THE TRANSITION FROM BRONZE TO IRON IN THE LATE BRONZE AGE

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ABSTRACT

This article deals with problems like the introduction of iron and iron metallurgy, how to combine metallurgy and archaeology and how to create an understanding for phenomena like metallurgy in our prehistory. Today there is more than a possibility that iron was produced in Sweden during the Late Bronze Age. Both production sites and iron objects, which indicate this, have been found. In the article both analyses of slags and iron are presented, together with early iron objects. Questions about diffusion and the center - periphery model are also discussed.

Introduction

We are trying to create an understanding for phenomena in our prehistory, which is a complex process, carried out by people with valuation systems and references, different from those of the prehistoric man. Consequently, the created history looks different depending on who is creating it. Our creation will therefore only be a way, within our own valuation system, of trying to perceive prehistory and from that standpoint make people of today to understand it.

Metallurgy, like all other phenomena, is complex. Different scholars have tried to create models, which would make it easier to understand the development of metallurgy and its place in society. But the difficulty is just that, to create understanding. Many so-called general models show only a course of events but do not explain why they happen.

Another problem is to combine metallurgy and archaeology, to be able to understand and interpret metallurgical processes within the archaeological context. This problem seems, furthermore, partly to permeate those models which have been drawn up for the development of metallurgy. It is very important that we come to terms with this. The results that will come out of a cooperation between metallurgy and archaeology will be much better than the ones we are getting now.

Today we have quite a number of iron production sites dated to the earlier part of the Pre-Roman Iron Age. In fact, one can talk about a period of high production, if one considers the size of the population and the demand which that population could have created. Still, if we look for large quantities of iron objects from that time, we will hardly find any items at all until the 2nd century BC. These production sites show a rather good technical standard and the process could be repeated without any problems. This has all been documented by Viking Wedberg i several articles (Wedberg 1984, 1988).

When, how and why was this technology introduced?

During the last decade, we have in Sweden found furnaces, slags and other waste materials related to iron production on sites which can be linked to a Bronze Age environment with, among other things, fire cracked stone heaps. Some of these sites also contain materials from bronze working, like moulds, crucibles, bronze rods and so on. Of course one also finds pottery. The problem is that many of these sites have been in more or less continuous use from the Late Bronze Age to the end of Early Iron Age. But with the help of stratigraphy the problems will be more manageable. In some cases there are very few dateable objects and the only solution has been ^{14}C. The problem with ^{14}C is not the method itself

