IRON METALLURGY IN LITHUANIA. AN ANALYSIS OF ARCHAEOLOGICAL FINDS (PART 1)

BIRUTĖ SALATKIENĖ

Abstract

Iron metallurgy in Lithuania has been a little-researched theme so far. More attention has been paid to smithery (Stankus) and iron smelting technologies (Navasaitis), but not much is known about the archaeological finds of iron smelting equipment, their functions, and interconnectedness. Archaeological research of the last few decades in the Kereliai hill-fort (Kupiškis district), Lieporiai (Šiauliai), Kernavė (Širvintai), Bakšiai (Alytus), Žardė (Klaipėda) and Virbaliūnai (Kaunas) settlements, as well as the Lazdininkai (Kretinga) cemetery, has afforded much new data to investigate the iron smelting occupation, and has provided the opportunity to examine more broadly and deeply the problem of iron metallurgy in Lithuania.

Iron metallurgy's research objective includes iron smelting equipment, tools, and the products of manufacture. The sources of research are the iron smelting archaeological finds stored in museums, archaeological research documentation, and reference as well as scientific publications.

Part 1 of this article is devoted to an analysis of the archaeological finds related to the preparatory stage of iron smelting and the making of charcoal. Iron ore has been found in Baitai (Klaipėda district), Lieporiai, Norkūnai (Prienai), Lavoriškės (Vilnius) and Krūminiai (Varėna). Roasted ore was additionally found in Varnupiai (Marijampolė) and Lieporiai. Ore washing equipment, roasting pits and crushing tools were found only in Lieporiai. It was established that the hydrated ore in Lieporiai was mined in an open fashion, washed with well water on a wooden flooring, and roasted in open fires in shallow pits. Flat rocks and ground stone were used for crushing and grinding it (comminution). Charcoal for the iron smelting was made in round pits or stacks (Lieporiai, Žygmantiškės).

Key words: iron metallurgy, mining iron ore, washing ore, roasting ore, crushing ore, making charcoal.

Introduction

People began extracting and processing iron 4,000 years ago. This is a material from which the manufactured weapons and tools far exceeded, in their quality and duration, the stone, bone and bronze artefacts made until then. Iron production had a huge impact on all areas of human life and activity, on the household, the economy and the social structure; thus its procurement, treatment and use is one of the most important issues for Iron Age material culture researchers. Lithuanian archaeological science so far has not given enough attention to it. The first data about iron metallurgical artefacts in Lithuania is known from the first half of the 20th century (Tarasenka 1927, 1928; Nagevičius 1935; Puzinas 1938); however, only after the Second World War were works devoted to this problem developed and published (Kulikauskas 1958; Stankus 1978, 2001). Having surveyed the research history of iron metallurgy (Salatkienė 2006b), certain incongruities are evident in previous iron metallurgy research. Until recent years, the use of iron (artefacts and their types, smithery, technologies, development) has been the best researched (Stankus 1978, 2001; Navasaitis 2003). Considerably less known is the stage of iron's procurement and initial treatment, since the equipment and tools for iron smelting are preserved somewhat more poorly than other artefacts. Lithuanian archaeological research and discoveries of the last few decades have provided much new and valuable material to research the iron metallurgy trade, as well as giving the opportunity to examine more widely and deeply the problem of iron metallurgy in Lithuania. Currently, more than 200 iron metallurgy find sites are known in Lithuania, but only 40 of them have provided more valuable information (Salatkienė 2007), while mostly just slag has been found in the others. Especially valuable are the finds from the Kereliai hill-fort (Kupiškis district), Lieporiai (Šiauliai), Kernavė (Širvintai), Bakšiai (Alytus), Žardė (Klaipėda) and Virbaliūnai (Kaunas) settlements, and the Lazdininkai (Kretinga) cemetery.

The aim of this article is to define and substantiate iron metallurgy's research and its structure, to discuss sources of information for the research and, most importantly, to analyse the accumulated archaeological finds and other metallurgy data in Lithuania to date, to systematise and typologise them, and to connect them into a unified system according to the technological processing stages of iron metallurgy. The chronological boundaries of the research include the last few centuries BC, from the craft's beginnings to the formation of the state in the 13th century. The article analyses

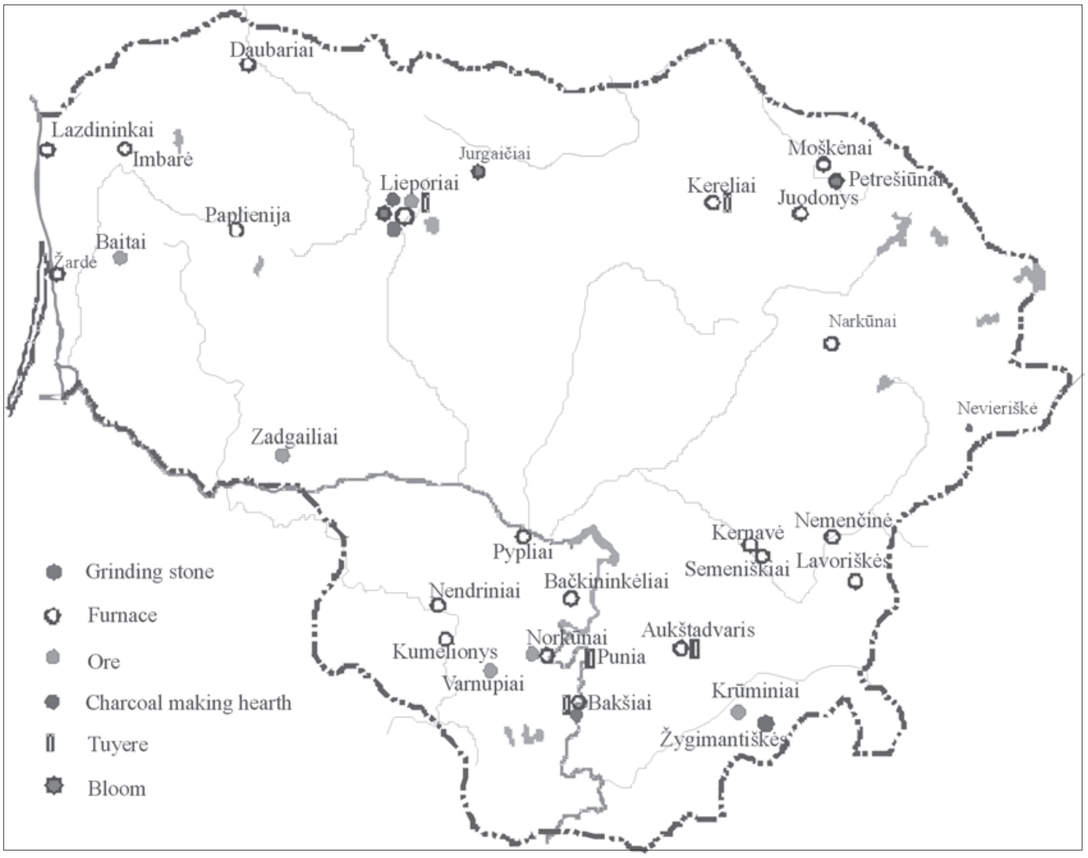

Fig. 1. The most important iron smelting findings in Lithuania.

the archaeological find complex characteristic of iron extraction and the initial treatment process, artefact types, functions, and their interconnectedness, beginning with iron ore, its acquisition and preparation, and ending with a discussion of the main technological products: bloom and slag artefacts.

Part 1 presents an analysis of the finds from the preparatory stage of iron smelting, finds of ore, its procurement, the remains from washing and roasting it, and from making charcoal. Iron smelting, its equipment, products, and waste will be elucidated in later parts of this article.

The research question

The Lithuanian archaeological heritage consists of three main parts: archaeological sites; artefact collections and exhibitions housed in museums; and published and archival scientific archaeological research material. The research into iron metallurgy, just like other questions of prehistory, includes all strata of this heritage; however, research documentation and artefact interpretation are especially important in the disclosure of iron metallurgy.

