et al.* (2013) discuss the size of furnaces in relation to chronology in a limited geographical area where there was a long continuity of iron production, even though the size of the furnaces may not necessarily be correlated to chronology. In an example from Viby parish in the province of Närke, the furnaces can be seen to have increased in size from the first century AD until the Migration period – Vendel period. Thereafter, the furnaces appear to have been constant in size, or possibly have become somewhat smaller later on in time. An equivalent pattern emerges if we add the iron production in Järnstad in Östergötland and in Horsås in Västergötland (ibid). Both these sites comprise furnaces with a chronology extending over several hundred years. Bloomery furnaces by the side of Motala Ström in

Motala vary in a corresponding way; the largest is dated to the Migration Period – Vendel Period (Fig. 9).

What does this observation about the size of the furnaces mean? Does it have anything to do with the efficiency of the process, or the product that was planned? The efficiency of the furnaces has often been assessed rather schematically with the help of the bulk content of iron in the slag; the less iron (iron oxide) in the slag, the better process and more iron extracted. In part, this is valid, but in this context another component needs to be taken into account, namely manganese. Manganese is an element chemically related to iron and is common in lake and bog iron ores. It can occur in concentrations of a tenth per cent or up to several tenths per cent, by weight. Variations in the content of manganese can be used to determine if iron ores of different compositions were used in the bloomery process. If there is a high content of manganese in the ore, there will also be a correspondingly high content in the slag, resulting in a lower content of iron, although this is misleadingly low if the efficiency of the process is to be determined.

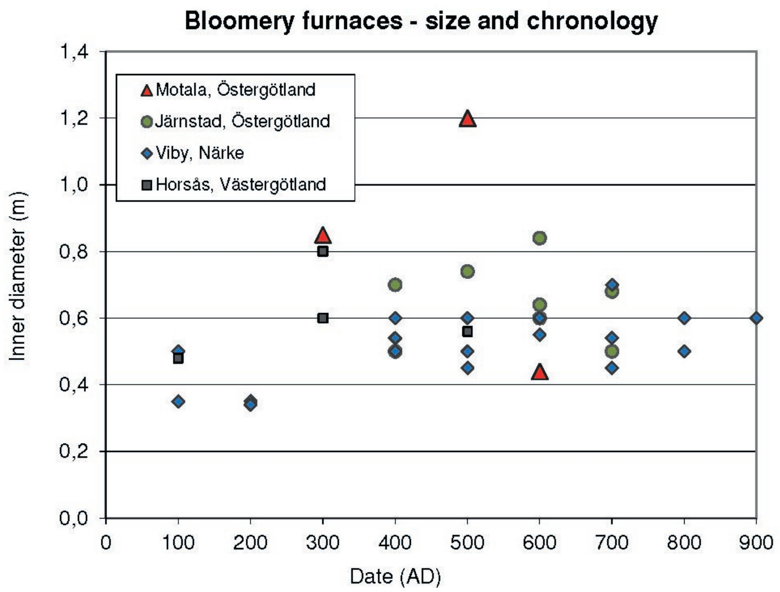

Fig. 9. Variation in bloomery furnace sizes (approximate inner diameter) with chronology. For the sake of simplicity, the chronology is indicated as exact years, but is in fact a time span with the selected date as the core value. Examples from Motala and three sites with a large number of furnaces, distributed over a period of time. The furnaces in Viby increased in size during the first hundred years. Later the size was relatively constant or reduced in the later furnaces. A similar situation is seen in Järnstad and Horsås, covering a shorter time interval. The three furnaces from Motala display the same pattern although the number is limited.
http://files.webb.uu.se/uploader/1338/Fig9.jpg

The product – iron and steel – a matter of quality and function

Consequently, manganese acts as an indicator for the composition of the iron ore. At the same time, together with iron, it gives an indication of the yield of the process. But why did the bloomery smiths use ore containing manganese? Was it an advantage or a disadvantage? Or did it not matter? A benefit of manganese is that it affects the reduction process enabling carbon to be alloyed with the metallic iron (For example Truffaut 2008). This provides favourable conditions for producing steel in the bloomery furnace. In many of the regions described in our survey, there are examples of the use of ores containing manganese, or even the use of ores that were extremely rich in manganese, which might be an indication that steel was one of the products yielded. Furthermore, at several sites the variation is considerable, ranging from no manganese, or very little, to concentrations of several tenths per cent (as MnO) in the slag. In the slag from Motala, varying concentrations of manganese have been observed, however, the maximum content (ca 7 %) is lower than that noted for slag from, for example, Järnstad, Horsås and Askersund (ibid) (Fig. 10).

