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Technological Characteristics of the Iron Items from the Early Iron Age and the Middle Ages (Based on the Materials from the Moscow Region Settlements)

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Abstract

The paper reviews the metallographic study of iron items from two sites in the Moscow region: Nastasyino, a fortified settlement of the Early Iron Age (Dyakovo culture), and a medieval unfortified village of Nastasyino from the Ancient Rus period. Iron items from the Nastasyino fortified settlement were made using all technological schemes known in the Early Iron Age. Medieval iron items is an example of more technologically advanced blacksmithing. Comparison of the Dyakovo iron items and the iron items from the Ancient Rus period demonstrates not only quantitative but also qualitative changes. Based on the analytical data, it is concluded that technological characteristics of a specific assemblage of iron artifacts can serve as an important indicator describing the level of social and economic development of a particular society.

Keywords: Fortified settlement of Nastasyino, Dyakovo culture; Middle Ages, Archaeometallography, Iron items, Blacksmithing, Technological schemes

Introduction

In 1999–2000 the excavations conducted in the vicinity of Nastasyino which is a village near Moscow revealed a fascinating archaeological site bearing the same name of Nastasyino (Figure 1). The distinguishing feature of this site is presence of two cultural and chronological horizons: a horizon dating to the Early Iron Age (Dyakovo culture, 6th century BC-2nd century AD) and the medieval period (Ancient Rus, 14th-15th centuries). Typologically, these sites are different, in the Early Iron Age it was a fortified settlement whereas in the Ancient Rus period it was an unfortified village.

The site is located 200 m north of the village of Nastasyino (Kolomna urban district, Moscow region) on the left bank of the Severka river which is a tributary of the Moskva river. The excavated area is 3634 m^2 (the excavations were led by A.V. Engovatova). The excavations revealed numerous archaeological artifacts characterizing material culture of the local population that lived in this place in different chronological periods. Employment of various scientific methods (palynology, archaeozoology, archaeobotany, and metallography) offers an opportunity to reconstruct activities carried out by its population.

According to the palynographic data, climatic conditions of these two chronologically different settlements did not differ significantly [1,2]. At the same time, differences in the economic

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systems were dramatic. In the Dyakovo period the main economic activity was animal husbandry, with agriculture being a supportive sector [3], whereas in the Middle Ages it was agriculture that played a key role [4]. Possible differences in production activity, in particular, blacksmithing, are of great interest (Figure 1).

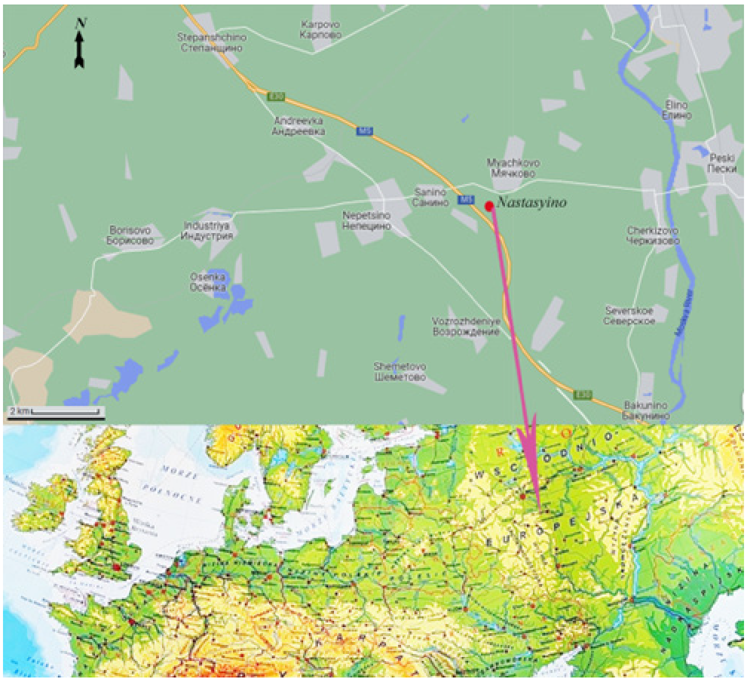

Figure 1: Location map of settlement Nastasyino (made by V.I. Zavyalov).