Iron metallurgy research consists of several parts:

1. Archaeological sites with iron metallurgical finds. Archaeological site types, chronology, diffusion, and the specific character of the finds discovered therein provide data about the mastery of iron smelting and the tendencies and directions of its expansion.
2. This work's main research question consists of all types of archaeological finds encountered at Lithuanian archaeological sites up to the 13th century that are related to iron metallurgy and that include all of the occupation's stages. These can be divided into several main types: features, artefacts and manufactured products. It is necessary to create such a structural model of iron metallurgy research because until now Lithuanian archaeologists have recorded only separate iron smelting artefacts, smelting furnaces, fragments of their walls, slag, etc, while the smelting process would be illuminated in publications only from a technological viewpoint, not connecting its separate stages with the archaeological finds. Every iron smelting stage has its characteristic specific raw material, equipment and tools; in addition, each stage leaves behind different manufactured products and waste. All archaeological finds related to the iron smelting process are important and must be researched together.

Features:

- Ore mining loci
  - ore deposits
  - ore mining pits
- means of preparing ore for smelting
  - ore washing loci and their respective equipment
    - wells
    - buckets for scooping water
  - ore roasting loci and their respective equipment
- charcoal making loci
  - pits
  - hearths
- iron smelting loci
  - smelteries
  - smelting furnaces, their loci, remains, fragments
- bloomeries (smithies, forges)
  - bloomery constructions
  - bloomery equipment (bloomery furnace)

Artefacts:

- ore mining tools
- means and tools for ore preparation
  - ore crushing stones
  - grinding stones
- means for processing blooms
  - anvils
  - hammers
- smith's tools
  - anvils
  - hammers
  - tongs
  - polishers
  - whetstones

Products of manufacture:

- blooms
  - unprocessed
  - processed
- preforms
- slag and its accumulation
- charcoal

3. Aside from the enumerated finds, the research includes materials that are used for the equipment, technological processes, and tools.
4. The research consists not only of the separate finds, but also of the entire system of iron metallurgy features and artefacts, their interconnectedness and distribution in the site, and the choice of location for the iron smelting or for its separate stages. This information is found in archaeological research reports and scientific publications.

Research methodology

A fundamental principal was adhered to while researching iron metallurgy in Lithuania in the first to the 13th centuries: to examine iron metallurgy as an integral process. Several methods were used in the work, all of which correspond to the work's aims: to collect and systematise all the known data to date concerning iron metallurgical finds in Lithuania up to the 13th century. One of the main methods in this work is typological. An effort was made to divide all the iron metallurgical finds found in Lithuania into the most important types according to technological stages, naming the artefacts, tools, and features of equipment characteristic of each stage. In instances in which more than one stage's finds are known (eg smelting furnace), either the commonly widespread typology is maintained or the typology of several stages is adapted. Typological artefact tables are presented in which an effort is made to show as much, and as precise, data as possible that substantiates the typological basis and motives. The application of the typological method not only allows the creation of a unified archaeological find system of iron metallurgy, but also eases its analysis, interpretation, and the determination of a chronology.

A comparative research method is also used in the work. Iron metallurgy finds are analysed by comparing them with each other, examining their similarities and differences, and establishing their possible types, as well as the type's diffusion areas and chronology. Moreover, Lithuania's archaeological finds are compared with finds and data from other European countries.

An analytical method is used in the discussion of the form, structure and determination of function of separate finds. The entire iron metallurgy's archaeological find system and typology is based on it. The synthetic method, as the main method, is used not only in summarising the results of the analysis and compiling a unified system and precise typology, but also in interpreting the development of iron metallurgy and reconstructing its surroundings.

Characterisation of iron metallurgy research information sources

Iron metallurgy sources of information are comprised of three groups: material finds, documentation and publications. All of these information sources are equally important. The first group consists of archaeological finds related to all stages of iron smelting in Lithuania's museum collections. Blooms, slag, smelting furnace wall fragments, fragments of bellows, iron ore pieces, stone anvils, grinding stones, and charcoal pieces find their way into museums. The second information source group would be archaeological site documentation or scientific research reports on finds of extracting iron ore, washing, roasting or smelting it, processing blooms, and making charcoal (these would be located in the Lithuanian History Institute's Archaeology Department archives). The volume, precision and comprehensiveness of the data presented vary. Stratigraphic data is especially important in iron metallurgy research, as it makes the interpretation of the finds (of both artefacts and features) and the determination of their interconnectedness more reliable. Iron metallurgy equipment is rarely well preserved, while the largest part of these archaeological finds is made up of processing waste (slag) or features that were destroyed or annihilated during the very process of production (smelting furnaces, ore roasting hearths). In many cases, only the archaeologist excavating iron metallurgy features can accurately name and link features and artefacts and interpret them, while a researcher utilising a scientific report in which the features and artefacts are only named, but not connected into a system, has much difficulty in doing so. It is likely that some of the features encountered in archaeological sites (hearths, pits, tools) that are associated with iron metallurgy, but not ascribed to it by the researcher, were not included in the research domain of iron metallurgy.

The third group is that of published material, starting with a list of find sites. The first such list and map was compiled by A. Endzinas (1968), although as an information source it is not entirely reliable. Endzinas compiled both a list and a map of 144 find sites, based on such sources as "Lithuanian museum funds. The research reports of archaeological expeditions of various years" (Endzinas 1968, p.162). This list includes the entire period in which iron was used, from the Early Iron Age up to the 20th century. The most serious flaw in this list is the inaccuracy of the references, and in many instances the lack of references altogether. Often the author limits himself to the reference *Lietuvos archeologijos bruožai* (An Outline of Lithuanian Archaeology) (without the referred page number) or to the note "VIEM," ie the current collection in the Lithuanian National Museum. Thirty references are included in this list, without any indication from where the information about the iron metallurgy artefacts was obtained. We can guess that some of the localities were surveyed by the author himself; however, he does not describe or present inventories of such surveys, the places where collected artefacts are curated, or any other data. Endzinas writes: "Small pieces of fine, worn iron slag were found in Neringa, between Šarkuva and Rasytė. Iron smelting must have occurred here before our era, and in the first half of the first millennium of our era" (Endzinas 1968, p.157). Endzinas does not indicate who found the slags and when, or under what circumstances, nor does he associate them with any site; yet he draws a categorical, irrefutable conclusion about the artefacts' chronology. Later archaeological publications do not confirm 75 of the list's references, and it is impossible to verify them due to the inaccuracy or nonexistence of the author's references. There are 14 references in the list that are not archaeological sites; the only thing indicated is that slag was found in the village fields. In the mentioned instances it is impossible to determine whether the reference is to slag from iron smelting or from a bloomery furnace, nor is there any mention of their chronology.

The second collection of iron metallurgy find sites was compiled in the *Lietuvos TSR archeologijos atlasas* (Lithuania SSR Archaeological Atlas) (LAA, 1977, pp.202-203). Three find site lists were published here according to find types: iron smelting furnaces, slag finds, and isolated finds (in burial sites). One hundred and one hill-forts and four open settlements are in these lists, and the fact that smelting furnaces were found in six archaeological sites is indicated. This is the first list of archaeological sites with iron metallurgy finds in which the data is accurate and the references are comprehensive. The most important merits of this collection are the provision of information about each site type, a presentation of the site's survey and research, a discussion of the most important finds, information about where the artefacts are curated, and a comprehensive list of references. A diffusion map of smelting furnaces and slag is also presented in the publication.

The *Kultūros paminklų enciklopedija* (Cultural Site Encyclopedia) (KPE, Vols I, II) is also ascribed to the discussed source of information. In addition to the earlier published information, it also contains iron metallurgy find sites not previously published. Of these, the hill-forts of Berzgainiai (Ukmergė district) (Vaitkunskienė 1996, p.98) and Maniuliškiai (Zarasai) are noteworthy (Grigalavičienė 1996, p.370).

Thus, Lithuanian iron metallurgy research information sources are rather varied and their investigation requires different methods. Only by their sum total, however, can we examine, interpret and typologise the archaeological finds associated with iron smelting in sufficient detail.