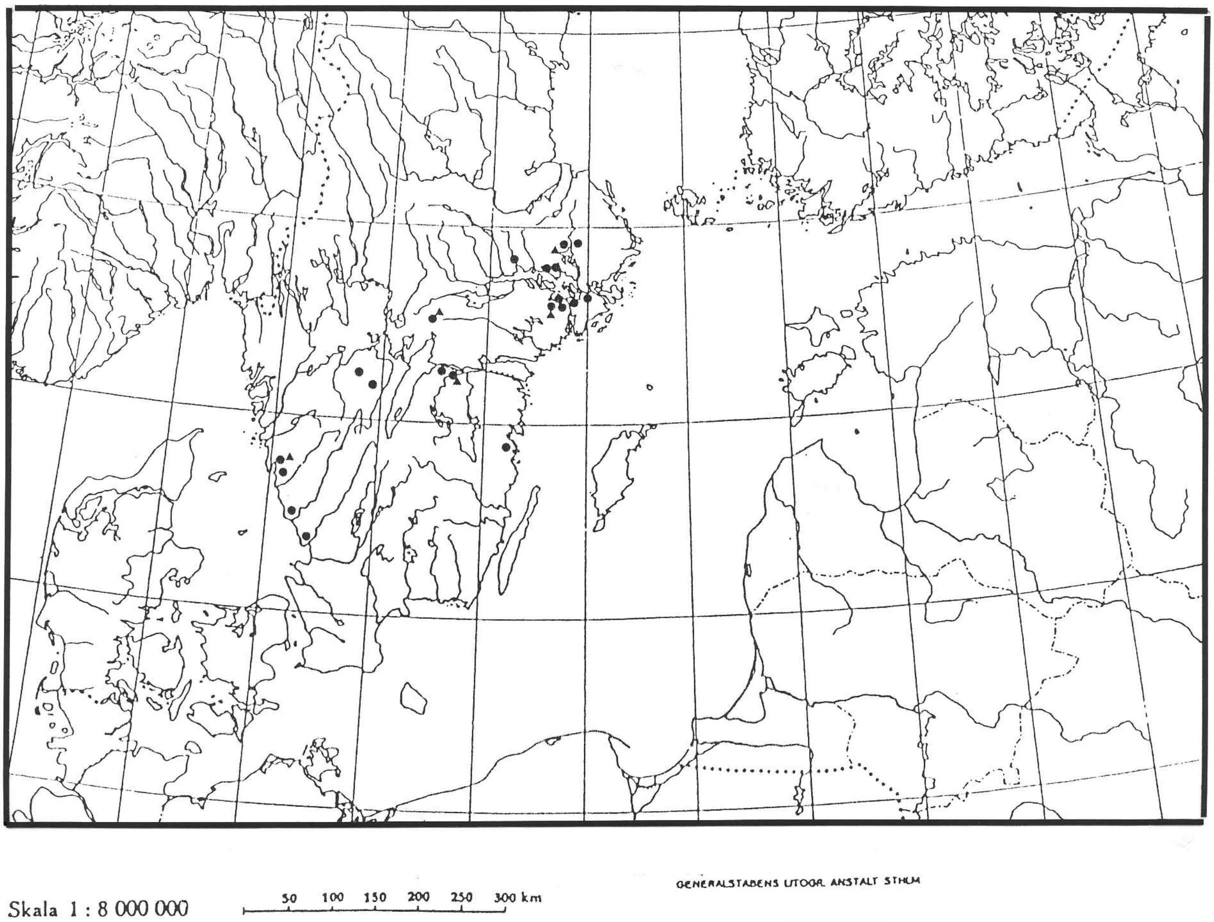


Fig 1. The distribution of iron slags and furnaces in Bronze Age contexts. triangles = furnaces.

but what we as archaeologists see as a closed context. It does not always seem to be so according to the ^{14}C results. Some of these sites, however, have been used for a shorter time and, in some cases, the settlement sites have been covered with stone-settings datable to at least Early Pre-Roman Iron Age or even period 6 of the Bronze Age.

The distribution of iron slags and iron objects

The sites with iron slags are almost evenly spread over the southern parts of Sweden (fig 1). There are also sites in northern Sweden that contain slag. Unfortunately, the contexts are very difficult to understand and because of that I will not include these occurrences in this discussion. One can complete the distribution of iron slags with the distribution of objects wholly or partly made of iron (fig 2). Most of those can be dated to the 5th and 6th period of the Bronze Age and some may be dated to the 1st period of the Pre-Roman Iron Age. But there are also objects that can be dated to the latter part of the 4th period of the Bronze Age. One example is a burned iron fragment from grave 6 at Simris in Scania, which was found together with a razor, datable to the transition between period 4 and 5, cremated bones, potsherds and resin caulking from a wooden box. As the razor shows traces of heavy wear, it dose not absolutely date the iron object to this early period (Stjernquist 1961;11,78). What I want to point out is that these objects are small and they are not only ornaments. Among these objects one can find both knives (fig 3) and chisels (fig 4) and, what is more interesting, a hanging bowl from Härnevi in Uppland, which has chaplets made of iron (fig 5). This hanging bowl can be dated to the 5th period.

The amount of slags which can be associated with this early period is small and the slags are often highly shattered. This possibly depends upon a poor separation between slag and iron. To be able to obtain the iron one was forced to break the bloom substantially. What can be pointed out is that the amount of iron required for the production of the early iron objects must have been restricted.

