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ETHNOARCHAEOLOGICAL RESEARCH ON INDIGENOUS IRON SMELTING IN SIBERIA*

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Abstract. The article presents an ethnoarchaeological study of iron smelting as practiced by the indigenous population of Siberia. The relevance of it is accounted for by the fact that archaeological (pre-written) and ethnographic (written) data demonstrate continuous development of traditional iron metallurgy in the region since the early first millennium A.D. up until the early 20th century. Author suggests that thanks to the common physical and chemical processes involved ethnographic descriptions of iron production can help us reconstruct iron smelting practices used even further back in time.

The undertaken research yielded the following results. Firstly, Siberian iron smelters used different types of iron ore together and the choice of ore depended on the quality of iron required. Secondly, ethnoarchaeological data revealed that they also had different types of blacksmith's bellows at their disposal. Thirdly, the Siberian climate with its changing summer and winter seasons, as well as the quantity of iron needed, had an impact on the types of iron smelting furnaces developed within the same culture. Finally, the 18th to the 20th century written data indicate certain similarities in iron smelting technologies applied in different Siberian cultures, and that seems to constitute a basis reliable enough for reconstructing ancient technologies of the pre-literary era.

Keywords: ethnoarchaeology, ethnography, iron smelting, Siberia

Introduction

Ethnoarchaeological research on iron metallurgy in indigenous peoples of Eurasia and Africa is of great importance for the reconstruction of ancient iron smelting technologies. Archaeological evidence by itself cannot give a comprehensive picture of the past. As Michael Pearson put it, "archaeologists can study incomplete systems of material culture communication (which itself is fragmentary since it is all that is left of a fuller system of verbal and non-verbal communication) since the relationships and associations embodied by material culture can be reconstructed into a system of re-

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lationships between signifiers" (Pearson 1982: 100). Studying "living" ethnographic reality can provide us with the answers to archaeological questions, help us build "bridges" and make the connections between scattered archaeological sources available.

The study of iron smelting and blacksmithing occupies a special place in ethnoarchaeology (Lane 2006: 412). In some cases, ethnoarchaeological models of iron smelting present in "living" cultures can be extrapolated to older times, especially when it comes to Siberia where traditional cultures continue to exist and there is archaeological (pre-written) and ethnographic (written) data available that demonstrate continuous development of iron metallurgy here since the early first millennium A.D. up until today.

Despite the wealth and uniqueness of the ethnographic data on traditional Siberian metallurgy, nearly all research on this theme is only available in Russian and is inaccessible to the wider international scientific community. Moreover, no comprehensive ethnoarchaeological studies have been conducted on each stage of the iron making cycle (from iron ore extraction to finished iron production) practiced by various Siberian iron smelters. It is also worth admitting that so far iron metallurgy in traditional cultures has been best studied in Africa (Ackerman et al. 1999; Haaland, Haaland 2000; Haaland 2004).

Thus, the present article aims to collect and summarise written data describing each stage of iron production in different Siberian peoples. It draws on sources such as ethnographic descriptions of smelting procedures made by scholars and travellers throughout the 18^{th} to the 20^{th} centuries, drawings by artists who had accompanied expeditions to the indigenous peoples of Siberia, and historical documents. It particularly focuses on technological characteristics of indigenous iron production.

Unfortunately, due to the limited volume of the article, the sacred and symbolic aspects of traditional iron smelting and ritual practices associated with this process are not discussed here. These have been studied thoroughly by Russian ethnographers and archaeologists (Popov 1933; Belikova 2010).

Mining and Preparation of Iron Ore

Mining and preparation of iron ore as practiced by the *Yakut people* in the late 19^{th} to the early 20^{th} centuries are described in great detail (Strelov 1928; Seroshevskiy 1993: 368). The *Yakuts* extracted ore in two ways: either from small pits or from natural outcrops. However, what they preferred was the open ore mining method whereby they would search for "iron stones" on the banks of rivers and on the slopes of river terraces. The search was carried out by both adult men and children. For example, a *Yakut* old man named Kapiton is known to have repeatedly sent his young grandchildren to look for iron ore on the banks of the Aldan River in the late 19^{th} century, and they would find the ore rich in iron and easy to smelt in simple Yakut furnaces (Seroshevskiy 1993: 385).

When the *Yakut* smelters found ore in small pits, they would leave it in heaps nearby for the winter. In the spring, the ore would be taken to furnaces where it was kindled in fireplaces, cleaned of stones and soil, pushed into powder, and sifted using special sieves with fine wires (Strelov 1928: 53; Seroshevskiy 1993: 368). The smelters would then ground the ore into powder in a special wooden trough with the help of a wooden mortar (Strelov 1928: 55).