Iron ore and its preparation (mineral dressing)

Iron ore finds. Till now archaeologists have very little direct information about ore deposits and their exploitation. The literature is usually limited to the general comment that bog ore is often found and is widespread throughout Lithuania (Stankus 2001, p.171), and that “to find bog iron was no more difficult than to find suitable clay for the production of pots” (Kulikauskas 1959, p.11). Not everyone is of this opinion, however. Endzinas, basing himself on Kaveckis, asserts that the mineralisation of subterranean waters in Samogitia’s highlands is lower, so there are fewer bog ore deposits there than in east or south Lithuania (Endzinas 1969, p.93). He was the first to try to describe iron ore mines. The researcher describes the Galeliai settlement (Utena district) where much slag has been found, and believes that iron there was smelted from sedimentary ore taken out from the bottom of Lake Lukna (Endzinas 1969, pp.93-94). The author links the slag finds from the Berzgainiai hill-fort with the Siesartis rivulet’s shores’ ferriferous tufa layer that contains 30% iron oxide, and the Jomantai hill-fort’s slag finds with the ferriferous soil of the Veivirža-Ašva valley (Endzinas 1969, p.97). Endzinas affirms that the ore in Lavoriškės was mined in the same place it was smelted, “right there on the shores of the River Vilnia, near the existing Margiai peat bog and surrounding bogs” (Endzinas 1967, p.39). He justifies his statement in that remnants of iron ore material that correspond to the composition of the ore from the Vilnia’s shores were found underneath the iron smelting waste pile.

Other ore deposits, such as Papilė, Mociškiai, Kazlų Rūda, and many others mentioned in the works of Endzinas, Malinauskas and Linčius (Malinauskas *et al.* 1999) and Stankus (2001), are not associated with specific archaeological sites. These authors describe ore deposits mentioned in historical references and linked with metallurgy in the Middle Ages. Moreover, in their article about limonite, Malinauskas and Linčius present not geological maps that indicate the diffusion of this mineral, but rather the toponymic maps compiled by Endzinas with the roots Gel-, Rūd-, Hut- and Būd-, as well as this same author’s slag find site maps (Malinauskas *et al.* 1999, pp.111-112, Figs. 1, 2). While it cannot strictly be denied that slag find sites were unknown in prehistoric times, we have no archaeological data that confirms this. Iron ore was found underneath the tillage in the Kivyliai village during an archaeological survey of the Būtingė-Mažeikiai terrace in 1996, but Stankus, its discoverer, does not associate it with any archaeological site (Stankus 2001, p.171).

There is no data about ore deposits that could be characterised as archaeological sites, ie, places of production. Archaeological finds of iron ore known till now are associated only with settlements or burial sites. Ore has been found in Baitai, Lieporiai, Norkūnai, Lavoriškės and Krūminiai (Fig. 1). Endzinas mentions bog ore discovered in Kaunas Castle in 1960 which, in the author’s opinion, must have been brought in from the area’s ore deposits (Endzinas 1964, p.195); however, there is no data about those ore deposits. One researcher recorded a 20 to 30-centimetre-thick layer of very ferriferous sand in a cemetery in Baitai (Klaipėda district), at a depth of 60 to 70 centimetres (Banytė 2002, p.107); this layer was orally recounted to this work’s author as one of iron ore. The same type of information was also received by this work’s author from the investigator of the fifth to sixth-century Kalniškiai cemetery (Raseiniai district), V. Kazakevičius. A very ferriferous layer of sand was also observed in this cemetery’s territory. E. Striškienė, who excavated the Krūminių (Varėna district) hill-fort settlement, notes in her research report that in plots XI and XII of the northwestern portion of the settlement, upon removing the 25 to 35-centimetre cultivated soil layer, the “undisturbed bed – limonite (marsh ore)” showed (Striškienė LII 3229, p.17, Photograph 19), although she does not append any laboratory analyses or geological summary data. Nowhere does she mention that the thickness or boundaries of that layer would be confirmed; however, the assertion of the layer being one of limonite is very important to us. Both in the research report and in the publication (Striškienė 2000), the author also mentions slag found in the cultural layer of the Krūminiai hill-fort foot settlement. Thus, we can affirm that the metallurgists of the Krūminiai community could have used the local ore deposit’s raw material.

While making the rampart’s profile of the Norkūnai 1 hill-fort (Prienai district), ferrous minerals, pieces of marsh ore, were found in stone pavement I. The hill-fort’s researcher, V. Daugudis, collected and submitted the larger ones (some were up to 7x10x7cm large) to the museum. It is most likely that these minerals got into the rampart together with other rocks that were brought in for the rampart’s reinforcement. What is clear is that they should not have been very far from the hill-fort, although other iron ore finds that survived in their original place were not recorded during the excavation. Not only slag, but also smelting furnace remains were found in the Norkūnai 1 hill-fort settlement, so the discovery of iron ore pieces in the hill-fort’s rampart is very important information about the use of ore deposits in the hill-fort’s environs.

While excavating a pile of iron dross (slag) in the ancient settlement of Lavoriškės (Vilnius district), Daugudis also found raw iron ore material. He writes: “… at a depth of 30 to 35 centimetres, near the centre of the dross pile, approximately between the sixth and 13th metres, a thin, two to five-centimetre layer of light brown soil composed of what resembled small, fine grains of gravel was observed. In the opinion of Doc. V. Babilius, this is the remains of raw iron ore material which, apparently, before smelting, would first be dried. It did not become clear during the excavation, however, why the dross and other waste material was heaped onto the place in which the iron ore was dried earlier" (Daugudis LII 201, p.5). Raw iron ore was found in Lavoriškės in 1978 during archaeological investigations. Stankus writes that he found a massive piece of ore there that weighed four kilograms (Stankus 2001, p.171).

Approximately 100 small pieces of roasted iron ore were found in the settlement on the top of the Varnupiai hill-fort (Marijampolė district) during the excavation there in 1970. The hill-fort's researcher, P. Kulikauskas, calls the pieces dross both in his research report (Kulikauskas LII 91, p.47) and in his publications (Kulikauskas 1972a, p.18; Kulikauskas 1982, p.57), although he notes that they are unusual. About 100 small pieces of metal were found in an approximately 30-centimetre-wide area and at a depth of 40 to 50 centimetres in Plot 2, Quadrant G9. Some of them resembled metal shivers, others dross. The author writes: "Since they were not analysed, a determination of their function cannot be made. Somehow they are fresh and sharp, different from the dross to which we are accustomed" (Kulikauskas LII 91, p.47). Having examined this find, which is stored in the National Museum's collections, the author of this article dares to assert that Kulikauskas' find is one of iron ore, since she has collected many similar pieces of ore in Lieporiai. We have no more data about the ore mine in the surroundings of the Varnupiai hill-fort from which the mentioned iron ore concretions were brought in. No other kinds of iron metallurgy finds were found during the excavation of the Varnupiai hill-fort, although Endzinas notes that "pieces of iron dross were found together with iron bloom in the crops along the hill-fort's eastern slope during the 1954 KDM (mistakenly cited as the Kaunas Art Museum) archaeological survey" (Endzinas 1958, p.153). Recent efforts to find data about this expedition and its archaeological finds in the Vytautas Magnus War Museum's Archaeology Department were unsuccessful. The head of the department, K. Rickevičiūtė, maintained that in the 1970s Endzinas had taken iron metallurgy finds for laboratory analyses, as well as expedition reports from many museum collections, for research concerning iron smelting in Lithuania, but did not return any of these to anyone. After his death, museologists were also unsuccessful in retrieving the materials from his relatives, so much iron metallurgy data and sources are gone.

The only reliable archaeological data we have about an iron ore deposit and its exploitation at this time is from the Lieporiai 1 settlement. The iron metallurgy finds discovered there have been analysed and published (Salatkienė 2003). We shall remind the reader in this work that, in the author's opinion, a small ore deposit was initially found and began to be exploited in Lieporiai, with the iron being smelted right there. Two iron smelting stages were recorded in this location, separated by a certain amount of time when the work was abandoned there. Only when all the ore was definitively exhausted did the people build houses and settle in the place where iron had been smelted. This small ore deposit was in the bottom of a shallow basin or depression, in a distinctly yellow sandy loam. In geological terms it is called a clayey yellow sand accumulation in the depressions of the moraine's relief (Stančikaitė ŠAM). Hydrated iron ore was found in the small ore deposit (Fig. 2). It was comprised of grey, ferrous nodules as large as hazelnuts, spread throughout the entire layer, concentrated in larger or smaller clusters in places. Roasted ore that had been extracted from this location was also found there. A large amount of it had fallen around the shaft of Furnace 14. As was shown by laboratory analyses (Table 1), the roasted ore differed in colour (light brown, rusty) and amount of iron from the nodules collected during the excavation.