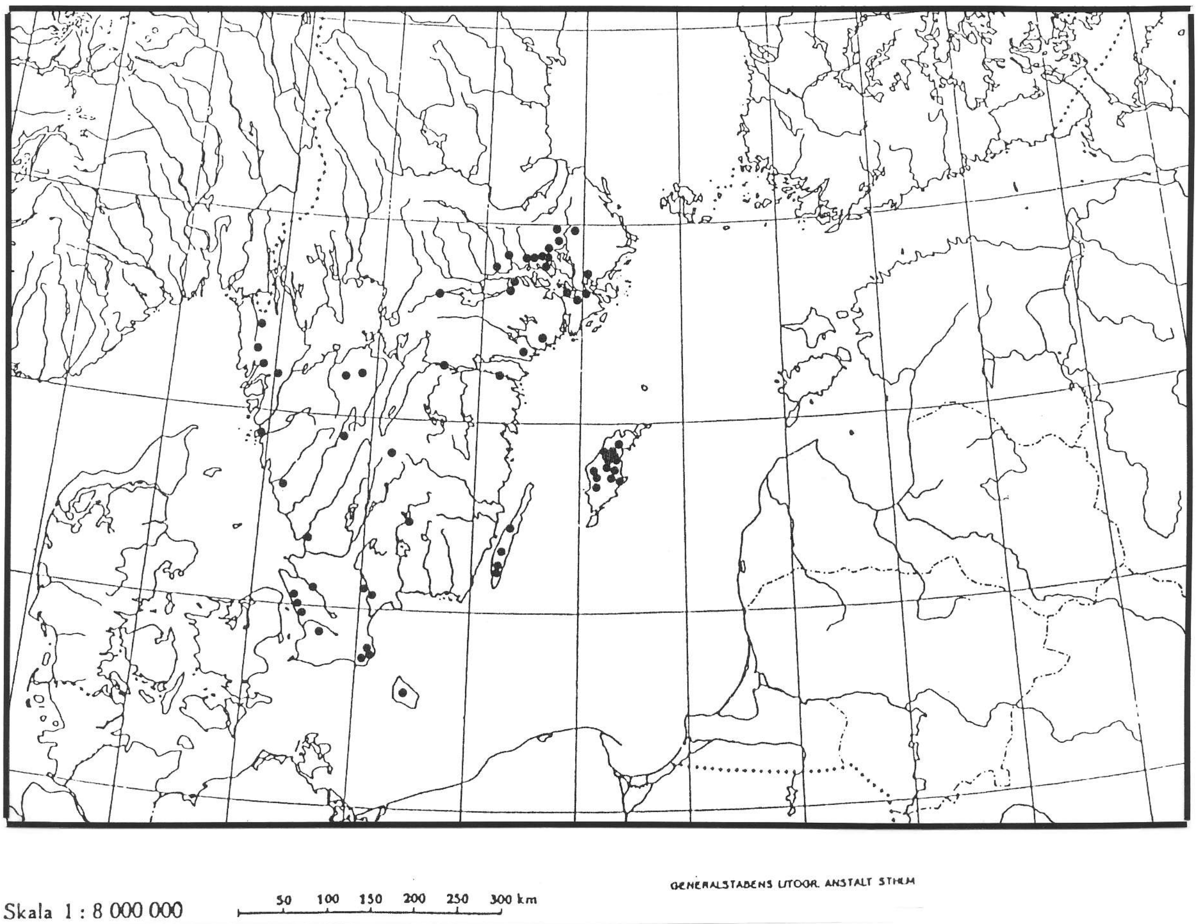


Fig 2. The distribution of settlement sites and grave fields with iron objects dated to Late Bronze Age and the earliest part of the Pre-Roman Iron Age.

The analyses and a way to interpret them

When I started my analytical work on slags from south central Sweden, with the help of the late Dr Inga Serning, the first question that came up was: Was this the product from the handling of copper or iron? The chemical analyses obtained indicated that this was the waste material from the handling of iron (figs 5,6,7). The second question was what type of ore had been used. So far, no suitable ore has been found on the sites. The ore found is always too low in iron content and sometimes also other elements differ too much. The pieces found might just represent discarded material. Chemical analyses of slags could be used to indicate ore compositions. The material from Hällby shows characteristic features with regard to manganese and phosphorous. The ratio between these two elements is fairly constant, indicating that the same type of ore has been used throughout the production at the site. The diagram (fig 8), following projections suggested by Kresten (1984;29 ff), indicates an "average ore", which is of the lake- or bog-ore type. The diagram of P_2O_5 versus MnO (fig 9) shows a group of slags with high contents of both elements. The three samples in this group are, according to their age, the oldest, an intermediate and the youngest sample. As more mature lake-ores tend to be enriched in these elements, the data can be interpreted in terms of fresh resources of ore being harvested recurrently during the whole time of production at the site. The chemical analyses showed rather common bloomery slags. This is confirmed by the sections studied. They show wüstite, fayalite and a glass phase (fig 10). The fayalite (light grey) is, according to semiquantitative analyses, virtually pure iron silicate, Fe_2SiO_4. The glass phase (dark grey) is composed of silica, alumina, alkalis, lime and iron. The sections, as well as the external appearance show that the slags have cooled slowly within the furnace (fig 11). So far, I have found only one piece of smithing slag. This slag differs from all other samples. Flow structure is lacking. In section, the slag is layered (fig 12). The main components are fayalite, glass, some wüstite

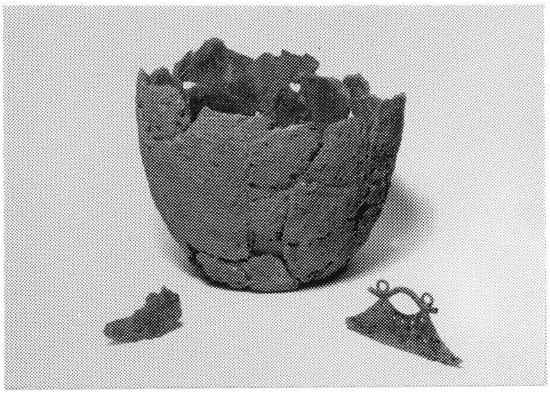


Fig 3. A grave find datable to period 6 of the Bronze Age. Krubbebacken, Vallkärra parish in Scania (SHM inv 13901).The knife to the left is made of iron. Photo G Hildebrand.

and abundant ferritic iron (fig 13). I also studied the iron enclosed in two production slags from different places. One sample is from a small bloom and it is in fact the only complete bloom that I have found (fig 14). The amount of iron that it contains was probably too small or, maybe, too hard to get at (fig 15). The other sample is from a piece of slag. Both samples show a fairly good carbon steel, with a carbon content of about 0,7%. It is pearlite with grain boundary ferrite (fig 16). From these analyses I drew the conclusion that they could make a fairly good carbon steel even if apparently not produced in any large quantities.

The problem is that there has been no investigation concerning the iron quality of Swedish early iron objects, ie, period 4-6 of the Bronze Age and period 1 of the Pre-Roman Iron Age. By contrast, Late Iron Age objects have been investigated extensively. Therefore, we do not know the smithing techniques used during Late Bronze Age and Early Iron Age.

Some scholars and scientists mean that the difficult part in the handling of iron is not the smelting, but the smithing process. So, if we want to know something about the technological level and the advancement, we have to be able to compare the iron enclosed in the slags or blooms with the iron quality found in the objects.

Professor Pleiner has presented some interesting results, where he has compared the iron quality in objects from Bronze Age (Pleiner 1986;238f) with the iron quality in objects from the beginning of the Iron Age (Pleiner 1980;388ff). The investigation showed that the objects made in the Bronze Age (about the period 11th - 8th century BC) showed a higher technical standard than the Iron Age objects. The Bronze Age objects were made of a homogeneous metal which was an eutectic steel, which means a steel with around 0.8% carbon. The objects investigated were mostly different kinds of blades. Later, in the beginning of the Iron Age, when the technology was more widely spread, the number of objects made of good carbon steel decreased drastically. About 2/3 of the objects were made of wrought iron or inhomogeneous carbon steel. The apparent deterioration in iron quality could have a number of interacting reasons, eg, dispersion of knowledge, inadequate copying, exhaustion of good quality ore deposits. Else, the production of softer iron was done by purpose.