The *Kondoma Tatars* (a people inhabiting the Tom River basin in the south of today's Kemerovo region in Siberia) also found iron ore in the 18th century in either outcrops on river banks or in swamps under the turf (Georgi 1776: 168). In his work, Johann G. Gmelin mentioned the fact that the *Tatars* living on the banks of the rivers of Kondoma and Mras-Su extracted iron ore from beneath the turf and, like the *Yakut people,* finely ground it before smelting (Gmelin 2003: 102–104) – a method similar to the one described by Gerhard F. Müller. In his field diary of 1734, Müller reported that the *Tatars* on the Kondoma River smelted iron into small pieces of wrought iron lumps but first they had to dig for the ore using iron hoes (Elert 1999: 43).

Some useful information on ore processing methods applied by the *Tatars* referred to by Gmelin and Müller is also contained in the Charter of Tsar Mikhail Fedorovich Romanov dated 11 September 1623. The Charter states that not far from Kuznetsk, on the rivers of Kondoma and Mras-Su, the *Kuznetsk Tatars* collected iron ore, kindled it using firewood, then crushed it with hammers and sieved it, and afterwards gradually placed it into furnace (Spasskiy 1819: 141). This tradition had been kept by the *Shor people* (a people inhabiting the Tom River basin in the south of today's Kemerovo region, Siberia) until the first half of the 20th century (Sunchugashev 1979: 157).

The Siberian smelters worked with several types of iron ore. In the first third of the 20th century *old Tubalar men* (inhabiting the north of today's Republic of Altai) told that in the past smelters had mined iron from different mountains. Certain types of ore had then produced soft malleable steel, whereas others had given brittle steel (Potapov 1933: 28). The *Yakut* metallurgists were familiar with *bog* ores located not very deep underground and with *siderite* ores which were extracted from outcrops on river banks. The smelters were very well aware of the fact that different ores produce iron of different quality and with different properties. Some ores were used to make knives, some – for nails, and others – for axes (Struminskiy 1948). At one point the smelters would get soft iron, and at some other point – high quality steel, but more often they got a mixture of both, that is, a flexible steel that could yet be hardened. The *Yakuts* valued this steel above all others, and for this reason they preferred to mine *siderite* ores on the banks of rivers (Seroshevskiy 1993: 368).

I believe that when doing archaeological research and trying to identify what raw materials were relied on in ancient metallurgy, the fact that the indigenous peoples of Siberia knew and used different types of ore should be taken into consideration as these ores leave slags different in their chemical composition. Moreover, different slags found in ancient settlements can serve as a marker of not only what technologies were used but also of what sources of ore there were. Also, one cannot exclude the possibility that ancient metallurgists could experiment and mix *different* ores in *one* furnace, thus seeking to make steel of higher quality. Such “experiments” would yield a specific group of slags different from all the others in their chemical composition.

Written ethnographic sources show that iron ore deposits of Siberia influenced the way the smelters settled. At the turn of the 19^{th} to the 20^{th} centuries, the *Yakut* metallurgists preferred to live in close proximity to iron ore outcrops (Strelov 1928: 55; Seroshevskiy 1993: 368). It was a common phenomenon to transport ore over the distance of 10 to 15 km away from the ore deposit to the settlement where furnaces and blacksmith workshops were located. For example, a *Yakut* smelter named Savin lived in the early 20^{th} century near the Shestakovskoe ore deposit but had to travel for ore to the mouth of the Tostur River, that is, 12 km away from home. He himself explained that was needed due to the low quality of ore available in the Shestakovskoe deposit (Strelov 1928: 58). In 1842, the *Altaians* told that blacksmiths mined ore for iron smelting near those settlements where their workshops were (Rosen 1983: 32–33). The same was true of the *Tatars* that lived in the Upper Tom region in the 17^{th} to the 18^{th} centuries (Spasskiy 1819: 141; Gmelin 2003: 102–104).