Is the use of manganese rich ores chronologically related across a wider area? This does not seem to be the case (Fig. 11). In Öna, Askersund, manganese rich ore was smelted in the oldest furnace (Early Roman Iron Age), while in the later furnace (Vendel period-Viking Age) ores with a lower content of manganese were smelted. The case was reversed in Viby parish a short distance to the north, where ore with an extremely high content of manganese was used during the same period (Vendel Period-Viking Age).

However, during the Roman Iron Age – the Migration Period, ores rich in manganese were used at several iron production sites (Järnstad, Viby, Horsås), but there are contemporary sites where ores with a much lower content of manganese were definitely included in the smelting process.

At the iron production sites, the availability and use of manganese rich ore can be identified, as well as the use of ore containing less manganese, but no clear chronological relation to the content of manganese can be seen, when considering these sites. This might have been the case if products with the specific properties provided by steel were demanded during any particular period. This means that during long periods of the Iron Age it was possible to control the process in the bloomery furnaces at these sites; steel could be produced by using ores with a high content of manganese. One of these sites is the bloomery iron production site at Motala.

As mentioned earlier, the actual product, the iron metal, is seldom found at the iron production sites. At Järnstad, however, where slag containing extremely high concentrations of manganese occurs, a few lumps of iron were recovered and analysed. Most of these were of steel. The correlation between manganese rich ore and steel is evident at the site of Öringe as well (to the east of Järnstad). Here, ores containing various concentrations of manganese were used and several lumps of iron have been observed, containing steel (with