As long as we lack analytical results concerning the quality of iron objects for most sites, we have to consider other features, which also could be important when it comes to questions such as which group or groups were responsible for the introduction of the new technology. Our early iron objects are both knives and ornaments. Sometimes, the iron was presumably used for mending bronze items like for example one of the two identical bridles from Eskelhem parish on Gotland (SHM inv 7994) which has a bit made of iron. The other bit is made of bronze. Another example is the two identical brooches from Ransten, Sundby parish in Södermanland (SHM inv 13771). They are made of bronze but their pins are made of iron (fig 17). It is most likely that these brooches when they were new had pins made of bronze. The iron has evidently also been used for making chaplets in the bronze industry (fig 5). If one looks at the ornaments, whether in bronze or iron, one can immediately see that both form and ornamentation is almost identical. Furthermore, there are closed grave finds with nearly all the different types of dresspins both in bronze and in iron, like for example grave 6/59 at Fole on Gotland (Nylén 1972;8,fig 7). Together with the fact that the early iron smelting is situated at Bronze Age sites and sometimes even found to-gether with materials from foundries, like for example at Svedaskogen Fjärås parish (SHM inv 31877), one may assume that the bronze founders' metallurgical knowledge actually was the start of the iron metallurgy. Later, in the Early Iron Age around 400 BC, the iron smelting is no longer connected with settlement sites. Instead, a very strong con-nection to the occurrences of raw materials is found. In conclusion, our native founders seem to have adopted the new technology and created the iron into forms, which were well known to the Nordic people. Furthermore, I think that the material shows that iron was no luxury product. Instead, it became very early a product used for a variety of purposes.

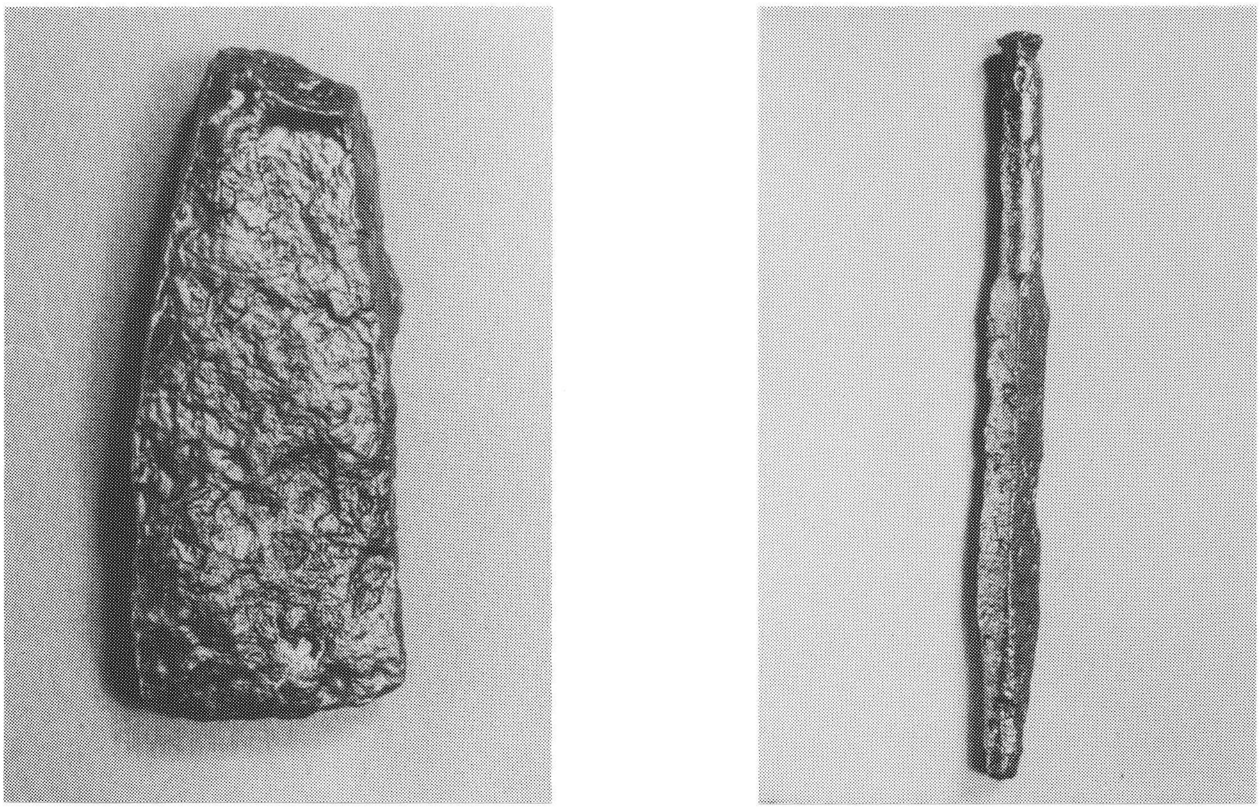


Fig 4 a,b. Chisels made of iron from the iron production site at Hällby, Litslena parish in Uppland. Photo ATA.