This link between settlements and ore deposits can also be traced through archaeological data of medieval metallurgy. The mapping of ore occurrences and medieval archaeological sites of black metallurgy in the Upper Ob region (in the south of Western Siberia) revealed a collection of workshops all located no further than 15 km away from ore deposits (Vodyasov 2015; Vodyasov, Zaitceva 2015: 474–475; Vodyasov, Zaitceva 2017). The average distance between the iron metallurgy sites and mineral and raw materials sources there ranged from 6 to 10 km. The same situation existed in the neighbouring territories and is characteristic of ancient metallurgy in Gornyy Altai (Zinyakov 1988: 201, 210, fig. 1, 10). In the Sayan-Altai mountainous region, there are numerous ore deposits rich in iron. This is why metallurgists of the Turkic Khaganates in the second half of the first millennium A.D. settled either directly at the mining sites here or nearby (Kyzlasov 1997: 27). The same is true of Khakassia where medieval furnaces were often built at the distance of 5 to 9 km away from ore deposits (Sunchugashev 1979: 52–54).

Charcoal Making

Metallurgists apparently burnt coal in one of the two ways characteristic of many Siberian peoples: the "heap" one (in Russian: *kuchnyy*) or the "pit" one (in Russian: *yamnyy*). The *Yakuts* are known to have used light and soft charcoal with a lot of charred wood. They produced charcoal by burning wood placed in a special cage in the open air and then extinguishing the fire with water (Seroshevskiy 1993: 370). Afterwards the *Yakuts* sifted the charcoal, selecting pieces of different size for smelting: from finely sifted coal powder to coal pieces of medium size of 1.5 cm (Strelov 1928: 54).

The "pit" method of making charcoal was described by the *Evenks* and consisted in that firewood was placed into pits and burnt with limited oxygen to form coals (Vasilevich 1969: 91). As this method of coal burning is universal, simple and accessible, it is not surprising that it is still widely used.

In this regard it seems relevant to suggest that in ancient and medieval times coal burning technologies were identical to the ones referred to above. Moreover, obtaining charcoal by any other method seems merely impossible in traditional cultures. The archaeologisation of actions associated with charcoal making can manifest itself either in the form of fireplaces if the 'heap' method was used or as pits with a large amount of ash and coal in case the 'pit' method was applied. However, here we are immediately confronted with the issue of how to identify the very places of charcoal making because fireplaces and pits with ash found in settlements can in fact be associated with many different events and factors. According to Ya.I. Sunchugashev, it is extremely rarely that one can manage to find pits for burning coal in territories with ancient workshops or in proximity to furnaces (Sunchugashev 1979: 59).

Indeed no evidence of ancient coal burning practices was discovered through archaeological methods in the Ob-Tomsk interfluve of Western Siberia. There seems to be quite a rational explanation for that fact: it was more convenient to burn coal in the forest and then to bring ready-to-use fuel back to the settlement than to transport massive logs to places for smelting to make charcoal (Sunchugashev 1979: 59). Interestingly, one of the Mongolian legends written down by Rashid-ad-Din in the 14^{th} century tells us that when a tribe needed some coal for iron smelting, its people went to the forest, and it was there that they got the coal which they then took to the mining site and started kindling it with bellows (Rashid-ad-Din 1952: 154).

Bellows

Bellows were used to pump air into the working chamber of the furnace. The principle underlying their operation was quite universal and thus their design did not differ across vast territories. According to written sources, *two types* of bellows were spread in traditional Siberian metallurgy.

The first type of bellows looked like bags and was made of the skin of horse hind legs. The skin was completely removed and a nozzle was then attached to its narrow end. In the second third of the 18th century, Gerhard F. Müller wrote that the *Yakut* bellows consisted of two leather bags which were thicker in the middle, with two narrow necks at their top and bottom. Attached to the bottom were iron tubes to be directed toward the fire. The top part was designed to let in air, with two round pieces of wood attached to it which the blacksmith, while raising the bags, parted with the help of the thumb and other fingers, thus letting in air. Then he squeezed them together when pressing the bellows and the air escaped from the bottom openings. In this way the blacksmith raised and lowered both bellows alternately with his right and left hand and smelted iron (Müller 2009: 285).

The *Mongolian* blacksmiths used this type of bellows in the late 18th century (Fig. 1).

Fig. 1. The Mongolian blacksmiths. Drawn by Peter Simon Pallas in the late 18th century (Source: Pallas 1776: tabl. 5)

Waclaw Seroshevskiy described this type of bellows (Fig. 2) as used by the *Yakut* blacksmiths in the late 19th century as follows: "Their bellows, just like the *Mongolian* ones, are bags of soft leather sewn in such a way that their form resembles a lot the skin removed as one piece from the backside of a mare; these bags are attached to a common two-necked wooden sleeve whose aperture is placed in the front wall of the furnace" (Seroshevskiy 1993: 369, fig. 83).