Table 1. Chemical composition of unroasted and roasted ore found in the Lieporiai 1 settlement

Composition	**Hydrated iron oxides (unroasted ore)**	**Roasted ore near Furnace 14**	
		Sample 1	**Sample 2**
Fe (general)	8.66-17.03	50.84	57.80
Fe_2O_3	12.39-24.34	72.70	82.65
SiO_2	63.63-66.43	18.30	12.85
AL_2O_3	6.97-8.60	1.74	1.91
CaO	1.14-1.33	3.35	1.16
P_2O_5	0.29-1.05	2.48	0.71
MnO	0.23-6.26	0.32	0.15
MgO	1.14-1.15	0.45	0.74
TiO_2	0.37-0.44	0.09	0.09
BaO	0.10-0.85	0.11	0.02
K_2O	2.89	0.52	–

Analyses performed by Dr A. Sveikauskaitė

One can see from the geological-geomorphological diagram of the Lieporiai environs compiled in 1997 (Stančikaitė ŠAM) that the Lieporiai 1 and Lieporiai 2 settlements were established in precisely those places where the mentioned yellow sandy loam with hydrated iron ore accumulations are found. Slag was also found in the location of the Lieporiai 2 settlement; thus, it is likely that the iron could have been smelted here as well. It could be assumed that the people of Lieporiai 1, and maybe even of Lieporiai 2, also settled there because they found hydrated iron ore there. The ore's

Fig. 2. Hydrated iron ore from Lieporiai.

attributes, as well as in which places and what kind of soil it could be found, should have been well known to the people. Hydrated ore (bean-shaped) was used for smelting in Belarus (Гурин 1982, p.24). Iron ore near or in the vicinity of smelting furnaces is found in Latvia. A piece of limonite weighing 95 grams was found in the Ķente hill-fort settlement (Stubavs 1976, p.90).

The Lieporiai, and in part Krūminiai, examples show that iron was smelted near an ore deposit; however, there are apparently more instances in which iron ore was mined from an ore deposit that was elsewhere, brought back to the settlement, and smelted there. So far there are no excavated sites where iron smelting is not associated with one or another type of settlement.

Mining ore. We have very little archaeological data concerning methods of mining ore. The literature is limited to the observation that ore was mined in the summer, while smelting occurred in the fall and winter (Kulikauskas 1959, p.12; Endzinas 1969, p.96; Stankus 2001, pp.171-172), but ore mining finds in archaeological sites or their surroundings are not indicated. When pieces of ore are collected from the ground surface, only the winter is not convenient for the task (Endzinas 1969, p.94). Sometimes the extraction of ore from the bottoms of lakes in the winter, after chopping ice holes, is mentioned (Endzinas 1969, pp.93-94).

In Lithuania, iron ore is found on the ground surface, in the soil, in layers under the turf, in swamps and streams, and on lakeshores (Malinauskas *et al.* 1999, p.111-114); thus, everywhere it had to be dug out, collected, or otherwise extracted via open means. It had to be mined from in or under the ground, but only in Lieporiai were such mining pits found. It was observed during the first years of archaeological excavations that some pits were dug and abandoned right away. They were irregularly shaped, with very uneven bottoms, and with small, thrown-out hillocks alongside them. Such pits were found not throughout the entire investigated plot, but rather only at the very bottom of the depression or small valley, in a distinctly yellow sandy loam. Only in this sandy loam is hydrated iron ore found as well. Its pieces are abundant throughout the sandy loam, although larger or smaller conglomerations or clusters of it are also found. Approximately a couple kilograms of small pieces of ore were collected from one such cluster during archaeological excavations (Plate VII:2). It is therefore believed that these pits were dug in different loci of hydrated ore clusters (Salatkienė 2003, pp.5-6). Having performed a chemical composition analysis of this ore, it became clear that it was of very poor quality (Table 1); however, ore that has little pure iron within it is also found in other European countries (Török 1999, pp.168-169).

Eighteen ore mining pits were found and researched in Lieporiai from 1992 to 2000. Their distribution on the ground surface, size, depth and shape were determined by the distribution, size and shape of the iron ore clusters. The shapes of all the pits were irregular, their sizes varied between 60 by 80 centimetres and 2.5 by two metres, and their depths reached between ten and 60 centimetres. So far this is the only iron ore mining method in Lithuania that has been confirmed by archaeological data.

Currently there is no information confirmed by archaeological finds about the tools, equipment and transport of ore. We can only guess about what was used to dig ditches or to dig the soil for hill-fort ramparts or for wells during the researched period. Nor has a single metal tool for digging been found in Lieporiai. They might have been dug with hoes or other tools (shovels?), while the ore pieces might have been collected by hand.

Washing ore. Irrespective of from where the iron ore was mined or collected, it had to be washed in order to remove the silt, sand and other organic and mineral impurities. Washing as one of the stages of preparing ore for smelting is emphasised by all iron metallurgy researchers (Kulikauskas 1959, p.12; Endzinas 1969, p.96; Stankus 2001, p.172; Navasaitis 2003, p.28). Endzinas maintains that washing ore compelled iron smelting to be concentrated near rivers and lakes, citing the Nemenčinė, Aukštadvaris, Punia, Bačkininkėliai and Paplienija hill-forts as examples (Endzinas 1969, p.96); but he does not mention any find that could prove this assertion. Navasaitis cites the recollections of 19th to 20th-century ore miners when lacking more abundant archaeological data. Not one of these researchers examined the methods, equipment or tools for washing ore.

The excavation of the Lieporiai settlement showed that yet another, more complex method of washing ore was known in Lithuania: sluicing the ore with well water. This method required a large complex of equipment, that consisted of wells with buckets, flooring, and a pond for gathering the outwash. It is likely that this ore washing method was as follows. The ore collected from the hydrated iron ore clusters would be poured onto the flooring laid out on the slope of a basin or depression, with a gradient to the bottom of the depression. Water would be scooped out from the wells with linden bark buckets, and poured onto the ore spread out on the gently inclined flooring. The running water would wash out the sand and other impurities from the ore. The water that flowed down off the flooring would accumulate at the bottom of the depression, where silt and a layer of very ferriferous sediments were found (Plate VII:3).

We will discuss all the elements of this complex. Three wells were found not far from the flooring, two of which had wooden constructions; the third well construction's flooring did not survive. Yet another well was found further away. Four linden bark buckets were submerged in each of two of the wells. A detailed analysis and reconstruction of the wells and buckets has been published elsewhere (Salatkienė 2006a), so here we will limit ourselves to a brief review. The simplest well was well 2. It had an almost round 60 to 70-centimetre-diameter pit on its bottom and about a three-centimetre-diameter on the surface of the undisturbed bed. Its depth was two metres from the present ground surface. A layering of sediments characteristic of a water reservoir was observed along the pit's edges, while a 15-centimetre-thick layer of silt had accumulated at its bottom. This belonged to a well lacking a sturdier wooden construction. It is possible that the well's walls were fortified with woven branches, which retained the round well's shape. When the branches decayed, the edges of the well's pit collapsed, and its outer perimeter significantly widened. The author has observed the walls of a well that were from about the same period and had been woven from branches in Poland, in the Prushkov Iron Smelting Museum. The Lieporiai well 2 might also have had a similar reinforcement; this is suggested by the silt at its bottom, which was not mixed with the undisturbed bed of the walls, but rather was easily separated from it. A very similar feature was found in 2006 in the Žardė settlement near Klaipėda (Masiulienė 2007, p.79). This was a round pit with steep walls and a silt accumulation at its bottom, as well as small, preserved vertical stakes along its edges that probably survived from the weaving of branches used for reinforcing the walls (Masiulienė 2007, p.79, Plate VII:3, Plate VII:1). Although the researcher does not associate feature 5, which might have been a well with iron smelting, the resemblance of the construction with the Lieporiai well and its existence in an environment of iron smelting finds (slag, charcoal making and ore roasting pits) allows us to make this supposition.

