Aleksey Tarasov & Maksim Gogolev

# ICP-MS ANALYSIS OF METATUFF FROM THE MIDDLE NEOLITHIC / ENEOLITHIC 'GREEN SLATE' WORKSHOPS IN THE LAKE ONEGA AREA

Abstract

The article is devoted to geochemical investigation of the lithic raw materials (slightly metamorphosed tuffs) used for producing tools of the so-called Russian Karelian type on the western shore of Lake Onega during the Middle Neolithic / Eneolithic period. The implements of this type are specifically noteworthy due to their role in long-distance exchange. Previous petrographic studies have shown that the material of these tools, including specimens found at the distance of c 1000 km from the present-day Karelian Republic, must have originated from the western shore of Lake Onega. The present geochemical study (20 samples from five workshop sites and one possible raw material collecting place), employing the ICP-MS method, confirmed principal unity of the raw material base of all studied workshops. It also demonstrated the procurement area to be connected with the outcrops of igneous rocks in the rock massif located to the north from the outfall of the Shuya River on the western Lake Onega shore.

Keywords: chopping tools, Eneolithic, ICP-MS, Lake Onega, metatuff, raw material provenience

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## INTRODUCTION

This article[1] discusses the results of geochemical investigation of the raw materials used for the production of chopping tools (such as axes, adzes, gouges) of the so-called Russian or East Karelian type that were manufactured in workshop sites of the western shore of Lake Onega in the Karelian Republic (Russia) (Figs. 1&2). According to the periodization scheme utilized by the Karelian archaeologists, this industry can be dated to the Eneolithic period, although the contemporary sites in the neighbouring Finland are considered to be still Neolithic, e.g. Middle Neolithic. The finely made tools of the Russian Karelian type were distinguished by researchers already in the second half of the 19th century. As a result of the investigations by J.R. Aspelin, L.V. Pääkkonen, J. Ailio, and A. Äyräpää, this type was recognized as a very specific feature of the Karelian archaeological complex. Further, Finnish researchers located the production centre of these tools next to the outfall of the Shuya River on the western shore of Lake Onega, and discovered that some items produced in this centre had been exported to very distant regions (Äyräpää 1944; Heikkurinen 1980: 1–10; Nordqvist & Seitsonen 2008; Kriiska et al. 2013). Russian archaeologists of the Soviet era were aware of this interpretation of the industry, though it was not universally accepted in Russia (Bryusov 1940; 1947; 1952: 104–6; Foss 1952: 196; Clark 1953: 246–7; Filatova 1971; Gurina 1974).

In the 1980 and 1990s, A.M. Zhul'nikov (1999) investigated a number of sites with asbestos and porous ceramics, which are dated to

*Fig. 1. An adze of Russian Karelian type from the Fofanovo XIII workshop site. Photo: A. Tarasov.*

the Eneolithic period in Karelia (c 3500–1400 calBC or 4700–3200 BP). The research demonstrated that tools of the Russian Karelian type are very common for sites with this kind of pottery, while they are absent at sites belonging to other cultural groups or phases (Tarasov 2008).

Mapping the find spots of Russian Karelian implements was done for the first time in the middle of the 20th century by A. Äyräpää (1944), and was resumed in the 2000s (Kriiska & Tarasov 2011; Kriiska et al. 2013; Tarasov 2015a; Tarasov & Kostyleva 2015). Besides the Lake Onega region, these items were identified in the archaeological collections from other parts of Russian Karelia, as well as from Finland, Estonia, Latvia, Lithuania, the Upper Volga region and the Vologda District in Russia (see Kriiska et al. 2013 with cited references; Piličiauskas et al. 2015; Tarasov & Kostyleva 2015). Their distribution up to the Ural Mountains has also been reported (Foss 1952: 196). Remarkably preforms, i.e. partly finished objects, originate mostly from the lower reaches of the Shuya River and none of them has been found outside the Lake Onega catchment area.

Since the mid-20th century and up to the 1990s, only episodic surveys were conducted in the outfall area of the Shuya River. Regular investigations, mostly also surveys and collecting of stray finds, started only during the last decade of the previous century. At the moment, some 100 archaeological sites have been recorded in this area, and roughly one third of them contain lithic debitage connected to the production of Russian Karelian type of tools. The first excavations of a specialized workshop site were conducted in 2000, when the site Fofanovo XIV was studied (400 $m^2$). The results have been partly published (Tarasov 2003).

In 2010–13, A.Yu. Tarasov conducted a series of small-scale excavations at five workshop sites containing production debris from the manufacture of Russian Karelian type of tools (Figs. 1&2). Four of them are located by the outlet of the Shuya River (Fofanovo XIII, Shuya XXI, Shuya XV, Nizovie I), and the fifth one c 40 km to the south, close to the Derevyannoye village (Derevyannoye XVIII). The excavated area varied from 6 to 30 $m^2$ (Tarasov & Zobkov 2015). The technological analysis of the production debris demonstrates that a full production cycle was taking place at the workshops located in the outfall of Shuya River (Tarasov & Stafeev 2014; Tarasov 2015b), while only finishing of preforms brought from somewhere else was done at Derevyannoye XVIII (Tarasov & Zobkov 2015).

## PREVIOUS STUDIES

Up to the moment, the raw materials for making Russian Karelian tools have been studied only petrographically. The most extensive investigations were conducted by Finnish researchers of the first half of the 20th century, who studied the material of chopping tools, mostly stray finds, found on the territories of present-day Finland and Russian Karelia. Finnish geologist E. Mäkinen identified the material of a group of artefacts in the collections of the National Museum of Finland (Helsinki), including also Russian Karelian tools, and found that tuff dominated among the analysed samples (Äyräpää 1944: 58).

Tools of the Russian Karelian type originating from Finland and Karelia were studied again in the end of 1970s by T. Heikkurinen and O. Näykki. The majority of the more than 500 items was defined to have been produced of 'Olonets green slate' – metatuff of green colour. Single objects were made of chlorite schist, mica schist and diabase (Heikkurinen 1980: 6–7).

In 2008–9, Estonian geologist J. Kirs conducted a petrographic study of this type of tools found from the territory of present-day Estonia. Fragments of flakes from the workshop site Fofanovo XIII and pieces of rock from a suspected raw material source in the Kraskov Navolok Peninsula by Lake Ukshezero (Fig. 2), including fragments of bedrock and boulders, were used as reference samples. Material of the majority of studied artefacts (19 out of the 22 analysed specimens) was identified as metatuff, i.e. slightly metamorphosed volcanic tuff, including such textural varieties as slate, ryolite, biotite slate metatuff, and metatuff with mica. Such material is absent in the Estonian territory even among erratic stones. At the same time, according to the petrographic study it is identical to the reference samples from Karelia (Kriiska et al. 2013).