Fig. 2. The Yakut blacksmiths. Drawn by V.L. Seroshevskiy in the late 19th century (Source: Seroshevskiy 1993: fig. 83)

The *Altaians* had similar bellows in the 19th century (Chikhachyov 1974: 139) as well as the *Tungus* people though the latter made bellows from seal-skin (Seroshevskiy 1993: 380). In the early 20th century, the *Shor* blacksmiths (in the south of Western Siberia) also produced bellows from the skin of horse hind legs (Fig. 3).

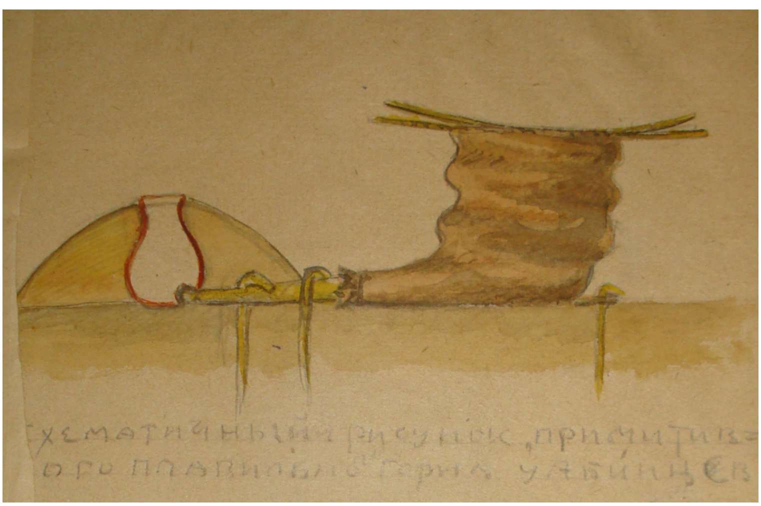

Fig. 3. Shor blacksmith bellows and smelting furnace. Drawn by Concordiy Evreinov in the first half of the 20th century. (Source: Evreinov, no year)

Thus, the available written sources show that this type of blacksmith bellows was widespread in Western and Eastern Siberia, as well as in Central Asia, throughout the 18th to the early 20th centuries. Despite the fact that archaeological research did not reveal the presence of blacksmith bellows in Siberia, we can hypothesise that smelters and blacksmiths used bellows of similar design here in medieval times as, for example, bellows of this type made from horse and sheep skin are known to have been used by the *Mongols* in the 13th to the 14th centuries, according to a legend written down by Rashid-ad-Din at that time (Rashid-ad-Din 1952: 154).

The second type of bellows was made up of two wooden covers tied together with leather. In 1734, Johann W. Lursenius made a drawing of such blacksmith bellows used by the *Shor* smelters (in the south of today's Kemerovo region, Siberia) (Fig. 4).

Fig. 4. Methods of producing alcohol from milk (*A*) and of smelting iron from ore (*B*) used by the Kondoma Tatars, A copy of the drawing made by Johann W. Lursenius on 19 September 1734 (Source: Vodyasov 2016: fig. 1)

The *Selkups* are also known to have used such bellows in the early 20th century (Sel'kupskaya… 2007: 252) as well as the *Vakhovskie Ostyaks* (Istoriya Yamala… 2010: 89) and the *Yakuts* (Strelov 1928: fig. 3). Notably, ethnographic data indicate the coexistence of the two types of blacksmith bellows in same traditional cultures. We cannot exclude the possibility that Siberian smelters could use both types much further back in time. The choice of bellows was most probably made depending on the quantity of air needed for a particular type of smelting and blacksmith furnaces.

It is also worth stressing that it is two bellows that many researchers mention that the smelter or the blacksmith alternated for continuous supply of air to the furnace, and the two bellows were put into one nozzle on the side of the furnace. This technology was found in many *Yakut* blacksmiths (Seroshevskiy 1993: 369; Strelov 1928). In the 18th century, Johann G. Georgi also described *Yakut* bellows as two leather bags tied together in such a way that pressing alternately one and then the other ensured a continuous flow of air into the furnace (Georgi 1776: 184). Two blacksmith bellows directed toward one furnace as done by the *Shors* were drawn by Concordiy Evreinov (Evreinov, no year). Gmelin also mentioned that fact when describing iron smelting in a *Tatar* yurt on the Kondoma River (in the south of today's Kemerovo region, Siberia) in 1734. (Gmelin 2003: 102).

Iron Smelting Furnaces

Drawing on the ethnographic descriptions of iron smelting we can identify *two major types* of smelting furnaces (Fig. 5).