Some ways of looking at metallurgy and society

Many of the models for metallurgical development that have been presented during the last 30-40 years have evolutionary features. Scholars have tried to make models which could be valid for different cultural environments. One model assumes that basic knowledge of mining and metallurgy has emanated from a few places only (Smith 1973, Wertime 1964, Muhly 1988). Other models imply that metallurgical innovation has occurred in different places at different times, independently of each other (Renfrew 1986;146). Maybe, there are some general features, but the question is whether or not they create an understanding of the process, ie, the interplay between various factors which had vital importance for the development. A technology, which has been adopted into one cultural context, does not necessarily show the same development as in another cultural context. "Technological systems, such as metallurgy, should be interpreted as an integral part of the cultural context in which they occur rather than as entities possessing their own dynamic, independent of context, which is uniform through time and space" (Stech & Maddin 1988;173). This means that stereotyped general models have no validity when

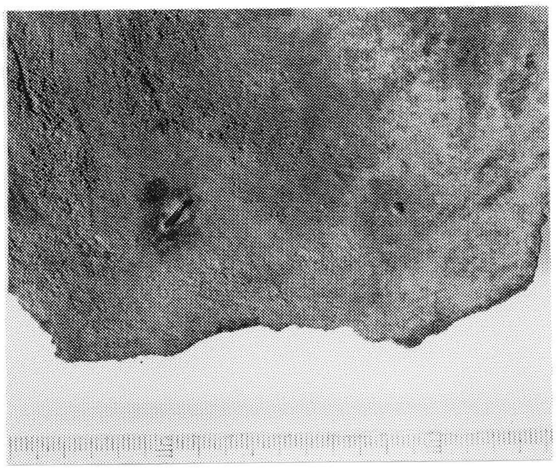


Fig 5. The remaining part of two of the chaplets made of iron. There have probably been 6 chaplets inside the hanging bowl. They were all made of iron. Härnevi, Härnevi parish in Uppland (SHM inv 11635). Photo G Hildebrand.

it comes to the admission of innovations into the society. They only show a course of events but do not explain why they happen. Metallurgy can be developed on either a large- or small-scale basis. What may have influenced the development is not just the need to demonstrate status in a major cultural change in society but also the needs which

	Sample nr	SiO2	TiO2	Al2O3	Fe met	Fe2O3	FeO	MnO	MgO	CaO	Na2O	K2O	H2O+	P2O5	S	Sum
1	B-5000-1	22.5	0.12	4.6	1.1	13.2	51.5	1.20	0.26	0.95	0.45	1.00	2.6	0.13	0.08	99.69
2	B-5000-10	21.2	0.23	5.9	2.9	22.7	39.5	2.72	0.41	1.32	0.45	0.87		0.17		98.34
3	B-5000-11	19.8	0.24	5.4	2.2	24.3	43.3	0.86	0.38	1.10	0.45	0.94		0.27		99.21
4	B-5000-12	15.9	0.15	5.1	1.5	26.6	48.1	0.76	0.28	0.85	0.33	0.64		0.21		100.37
5	B-5000-13	21.3	0.19	4.5	2.6	21.0	45.2	1.45	0.54	0.74	0.41	0.89		0.17		98.96
6	C-6000-88	21.0	1.04	11.1	2.2	15.2	15.4	0.14	2.17	5.80	1.31	4.28		0.42		80.04
7	C-6000-356	14.6	0.21	3.6	3.8	15.4	56.2	0.23	0.84	1.40	0.32	1.04	1.9	0.13	0.04	99.71
8	C-6000-366	20.8	0.33	5.4	5.5	21.4	38.2	0.12	0.92	2.16	0.75	1.69		0.29		97.51
9	C-6000-404	30.0	0.45	6.8		9.4	41.4	0.20	1.50	3.10	1.08	2.30		0.31	0.02	96.56
10	C-6000-658	23.3	0.12	18.0	0.8	9.0	44.6	1.15	0.70	2.10	0.60	1.20		2.50		104.07
11	C-6000-991	19.7	0.13	2.2	6.3	27.0	41.0	0.05	0.29	0.66	0.10	0.00		0.58		98.05
12	C-6000-2025	33.6	0.06	12.0	1.5	2.9	48.5	0.76	0.40	1.30	1.00	1.60		1.50		105.12
13	C-6000-2035	10.4	0.05	10.1	1.0	16.5	63.6	0.49	0.50	1.10	0.20	0.30		2.20		106.44
14	C-6000-3086	47.3	0.50	11.2	1.1	2.6	22.2	0.10	1.60	4.90	1.80	3.00		0.50	0.03	96.83
15	C-6004-124	25.5	0.29	4.8	0.5	7.0	55.0	0.25	0.92	1.40	0.84	1.49	1.5	0.19	0.02	99.70
16	D-8000-22-1	24.7	0.29	5.9	4.3	15.4	34.9	7.16	0.53	1.37	0.50	1.52		0.48		97.07
17	D-8000-22-2	17.8	0.20	4.4	3.2	32.2	30.5	5.64	0.38	0.76	0.29	0.78		0.40		96.59
18	D-8004-464	26.0	0.10	5.4	3.5	7.8	43.2	0.26	1.67	4.45	0.55	3.54		0.60		97.06
19	E-100002-263-1	12.1	0.15	2.7	5.4	31.0	44.0	1.20	0.29	1.09	0.20	0.72		0.30		99.16

Fig 6. Chemical analyses of slags from six sites with iron production and/or smithing activities from south central Sweden (induced coupled plasma and wet-chemical techniques).