Well 1, found in 1992, was much better installed. A pit two by three metres large and 4.65 centimetres deep from the present ground surface was dug for it, and a 1.3-metre-long and 60 to 70-centimetre-wide construction of wood slabs as well as cleaved and squared boards was installed within it, reinforced with stakes and crossbeams from both the inside and outside (Plate VII:1). The side walls consisted of horizontal slabs, their ends of upright slabs. A 2.5-metre-high bottom part of the construction has survived. The space between the construction and the walls of the well's pit was filled up with soil and burnt material, ash and coals. This well was dug out in a water vein. The western wall of the well was washed out by the water vein, collapsed and fixed, but then destroyed again.

Well 3, excavated in 1997, was built along the same principles, only its construction was somewhat simpler. Apparently, a 3.4-metre-deep pit was first dug out and water was scooped from that. Only when the walls began to cave in were the walls of the well's pit reinforced with squared boards about 60 centimetres above the bottom of the well's pit. The reinforcement was not hermetic, since lots of sand had fallen into the corners of the well. Only an 80-centimetre-high wooden construction fragment survived (Plate VII:3). Well 4, excavated in 1998, was installed in the same way as wells 1 and 3, only its side walls consisted of round poles with bark, while squared boards were used only for the ends. The size of the wooden construction was 165 by 55 to 65 centimetres, at a depth of 2.4 metres below the present ground surface. A 70-centimetre-tall bottom part of the construction has survived (Plate VII:3).

The wells would quickly silt up, their walls would cave in and be repaired (well 1). Apparently, that is why four of them were dug instead of only one. On the other hand, a silted-up well would not simply be left alone. All of them were filled up with logs, sticks and rocks, and covered with ash and soil. A rich, black silt with many admixtures, sand, organic material, ash, sinters, coals, firebrands, rocks, sticks, and tree bark that had poured out from the walls, was at the bottoms of all the wells. Axe-sharpened poles and squared ends of beams, stumps, ends of boards, and many wood chips were thrown into all the wells, especially wells 3 and 4. Artefacts were also found in the soil used to fill up the abandoned wells: clay pots and their shards, grinding stones, slag, clay plaster pieces, as well as animal bones and teeth.

Buildings were later constructed where the wells once stood, and household finds such as pottery shards, bones, clay plaster and others were found only in the soil that had filled in the silted-up wells, thus they are all allotted to the Lieporiai settlement's iron smelting period. Wells 2, 3 and 4 were both dated by radiocarbon and dendrochronological methods. It was determined that well 1 was installed approximately AD 318±38 (Kairaitis *et al.* 1997). Wells 3 and 4 were dated AD 374±50 and AD 523±50, respectively (Mažeika *et al.* 1999). These were not wells that were dug for everyday life, for drinking water, but were dug because there was no water reservoir close by and their water was used for washing iron ore before smelting.

This article's author has seen a wooden well analogy in the Prushkov (Poland) Iron Smelting Museum, where the first to fourth-century iron smelting of Biskupice has been reconstructed (Muzeum Starożytnego Hutnictva w Pruszkowie. Wystawa – Czas Źelaza. Panorama mazowieckiej wsi hutniczej z pierwszych wieków n.e.).

Eight buckets used for scooping water were submerged in wells 1 and 3, four in each well, all made from linden bark. All of them were very similar, 25 to 27 centimetres in diameter, of the same height, and with an eight or nine-litre capacity. They were sewn together with a linden bast ropelet and had handles made from a thicker twisted linden bast rope (Plate VII:1). Having made a reconstruction of the buckets, it became clear that they were sufficiently hermetic, suitable for scooping water, light and comfortable; however, apparently they wore out quickly. The author has found no analogues of linden bark buckets from the first half of the first millennium.

The second feature of this complex was flooring installed in the northern slope of the shallow depression. This was a light brown-greyish, approximately five-metre-long area of decomposed organic material, with a narrower more slanting end (about one metre) and a wider higher end (about two metres). One of its edges was entirely straight, while its thickness ranged from five to ten centimetres. The cross-section showed that the flooring's bottom half was uneven or wavy in places. The flooring's boards were laid out on top of the undisturbed bed and the flooring must have been made from split boards, most likely squared on one end. The side boards must have been laid out on the edge so as to make the edge higher. The better-preserved eastern side of the flooring was totally straight. The flooring was laid out very tightly, without any gaps. It looks as if it could have been made of split boards, in between which were also boards with a semi-circular cross-section, from the trunk's edge (Plate VII:1). The wooden construction of the three Lieporiai settlement's wells, in which such boards were used, made it possible to determine the appearance of the flooring's boards. The boards were of various sizes, ranging from 1.8 by 0.5 metres to 0.23 by 0.30 metres. Their thickness ranged from five to ten centimetres. Some of them were only split, while others were very evenly squared.

It is precisely this type of installation and reconstruction of a well that was built in a very similar fashion that is demonstrated in Prushkov. The only difference is that the Biskupice flooring is raised from the ground, with its boards laid out on a construction of stakes and crosspieces, while at Lieporiai it was laid out straight on the ground.

The third element of the ore washing installation was the pond found two metres south of the surviving part of the flooring, at the very bottom of the depression. Part of it was demolished by a new pit, while the size of the excavated portion of the pond was seven by 3.4 metres. The pond was oblong, irregularly shaped, 55 centimetres deep in its centre, and progressively more shallower along its edges. It had filled up with a dark greenish, rich silt, in which there were many rust impurities, especially on the bottom. The rust had accumulated in the silt due to the fine ore particles that had flowed down with the water. The consistency of the pond's silt was exactly the same as that accumulated in the wells, differing only in its colour and impurities. The silt was full of split rocks, many of which were scorched or burnt through, many very decayed animal bones, and even some large pieces of slag. Both the edges and the bottom line of the pond were very clear; thus, it appears that this was not a natural indentation of the ground surface, but rather a shallow pit specially dug to gather the sewage from the washing of the ore (Plate VII:1). The flooring should have reached the northern edge of the pond, but, as mentioned, this part of the flooring did not survive.

It might have been that the ore at Lieporiai was washed twice, as soon as it was dug out and after roasting. Dur-

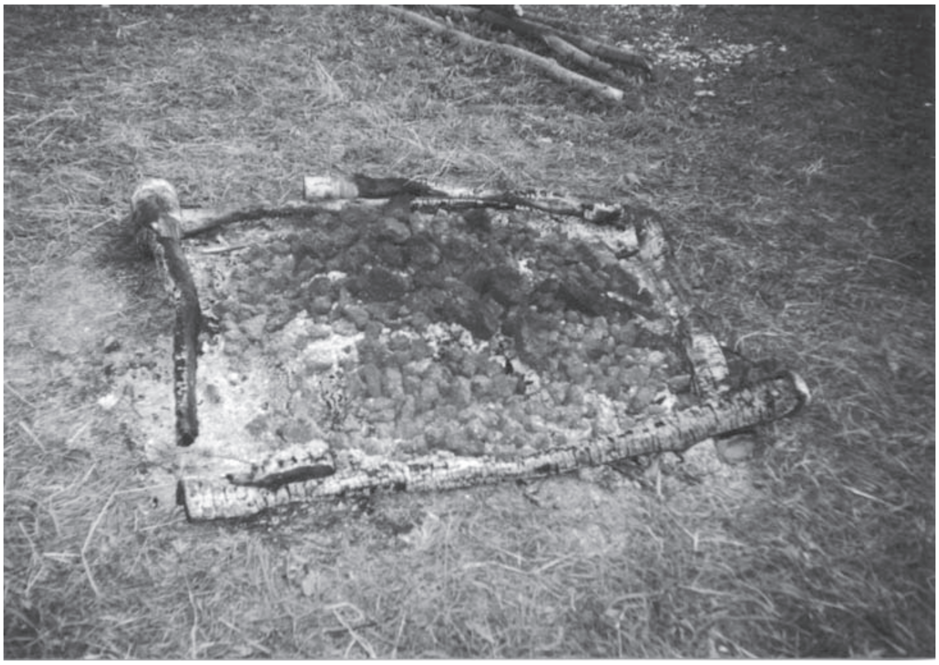

Fig. 3. Iron ore roasting at Kernavė archaeology festival.

ing an experiment at Kernavė in 2000, it was observed that the ore that had been collected from the fire and immediately poured into the furnace was very contaminated with sand and other mineral particles.