Metatuff used for producing chopping tools of the Russian Karelian type is quite rare in nature. In the beginning of the 20th century, geologist W. Ramsey localized its source area in Karelia, on the coast of Lake Onega. The variety of green colour (also called 'Onega' or 'Olonets green slate') is found in an even narrower territory to the north of Petrozavodsk, including the outfall of the Shuya River. Quaternary glaciers transported it also to areas to the south and south-east from the place of origin in the form of pebbles and

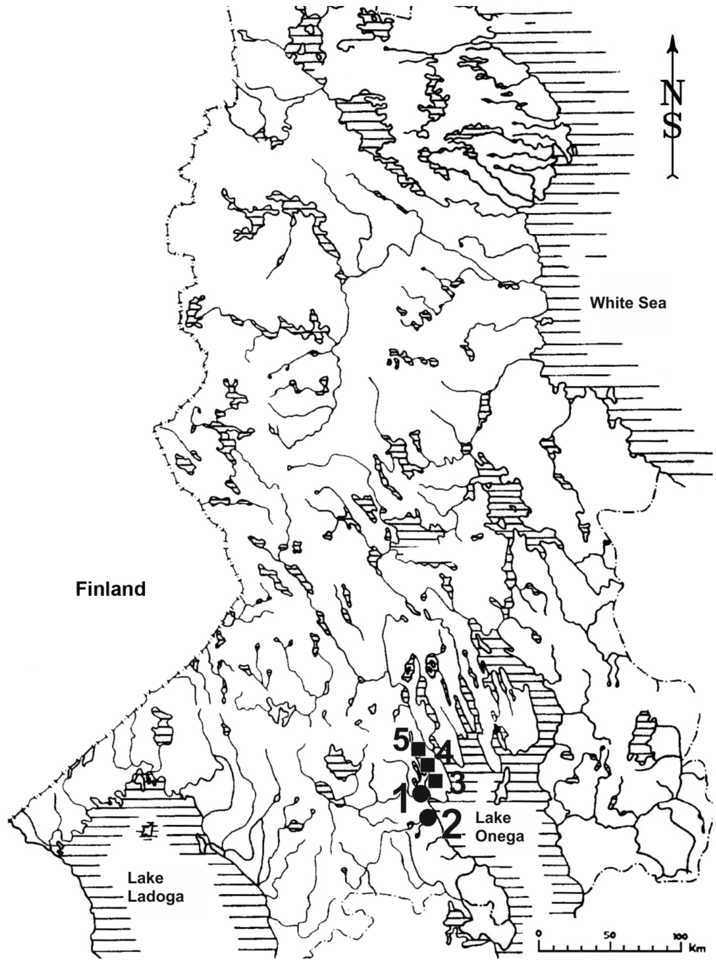


*Fig. 2. Locations of the studied workshop sites (dots) and origins of the collected metatuff rock samples (squares): 1) workshops Fofanovo XIII, Shuya XXI, Shuya XXV and Nizovie I; 2) workshop Derevyannoye XVIII; 3) geological samples SV01-15–SV07-15 (Shuiskaya station); 4) geological sample SV08-15; 5) geological samples SV09-15–SV17-15 (Shuiskaya Chupa village). Base map after Kosmenko & Kochkurkina 1996.*

boulders (Äyräpää 1944: 59; Heikkurinen 1980: 5). With a few exceptions, the tools of this type analysed so far were made of a rock originating from the north-western coast of Lake Onega, where slightly metamorphosed sediments of volcanic origin (including metatuff) dated to the Early Proterozoic (2.3–1.7 billion years ago), so-called Yatily–Vepsy complexes, are known (Sokolov et al. 1987).

## GOALS OF THE STUDY

Previous investigations have convincingly demonstrated that sources of raw materials used for making Russian Karelian implements must have been located on the western shore of Lake Onega, in the vicinity of workshop sites containing characteristic production debitage. Nevertheless, up to the moment the actual places for acquiring the metatuff nodules have not been identified. Moreover, it has not been clarified if there was just one or a number of exploited deposits.

It must be also emphasized that petrographical analysis cannot be free from a certain degree of subjectivity and the influence of the previous experience of a researcher. Similarly, classification schemes used for assessing thin sections are not universal, as same items and phenomena can be classified basing on different grounds. Concerning the object of our study, one example of the diverging classification schemes derives from the petrographic analysis of 'slate' artefacts from the Okhta I site in Saint Petersburg, Russia (Zheltova et al. 2015). The assemblage contains a very remarkable collection of Russian Karelian tools (Tarasov & Gusentsova 2012). However, the term 'tuff' and its derivatives are absent among the definitions used by the authors of this study for describing the varieties of slate-like raw materials in the assemblage.

Based on these considerations, we can define the following goals for the geochemical investigation of the raw materials of Russian Karelian chopping tools:

- To locate the potential raw material sources (as precisely as possible);
- To find out whether the raw material deposits were common for all workshops or were there several centres of raw material acquisition supplying different workshops;
- To determine the 'geochemical fingerprint' of different varieties of metatuff material used for the production of Russian Karelian tools – this can be used as the reference data for studying the material of finds originating from different regions, and further, investigating the spread of products of the Lake Onega workshops and, consequently, the contacts and interaction of ancient societies.

## MATERIALS AND METHODS

Our research is the first attempt of geochemical investigation of raw materials used for manufacturing chopping tools in the workshops on the western shore of Lake Onega, and does not aim to provide exhaustive characteristics of all materials. At the moment, we analysed 20 samples with the aid of only one method – inductively coupled plasma mass spectrometry (ICP-MS). This method was chosen because it is very precise but fast at the same time. It also requires very small amount of sample material (starting from 50 mg), which allows minimizing the damage to the analysed specimen. Last but not least, this method was used primarily in the recent geochemical investigations of the rocky massifs of volcanic origin on the western shore of Lake Onega conducted by the Institute of Geology of the Karelian Research Centre (Petrozavodsk), which provided reference materials for the present study. The studied samples consist of 15 artefacts, namely flakes from workshop sites, and five pieces of rock that were collected in one suspected location for raw material acquisition.

Flakes were taken from assemblages obtained through excavations and collecting of stray finds at the following sites: Fofanovo XIII (samples 1–4), Fofanovo VI (samples 5–6), Shuya XXV (samples 7–8), Shuya XXI (samples 9–10), Nizovie I (samples 14–15), Derevyannoye XVIII (samples 11–13) (Fig. 2; Appendix 1). All the samples had characteristic morphological features allowing their attribution as waste by-products from making tools of the type under discussion (Tarasov & Stafeev 2014; Tarasov 2015b). Only one of the sites can be reliably dated by the radiocarbon method. This site is Fofanovo XIII, which is also distinguished by an unprecedented density of finds in the cultural layer. The excavations produced c 350,000 artefacts from an area of just 30 $m^2$ – the thickness of cultural layer varied from 0.5 to 0.8 m (Tarasov 2015b). The dates obtained from crust on sherds of asbestos-tempered ceramics of Voynavolok and Orovnavolok types (according to the typology developed by A.M. Zhul'nikov; see Zhul'nikov 1999) and from burnt bones place the use of this site to c 3500–3300 calBC (c 4700 – 4400 BP; see Tarasov et al. 2017). The site Fofanovo VI, which is located very close to Fofanovo XIII, can be dated by the finds of asbestos ceramics of Voynavolok type to c 3600–3000 calBC (c 4700–4300 BP; see Tarasov et al. 2017). Sites Shuya XXI, Nizovie I and Derevyannoye XVIII can be dated by the finds of asbestos ceramics of Orovnavolok type. The time span for the existence of this type, according to the available data, is c 3300–2600 calBC (c 4400–3800 BP; see Tarasov et al. 2017). The sherds with asbestos tempering from Shuya XXV cannot be identified typologically because of their very small size, but it is very likely that this site was generally contemporaneous with the others and functioned during the period of asbestos ceramics of Voynavolok and Orovnavolok types. According to the climatic periodization, all the studied sites existed during the Subboreal period.