Unfortunately, there are no traces of local iron production in the archaeological record at Nastasyino either in the Early Iron Age or the medieval period. However, the study of iron items using a metallographic method offers an opportunity to determine the development level and explore technological characteristics of blacksmithing in each of the specified periods rather objectively.

When people learned to use iron, ferrous metallurgy and metalworking that provide main tools for other sectors of economy became main production factors in societal development. At the same time, the level of production development directly depends on knowledge and production skills of a smith. Ancient artifacts can provide clues about these factors and it is the task of researchers to retrieve this information. In most cases, archaeology deals with the end product of the metallurgical process, i.e. with what was produced. However, to describe production, the question to answer is how it was produced. In that respect, possibilities of traditional archaeological methods are very limited. Metal items can be considered to be a valid historical source only if comprehensive analytical methods of research (in particular, metallographic methods) are applied to study them.

In this context, of great interest is the study of the level of blacksmithing development in societies that lived in similar natural and geographic conditions but were at different levels of social and economic development. The conclusion seems obvious: in Ancient Rus the level of ironworking development will be higher than in the Early Iron Age. But how do such differences in iron item production manifest themselves? It is this question that we will try to answer.

Materials and Methods

Archaeometallographic analysis is the main method for examining iron items. The analyzes were carried out at the Laboratory of Natural Sciences of the Institute of Archeology of RAS. The traditional archaeological approach to the study of metal artefacts has some restrictions. It does not allow to reveal the information about the techniques of their manufacturing, i.e. about the knowledge and skills of the craftsman and, ultimately, about the craft production of a given society. The introduction of metallographic methods in archaeology permitted to obtain such information. The basis of the archaeometallographic method is the identification of the process used for the object's manufacturing, which shows the nature of the raw material used and the sequence of technical operations. The generalization of results of the conducted research allows to create a historical and a technological concept that sheds light on socio-economic questions. This way, metal artifacts become a full-fledged historical source. In this regard, items from the sites of Ancient Rus' [5,6] have demonstrated a significant potential of the method of archaeological metallography.

A standard procedure was used for archaeometallographic analysis. The examined samples were cut out from the cutting edges of knives or from other functional parts of the objects. The samples were then mounted into Wood' alloy (Sn-12.5%, Pb-25%, Cd-12.5%, Bi-0%), grinded and then polished with chromium oxide. The microstructures of iron objects were determined with an MMR-2R optical microscope at magnifications of 150x and 490x, after etching the polished sample with Nital reagent (3% solution of HNO3 in ethyl alcohol). The size of the grains was evaluated according the Russian state standard (GOST R ISO 643-2011)[1]. Microhardness was measured on a microhardness machine PMT-3 with a diamond pyramidal indenter with 100 g load. The measurement of hardness of ferrite grains was used to identify objects with high content of phosphorus[2], as was performed in the studies by J. Piaskowski [7], Ä. Thiele and J. Hosek [8], M.F. Gurin [9], L.S. Rozanova [10] and others.

The assemblage of Early Iron Age items analyzed using the metallographic method consists of 39 items, including 20 knives, a sickle, a socketed axe and 17 arrowheads. Given that the spread of iron industry in the forest belt of eastern Europe did not begin until the 3rd century BC [11], the assemblage from the Nastasyino fortified settlement can be dated to the 3rd century BC–2nd century AD.

The medieval assemblage of the iron items from Nastasyino which was examined by metallographic analysis is composed mostly of knives (40 items). This assemblage also includes two agricultural implements–a sickle and a scythe (Table 1).

Table: Distribution of technological schemes for the manufacture of knives by chronological periods.