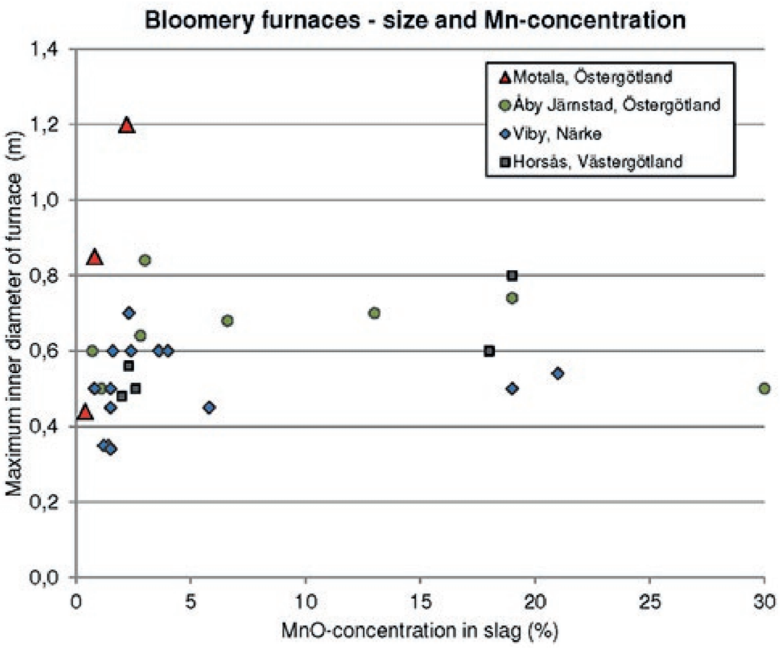

Fig. 10. Variation in bloomery furnace size (approximate inner diameter) with bloomery slags containing manganese (as MnO). Within several of the bloomery sites, there is a large variation in concentrations of manganese. In Motala, the variation is more limited. However, there is no correlation between furnace size and content of manganese.
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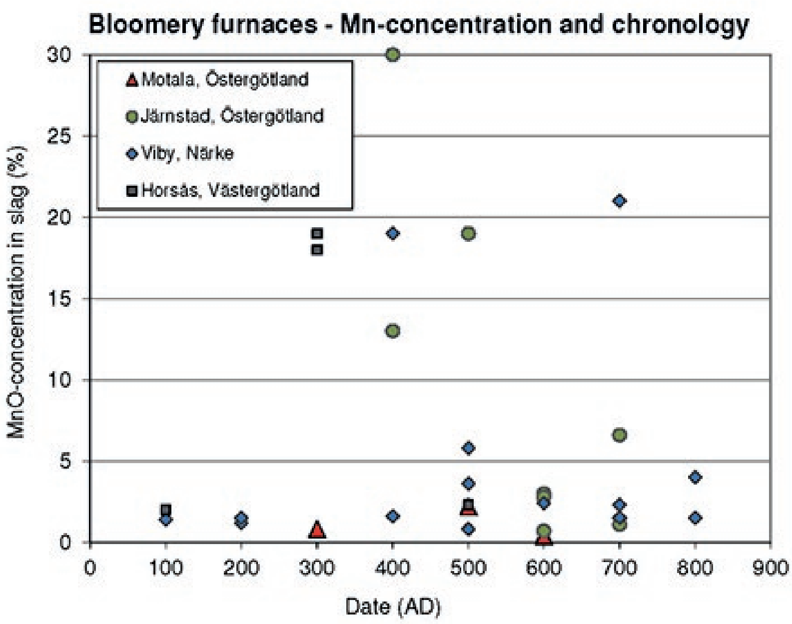

Fig. 11. Variations in manganese concentration (as MnO) in the bloomery slags, with chronology. Within several of the bloomery sites, there is a large variation in the content of manganese in slag. There is also intra-site as well as inter-site variation within the same chronological periods. In Motala the variation is more limited.
http://files.webb.uu.se/uploader/1338/Fig11.jpg

both low and high content of carbon), as well as softer iron (without carbon). During the excavation at Motala, only a few lumps of iron were recovered and analysed, although these were not contextually related to the furnaces. Among these, there was soft iron and steel with a low content of carbon. This shows that conditions were adequate for producing different qualities of iron. Consequently, the knowledge of which ore that was appropriate for which type of iron most likely existed as well.

The use of ore containing manganese to produce steel is not unique for Scandinavia. There was also an extensive production in the Roman province of Noricum, largely situated in the present day Austrian Alps. The iron ore in this area is of a type (carbonate ore) different to the Scandinavian limonite ore, but it contains manganese, which means that steel as well as carbon-free iron could be produced. Steel was here also used for manufacturing knives, scythes and weapons (for example Buchwald 2005:124–127 with references). Whether or not iron and steel were used in Östergötland for weapons is not possible to determine considering the available material. Hardly any artefacts from Östergötland or Västergötland contemporary with the iron production have been analysed. Nonetheless, there is one project from Västergötland, 'Offerplats Finnestorp' [The sacrificial site at Finnestorp], led by B. Nordqvist, in which analysis of weapons has been conducted. The examination of this material shows smith-work of the finest quality using soft iron, carbon iron and phosphorus iron in a variety of combinations, resulting in weapons with excellent properties (Grandin & Hjärthner-Holdar 2014). Artefacts for everyday use also show signs of advanced smithing techniques, for example, knives made of different types of iron that have been welded together into different combinations (Grandin 2009c).

How do we assess the volume of the production?