Rock samples originate from the Kraskov Navolok Peninsula that is located between the Lakes Ukshezero and Surgubskoye, just to the north from the mouth of the Shuya River. Currently it is the only one place known to the authors where it is possible to collect big enough nodules of suitable quality – pieces of metatuff rock collected here were also used in a series of experiments aimed at making replicas of Russian Karelian implements. The goal of these experiments was to clarify the used technology and to obtain a reference collection of resulting debitage, which was then used as the basis for calculating the amount of finished tools that could have been produced within the excavated area of Fofanovo XIII site (Tarasov & Stafeev 2014). Single flakes produced during the experiments were used as samples in the present geochemical study (Appendix 1).

The deposit in the Kraskov Navolok consists of two parts. The first is a rock massif with a cliff in its northern end. At the foot of this cliff lays a horizon of quite homogeneous and hard metatuff rock. This horizon is considerably weathered, has numerous cracks and is crumbling. Due to weathering (?) processes, a shallow rock shelter has been formed in it but no unquestionable evidence of past human activity has been found here. Nevertheless, it should be stressed that weathering has affected only the horizon containing material suitable for making stone tools. The second part of the deposit consists of a nearby pebble shore, where it is possible to find suitable pebbles and boulders. For the geochemical analysis, we used three flakes of the bedrock material (samples 17–9) and two flakes from boulders (samples 16, 20).

The geochemical analysis of samples was performed with the aid of quadruple mass-spectrometer X Series 2 (Thermo Fisher Scientific) in the analytical laboratory of the Institute of Geology, Karelian Research Centre, Russian Academy of Sciences (Petrozavodsk). The technique of sample preparation followed the standard procedure (Svetov et al. 2015): the samples were pounded into homogeneous powder and then acid digested. The accuracy of analyses was monitored through the measurement of blank samples, in-house (SGD1A) and international (BHVO2) standards. The precision is better than 5% for the majority of trace elements.

## RESULTS OF THE ICP-MS ANALYSIS

During the analytical session we obtained data concerning the chemical composition of archaeological samples, which includes the following elements: $^{7}$Li, $^{9}$Be, $^{31}$P, $^{45}$Sc, $^{47}$Ti, $^{51}$V, $^{52}$Cr, $^{55}$Mn, $^{59}$Co, $^{60}$Ni, $^{65}$Cu, $^{66}$Zn, $^{69}$Ga, $^{85}$Rb, $^{88}$Sr, $^{89}$Y, $^{90}$Zr, $^{93}$Nb, $^{95}$Mo, $^{107}$Ag, $^{111}$Cd, $^{116}$Sn, $^{121}$Sb, $^{125}$Te, $^{133}$Cs, $^{138}$Ba, $^{139}$La, $^{140}$Ce, $^{141}$Pr, $^{142}$Nd, $^{147}$Sm, $^{151}$Eu, $^{157}$Gd, $^{159}$Tb, $^{161}$Dy, $^{165}$Ho, $^{166}$Er, $^{169}$Tm, $^{172}$Yb, $^{175}$Lu, $^{178}$Hf, $^{181}$Ta, $^{182}$W, $^{203}$Tl, $^{206}$Pb, $^{209}$Bi, $^{232}$Th, $^{238}$U.

For defining the material of archaeological specimens, we compared the obtained data to the composition of homogeneous rock complexes of Paleoproterozoic age within the Onega structure. As the reference samples, we used samples obtained from the closest deposits to the studied archaeological sites (see above and Table 1). The reference database was granted by S.A. Svetov (Svetov et al. 2015). Juxtaposition was performed between reference geologi-

| Sample | Stratigraphy | Location | Rock |
|---|---|---|---|
| SV-05-15 | Suisarskaya suite | Shuiskaya station | Tuff breccia matrix |
| SV-06-15 | Suisarskaya suite | Intersection to Girvas, M18 road | Fine-grained matrix of tuff breccia, zone almost free of clasts |
| SV-02-15 | Suisarskaya suite | Shuiskaya station | Clast(?) of fine-grained porphyrites |
| SV-03-15 | Suisarskaya suite | Shuiskaya station | Bomb 10x10 cm, light-grey material |
| SV-03a-15 | Suisarskaya suite | Shuiskaya station | Bomb 10x10 cm, red material |
| SV-04-15 | Suisarskaya suite | Shuiskaya station | Big bomb in 3 m downslope from 03-15 sample, fine-grained massive slightly porphyry rocks |
| SV-07-15 | Suisarskaya suite | Intersection to Girvas, M18 road | Fine-grained rock from a big clast |
| SV-14-15 | Suisarskaya suite | Sampo Hill | Fine-grained rock from a clast in tuff breccia |
| SV-08-15 | Zaonezhskaya suite | Shuiskaya Chupa | Pl-porphyry basalts |
| SV-10-15 | Zaonezhskaya suite | Coast of Lake Konchezero to north from Shuiskaya Chupa | Massive part of a pillow at the water's edge of Lake Konchezero |
| SV-11-15 | Zaonezhskaya suite | Coast of Lake Konchezero to north from Shuiskaya Chupa | Thinly foliated sediments at the contact with tuff breccia |
| SV-09-15 | Suisarskaya suite | Coast of Lake Konchezero to north from Shuiskaya Chupa | Central part of dike, spreading 20˚ |
| SV-12-15 | Suisarskaya suite | Tsarevichi village, Lake Ukshezero | Clast of porphyry picrobasalts in tuff breccia |
| SV-13-15 | Suisarskaya suite | Tsarevichi village, Lake Ukshezero | Massive porphyry picrobasalts, quite a big body |
| SV-15-15 | Suisarskaya suite | Spasskaya Guba, to west from road | Small-grained dolerite, western edge part of the body |
| SV-16-15 | Suisarskaya suite | Spasskaya Guba, to west from road | Small to medium-grained dolerites in the central part of the body |
| SV-17-15 | Suisarskaya suite | Spasskaya Guba, to west from road | Small-grained dolerite, eastern edge part of the body |

*Table 1. Geological reference samples of rocks of Paleoproterozoic age within the Onega structure (Svetov et al. 2015). Rocks are coloured according to the similarity of their morphological traits: dark grey – tuff matrix; light grey – clasts and bombs in tuffs; white – other rocks.*