	From ferritic iron	From heterogeneously carburized steel	From pass-through cementation steel	Cementation of the blade	piling of iron and steel bands	Welding-on	Welding-in	Total
Early Iron Age								
Knives	6	4		2	2	5	1	20
Sickle		1						1
Socketed axe						1		1
Arrowheads	7	9	1					17
Total	13	14	1	2	2	6	1	39
Medieval Age								
Knives	4	9	2	6	4	14	1	40
Sickle		1						1
Scythe				1				1
Total	4	10	2	7	4	14	1	42

Results and Discussion

As has been demonstrated by multiple studies, from the technological point of view, knives are of special interest because the entire known set of various technological schemes has been used in making this general purpose tool.

Results of the study of the Early Iron Age iron items

A considerable part of the examined knives that can be classified into various types were ascribed to a typological group of sickle-shaped knives typical for an early development stage of Dyakovo ironworking (the period from the 4th-3rd centuries BC to the 2nd -3rd centuries AD) [12]. One knife was classified as a tool with an elevated (hump) back. According to K.A. Smirnov, such knives should be dated to the end of the first millennium BC–5th century AD [13].

Six technological schemes were applied to make Dyakovo knives[3].

Four knives were forged from ferritic iron, with no additional operations to improve their performance used (Figure. 2, an. 10563). Judging by a large ferrite grain and a high microhardness value (221-236 HV0.1), one knife was forged from phosphoric iron.

Five knives were made from heterogeneously carburized steel (Figure. 2, an. 10561). Because of carbon contents, quality characteristics of this group of tools were improved by heat treatment. Metastable structures were identified in four tools. Three tools were quenched to martensitic structure and ferritic-martensitic structure while one knife was tempered after quenching (sorbitic perlite structure). The carbon contents on the sections that were not quenched do not exceed 0.2-0.3%. The microhardness value of the metastable structures is 221-383 HV0.1. It should be noted that the knives made from heterogeneously carburized steel were better forged than the ferritic iron knives.

[1] GOST R ISO 643-2011 is The State standard of Russian Federation.
[2] Phosphoric iron was determined based on the ferrite grain size (coarse grain), the presence of ghost structure and the high microhardness of the ferrite (above 206 HV0,1).

[3] A technological scheme means a set of blacksmithing actions and operations performed to make an artifact. Technical quality of one knife is high.

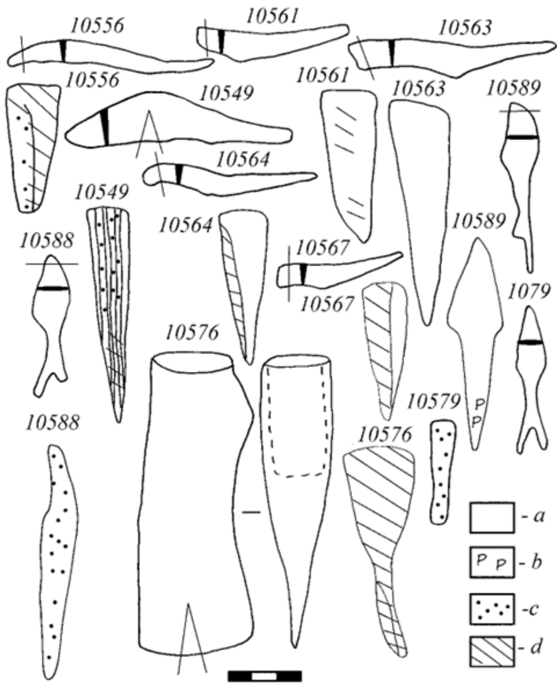

Figure 2: Technological scheme of iron articles from Nastasyino (Early Iron Age). Keys: a – ferritic iron; b - phosphoric iron; c – steel; d – tempered steel (made by V.I. Zavyalov).