Assessing the quantity of the iron production has long been a challenge (Englund 2002:288 with references). Difficulties arise, no matter whether the assessment is based on the amount of slag or size of furnace, or whether both the amount of slag and the size of furnace are considered together. It can be stated that the number of bloomery sites of known size in Sweden, dating from the Iron Age and the Middle Ages, amounts to around 3,670 sites, and the volume of slag from these sites is 70,740 cubic metres. A further 3,400 sites with occurrences of slag are registered, but these offer no information as to the amount of slag. Based on the amount of slag recovered from medieval sites, Berglund (2015) has attempted to estimate the volume of iron that was produced. The same type of calculation might be conducted concerning prehistoric sites. Presuming that only 30 % of the calculated amount of slag originates from prehistoric sites and that around 40 % of this has been discovered, and assuming that 1 kilo slag corresponds to 1 kilo iron, the amount of iron produced would be at least 185,000 tons during this period (Berglund 2015:108–109). This provides a clue to the availability of iron. The calculation is indeed rather uncertain, but it might give an indication about the significance of the iron.

In the exposition above, similar characteristics occur. In some places, a few furnaces are placed immediately adjacent to a settlement site. This is a pattern that also emerges in the areas that are exemplified in the survey above of regions to the south and to the west of the Motala site. It is also a situation that occurs at some of the bloomery sites in Östergötland, such as those mentioned at Järnstad (Räf & Norr 2009) and possibly at the bloomery site at Motala. The fact that iron production was performed near the settlement site, however, should not mean that it can be considered small-scale, or on the scale of self-sufficiency, which unfortunately was the general assumption previously. The occurrence of a large number of relatively contemporaneous small production sites, instead suggests that the total extent of the production was considerable.

On some iron production sites, there are slagheaps, on others there are none. The latter circumstance is no proof that a small amount of iron was produced. Slag was reused as filling in, for instance, roads or as fertiliser on fields. A common trait is that recovered slag largely comes from slag-pits underneath furnaces. In other words, there are no large amounts of slag either in layers or in distinct heaps (compare with Järnstad in Östergötland and Valbo in Gästrikland). Whether slag ever existed on a site or not is usually not possible to prove. Therefore, it is exceedingly difficult to obtain an idea of the quantity of iron produced if this estimation is only based on the amount of slag.

It is possible to find out how much iron was produced on a single site if both iron ore and slag is to be found on the site. Chemical analysis can then determine how much iron in relation to slag that has been extracted. This varied considerably, but an approximate calculation for Swedish limonite is that it yields as much iron as slag. Thus, if the slag from the bottom of a large furnace weighs 350 kilos, theoretically, the bloom would then have weighed around 350 kilos. This does not mean that a small furnace generally would have yielded a small quantity of iron and a large furnace a larger amount. A small furnace might have been fired multiple times and could thus in theory have produced a large volume of iron. In some cases, it might be discussed whether the site was used continually for a long time, maybe resulting in a smaller yield each time. Alternatively, specific campaigns might have been undertaken, with a larger production each time. Whichever the case, the quantity of furnaces and their placement appears to indicate continuity in the overall organisation. Altogether, during the Roman Iron Age – the Late Iron Age, the quantities of iron produced would have resulted in a surplus over and above local requirements. This is also clearly shown by the assessment above of the amount of iron produced, based on the number of iron production sites and quantities of slag.

In this perspective, it seems more fruitful to consider an interpretation of the structural, spatial and chronological relationships between the sites than regarding them as separate self-sufficient isolated units. There is thus much to suggest that these sites represent a decentralised production, at least in the case of iron smelting; in a greater or lesser degree, the smiths produced iron to be offered for sale. This can be considered in the context of capacity, one firing could produce a bloom of up to 350 kilos of iron. Even if there is a great loss in the subsequent smithing, this is still a large amount for a farm/village; the annual consumption for a farm during the Late Iron Age is estimated to not amount to more than 5 kilos of malleable iron (Hansson 1989:75; Hjärthner-Holdar *et al.* 2014:273). Moreover, it has recently been shown that this quantity stayed constant throughout the High Middle Ages and Late Middle Ages in rural contexts (Karlsson 2015:264–266). Hence, a local and regional market for iron can be observed. Was there also an interregional market for metal, where good quality iron could be exchanged for other metals such as gold, copper, etc. or other desirable commodities on the European market? In our opinion, this is entirely plausible.