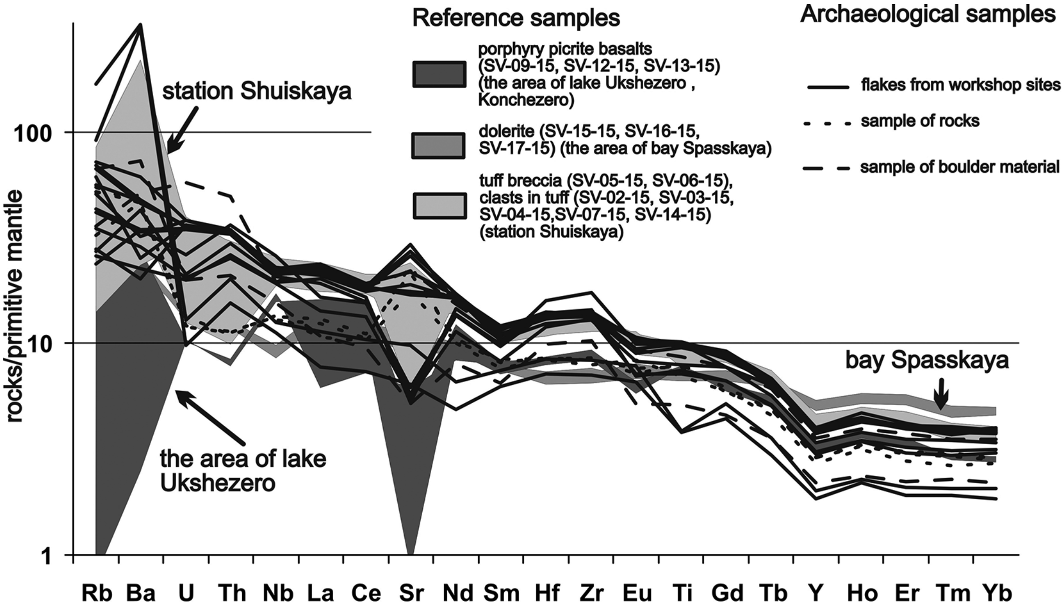


*Fig. 3. Distribution of rare elements in the geological reference samples and archaeological samples (including the samples of bedrock and boulder materials from the Kraskov Navolok Peninsula), normalized by primitive mantle (Sun & McDonough 1989). Rocks of the Suisarskaya formation.*

cal samples and archaeological samples on the basis of defining common topological groups in the distribution of rare and rare-earth elements using spidergrams normalized by primitive mantle, i.e. chondrite normalization (Sun & McDonough 1989). The full distribution of rare elements in the reference samples of picrite basalts from Suisarskaya formation is given in Fig. 3. Rocks of Zaonezhskaya formation, including Pl-porphyrite basalts, sedimentary lithotypes and clasts of rocks from Suisarskiy complex, are shown in Fig. 4.

As the result of juxtaposing we found:

1. Two samples of artefacts from workshop sites (3, 4) and one sample of boulder material from the Kraskov Navolok deposit (16) are relatively poor in rare-earth elements (Fig. 3). Analogies are not quite obvious among the other rocks of the Onega structure.
2. The majority of archaeological samples, namely 14 specimens, are very similar to the reference samples from the area close to the railway station of Shuiskaya. Archaeological samples 1, 2, 6, 15 are chemically similar to the matrix (the main material) of tuff breccia and 10 samples (5, 7, 8, 9, 10, 11, 12, 13, 14, 20) are analogous to the fragments (big clasts in tuff) from tuff breccia (Fig. 4). The difference in the concentration of Ba, is most likely the result of a different level of secondary preparation of reference samples compared to the archaeological samples.
3. According to their geochemistry, three samples of bedrock from the Kraskov Navolok deposit (17, 18, 19) are best-comparable to porphyry picrite basalts from the area of Lake Konchezero and, except for a Sr anomaly, from the area of Lake Ukshezero (SV-09-15, SV-10-15, SV-13-15) (Fig. 5).

## DISCUSSION

The results convincingly demonstrated that the raw materials from tuff deposits of the western shore of Lake Onega, just to the north from the outfall of the Shuya River, were used in the workshops located on the banks of the lower

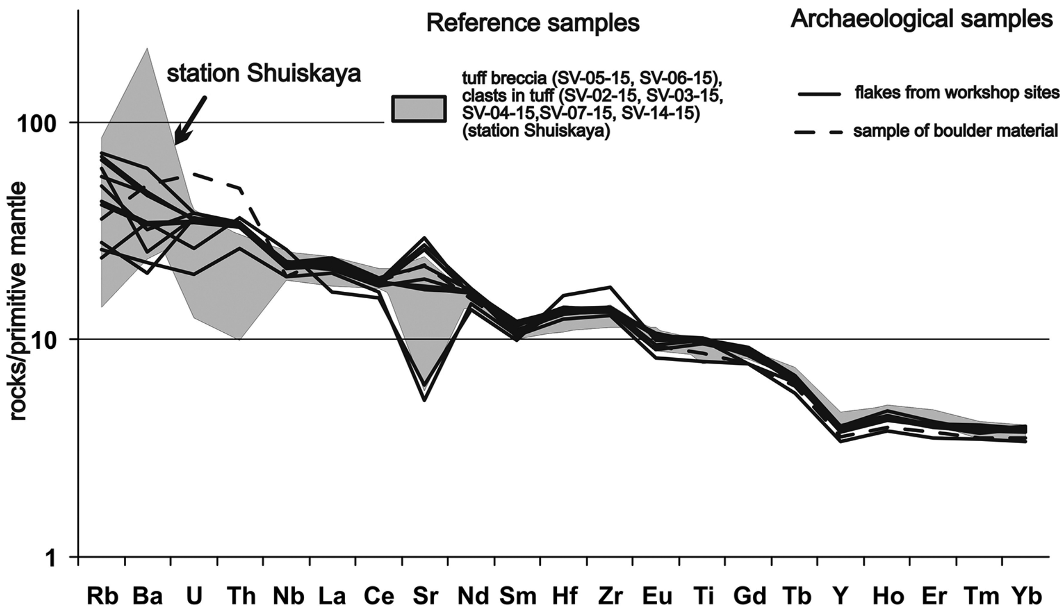


*Fig. 4. Distribution of rare elements in the geological reference samples and archaeological samples (including the samples of bedrock and boulder materials from the Kraskov Navolok Peninsula), normalized by primitive mantle (Sun & McDonough 1989). Rocks of the Zaonezhskaya formation.*

reaches of the river. The absolute majority of artefact samples from all sites included in this study have very similar chemical characteristics, and coincide with the characteristics of reference samples from the area between the Shuiskaya station and the village Shuiskaya Chupa to the north from Petrozavodsk. The spots where the samples with parameters closest to those of the artefact samples were collected are located at the distance of c 3–3.7 km from the nearest workshops (Fig. 2), and in a relative proximity to the Subboreal coastline. This means that transportation of nodules from the rock massif to the workshops was possible. At the moment, we do not know any ancient quarries in this area. However, the area has not been properly surveyed, and we have all the reasons to expect that such quarries will be discovered in the future.

The analysis also showed that in addition to the material from the main deposit in the vicinity of the Shuiskaya station, materials from some other places, which do not find analogies among the geological reference samples listed in Table 1, were used as well. Such material is characteristic for two samples from Fofanovo XIII, that is for half of the samples analysed from this site, but absent among the samples taken from other studied sites. Similar geochemical composition is also present in one sample from the Kraskov Navolok deposit. This is a flake detached from a boulder and we can propose that samples from Fofanovo XIII with similar composition were also detached from boulders that were used as raw material. The use of boulders was also indicated by the presence of boulder cortex in a number of flakes and roughouts found at this site.