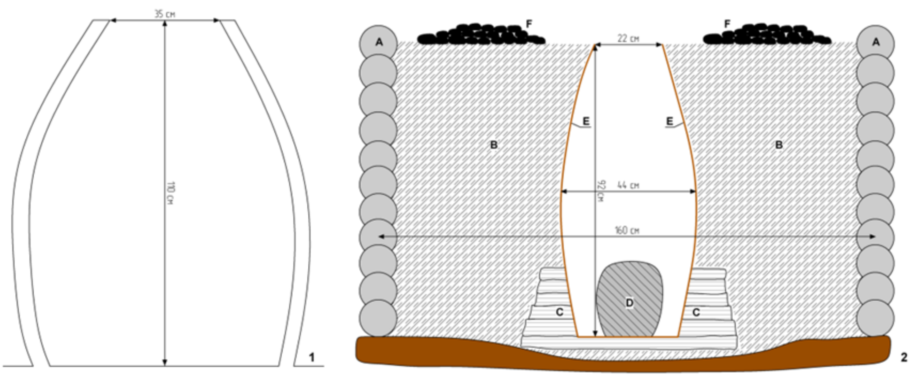

Fig. 5. Major types of Yakut smelting furnaces used in the late 19th to the 20th centuries. The reconstruction is made by Evgeny Vodyasov and is based on ethnographic materials (Strelov 1928: 53–54; Seroshevskiy 1993: 367). *1* – Furnaces of the first type; *2* – Furnaces of the second type. The "log frame" furnace in section. *A* – log frame; *B* – clay; *C* – chert; *D* – a hole in the furnace; *E* – refractory clay on the inner walls of the smelting chamber; *F* – charcoal for smelting

The first type is represented by ground constructions made of clay (Fig. 5, *1*). In different cultures their size varies. In the 18th century, the *Kondoma Tatars* built small clay furnaces of 30 cm in height with the diameter of the base equal to only 15 cm. The top hole for loading coal and ore did not exceed 4 cm in diameter. There was an opening in the front which was clogged with clay during smelting, and two bellows were inserted on the side (Gmelin 2003). Similar parameters of furnaces were described by Concordiy Evreinov as they existed in the *Shors* in the early 20th century. He identified four types of furnaces in accordance with the diameter of the base of the ground clay dome: 1) 20–25 cm; 2) 20–30 cm; 3) 40–45 cm; and 4) 40–

50 cm (Evreinov, no year). The general design of the early 20th century *Shor* furnaces was not different from that described 200 years ago by Gmelin.

Müller wrote that the *Yakut* furnaces were much bigger than the *Tatar* ones, and thus wrought iron blooms produced by the *Yakuts* was heavier (Müller 2009: 285). Waclaw Seroshevskiy described the *Yakut* furnaces as “jug-shaped” constructions 110 cm high, with a top hole for filling coal and ore of around 30 cm in diameter and with a bottom hole for bellows. The walls of the furnace were maximum 5 cm thick (Seroshevskiy 1993: 367).

The second type of smelting furnaces could be called the “log frame” one (Fig. 5, *2*). In the late 19th to the early 20th centuries, the *Yakuts* constructed wooden square log frames, with logs around 10 cm thick. The log frame was around 110 cm high and 160 cm wide. It was filled up with clay to the top edge, and a full-height furnace was built in the centre of it. The inner walls of the smelting chamber were covered with refractory clay. At the bottom of the chamber there was a hole for heating the furnace with firewood, releasing liquid slags, and pumping air with bellows. At the top, there was also a hole (of around 20 cm in diameter) for loading coal and ore. Charcoal was piled around the top hole and added to the furnace when needed (Strelov 1928: 53–54).

Interestingly, such “log frame” furnaces were found in the first half of the 20th century in Gornaya Shoria (in the south of today’s Kemerovo region, Siberia). In 1935, a local history specialist Concordiy Evreinov learnt from old *Shor* men that smelting furnaces were placed in a separate workshop which was a log construction filled with tamped clay, with a semicircular hole in the center; also, two blacksmith bellows were inserted on its side (Fig. 6).