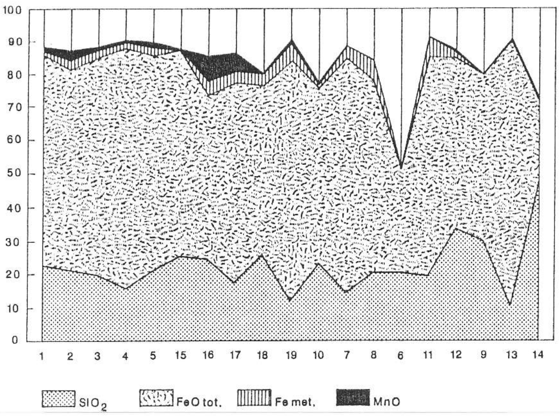


Fig 7.

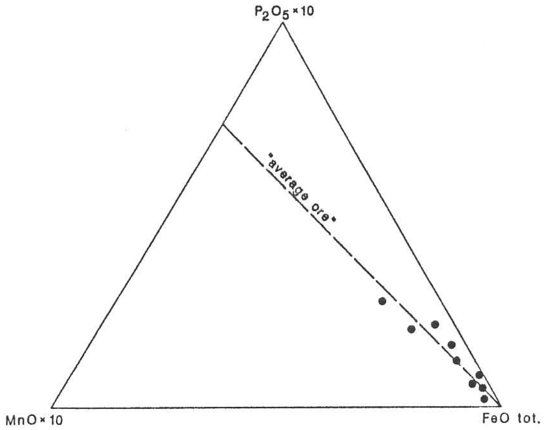


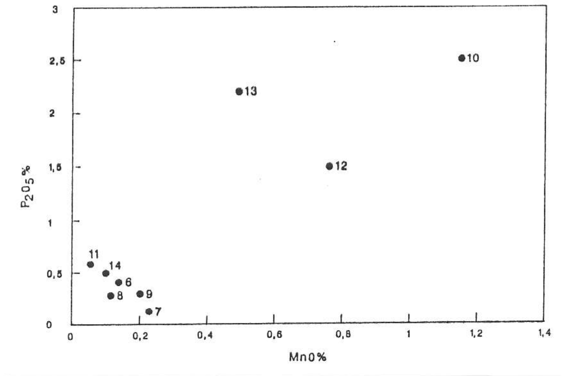
Fig 8.

Fig 7. Diagram over the analysed slags from the six sites. The sites are B-5000 = Linga, Överjärna parish, Södermanland; C-6000 = Hällby, Litslena parish, Uppland; C-6004 = Storvreta, Gamla Uppsala parish, Uppland; D-8000 = Jäder, Lunda parish, Södermanland; D-8004 = Sille, Västerljung parish, Södermanland; E-10000 = Bosgård Viby parish, Östergötland. The slags from Hällby (C-6000) are in chronological order. Sample 658 is the oldest, ^{14}C dated to the 10th century BC. Samples 88, 356, 366, 991 can, according to ^{14}C, be dated to the 9th- and 8th centuries BC. Sample 2025 is ^{14}C dated to the 5th century BC, sample 404 to the 2nd century BC, sample 2035 to the 1st century AD and sample 3086 probably to the 4th century AD (Hjärthner-Holdar 1984:90ff & 1987:109ff).

Fig 8. Plot of Hällby slag compositions. Fairly constant Mn-P-ratios indicate that all slags have been derived from the same type of ore (lake- or bog ore).

develop in a fairly continuous society. Some structures may prevent new innovations because of the fear for changes in the social structure. This can, from an archaeological standpoint, probably be seen in a major delay in the introduction of different phenomena.

Now to the problem: There are no iron production sites that can be dated prior to 500 BC in northern Europe, excluding Scandinavia. But there are some early production sites in east central Europe. Is there any possibility to explain our early iron production, for example, by looking at phenomena as diffusion and models about center - periphery. If our results are correct and if we, firstly, consider diffusion in the normal sense, there should be some traces of early iron smelting in northern Europe. But at the moment the answer is no. But is diffusion really a straight line or like ripples on the water? Of course it is more to diffusion than that. Secondly, does the center-periphery model really tell us what is actually happening? Some scholars (Stig Sorensen 1990;12f),



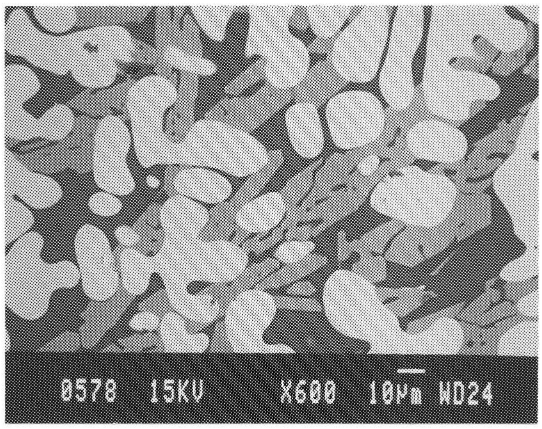


Fig 9.

Fig 10.

Fig 9. Slag compositions from Hällby define two distinct groups according to Mn and P. Samples from the high P-Mn-group have been produced recurrently with regular intervals during the whole time the site had been used.