It is noteworthy, that bedrock samples from the Kraskov Navolok deposit did not find analogies among the artefacts from excavations. The amount of analysed samples is, of course, very small, and the possibility that materials originating from this place were also used cannot be completely ruled out. However, we can be quite certain that this outcrop was not the main source of raw material for the Shuya workshops. At the same time, one sample of boulder material from the shore of this peninsula turned out to be very similar to some of the artefacts. Taking into account that this is the closest place known to us

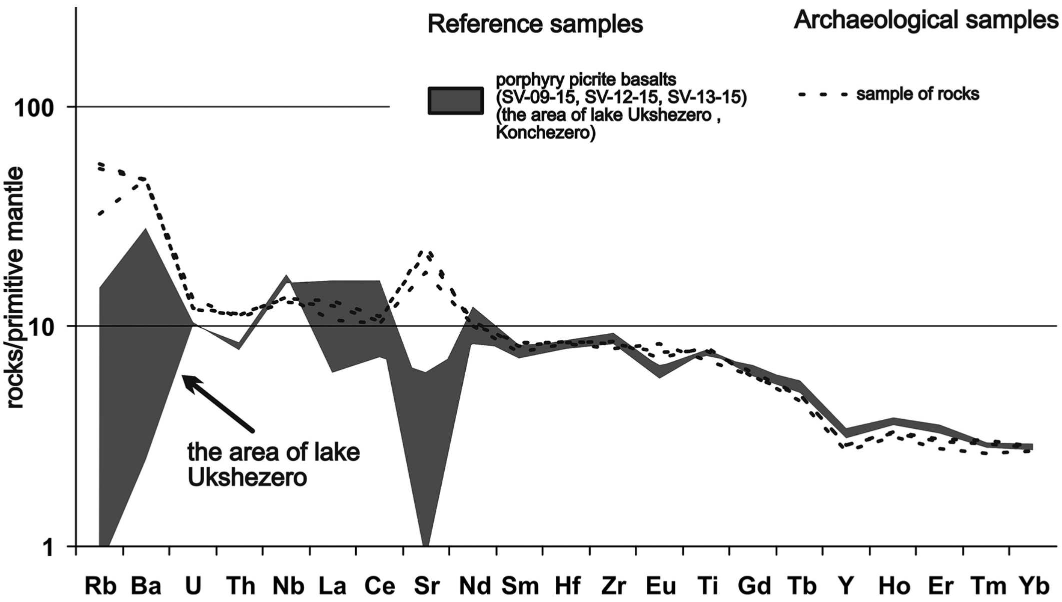


*Fig. 5. Distribution of rare elements in the geological reference samples and archaeological samples (including the samples of bedrock and boulder materials from the Kraskov Navolok Peninsula), normalized by primitive mantle (Sun & McDonough 1989). Rocks of the Konchezero and Ukshezero Lakes' area.*

for pebble and boulder collecting, we have all the reasons to argue that among other sources, also pieces of raw material originating from Kraskov Navolok were used for the production of axes and adzes.

Finally, another very important outcome of the analysis is the observation that the samples from the Derevyannoye XVIII site, quite distant from the outfall of the Shuya River, turned out to be fully similar to the material from the studied Shuya workshops. Therefore, there are no reasons to suspect that this workshop would have been supplied from an alternative source. Based on an earlier technological analysis of production debitage, we concluded that only the final stage of knapping of partly finished preforms took place at this site and that the preforms were imported from another place, most likely the lower reaches of the Shuya River (Tarasov & Zobkov 2015). Consequently, the results of the present geochemical investigations confirm that the Shuya workshops are the most probable source for the semi-finished products transported to the area of Derevyannoye village.

## CONCLUSIONS

Rocky massifs to the north from the outfall of the Shuya River, especially in the vicinity of the Shuiskaya railway station and the village of Shuiskaya Chupa, can be reliably considered to be the source of raw materials for the manufacture of chopping tools of the Russian Karelian (East Karelian) type in the workshops of the western coast of Lake Onega. Pebbles and boulders scattered along the shores of nearby lakes can be considered as an additional source.

The data available at the moment testifies that there was only one substantial deposit serving as the raw material source for these workshops – of course, it could have consisted of a number of quarries placed relatively close to each other. Arguments to propose the existence of an alternative centre of supply are lacking so far.

The geochemical fingerprint of lithic raw material used for the production of Russian Karelian tools, obtained during this study, can be used as a reference sample when studying artefacts of this type originating from other regions.

In the future we need to, first of all, perform similar analysis for finds from other parts of the Lake Onega coast. Partly finished preforms belonging to the late stages of the manufacturing process are quite common at sites in this region (Tarasov 2015b). Analysis of these materials is vital for verifying the possible existence of an alternative source (sources) of raw material acquisition, currently unknown to us. After the full exclusion (or confirmation) of this possibility, we will be able to conduct reliable comparisons also with artefacts originating from more distant areas where only finished objects but no preforms are known.

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## NOTES

[1] Results of this research have been published previously in Russian (see Tarasov & Gogolev 2017).

## REFERENCES

### *Literature*

Äyräpää, A. 1994. Itä-Karjala kivikautisen asekaupan keskustana. Tuloksia Kansallismuseon itäkarjalaisten kokoelmien tutkimuksista. *Muinaista ja vanhaa Itä-Karjalaa. Tutkielmia Itä-Karjalan esihistorian, kulttuurihistorian ja kansankulttuurin alalta*: 53–73. Correction print. Helsinki: Suomen Muinaismuistoyhdistys.

Bryusov, A.Ya. 1940. *Istoriya drevney Karelii.* Trudy Gosudarstvennogo istoricheskogo museya 9.

Bryusov, A.Ya. 1947. Arkheologicheskie pamyatniki III–I tysyacheletiy do nashey ery v Karelo-Finskoy SSR. *Arkheologicheskiy sbornik*: 9–34. Petrozavodsk: Karelskiy filial Akademii Nauk SSSR.

Bryusov, A.Ya. 1952. *Ocherki po istorii plemen Evropeyskoy Chasti SSSR v neoliticheskuyu epokhu*. Moskva: Izd. Akademii Nauk SSSR.

Clark, J.G.D. 1953. *Doistoricheskaya Evropa: Ekonomicheskiy ocherk*. Moskva: Nauka.

Filatova, V.F. 1971. Russko-karel'skiy tip orudiy v neolite Karelii. *Sovetskaya Arkheologiya* 1971 (2): 32–8.

Foss, M.E. 1952. *Drevneishaya istoriya Severa Evropejskoy Chasti SSSR*. Materialy i issledovaniya po arkheologii SSSR 29.

Gurina, N.N. 1974. K voprosu ob obmene v neoliticheskuyu epokhu. *Kratkie soobshcheniya Instituta Arkheologii* 138: 12–23.

Heikkurinen, T. 1980. *Itäkarjalaiset tasa- ja kourutaltat*. Helsingin yliopiston arkeologian laitos, moniste 21.

Kosmenko, M.G. & Kochkurkina, S.I. (eds.) 1996. *Arkheologiya Karelii*. Petrozavodsk: Karel'skiy nauchniy tsentr.

Kriiska, A. & Tarasov, A. 2011. Wood-chopping tools of Russian-Karelian type from Latvia. *Arheoloģija un Etnogrāfija* 25: 57–72.

Kriiska, A., Tarasov, A. & Kirs, J. 2013. Wood-chopping tools of Russian-Karelian type from Estonia. In K. Johanson & M. Tõrv (eds.) *Man, his Time and Space. Collection of Articles Dedicated to Richard Indreko*: 317–45. Muinasaja Teadus 19.

Nordqvist, K. & Seitsonen, O. 2008. Finnish archaeological activities in the present-day Karelian Republic until 1944. *Fennoscandia Archaeologica* XXV: 27–60.