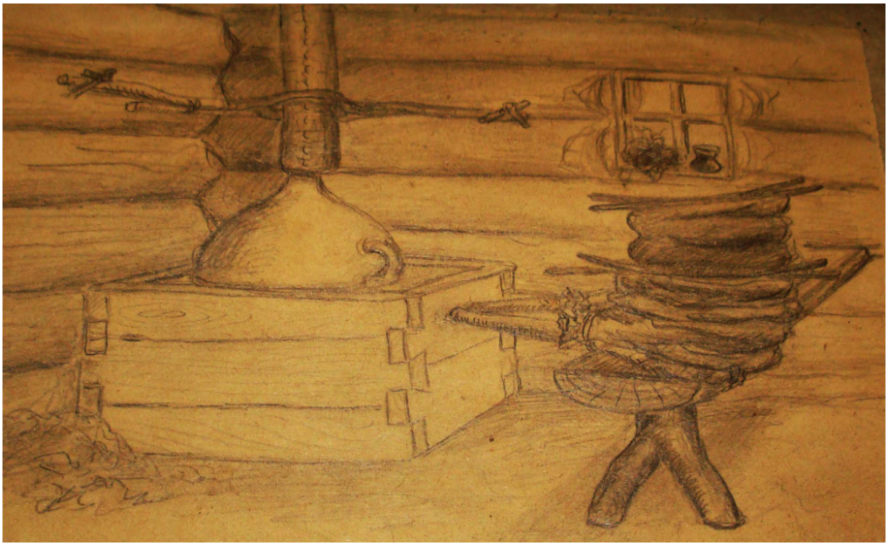

Fig. 6. The Shor “log frame” furnace. The first half of the 20th century.
Drawn by Concordiy Evreinov (Source: Evreinov, no year)

Doing archaeological research on ancient iron production technologies it is important to consider the fact that *different types* of furnaces could coexist in one same culture. Ethnographic materials show that smelters in Western and Eastern Siberia used both “classic” clay furnaces and “log frame” constructions. The choice of a particular type of furnace was most probably dictated by natural conditions. In the late 19th century, Waclaw Seroshevskiy wrote that the *Yakuts* used “log frame” furnaces in the winter in order to save heat (Seroshevskiy 1993: 367). Indeed, in the severe Siberian climate, especially in cold winter time, thin clay walls of the furnace of the first type did not create the conditions needed for the extraction of iron from ore. The problem of ensuring necessary heat capacity of the smelting chamber was resolved through the use of the “log frame” construction with an enormous amount of clay inside. It can be calculated that smelters needed around 2.3 cubic meters of clay weighing up to 5 tons (!) in order to build a *Yakut* furnace (Fig. 5, *2*). Moreover, “log frame” furnaces produced much more iron than small “classic” clay furnaces known to be used by the *Kondoma Tatars* in Western Siberia. From an ethnoarchaeological point of view, it is important to note that whereas the first type of clay furnaces is widely present on archaeological sites of Western Siberia, “log frame” furnaces have not so far been discovered through archaeological research. However, if to imagine a model of archaeologisation of such furnaces, it will become clear that logs rot and tamped clay, with the passage of time, turns into an amorphous stain which does not allow reconstructing the initial appearance of the furnace. Moreover, if such constructions were ground ones, then trying to recognise a log frame in a cluster of clay would be merely impossible. Thus, it still remains unknown whether iron was indeed produced in log frame constructions in Western Siberia in ancient and medieval times.

Iron Smelting Process

Ethnographic descriptions of iron smelting in Siberia constitute a significant basis for making archaeological reconstructions of and experimental research on ancient technologies. Below i present a detailed overview of iron production technologies applied in each of the types of furnaces described above.

In 1734, Gmelin wrote about iron smelting process as practiced by the *Kondoma Tatars*. They used small clay furnaces of about 30 cm in height. All work was done by two *Tatar men*. The one would alternately add coal and ore (the amount of finely ground ore taken here was small enough to fit onto the tip of a knife) until the furnace was full, while the other was pumping air into the furnace with two bellows. As soon as the volume of the coal became less, another portion of ore and coal was loaded, and the whole process would continue until the furnace was filled with around 3 pounds there-of (i.e., 1.2 kg) – the maximum amount it could contain at a time. After the last portion of ore was inside the furnace, the smelter pumped some more air with the bellows and, using forceps, took out from the bottom of the furnace pieces of wrought iron bloom, cleaning them of slags and coals. This process lasted for 1.5 hours in total (Gmelin 2003).