Discussion and conclusion

Bloomery iron production in a macro perspective

A number of aspects emerge distinctly when bloomery iron production is regarded in a macro perspective. One of these is placement, which was often determined by access to raw materials and by communication strategies. This appears largely to have been valid even for small-scale bloomeries. Thus, it was not only the large-scale production, mainly occurring during the Late Iron Age that was governed by access to raw materials and well-functioning networks of communication. In this respect, the significance of the waterways must undoubtedly be emphasised. They should also be seen in light of the necessity of maintaining close contacts with the purpose of keeping up the supply chain of the iron trade.

It is also worth noting that the bloomery technology appears to have been highly adapted to the available raw materials. Bloomery smiths seem to have adapted the production process intentionally to the required final result, as well as to the availability of a variety of raw materials.

The iron production site at Motala fits well into the pattern described above. The continual use of the site for almost 400 years, as the evidence of the dated furnaces indicates, suggests a long period of bloomery iron production. However, the excavated area was small and the archaeological material primarily implies bloomery iron production of smaller quantity. Since similar remains have been discovered just to the north of Motala Ström, as previously mentioned, this supports the idea that the production occurred more extensively in the area. Even if the iron production here was smaller than at sites found in for example Valbo in Gästrikland, which evidently represent large-scale production, the location is still equivalent, not least in regard to communication and access to raw materials, but also, as previously shown, nearness to settlement.

The conclusion that can be drawn is primarily that the location of iron production sites should be searched for in places with access to raw materials and within reach of communication routes. Both these factors are signs of entrepreneurship and the desire to invest, governed by predominantly economic motives. This should be regarded in relation to the production. In this case, it is possible that we should consider the bloomery iron production of the later Scandinavian Iron Age as a decentralised production with numerous units, both small and large, which if summarised, renders a large production of iron. The knowledge of quality is evident and there might have been specialisation on certain types of iron. Such circumstances must also have contributed to make the production profitable.

The routes of the iron

In the landscape of Östergötland, a significant point is that the iron production took place on the southern and northern sides of the extensively farmed plain. On the plain, surveyed sites where iron was worked exclusively show signs of smithing (Räf 2008). These sites should therefore mainly be regarded as representing operators on the consumer level of the iron trade. This circumstance can also be observed in other regions where iron production occurs.

We consider that the iron production site at Motala was a site where different types of iron were produced, but where manufacture of artefacts hardly occurred. This means that the bloomery smiths forged their iron into billets or artefacts at other locations and/or sold the blooms (non-forged iron) as they were. It is not known where the forging was performed. We have moreover seen that different types of iron were smelted, for example carbon steel, which indicates that those who worked with the iron production had an advanced knowledge of metallurgy.

The site is placed relatively centrally in a communicative spot in the landscape, near the rich settlement areas of the plain. The location of raw materials is the prime factor in the placement of the site. In comparison with the site in Järnstad and other iron production sites discussed above, it is placed in a similar way in the landscape, in resembling surroundings. A noteworthy point is that despite the considerable restructuring of society occurring in the first half of the Late Iron Age, the placement of iron production does not seem to have been affected. Iron production continued as if nothing had happened. The location is obviously a significant factor, since the production was placed near the raw materials and was perhaps therefore not affected by the restructuring. It may also be an indication that iron production was a vital aspect of society and that it was possible to invest in it. In turn, this would mean that it was profitable, if expressed in modern terms. Would there have been space for entrepreneurship within the social structure even as early as during the Early Iron Age? Was status in society based on knowledge and function as well as on kinship and the building up and consolidation of alliances; that is to say, a heterarchical society? We believe that this is the case;

thus, iron production was a factor in society involving social mobility and may thereby have had an impact on old power structures. This is what we see and understand as a thorough restructuring of society. Considering the production in a general perspective, the gains of the production might have been expressed, for example in the richly equipped graves that also occur during this period. In this context, some of these statements should be considered as hypothetical, based on indications that emerge in the overall picture of the management of iron production. However, we believe that iron production and the organisation of it were vital factors in the process.