The complex installation for washing ore at Lieporiai, and especially the fact that it was not a natural water reservoir that was used, but rather wells that were dug for that purpose, testify that metallurgy was not so primitive in the first half of the first millennium, nor were iron smelters as inexperienced as is often emphasised in Lithuanian archaeological literature.

Endzinas writes extensively about the drying and storing of ore not in the open air, but rather under a roof (Endzinas 1969, p.96; Endzinas 1964, pp.193, 196). He maintains that special buildings were used for that purpose, dug-out *cubicles* (Endzinas 1964, pp.193, 195-196). There is no archaeological data that confirms that such a storage method was used in our researched period. A larger, prepared quantity of ore that could have been kept as an ore reserve was not found in any of the known iron metallurgy find sites.

Roasting ore. The roasting of ore is the next stage in preparing it for smelting (Fig. 3). Roasting the ore removed any organic impurities that had not been removed by washing it. Lithuanian iron metallurgy researchers emphasise the importance of roasting in their work.

We do not have much data on the roasting of ore. Stankus observes that it was roasted in open fires (Stankus 1978, p.77; Stankus 2001, p.172), but he does not point out a single archaeological find. So far, it is unknown where ore used to be roasted most, in the mine or in the place where it was washed or smelted. It must be emphasised that in all the excavated archaeological sites where smelting furnaces have been found, researchers indicate the presence of hearths in their surroundings, in some of which slag has also been found (Brazaitis LII 2788, p.9); however, not one of the researchers associates the hearths either with the furnaces or with iron smelting in general. Using only those sites' research reports and publications, and not having seen the actual hearths, there is no point in trying to connect the furnaces and some of the hearths with the complex of iron metallurgy finds, only the excavator can do this.

We have reliable data about ore roasting in open hearths from Lieporiai (Salatkienė 2003, pp.7-8). Besides the already-described ore mining pits filled in with mixed cultural layer soil, several shallow pits were found in the iron smelting area, whose contents stood out by their abundance of fire-stained soil and coals, as well as, most importantly, rust admixtures and sparse pieces of roasted ore. Apparently, the ore was saved and carefully picked out of the pits (Fig. 6). The ore's roasting pits were usually irregularly shaped, approximately 0.8 by 1.5 metres large, and seven to ten centimetres deep. It appears that a portion of the ore mining pits were later used for ore roasting as well, which is suggested by their contents of fire-stained soil and rust. These pits were deeper and their bottoms were not flat, but rather very uneven. New information about iron ore roasting in pits was provided by the excavations at the Žardė

Fig. 4. Ore crushing tolls: a flat rock; b grinding stone.

complex of settlement sites. Masiulienė surmises that feature 25 was allotted for roasting iron ore. This was a 2.4 by 1.8-metre-large and 15 to 20-centimetre-deep pit, filled in with dark, burnt sand and rocks. Thirty-six pieces of roasted iron ore were found in the pit, thus the pit's function was associated with ore roasting (Masiulienė 2007, p.80).

Ore roasting pits have also been found in Latvia, at the Salapils settlement of Spietini (Daiga 1964, p.32), and in Hungary (Gömöri 1999, pp.149-152). It is likely that ore was also roasted in overground fires. A three to five-centimetre layer of fire-stained soil with rust is left behind in such a place. The most shallow, flat and even-bottomed hearths are ascribed to the overground ore roasting hearths. Such features were also found in the Lieporiai smeltery (Fig. 3). This method of roasting ore was tried out during experiments at the Kernavė living archaeology festival and was justified (Fig. 3).

Crushing and grinding ore (comminution). Some types of ore are found deposited in layers or in rather large pieces, thus they need to be crushed before being roasted. Roasted ore also often hardens into pieces, thus even after roasting it may need to be crushed. The roasted pieces are friable, and much force and complex equipment are not needed to crush them. Most researchers only mention the comminution of roasted ore by crushing or grinding (Endzinas 1964, p.192; Stankus 1978, p.77; Malonaitis 2003, p.251), but they do not indicate the means or tools used for this. Only Kulikauskas conjectures that a portion of the many grinding stones found at the Moškėnai hill-fort might have been used for crushing and grinding ore (Kulikauskas 1958, p.13). Such grinding stones can be found in the descriptions of previous iron smelting spots of some settlements, at Bakšiai (Steponaitis 2000, p.115-116), or in descriptions of settlements with iron smelting that have ground stone, at Žasliai (Girininkas 1996, p.293), Šereitlaukis (Balčiūnas *et al*. 1994, p.282), Šatrija (Valatkienė 1986, pp.38-39) and Imbarė (Daugudis LII 652, p.33; 1980, pp.24-25). The stones in these settlements were found in the furnace surroundings or together with pieces of slag. Not one of these authors directly associated the finds specifically with ore comminution or generally with iron smelting, thus we can only presume that the grinding stones might also have been used for crushing and grinding ore.

Several artefacts were found in the Lieporiai iron smeltery that might have been used as tools for crushing ore. These are several flat, polished stones and several grinding stones (Salatkienė 2003, p.8). The flat ore crushing rocks were quadrangular, with rounded edges and corners, 23 by 18 centimetres large and about eight centimetres thick, one of whose large surfaces was somewhat sunken and uneven, as if it was knocked out (Fig. 4). Grinding stones found in the Lieporiai smeltery differed from ordinary ground stone in that their worked surfaces were not convex and ground, but rather the opposite, sunken, uneven, crumbled, similar to the flat rocks just described (Fig. 4). It would seem that the surfaces of the rocks could be affected in this way by rather hard and coarse iron ore. The fired ore strewn around furnace 14 was not roasted, but rather chopped up into bean-sized pieces. This shows that the stone tools used to make it fine were used in preparing the iron for smelting in the furnace. Such a method of crushing ore, by the way, was also known in Hungary (Gömöri 1999a, pp.170-192).

Although some Lithuanian iron metallurgy researchers reason quite broadly about the storage and preservation of iron ore prepared for smelting (Endzinas 1964, p.195), till now not a single archaeological site is known with such a large amount of iron ore that it could be called a reserve. A small amount of roasted iron ore has been found in only two places, and these cannot be considered reserves. One of these is the already-mentioned iron smeltery of Lieporiai, where roasted ore was strewn around the furnace. According to its arrangement in a circle, even the outer diameter of the furnace was ascertained. This find casts no doubts: this truly was ore prepared for smelting, which was also

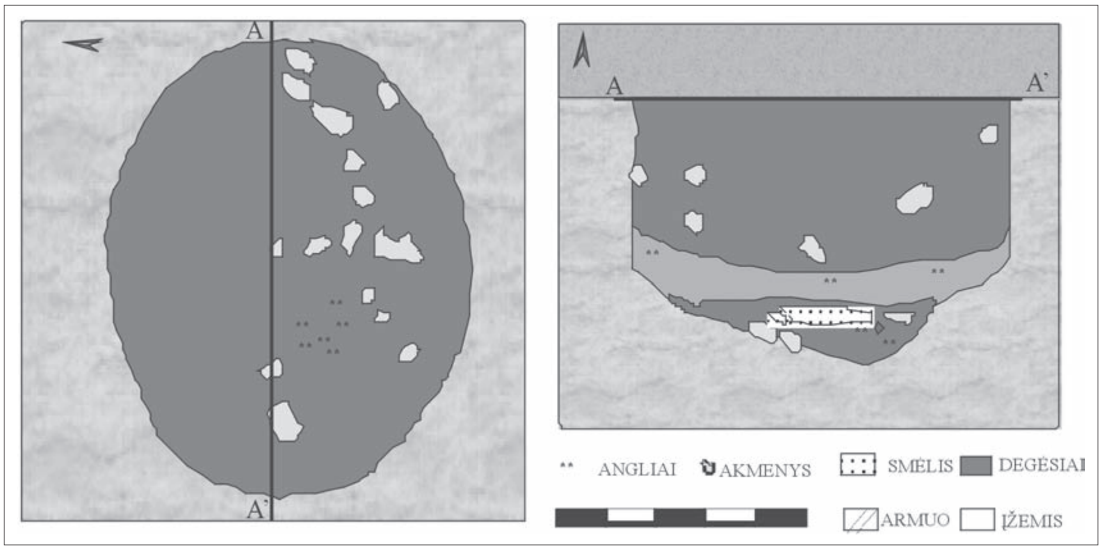

Fig. 5. Charcoal making pit at Lieporiai.

confirmed by laboratory analysis (Table 1). The other instance is the approximately one kilogram of roasted ore pieces that filled a small pit and were collected at the Varnupiai hill-fort. While this latter find has not yet been analysed in the laboratory, its appearance is analogous to the roasted ore of Lieporiai.