Fig 10. Polished section of sample C-6000:356, showing wüstite (white), fayalite (light grey; according to semiquatitative analyses, virtually pure iron silicate Fe_2SiO_4) and glass (dark grey; mainly silica, alumina, alkalis, lime and iron). Photo D Noréus, Department of Structural Chemistry, Stockholm University.

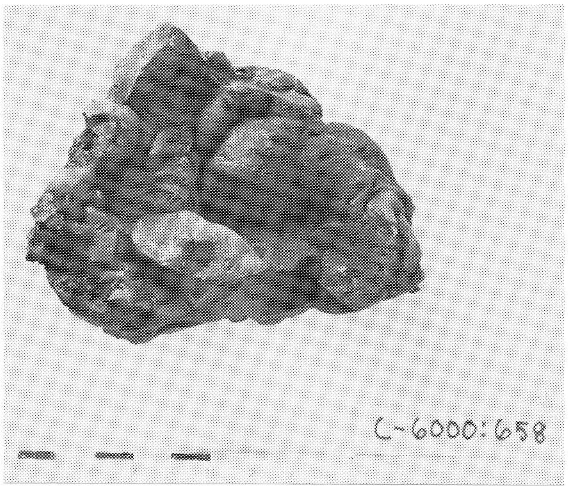


Fig 11. A piece of slag, sample C-6000:658. The external appearance shows that the slag most likely cooled slowly within the furnace. Photo E Hjärthner-Holdar.

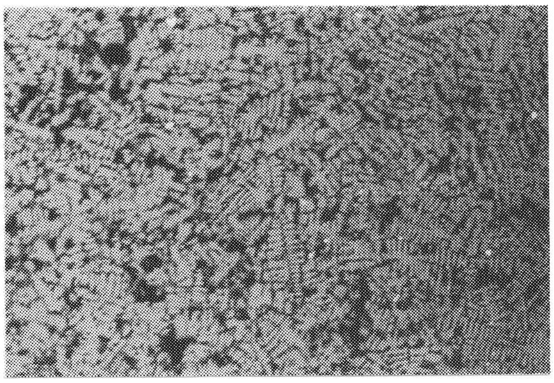


Fig 12a.

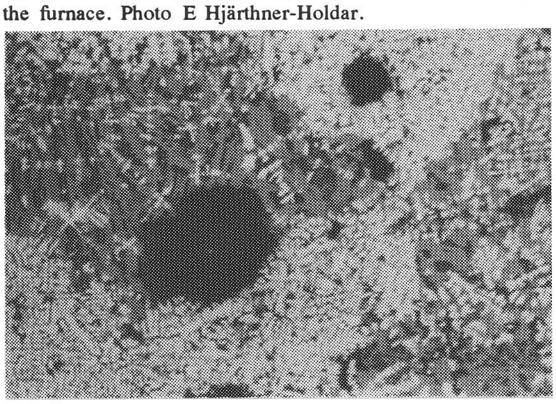


Fig 12 b.

Fig 12. Thin section of C-6000:2025b.The layered structure is indicative of a smithing slag. Main components are fayalite, glass, some wüstite and abundant ferritic iron. Photo P.Kresten.

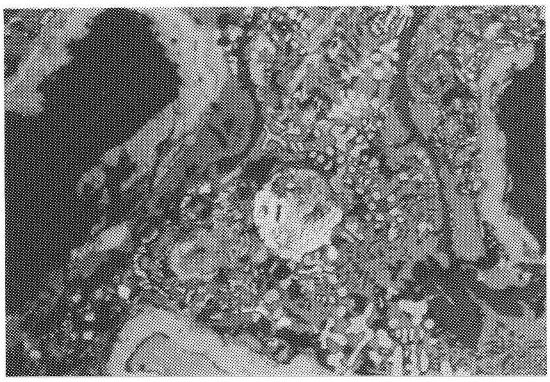
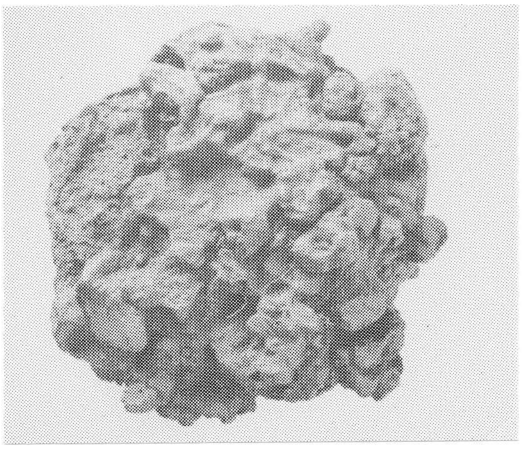


Fig 13. The ferritic iron in sample C-6000:2025b.Etched with 1% nital. Photo P Kresten.



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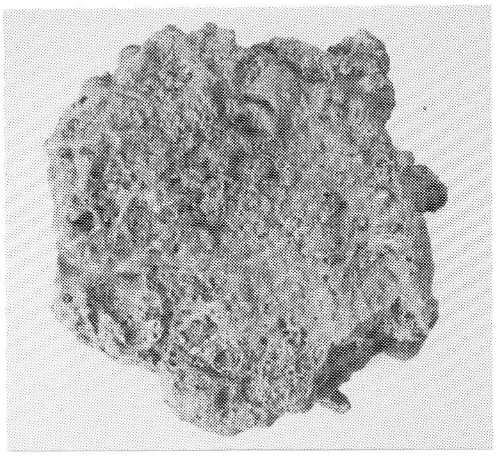


b.