More information is available on iron smelting by the *Yakuts* done in "log frame" furnaces. The first thing to do was to heat the furnace using firewood. Then the *Yakuts* formed a finely ground charcoal layer of 6.5 cm in thickness covered with another layer of the same thickness but with charcoal pieces of 1.5 cm. The *Yakuts* called these two layers the "bed" for iron. Following that, the smelters inserted two bellows into the furnace and closed its front hole. Then a small amount of hot coals was put into the furnace and the next step was to fill the furnace with cold coal up to the level of 20 cm above its surface. When the one smelter started pumping air, the other put 2.8 kg of iron ore ground into powder onto the coal. When, in around 20 minutes, the coal burnt to an extent it was no longer visible above the furnace, they added more coal to form a small mound of 20 cm in height and the same amount of ore. The process repeated 5 times. In this way the *Yakuts* smelted around 20 kg of ore during one smelting cycle. In 1 hour and 15 minutes after the first portion of ore was added, with less than half of the coal left in the furnace, the *Yakut* smelters stopped pumping air with the bellows and made holes at the bottom to let liquid slag out. Then the holes were closed and the bellows were reapplied to burn the rest of the coal. By the end of the smelting cycle the *Yakuts* reopened the hole and removed a piece of iron bloom about 7 cm thick. They threw it onto the snow, cleaned it of any remaining slags using a piece of wood and cut it with an axe in order to assess the quality of iron produced. The total duration of the cycle was about 2 hours (Strelov 1928: 54–55).

In the late 19th century, Waclaw Seroshevskiy described iron smelting in "log frame" constructions practiced exactly the same way by the *Yakuts,* with only one exception, that is, that the *Yakut* smelters would load coal and ore 15 to 20 times (Seroshevskiy 1993: 367–368). No ethnographic description of indigenous iron smelting in Siberia reports the use of flux. Waclaw Seroshevskiy indicated directly that the *Yakuts* did not use flux during smelting and could not manage the process so as to produce the required kind of iron (Seroshevskiy 1993: 368).

Iron production technologies seem to have varied depending on the experience and knowledge of the smelter, although, on the whole, many 18th and 19th century scientists pointed to the similar nature of technologies applied by different indigenous peoples of Siberia. As early as in the 18th century, Georgi paid attention to similar iron making methods used by the *Abinsk Tatars*, *Yakuts*, and *Yenisei Ostyaks* (Georgi 1776: 184; 1777: 23). It is noteworthy that in 1734 Gmelin wrote in relation to the *Kuznetsk Tatars* that "…although they had many places for iron smelting, becoming familiar with one of these places was enough since they all did the smelting in the same way" (Gmelin 2003: 102).

For that reason, the fact that there are common physical and chemical foundations underlying iron making is of invaluable help for the reconstruction of this process whose very nature determined similarities in technologies used for burning and crushing ore, getting charcoal, designing furnaces and bellows, and for smelting as such, both in Siberia and beyond.

Yield of Iron

In ethnoarchaeological research on Siberian iron smelting technologies, the issue of smelting furnaces productivity is of particular significance. Such data which can be verified by experimental methods are crucial for the reconstruction of the scale of ancient iron production in a particular settlement.

With regard to the *Yakut* iron, Waclaw Seroshevskiy wrote that 1.4 to 1.6 kg of iron could be made out of 16 kg of iron ore. The weight of wrought bloom ranged from 10 to 16 kg, and this iron was porous and covered with a layer of slag, and so it had to be repeatedly heated to be cleaned, as a result of which half of its weight was gone. Out of 16 kg of wrought iron maximum 10 kg of iron was produced (Seroshevskiy 1993: 368). Thus, of a particular amount of ore only 8 to 10 % of iron was extracted.

Strelov, however, provides some different data on the *Yakut* metallurgy. According to him, on average, out of 16 kg of ground ore 7.4 to 8.2 kg of iron was produced, that is, 50 to 57 %. Another description of iron smelting process as practiced by the *Yakuts* indicates that from an equal amount of ore and coal (24.5 kg each), 8.2 kg of wrought iron was produced, that is, 33 % of the total amount of ore (Strelov 1928: 55–57). Gmelin writing on the *Kuznetsk Tatars* reported an even greater amount of iron yielded – at 65 % (Gmelin 2003: 102–103). However, if to consider significant losses of wrought iron after forging referred to neither by Strelov nor by Gmelin, we can see that the yield of iron varies from 8 to 20% depending on the quality of ore and technologies applied. The losses of wrought iron during forging reported to be equal to 40 to 50% (according to ethnographic descriptions), as well as the amount of iron produced from ore, are confirmed through contemporary experimental research (Crew, Maentwrog, Salter 1993).

Of great significance are the data of Waclaw Seroshevskiy on the total weight of iron consumed by one *Yakut* family in the late 19th century. Iron objects needed in a family of 5 persons include an axe (adze), 2 knives, a tinderbox, needles, awls, buckles, etc., with the total weight of 2.5 kg. If to add locksmith and blacksmith tools, weapons and a bridle set, then the average amount of iron needed will amount to 4 kg per year (Seroshevskiy 1993: 375–377). Thus, a few successful "log frame" smelting cycles can provide one family with the necessary amount of iron for at least a year.