The making of charcoal

Charcoal is the only fuel that could have been used in Lithuania for smelting iron in a furnace. Its pieces and impressions are found in the pieces of dross found at the bottom of furnaces. Several ways for making the charcoal needed to smelt iron are mentioned in archaeological literature. These include making it in a closed pit (Stankus 1978, p.78; Gömöri 1999, p.149; Navasaitis 2003, p.33, Fig. 3.1), in a pile on the ground's surface underneath the turf or a layer of soil (Гурин 1982, p.24), or making it in the very same furnace (Espelund 1999, p.54). In describing the making of charcoal, Stankus does not present any references to archaeological finds, nor literature, nor ethnographic material (Stankus 1978, p.78). While excavating the centre of the Kereliai hill-fort's levelled summit, Grigalavičienė found a place with a circular structure, two rings of postholes, at the level of the hill-fort's earliest cultural layer (from the first millennium BC to the first centuries AD). The researcher stated that this was a structure with an economic function "since there had been an iron smelting furnace and two pits for making coal near the entrance" (Grigalavičienė 1986a, p.25). In a later publication, the author ascribed the iron smelting finds to the middle cultural level (second to fifth centuries AD), interpreting them somewhat differently. In her article about the Kereliai hill-fort, Grigalavičienė described two furnaces and a pit found in between them, designated for storing charcoal (Grigalavičienė 1992, p.96). Thus, we have no data about the making of charcoal from Kereliai.

There are finds that were called one thing at the time they were excavated, and interpreted in another way after special analyses. One example is the seven hearths found in the Aukštadvaris hill-fort foot settlement. They were situated in one line, at a distance of 0.5 to one metre from each other, somewhat irregularly round, ranging from 0.7 by 0.8 metres to one by 1.2 metres large, and 40 to 50 centimetres deep. Their pits' profile was semi-circular, somewhat narrowing toward the bottom, while thin layers of partially baked clay were found on the top. The hill-fort's researcher Daugudis did not establish the precise function of these hearths, but he thought that they were associated with metal smelting, even though he did not indicate what kind of metal it could be (Daugudis 1962, pp.55-56). Navasaitis disagrees with the opinion of this researcher, and believes that these hearths could have been charcoal making pits (Navasaitis 2003, p.37).

Three features were found in the Lieporiai settlement that were related to charcoal making (Salatkienė 2003, pp.8-9). One of them was a charcoal making pit that was 50 metres from the iron smeltery, on a small hill. There was no settlement cultural layer there, but a thin forest topsoil layer was observed underneath the tillage; it had formed on top of the hard, brown undisturbed clay bed. A somewhat oblong, approximately one-metre-diameter and one-metre-deep cylindrical pit with vertical walls was dug out for making the coal. It was entirely filled up with black, fire-stained soil, with occasional larger pieces of charcoal and rocks (Fig. 5). The pit consisted of two layers: the fire-stained soil that had accumulated at the bottom of the pit was covered with a five to ten-centimetre-thick layer of light mixed soil, while a second, approximately 80-centimetre-thick layer of fire-stained soil lay above it. About 0.8 cubic metres of charcoal could have been burnt down in such a pit at one time. In its size, shape and large amount of accumulated fire-stained soil, this pit is very reminiscent of charcoal roasting pits described in ethnographic literature (Laikūnas 1934, p.29-30). A similar, only somewhat larger charcoal roasting pit was found in Latvia, at the third to fifth-century Jaunlīve settlement. It was installed 40 metres from the furnace. The pit's diameter was three to 3.9 metres, and its depth was 2.5 metres from the current ground surface (Atgāzis 1994, pp.87-90).

The other two Lieporiai features are associated with the ground surface method of making charcoal. Two almost identical hearths were discovered in the western part of the iron smeltery, alongside each other, and separated by a distance of two metres. Both hearths were oblong and elliptical; one was 2.4 by 1.8 metres and the other 2.3 by 1.55 metres large. They both had flat and level bottoms and were five to ten centimetres deep (Fig.). Both had a very uniform layer of black, fire-stained soil and coal, and no other admixtures. The conclusion was drawn that poles and other wood were stacked in a pile in the hearth, the pile was covered with turf (that perhaps was stripped off from the place of the hearth, thus deepening the wood somewhat into the clay), and perhaps also dug over with soil, so that the wood could char.

New data about charcoal making in an iron smeltery was found in the Virbaliūnai (Kaunas district) settlement (Žalnierius *et al.* 2006). Nine furnaces, two charcoal making pits, and other finds were discovered in the Virbaliūnai iron smeltery. Both pits were found in the first furnace group. They were 80 by 98 centimetres and 125 by 120 centimetres large, with depths of 30 centimetres and 50 centimetres respectively. The pits were filled with fire-stained soil, and pieces of slag were found within them. Since the pits were only 2.25 metres from the furnace and full of fire-stained soil, the researchers drew the conclusion that their function was making charcoal (Žalnierius *et al*. 2006, pp.66, 69, 70-71).

One more charcoal roasting pit was found at the Žardė settlement's iron smeltery (Masiulienė 2007, pp.77-79). It was round with steep walls, two metres in diameter, 80 centimetres deep, and filled with dark, fire-stained soil that had accumulated mostly at the bottom. The researcher assumed that the pit was intended for making the charcoal necessary for iron smelting.

Such a method of making charcoal was used in ancient metallurgy in Belarus (Гурин 1982, p.24). Charcoal making pits very close to furnaces have been found in Germany, at the Late Roman Period smeltery in Wolkenberg (Spazier 2003, p.40). While this smeltery is incomparably larger (approximately 1,000 furnaces have been found and investigated here) and the charcoal pits are quadrangular and somewhat larger, what is important for us is that the charcoal made for smelting and the iron smelted were in the same place.

It is worth reminding the reader of the recently excavated charcoal roasting furnace of Žygmantiškiai, even though it is later (15th to 16th centuries) than the investigated archaeological sites in this work (Vėlius 2000). Charcoal was roasted on the ground's surface, in stacks, in Žygmantiškiai. The investigator states that it is known from historical sources that "in these places charcoal was already made in the 15th-16th centuries; it was used to extract iron from bog ore" (Vėlius 2000, p.391). Although in its area and work extent this roasting furnace is somewhat larger than prehistoric finds, apparently the occupation's earlier traditions and techniques were continued within it.

In summary, it must be noted that at this time in Lithuania, two methods for making charcoal are known from archaeological sources, in pits and in stacks. Only the investigations at the ancient settlement of Lieporiai have yielded reliable data regarding this research problem. The investigations at the Žygmantiškiai roasting furnace and ethnographic sources show that the mentioned methods for making charcoal also survived in historical times, although roasting pits survived longer.

Conclusions

1. Iron metallurgy research includes iron smelting equipment, tools and manufactured products.

2. Iron metallurgy information sources consist of archaeological finds stored in museum collections and research documentation, as well as reference and scientific publications.

3. More than 200 iron metallurgy find sites are known at this time in Lithuania, 40 of which have provided valuable new data about iron metallurgy and its equipment.