Fig 14. Both sides of sample C-6000:356,most likely a bloom. Photo E Hjärthner-Holdar.

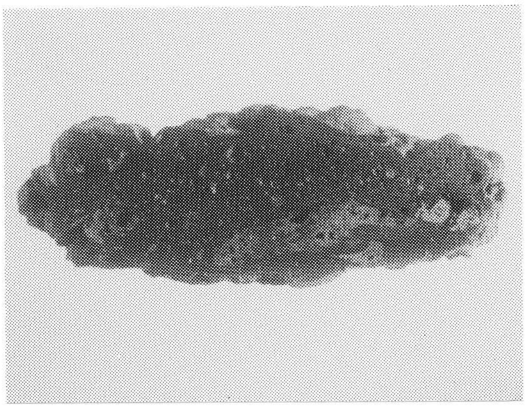
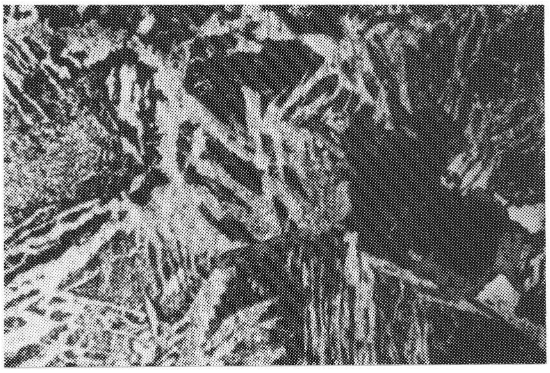


Fig 15. A section of the bloom, sample C-6000:356.It has a fairly large piece of iron in the center. Photo E Hjärthner-Holdar.



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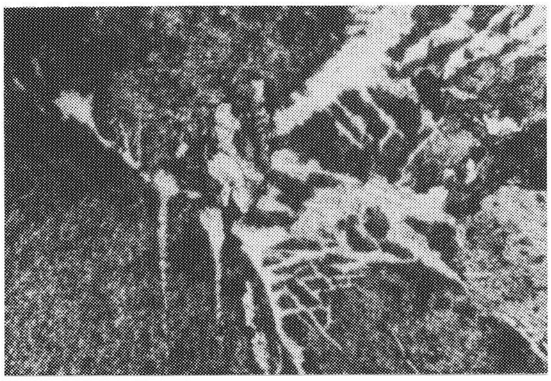

b.

Fig 16 a, b. Two sections, sample C-6000:356and B-5000:B. The samples show a fairly good carbon steel. It is pearlite with grain boundary ferrite. 180x,etched with 1% nital. Photo E Hjärthner-Holdar.

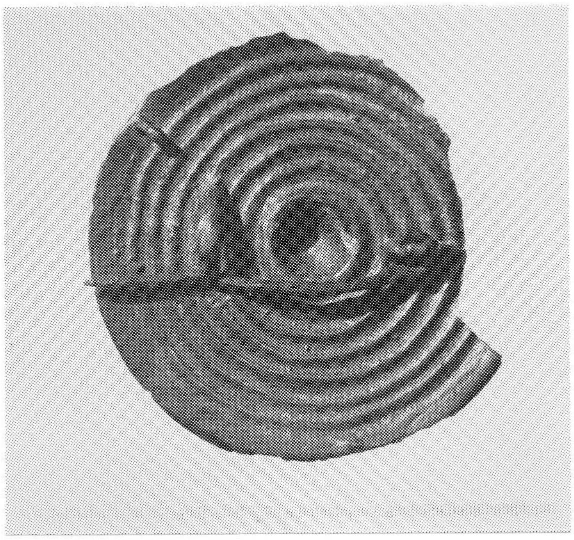

Fig 17. The backside of one of the identical brooches from Ransten, Sundby parish in Södermanland. It is made of bronze but the pin is made of iron. Photo G Hildebrand.

1990;12f),including myself, have given this question a lot of consideration. The center - periphery model is very one-sided. There is no room for a special development within the periphery. But if we look at the periphery both from a global and a regional perspective one nearly always sees differences. That is the crucial point. There is a development in the periphery that one cannot relate to the center and different areas within the so called periphery develop differently. That is because different groups adopt different phenomena from the center. This also gives us a way of solving the problem of diffusion. The reason is that different areas adopt phenomena according to their own needs within the social system or in order to change it. Therefore, there is no necessity for neighbours who live between one and the so called center to adopt the same phenomena. If we apply this to the introduction of iron production, we can see that it was not related to any major changes in society. In the long run, it may have affected the social structure. Like in so many cultures, iron was peacefully introduced and adopted into the Bronze Age society. With respect to the south central Swedish occurrences, there may be complementary reasons for an early start of the iron production. Perhaps, different cultural relations may have played a vital roll in this matter. The subject will be treated in forthcoming papers.

Acknowledgments

I am delighted to dedicate this article to the late Dr Inga Serning, who has done so much to advance the study of archeometallurgy in Sweden. I would like to thank Dr Peter Kresten, who has generously given me the benefit of his expertise on several occasions. I would also like to thank Dr Dag Noréus who has helped me with some of the analyses, and with whom I have had a very fruitful discussion. I wish to thank Dr Gunborg Janzon who has encouraged me in my work about the iron metallurgy dated to Swedish Bronze Age.

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