Smelters or Blacksmiths: Division of Labour

Written sources on Siberian metallurgy demonstrate that in different communities of metallurgists different forms of division of labour existed between smelters and blacksmiths. Siberian metallurgists can be, with certain reservations, divided into three categories: smelters-blacksmiths who knew how to smelt ore and forge iron; smelters who only made wrought iron and sold it (or exchanged it) to other communities; and blacksmiths who did not smelt ore but forged wrought iron they obtained from others.

Interestingly, these three categories could coexist within one culture. For example, in the second third of the 18th century, Müller mentioned the fact that there were the *Yakut* metallurgists who could both smelt ore and forge different objects: knives, axes, arrows, tinderboxes, etc. (Müller 2009: 285). Waclaw Seroshevskiy gave another example from the late 19th century. He wrote that the *Yakut* smelters rarely processed wrought iron. More often, they sold it to the city or exchanged it with blacksmiths (Seroshevskiy 1993: 369). It is also known that in Siberia indigenous smelters subject to tribute could pay it with wrought iron (30 to 40 pieces of wrought iron (or 16 kg) instead of one sable) (Shirin 1999). 17th century written documents state that the *Yakuts* exchanged wrought iron for weapons, decorative items (small beads), deer, and sable fur (Ivanov 1966: 72–73). Finally, scientists also described communities of *Yakut* blacksmiths who did not smelt iron but obtained wrought iron and forged it for their own needs as well as exchanged finished iron products with the *Yukagirs, Chukchi, Kamchadals*, and other peoples unfamiliar with metallurgy (Müller 2009: 285). Throughout the 17th to the 19th centuries, many *Ostyaks, Tungus people, Samoyeds, and Yukagirs* did not practice iron smelting but forged wrought iron (Ivanov 1966: 72–73; Seroshevskiy 1993: 380; Müller 2009: 284–285). The *Ostyak* and *Tungus* blacksmiths made only simple arrowheads and could not produce axes or knives (Müller 2009: 284–285).

Thus, written evidence gives us a complex picture of smelting and blacksmithing technologies present even in one culture and that should be taken into account when interpreting archaeological sources. Through the example of the 17th to the 19th century *Yakut* metallurgists, at least three groups can be identified: smelters-blacksmiths, smelters, and blacksmiths. It is noteworthy that in early medieval times in the Upper and Middle Ob region no remains of iron smelting technologies were found and all the traces of iron metallurgy that were discovered are in fact indicative of blacksmithing (Vodyasov, Zaytseva 2017: 244). In the Middle Ages, there most probably were communities of metallurgists-blacksmiths as well who did not smelt ore but used ready-to-use wrought iron made by professional smelters from other communities.

Conclusions

Ethnoarchaeological research on indigenous iron smelting in Siberia provides a more comprehensive picture than separate archaeological sources. Written descriptions enable us to reconstruct many aspects of iron production adding to the archaeological knowledge of this problem. The analysis of written and ethnographic data revealed a number of noticeable characteristics of Siberian metallurgy which may be useful in archaeological and experimental research. Firstly, Siberian smelters used different types of iron ore together, and the choice of ore was made depending on the quality of iron required. Secondly, ethnoarchaeological data show that smelters also combined different types of bellows: all the scientists in the 18th to the 20th centuries mentioned the fact that two bellows were involved in smelting. Ethnoarchaeological evidence seems to be the only source for reconstructing the design of ancient bellows because these are not preserved in the archaeological layer. Thirdly, the climate with its changing summer and winter seasons, as well as the quantity of iron needed, had an impact on the types of iron smelting furnaces. In Western and Eastern Siberia, small furnaces with clay ground elements coexisted with “log frame” furnaces filled up with clay which produced wrought iron pieces of up to 16 kg. Finally, written data reveal similarities in smelting technologies in different cultures of Siberia; among these – the preliminary drying and burning of ores before smelting, the use of ore ground into powder, similar ways of making charcoal and types of smelting furnaces used, the use of two bellows for continuous supply of air into the furnace, and the repeated loading of coal and ore (where the furnace was filled up with coal onto which ore was placed).

To conclude, i believe that of further research interest would be a series of archaeological experiments with the “log frame” furnace, thanks to a detailed description available in the *Yakut* culture of its design and of the smelting process itself. Also, we are not aware of such experiments to be ever conducted before – the fact that only adds to their relevance for taking the current ethnoarchaeological research on indigenous iron smelting in Siberia further.

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