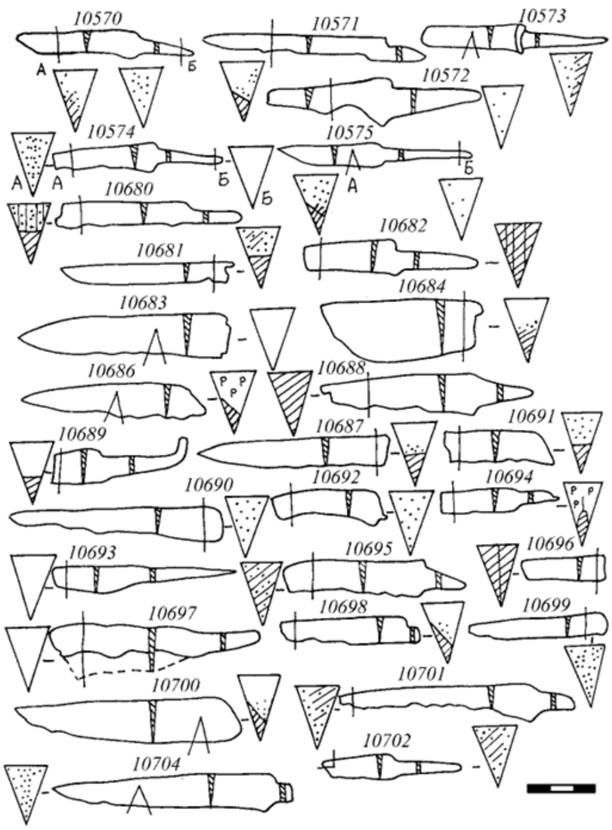

Figure 3: Technological scheme of iron articles from Nastasyino (Medieval Age). Keys see in the figure 2 (made by V.I. Zavyalov).

Technical quality of one knife is high. The metallographic analysis found that the item had been made from pass-through cementation steel with high carbon contents (0.7-0.8%C) which was carefully forged. Most likely, this tool was imported or was made from imported material.

Five tools were made by piling low carbon steel and ferritic iron bands. One tool was probably manufactured from a blank made intentionally from alternating bands of iron and heterogeneously carburized steel (Figure. 2, an. 10549). Visible weld lines between the two irons around 0.025 mm wide run parallel to each other. All other samples display chaotically placed weld lines, which means that scrap metal was used to make blanks for these tools. Three items from this group were rapidly quenched. The microhardness value of martensite is 274-383 HV0.1.

The technological scheme of welding two bands (iron and steel) was recorded in four knives (Figure. 2, an. 10567). All these knives refer to the group of sickle-shaped knives, i.e. the earliest items of the Dyakovo type. Welding in all tools from this group was not to high quality standards. The three knives had martensitic structure.

Another welding type is represented by a butt-welding scheme. It was identified in a sickle-shaped knife (Figure. 2, an. 10556, 10564). The structures of the iron base and the welded blade are practically identical, it is martensite plus ferrite. It means that heterogeneously carburized steel was used to make both the iron base and the blade. The weld line looks like a very thick white band. Possibly, the blade was better forged and because of quenching it had a higher microhardness value than the iron base.

The socketed axe was forged from heterogeneously carburized steel. A blade, also made from heterogeneously carburized steel, was welded onto the iron base. Quenching was the final operation (Figure. 2, an. 10576). The socket of the axe was not heat treated.

The sickle was made from heterogeneously carburized steel. The carbon contents in specific sections vary from 0.2-0.3%C to 0.6-0.7%C.

All 16 arrowheads included in the metallographic analysis belong to a type of lance-shaped arrowheads with a semilunar shaft end (dovetail shape). Six items were forged from ferritic iron (Figure 2, an. 10589), ten arrowheads were made from heterogeneously carburized steel (Figure. 2, an. 10579, 10588). No additional operations to improve their performance were carried out.