Piličiauskas, G., Luik, H. & Piličiauskiene, G. 2015. Reconsidered Late Mesolithic and Early Neolithic of the Lithuanian coast: the Smeltė and Palanga sites. *Estonian Journal of Archaeology* 19 (1): 3–28.

Sokolov, V.A., Kulikov, V.S. & Stenar, M.M. (eds.) 1987. *Geologiya Karelii.* Leningrad: Nauka.

Sun, S.S. & McDonough, W.F. 1989. Chemical and isotopic systematics of oceanic basalts:

implications for mantle composition and processes. In A.D. Saunders & M.J. Norry (eds.) *Magmatism in the Ocean Basins*: 313–45. Geological Society of London Special Publications 42.

Svetov, S.A., Golubev, A.I., Stepanova, A.V. & Kulikov, V.S. 2015. Paleoprotorozoyskie vulkano-plutonicheskie kompleksy Onezhskoy struktury. *Putevoditel' geologicheskikh ekskursiy XII Vserossiyskogo petrograficheskogo soveshchaniya*: 28–54. Petrozavodsk: Karel'skiy nauchniy tsentr.

Tarasov, A.Yu. 2008. Eneoliticheskaya industriya kamennykh makroorudiy Karelii v ryadu Evropeiskikh industriy pozdnego kamennogo veka. In G.A. Khlopachev (ed.) *Khronogiya, periodizatsiya i krosskul'turnye svyazi v kamennom veke*: 190–201. Zamyatninskiy sbornik 1.

Tarasov, A. 2015a. Spatial separation between manufacturing and consumption of stone axes as an evidence of craft specialization in prehistoric Russian Karelia. *Estonian Journal of Archaeology* 19 (2): 83–109.

Tarasov, A.Yu. 2015b. Fofanovo XIII – primer intensivnoy proizvodstvennoy deyatel'nosti epokhi rannego metalla v lesnoy zone. In G.A. Khlopachev (ed.) *Drevnie kul'tury Vostochnoy Evropy: Etalonnye pamyatniki i opornye kompleksy v kontekste sovremennykh arkheologicheskikh issledovaniy*: 307–17. Zamyatninskiy sbornik 4.

Tarasov, A.Yu. & Gogolev, M.A. 2017. Syr'evaya baza eneoliticheskoy industrii rubyashchikh orudiy regiona Onezhskogo ozera (opyt geokhimicheskogo issledovaniya). *Uchenye zapiski Petrozavodskogo Gosudarstvennogo universiteta* 3 (164): 18–26.

Tarasov, A.Yu. & Gusentsova, T.M. 2012. Rubyashchie orudiya poseleniya Okhta 1 v Sankt-Peterburge (iz raskopok 2008–2009 gg.). In S.A. Vasil'ev & V.Ya. Shumkin (eds.) *Mezolit i neolit Vostochnoy Evropy: Khronologiya i kul'turnoe vzaimodeystvie*: 207–14. Sankt-Peterburg: Institut istorii material'noy kultury.

Tarasov, A.Yu. & Kostyleva, E.L. 2015. Rubyashchie orudiya iz volosovskikh kompleksov Sakhtyshskikh stoyanok. Tekhniko-tipologicheskiy i planigraficheskiy analiz. *Tverskoy Arkheologicheskiy Sbornik* 10 (1): 375–406.

Tarasov, A. & Stafeev, S. 2014. Estimating the scale of stone axe production: a case study from Onega Lake, Russian Karelia. *Journal of Lithic Studies* 1 (1): 239–61.

Tarasov, A.Yu. & Zobkov, M.B. 2015. Eneoliticheskie masterskie zapadnogo poberezh'ya Onezhskogo ozera: Statistiko-planigraficheskiy analiz. *Trudy Karel'skogo nauchnogo tsentra Rossiyskoy Akademii Nauk* 8: 3–16.

Tarasov, A., Nordqvist, K., Mökkönen, T. & Khoroshun, T. 2017. Radiocarbon chronology of the Neolithic–Eneolithic period in the Karelian Republic (Russia). *Documenta Praehistorica* XLIV: 98–121.

Zheltova, M.N., Gusentsova, T.M. & Kul'kova, M.A. 2015. Kamennyi inventar' neolita i epokhi rannego metalla pamyatnika Okhta 1 v Sankt-Peterburge (2008–2009 gg.). *Tverskoy Arkheologicheskiy Sbornik* 10 (1): 362–74.

Zhul'nikov A.M. 1999. *Eneolit Karelii (pamyatniki s poristoy i asbestovoy keramikoy)*. Petrozavodsk: Karel'skiy nauchniy tsentr.