4. All of the iron metallurgy find sites are associated with places that have been inhabited; not one has been found which could solely be considered a place of production.

5. Iron ore has been found in Baitai, Lieporiai, Norkūnai, Lavoriškės, Krūminiai and Varnupiai, while hydrated ore mining pits survived at Lieporiai, and it

was established that an open mining method was used to extract ore there.

6. Iron ore was washed with well water on wooden flooring and the water was poured using linden bark buckets (Lieporiai).

7. The ore was roasted in open fires, in shallow pits (Lieporiai, Žardė).

8. Flat rocks and ground stone were used for crushing and grinding the ore.

9. Charcoal was made in pits (Lieporiai, Virbaliūnai, Žardė) and stacks (Lieporiai, Žygmantiškiai).

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Birutė Salatkienė
Faculty of Humanities History Department
Šiauliai University
P. Višinskio g. 38
LT-76285 Šiauliai
LITHUANIA
puniskyte@gmail.com

GELEŽIES METALURGIJA LIETUVOS TERITORIJOJE. ARCHEOLOGINIŲ DIRBINIŲ ANALIZĖ

Birutė Salatkienė

Santrauka

Pirmieji duomenys apie geležies metalurgijos radinius Lietuvoje žinomi iš XX a. pirmosios pusės, o pokario metais tyrimai buvo išplėtoti. Geriausiai ištyrinėtas geležies panaudojimas – dirbiniai ir jų tipai, kalvystė, jos technologijos bei raida, o geležies išgavimo ir pirminio apdorojimo etapas pažįstamas menkiau. Pastarųjų dešimtmečių archeologiniai tyrimai Kerelių (Kupiškio raj.) piliakalnyje, Lieporių (Šiauliai), Kernavės (Širvintų raj.), Bakšių (Alytaus raj.), Žardės (Klaipėda), Virbaliūnų (Kauno raj.) gyvenvietėse, Lazdininkų (Kretingos raj.) kapinyne suteikė daug naujų duomenų geležies lydymo verslui tirti ir sudarė galimybę plačiau ir giliau išnagrinėti geležies metalurgijos Lietuvos teritorijoje problemą.

Šio straipsnio tikslas yra apibrėžti bei pagrįsti geležies metalurgijos tyrimų objektą, jo struktūrą, aptarti tyrimų šaltinius ir išanalizuoti iki šiol Lietuvoje sukauptus geležies metalurgijos archeologinius radinius bei kitus duomenis, juos sisteminti ir tipologizuoti, sujungti į vieną sistemą pagal geležies metalurgijos technologinės eigos etapus. Tyrimų objektas – archeologinės vietos su geležies metalurgijos radiniais, visų tipų archeologiniai radiniai, susiję su geležies metalurgija ir apimantys visus šio verslo etapus (objektai, dirbiniai, gamybos produktai ir atliekos, medžiagos), taip pat geležies metalurgijos objektų bei radinių sistema. Analizuojant archeologinius radinius laikomasi tos pačios tvarkos kaip ir lydant geležį – aptariama žaliava, jos paieškos ir paruošimas, kuras ir jo paruošimas, geležies lydymo įranga ir įrankiai, kritė ir jos apdorojimas. Analizuojami parengiamojo geležies lydymo etapo – rūdos, jos išgavimo, plovimo bei degimo ir medžio anglies degimo radiniai, apžvelgiamas geležies lydymas, jo įranga, produktai ir gamybos atliekos.

Iki šiol archeologai turi labai mažai tiesioginių žinių apie rūdynus ir jų eksploatavimą Lietuvoje. Archeologiniai geležies rūdos radiniai siejami tik su gyvenvietėmis ar laidojimo paminklais. Rūdos rasta Baituose, Lieporiuose, Norkūnuose, Lavoriškėse, Krūminiuose, Varnupių piliakalnio aikštelėje. Šiuo metu patikimų archeologinių duomenų apie geležies rūdos telkinį ir jo eksploatavimą turime tik iš Lieporių 1-osios gy-

venvietės. Mūsų krašte geležies rūda randama žemės paviršiuje, dirvožemyje, sluoksniais po velėna, pelkėse, upelių ir ežerų pakrantėse, todėl visur ji turėjo būti kasama, renkama ar kitaip išgaunama atviru būdu, tačiau tik Lieporiuose buvo atrasta rūdos kasimo duobių. Šiuo metu visai nėra archeologiniais radiniais patvirtintų žinių apie rūdos kasimo įrankius, kitą įrangą ir transportavimą. Lieporių gyvenvietės tyrinėjimai parodė, kad Lietuvoje buvo žinomas rūdos plovimas ne tik gamtiniuose vandens telkiniuose, bet ir šulinių vandeniu. Šis būdas reikalavo didelio įrenginių komplekso, kurį sudarė šuliniai su kibirėliais, klojinys ir kūdra nuoplovoms subėgti. Rūdos degimas yra tolesnis jos paruošimo lydymui etapas. Archeologinių duomenų apie rūdos degimą nėra daug. Iki šiol nežinoma, kur daugiausia rūda būdavo degama – rūdyne, plovimo ar lydymo vietoje. Tyrinėtojai nurodo rudnelių aplinkoje buvus židinius, kai kuriuose randama šlako. Patikimų duomenų apie rūdos degimą atviruose laužuose turime iš Lieporių, kur aptikta keletas seklių duobių, kurių turinys išsiskyrė degėsių bei angliukų gausa ir rūdžių priemaišomis bei negausiais apdegusios rūdos gabaliukais. Naujos informacijos apie geležies rūdos degimą duobėje suteikė Žardės gyvenviečių komplekso tyrimai, kur aptikta duobė, užsipildžiusi tamsiu, perdegusiu smėliu bei akmenimis ir degtos geležies rūdos gabalais. Panašių rasta Latvijoje, Salaspilio Spietinių gyvenvietėje, ir Vengrijoje.

Degama rūda sukempa į didesnius ar mažesnius gabalus, todėl ir po degimo ji dar gali būti smulkinama. Geležies lydymo vietų aprašymuose (Bakšiai, Žasliai, Šereitlaukis, Šatrija, Imbarė) paminėti akmeniniai trintuvai, gludinti akmenys, kurie rasti rudnelių aplinkoje ar kartu su šlako gabalais, todėl galima padaryti prielaidą, jog jie naudoti ir rūdai smulkinti. Lieporių geležies lydykloje rasta keletas dirbinių, kurie gali būti įvardyti kaip rūdos smulkinimo įrankiai – apgludinti plokšti akmenys ir akmeniniai trintuvai. Panašus rūdos smulkinimo būdas buvo žinomas ir Vengrijoje.

Medžio anglis yra vienintelis kuras, kuris mūsų krašte galėjo būti naudojamas geležies lydymui rudnelėje. Jos gabaliukų ir atspaudų randama rudnelės dugno gargažės gabaluose. Žinoma keletas medžio anglies, reikalingos geležiai lydyti, degimo būdų. Tai degimas uždaroje duobėje, krūvoje ant žemės paviršiaus po velėnos ar žemių sluoksniu ir degimas toje pačioje rudnelėje. E. Grigalavičienė Kerelių piliakalnyje aptiko dvi rudneles ir tarp jų duobę, skirtą medžio anglims kaupti. Lieporių gyvenvietėje buvo aptikti trys objektai, sietini su medžio anglies degimu – tai anglies degimo duobė ir du elipsės formos židiniai. Naujų duomenų apie anglies degimą geležies lydykloje aptikta Virbaliūnų gyvenvietėje, kur rastos 9 rudnelės, dvi anglių degimo duobės ir kitų radinių. Duobės buvo užpildytos degėsiais, juose aptikta šlako gabalų. Dar viena anglies degimo duobė rasta Žardės gyvenvietės geležies lydykloje. Medžio anglies degimo duobėje radinių buvo aptikta Latvijoje, Jaunlyvės III–V a. gyvenvietėje. Anglies degimas židiniuose senovės metalurgų naudotas Baltarusijoje, Vokietijoje, Volkenberg vėlyvojo romėniškojo laikotarpio lydykloje.