It has long been debated whether the elite and the kings of the emerging kingdom of Svearike in part built their power on the control of iron, which was produced in peripheral areas in the region of Lake Mälaren and its surrounding areas (cf. Ambrosiani 1983:22; Sundkvist 2010:142). The question is, when this control, in theory wielded by the elite and the kings, developed during prehistory, might it then have been founded in the entrepreneurship of producers of iron in the Late Iron Age. Even if production sites found in Östergötland are not extensive in number or size, the knowledge of iron smelting would have enabled producers to build up an economy and social standing, which would have given the opportunity to rise higher in social rank. This suggests that society was not founded on kinship and alliances alone, but had a structure with a more flexible system based on knowledge and function; in other words, a social structure that was a system of heterarchy (e.g. Ehrenreich 1995). The high status of the management of iron production is reflected in the fact that artefacts directly related to iron production and smithing occur in high status graves in for example Birka, Valsgärde and Vendel in Uppland. This should be understood as an expression for ownership, knowledge and skill (Hjärthner-Holdar 2009; Hjärthner-Holdar *et al.* 2014 with references). From economic and social perspectives, the status of the smith would be equivalent in Östergötland, particularly considering the hammer that was found in a high status grave in Aska. In a similar way, if we apply the knowledge about qualities of iron and technology from other sites, the conclusion must be that the smiths in Motala mastered considerable skills within their field.

Competence in metallurgy – a competitive advantage

The simplified model presented here (Fig. 8) illustrates that the primary distinguishing factor among the different levels of operators is their fields of competence. The basic assumptions, in our opinion, is that the various levels had the power to influence their own situation and that there was a strong awareness of quality throughout all levels. The producers had the skill to perform the production; they had the metallurgic knowledge to produce qualitative iron of various types. Quality is therefore to be seen as just as important a factor as quantity when discussing the commodity value of the iron and steel produced, and the demand associated with this value. The distributors maintained the regional and interregional networks, but they also had the competence to evaluate the semi-finished products and the quality of these. The last link of the supply chain kept up the demand for produced iron. At this level, the competence of the operators involved assessment and valuation of the finished products. Thus, at the level of the consumers, the final quality control was performed, as well as the regulation of the demand for the products. However, by applying their respective special competences, the producers and distributors have very intentionally taken advantage of the consumers' demand.

Without a doubt, the space for the entrepreneurs of iron management should be sought within these separate spheres of competence. Even if the defined levels of operators probably in reality fluctuated and merged, there is in the model a distinct division between them, practically as well as conceptually (i.e. in the way the different roles contributed to creating identity and in the way they were part of people's understanding of their surroundings). The specialised competences in all three levels of operators should be regarded as a fundamental condition for the management of the iron production, as important as the necessary raw materials. The important point in this context is that market competences are also thoroughly incorporated into discussions about the management and trade of iron production.

As previously mentioned, the fundamental metallurgic competence required for the bloomery iron production was firmly established both geographically and chronologically during the Late Iron Age. It is of significance to consider whether this competence in metallurgy was general knowledge in the contemporary society, or if it was exclusive knowledge maintained and kept confidentially among the operators of the operator/commodity chain, with the intention of creating marketing advantages. In seventeenth century Sweden, severe measures were taken to counter secrecy and monopoly of the knowledge that was exploited by the decentralised iron producers in the commodity chain of operators (Florén & Rydén 1992:5). In this case, it is clear that regulation in the form of pricing policies, quality control of the finished product and demand management were not considered enough, if power was to be exercised in a desired way. If we consider our interpretations of the iron production, might we expect Iron Age smiths to have been engaged in a similar kind of monopoly of knowledge, as a means of power? One of the purposes of the simplified model presented above is to leave aside the dominant line of conflict-based conclusions concerning the interplay between the operators of the management of iron production. Instead, we want to suggest a more holistic perspective. By distinguishing the separate interdependent levels of the collective management of the iron production, we can provide a more balanced picture of a flexible market-based arena within which the Iron Age bloomery smiths worked. In such a flexible production- and trade-network, there is space for innovations and entrepreneurship at several levels, in collaboration and in conflict. We consider that the bloomery iron production of the Iron Age, as we see it in the hitherto available archaeological source material, reflects this particular kind of market-based arena.

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