## APPENDIX 1. CONCENTRATION OF ELEMENTS IN THE STUDIED SAMPLES, AS IDENTIFIED BY THE ICP-MS ANALYSIS.

| No | Sample description | Concentration of elements (ppm grams per tonne) | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $^{7}$Li | $^{9}$Be | $^{31}$P | $^{45}$Sc | $^{47}$Ti | $^{51}$V | $^{52}$Cr | $^{55}$Mn | $^{59}$Co | $^{60}$Ni | $^{65}$Cu | $^{66}$Zn | $^{69}$Ga | $^{85}$Rb | $^{88}$Sr | $^{89}$Y |
| 1 | Fofanovo XIII, excavations, flake | 21.53 | 0.96 | 682.80 | 12.53 | 9682.00 | 143.70 | 164.10 | 818.50 | 33.51 | 152.70 | 36.73 | 87.05 | 10.77 | 17.24 | 120.50 | 13.90 |
| 2 | Fofanovo XIII, excavations, flake | 11.32 | 0.83 | 873.80 | 12.64 | 10330.00 | 164.70 | 270.50 | 945.20 | 30.51 | 151.90 | 148.20 | 70.83 | 9.77 | 16.43 | 111.10 | 15.40 |
| 3 | Fofanovo XIII, excavations, flake | 12.29 | <PO | 661.60 | 7.92 | 4974.00 | 123.90 | 374.20 | 1039.00 | 28.91 | 191.40 | 136.70 | 59.28 | 8.14 | 107.10 | 207.10 | 9.11 |
| 4 | Fofanovo XIII, excavations, flake | 16.88 | <PO | <PO | <PO | 4939.00 | 66.48 | 226.10 | 910.90 | 23.15 | 77.68 | 108.80 | 58.88 | <PO | 58.16 | 134.70 | 8.34 |
| 5 | Fofanovo VI, stray find, flake | 33.84 | 1.05 | 817.00 | 30.61 | 13160.00 | 248.00 | 132.70 | 1282.00 | 39.69 | 103.80 | 160.30 | 108.60 | 17.85 | 17.72 | 363.60 | 17.95 |
| 6 | Fofanovo VI, stray find, flake | 23.22 | 0.93 | 1043.00 | 31.41 | 12860.00 | 222.10 | 291.60 | 884.20 | 40.01 | 162.30 | 76.60 | 108.80 | 18.46 | 15.00 | 130.50 | 17.51 |
| 7 | Shuya XXV, excavations, flake | 24.45 | 1.13 | 1023.00 | 27.30 | 12920.00 | 269.00 | 145.10 | 1334.00 | 40.35 | 112.50 | 177.90 | 105.00 | 18.09 | 35.56 | 399.30 | 18.12 |
| 8 | Shuya XXV, excavations, flake | 22.42 | 0.85 | 799.60 | 28.21 | 12550.00 | 249.00 | 164.00 | 1425.00 | 39.03 | 119.60 | 177.80 | 99.85 | 18.51 | 26.47 | 576.30 | 17.49 |
| 9 | Shuya XXI, excavations, flake | 21.32 | 1.10 | 789.40 | 28.01 | 12520.00 | 237.50 | 138.20 | 1350.00 | 38.23 | 105.10 | 159.10 | 108.60 | 17.07 | 38.99 | 357.90 | 17.34 |
| 10 | Shuya XXI, excavations, flake | 19.46 | 1.05 | 883.00 | 28.24 | 12470.00 | 238.10 | 166.50 | 1176.00 | 38.13 | 121.00 | 175.80 | 98.04 | 16.14 | 27.36 | 371.00 | 17.18 |
| 11 | Derevyannoye XVIII, stray find, flake | 23.77 | 1.08 | 1042.00 | 32.37 | 12560.00 | 249.30 | 143.10 | 1536.00 | 40.55 | 112.20 | 177.20 | 117.20 | 18.17 | 42.68 | 623.00 | 17.59 |
| 12 | Derevyannoye XVIII, stray find, flake | 23.14 | 1.32 | 760.50 | 26.88 | 12540.00 | 227.20 | 129.90 | 1280.00 | 40.27 | 104.80 | 216.80 | 103.50 | 17.22 | 32.32 | 363.00 | 17.43 |
| 13 | Derevyannoye XVIII, stray find, flake | 24.59 | 1.00 | 578.50 | 30.08 | 12480.00 | 240.20 | 134.00 | 1494.00 | 39.34 | 106.90 | 172.70 | 111.90 | 17.13 | 43.80 | 544.00 | 17.16 |
| 14 | Nizovie I, excavations, flake | 24.97 | 1.19 | 1146.00 | 31.70 | 13110.00 | 250.00 | 122.70 | 1309.00 | 41.25 | 103.10 | 64.80 | 115.60 | 17.93 | 45.70 | 456.80 | 18.17 |
| 15 | Nizovie I, excavations, flake | 17.58 | 0.90 | 740.50 | 21.15 | 9298.00 | 154.60 | 185.70 | 859.60 | 36.15 | 182.60 | 69.90 | 85.10 | 10.34 | 22.16 | 117.40 | 13.68 |
| 16 | Experimental flake, boulder from the Kraskov Navolok deposit | 36.75 | 0.42 | 410.80 | 19.92 | 6683.00 | 123.30 | 219.20 | 611.10 | 19.36 | 113.00 | 119.60 | 66.20 | 9.97 | 42.24 | 109.80 | 10.01 |
| 17 | Experimental flake, bedrock from the Kraskov Navolok deposit | 37.22 | 0.78 | 672.00 | 32.36 | 10420.00 | 230.40 | 356.40 | 1317.00 | 47.76 | 129.10 | 90.67 | 98.39 | 15.44 | 34.75 | 373.10 | 13.14 |
| 18 | Experimental flake, bedrock from the Kraskov Navolok deposit | 19.27 | 0.78 | 777.20 | 31.67 | 9049.00 | 199.80 | 344.20 | 1191.00 | 41.77 | 117.20 | 117.70 | 86.26 | 14.51 | 32.96 | 494.90 | 12.28 |
| 19 | Experimental flake, bedrock from the Kraskov Navolok deposit | 31.71 | 0.45 | 693.50 | 34.69 | 10010.00 | 205.60 | 237.50 | 1338.00 | 46.01 | 108.80 | 118.40 | 93.57 | 15.95 | 20.51 | 455.00 | 13.10 |
| 20 | Experimental flake, boulder from the Kraskov Navolok deposit | 23.10 | 1.20 | 733.30 | 23.63 | 11310.00 | 214.00 | 166.50 | 1309.00 | 38.04 | 93.79 | 114.40 | 91.49 | 16.31 | 22.66 | 462.20 | 16.29 |

| No | Sample description | Concentration of elements (ppm grams per tonne) | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $^{90}$Zr | $^{93}$Nb | $^{95}$Mo | $^{107}$Ag | $^{111}$Cd | $^{116}$Sn | $^{121}$Sb | $^{125}$Te | $^{133}$Cs | $^{138}$Ba | $^{139}$La | $^{140}$Ce | $^{141}$Pr | $^{142}$Nd | $^{147}$Sm | $^{151}$Eu |
| 1 | Fofanovo XIII, excavations, flake | 161.20 | 14.71 | 0.13 | 0.13 | 0.19 | 1.30 | 0.21 | 2.01 | <PO | 297.80 | 13.20 | 27.85 | 4.32 | 18.43 | 4.30 | 1.18 |
| 2 | Fofanovo XIII, excavations, flake | 143.50 | 13.86 | 0.73 | 0.24 | 0.19 | 1.20 | 0.18 | 2.12 | <PO | 157.50 | 13.90 | 29.22 | 4.70 | 19.80 | 4.61 | 1.39 |
| 3 | Fofanovo XIII, excavations, flake | 93.03 | 8.93 | 1.94 | 0.08 | 0.06 | 1.10 | 0.10 | 1.03 | <PO | 2247.00 | 7.81 | 18.58 | 2.86 | 8.86 | 3.30 | 1.31 |
| 4 | Fofanovo XIII, excavations, flake | 78.88 | 8.05 | 0.25 | 0.09 | 0.05 | 0.79 | 0.07 | 0.98 | <PO | 2178.00 | 5.34 | 13.03 | 1.99 | 6.57 | 2.78 | 1.11 |
| 5 | Fofanovo VI, stray find, flake | 157.30 | 15.84 | 1.06 | 0.22 | 0.38 | 1.42 | 0.23 | <PO | 0.23 | 141.10 | 15.82 | 32.94 | 4.95 | 22.21 | 5.17 | 1.76 |
| 6 | Fofanovo VI, stray find, flake | 195.30 | 18.54 | 0.29 | 0.37 | 0.41 | 1.76 | 0.28 | 2.65 | 0.17 | 241.30 | 11.38 | 27.50 | 4.24 | 18.63 | 4.39 | 1.67 |
| 7 | Shuya XXV, excavations, flake | 155.80 | 15.78 | 1.60 | 0.33 | 0.44 | 1.58 | 0.19 | 2.12 | 0.30 | 329.00 | 14.36 | 31.36 | 4.89 | 22.12 | 5.15 | 1.59 |
| 8 | Shuya XXV, excavations, flake | 152.10 | 15.59 | 1.45 | 0.39 | 0.42 | 1.59 | 0.14 | 2.35 | 0.27 | 234.80 | 15.43 | 32.41 | 4.93 | 23.14 | 5.15 | 1.74 |
| 9 | Shuya XXI, excavations, flake | 154.60 | 15.47 | 1.07 | 0.24 | 0.42 | 1.46 | 0.22 | 2.07 | 0.67 | 175.90 | 16.19 | 32.90 | 4.93 | 22.50 | 4.56 | 1.75 |
| 10 | Shuya XXI, excavations, flake | 153.00 | 15.45 | 1.29 | 0.22 | 0.42 | 1.59 | 0.13 | 1.98 | 0.52 | 240.40 | 16.05 | 32.50 | 4.67 | 22.63 | 4.92 | 1.79 |
| 11 | Derevyannoye XVIII, stray find, flake | 153.00 | 16.37 | 1.98 | 0.65 | 0.38 | 1.51 | 0.72 | 1.98 | 0.72 | 319.30 | 15.00 | 32.75 | 4.75 | 21.26 | 5.10 | 1.78 |
| 12 | Derevyannoye XVIII, stray find, flake | 154.20 | 15.54 | 1.41 | 0.24 | 0.38 | 1.48 | 0.19 | 1.82 | 0.45 | 224.90 | 15.27 | 32.85 | 5.27 | 22.26 | 5.24 | 1.79 |
| 13 | Derevyannoye XVIII, stray find, flake | 150.60 | 15.13 | 1.03 | 0.22 | 0.36 | 1.51 | 0.17 | 1.70 | 0.40 | 333.90 | 14.91 | 31.66 | 4.71 | 21.88 | 4.78 | 1.51 |
| 14 | Nizovie I, excavations, flake | 158.30 | 16.18 | 0.65 | 0.32 | 0.30 | 1.54 | 0.13 | 2.25 | 0.33 | 430.30 | 16.41 | 33.98 | 5.33 | 22.59 | 5.36 | 1.73 |
| 15 | Nizovie I, excavations, flake | 146.30 | 13.72 | 0.49 | 0.29 | 0.28 | 1.24 | 0.23 | 1.44 | 0.18 | 199.30 | 9.79 | 23.83 | 3.58 | 15.39 | 3.65 | 1.20 |
| 16 | Experimental flake, boulder from the Kraskov Navolok deposit | 116.00 | 11.12 | 1.19 | 0.22 | <PO | 1.32 | 0.12 | 1.18 | 0.44 | 507.50 | 7.42 | 17.04 | 2.50 | 10.84 | 2.87 | 0.88 |
| 17 | Experimental flake, bedrock from the Kraskov Navolok deposit | 95.26 | 9.71 | 0.52 | 0.23 | 0.19 | 1.11 | 0.08 | 1.25 | 0.90 | 320.00 | 7.33 | 18.18 | 2.99 | 13.73 | 3.77 | 1.20 |
| 18 | Experimental flake, bedrock from the Kraskov Navolok deposit | 89.06 | 9.22 | 0.95 | 0.21 | 0.15 | 0.96 | 0.15 | 1.11 | 2.03 | 325.00 | 8.56 | 18.82 | 3.14 | 13.55 | 3.37 | 1.39 |
| 19 | Experimental flake, bedrock from the Kraskov Navolok deposit | 93.30 | 9.54 | 0.45 | 0.12 | 0.13 | 0.93 | 0.13 | 1.27 | 0.85 | 323.40 | 9.01 | 19.75 | 3.22 | 14.28 | 3.59 | 1.28 |
| 20 | Experimental flake, boulder from the Kraskov Navolok deposit | 149.80 | 13.95 | 0.87 | 0.28 | 0.30 | 1.34 | 0.24 | 1.86 | 0.53 | 358.70 | 16.54 | 33.02 | 5.04 | 20.79 | 4.92 | 1.57 |