Results of the study of the medieval iron items

Seven technological schemes were applied in making Ancient Rus knives. The ferrite structure was identified in four artifacts. The blade is missing on all four knives (Figure. 3, an. 10693, 10697). Therefore, it cannot be excluded that technical properties of these items were improved by applying additional techniques (such as steel blade welding-on or cementation). One knife was made from phosphoric iron (the microhardness value is 254-297 HV0.1 . Figure 3. Technological scheme of iron articles from Nastasyino (Medieval Age). Keys see in the Figure 2 (made by V.I. Zavyalov).

Nine knives were forged from heterogeneously carburized steel (Figure. 3, an. 10574, 10690, 10699). The carbon contents vary from 0.1 to 0.6%. Four knives preserved traces of heat treatment, they were hardened by heating and then quenched to form martensite (Figure. 3, an. 10695, 10701, 10702). The microhardness value of martensite is 350-572 HV0.1.

Two tools were forged from pass-through cementation steel. One knife has a plate tang to which a handle was attached by rivets. The tang of another tool is awl-shaped, it could be driven into a wooden or bone handle (fig. 3, an. 10688). Both knives were made from hardened martensitic steel (the microhardness value is 420-642 HV0.1).

The cementation of the blade was identified in six samples (Figure. 3, an. 10570, 10573, 10684). The microhardness value of the ferritic plus pearlite structures is 143-206 HV0.1. Quenching was the final operation for all samples (martensite and martensite plus troostite structures, the microhardness value is 274-642 HV0.1).

Four tools were forged by piling low carbon steel and ferritic iron bands (Figure. 3, an. 10682, 10696). Two or several steel bands welded together were then used as a blank for these tools. Possibly, scrap metal was used in their manufacturing. All blades were quenched (the hardness value of martensite is 383-642 HV0.1).

The analysis revealed that a technological scheme of butt-welding was used to produce seven tools (fig. 3, an. 10680, 10681, 10687, 10689, 10691). In this case the iron base and the steel blade were placed end-to-end and then welded along the joint. All blades were made from hardened martensitic steel (the microhardness value is 420-572 HV0.1).

Seven more tools were made by scarf-welding when a steel blade is welded onto the iron base (Figure. 3, an. 10571, 10575, 10683, 10698, 10700). Two knives referred to this group had a plate tang. All knives were made from hardened martensitic steel. The blade steel has relatively high contents of carbon, the hardness value of martensite varies from 420 to 946 HV0.1. The blade of one knife was forged from phosphoric iron (the microhardness value of ferrite is 221-275 HV0.1).

One knife was made using a welding-in technology when a steel blade is welded into an iron base. The tool was quenched and then tempered (the martensite plus sorbite structure). The iron base of the knife was forged from phosphoric iron (the microhardness value of ferrite is 254-322 HV0.1). It should be noted that the welding-in technology was typical for Ancient Rus blacksmithing in earlier centuries, i.e. in the 10th-12th centuries. It is possible that the knife in question dates to this period and, due to some circumstances, was preserved in the layers of the 14th–15th centuries.

The sickle was forged from heterogeneously carburized steel. The carbon contents vary from 0.1 to 0.8%. The structure is dendritic. The microhardness value of ferrite is 254-297 HV0.1. The hardness value indicates the use of phosphoric iron. The sickle was not heat treated.

The scythe was forged from ordinary iron (the microhardness value of ferrite is 110-116 HV0.1). One side of the artifact was subjected to a cementation process and then quenched to form martensite (the microhardness value of the blade is 322 HV0.1).

Discussion

The following conclusions can be made based on the metallographic analyses of the Nastasyino items dating to the Early Iron Age. These items were made from iron and heterogeneously carburized steel. Pass-through cementation steel identified in a poorly preserved knife fragment was used only once. Dating this item to a later (Ancient Rus?) period cannot be excluded.

Quality of metal treatment was not good, both iron and heterogeneously carburized steel have small and large slag inclusions. Weld lines are wide, and often have non-metallic inclusions. Smiths had a rather poor idea of differences between iron and steel properties; in several cases technological welding of homogeneous materials was recorded. Rapid quenching (to form martensite) was the main method of heat treatment.

All technological schemes known in the Dyakovo time were applied in making iron items from the Nastasyino fortified settlement [14-16]. Percentage shares of the iron items made by particular technological schemes are provided in Table 1. Interestingly, the percentage share of the items made using technological welding is rather high, though, on the whole, it is not typical for the Dyakovo items of that period.

Extensive metallographic studies of the Dyakovo metal items conducted by G.A. Voznesenskaya and L.S. Rozanova (Khomutova) provided convincing evidence that two metalworking centers coexisted at an early Dyakovo stage, one center achieved a high level of blacksmithing (application of technological welding, Troitskoye fortified settlement) while the other center used simpler blacksmithing techniques (forging items from all-steel blanks, Sherbinksoye, Borsheva, Kuznechiki fortified settlements), such coexistence of two metalworking centers is a distinctive feature of ironworking development at the Dyakovo sites [15 ,12]. The results of the metallographic study show that, regarding their technical and technological characteristics, the iron items from the Nastasyino fortified settlement are closest to the items from Troitskoye. However, quality of metal treatment and some operations performed to make the Nastasyino iron items is substantially lower. As noted by G.A. Voznesenskaya, iron and steel used to make the items retrieved from the lower layer at the Troitskoye fortified settlement, 'are of good quality, metal is small-grained and has almost all slags removed, the ferrite hardness value is higher while steel is evenly carburized…. Blacksmiths were proficient in such technological operations as iron and steel welding, welding thin steel blades on the iron base of a knife or a sickle and heat treatment' [14]. Subsequently, in the middle of the first millennium AD this knowledge was disseminated across the entire Dyakovo area.

The medieval iron items demonstrate more technologically advanced blacksmithing techniques. In Ancient Rus blacksmiths used various types of raw materials such as ordinary and phosphoric iron, heterogeneously carburized steel and pass-through cementation steel. The set of technological schemes applied was varied. At the same time we cannot say that an item of a particular shape was produced using a specific technological scheme. For example, knives with a plate tang were forged from both heterogeneously carburized steel and pass-through cementation steel, and could be made by using butt-welding or scarf-welding.

Quality of smithing operations, in particular, welding, is good, the items do not exhibit any traces of overheating or metal burning. Weld lines are thin and have no slag inclusions, welding was performed using an appropriate temperature regime.

Conclusion

This paper is a review of technological characteristics of iron item production at the Early Iron Age and medieval sites. The results obtained show that in both cases the technological data fit into the historical and technological context of iron industry development in eastern Europe.

No ironworking traces in the archaeological record at Nastasyino of the Dyakovo period imply that iron items were imported from a center of crafts with a level of development close to that at Troitskoye. It is quite possible that it is the Nastasyino artifacts that reflected an early stage of more advanced ironworking technology dissemination in the Dyakovo environment.

It can be inferred from the metallographic studies of the Nastasyino settlement of the Ancient Rus period that, most likely, the items analyzed were produced by skilled, presumably, urban smiths proficient in blacksmithing techniques. At the same time, a rather high share of the items forged from heterogeneously carburized steel (around one quarter of all examined items) and the items fabricated using cementation (more than 15%)[4] in the studied assemblage demonstrates that a substantial portion of the products was supplied to the Nastasyino population from a rural production center.

According to the results of this study, technological characteristics of a specific assemblage of iron artifacts can serve as an important indicator describing the level of social and economic development of a particular society.

Acknowledgement

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Conflict of Interest

No Conflict of interest.

[4] It should be noted that a significant percentage share of the items made from heterogeneously carburized steel along with a rather high percentage share of the items made from pass-through cementation steel (within 12-15%) is a distinctive feature of rural blacksmithing (Zavyalov, Terekhova, 2021).

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