| No | Sample description | Concentration of elements (ppm grams per tonne) | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $^{7}$Li | $^{9}$Be | $^{31}$P | $^{45}$Sc | $^{47}$Ti | $^{51}$V | $^{52}$Cr | $^{55}$Mn | $^{59}$Co | $^{60}$Ni | $^{65}$Cu | $^{66}$Zn | $^{69}$Ga | $^{85}$Rb | $^{88}$Sr | $^{89}$Y |
| 1 | Fofanovo XIII, excavations, flake | 3.95 | 0.55 | 3.19 | 0.57 | 1.55 | 0.23 | 1.56 | 0.20 | 4.31 | 0.91 | 0.30 | 0.05 | 1.50 | <PO | 2.54 | 0.45 |
| 2 | Fofanovo XIII, excavations, flake | 4.60 | 0.61 | 3.58 | 0.62 | 1.69 | 0.26 | 1.66 | 0.23 | 3.86 | 0.79 | 0.35 | 0.11 | 1.86 | <PO | 2.23 | 0.42 |
| 3 | Fofanovo XIII, excavations, flake | 3.10 | 0.39 | 2.17 | 0.38 | 1.01 | 0.15 | 1.02 | 0.15 | 2.60 | 0.55 | 0.73 | 0.39 | 2.26 | <PO | 1.72 | 0.27 |
| 4 | Fofanovo XIII, excavations, flake | 2.61 | 0.32 | 2.13 | 0.36 | 0.92 | 0.14 | 0.91 | 0.13 | 2.20 | 0.47 | 0.13 | 0.24 | 1.49 | <PO | 1.32 | 0.21 |
| 5 | Fofanovo VI, stray find, flake | 5.27 | 0.71 | 4.29 | 0.72 | 1.96 | 0.30 | 1.92 | 0.25 | 4.27 | 0.94 | 0.30 | 0.13 | 4.54 | 0.02 | 2.84 | 0.76 |
| 6 | Fofanovo VI, stray find, flake | 4.62 | 0.68 | 4.00 | 0.71 | 1.92 | 0.29 | 1.94 | 0.26 | 4.91 | 1.05 | 0.32 | 0.08 | 3.82 | 0.02 | 3.09 | 0.55 |
| 7 | Shuya XXV, excavations, flake | 5.04 | 0.71 | 4.16 | 0.73 | 1.95 | 0.29 | 1.88 | 0.26 | 4.17 | 0.94 | 0.47 | 0.24 | 4.25 | 0.03 | 2.85 | 0.75 |
| 8 | Shuya XXV, excavations, flake | 5.30 | 0.70 | 4.11 | 0.73 | 1.94 | 0.29 | 1.87 | 0.27 | 4.07 | 0.95 | 0.40 | 0.18 | 5.10 | 0.03 | 2.81 | 0.72 |
| 9 | Shuya XXI, excavations, flake | 5.36 | 0.71 | 4.30 | 0.72 | 1.91 | 0.29 | 1.90 | 0.26 | 4.27 | 0.93 | 0.35 | 0.27 | 3.80 | 0.03 | 2.86 | 0.76 |
| 10 | Shuya XXI, excavations, flake | 5.19 | 0.69 | 4.07 | 0.71 | 1.88 | 0.28 | 1.84 | 0.25 | 4.04 | 0.92 | 0.38 | 0.18 | 4.89 | 0.03 | 2.82 | 0.73 |
| 11 | Derevyannoye XVIII, stray find, flake | 5.44 | 0.70 | 4.36 | 0.71 | 1.92 | 0.29 | 1.88 | 0.26 | 4.34 | 1.56 | 0.94 | 0.29 | 5.21 | 0.09 | 2.86 | 0.75 |
| 12 | Derevyannoye XVIII, stray find, flake | 5.08 | 0.71 | 3.98 | 0.71 | 1.95 | 0.28 | 1.88 | 0.27 | 4.35 | 1.14 | 0.53 | 0.52 | 4.96 | 0.04 | 2.88 | 0.81 |
| 13 | Derevyannoye XVIII, stray find, flake | 5.14 | 0.69 | 4.15 | 0.70 | 1.92 | 0.27 | 1.92 | 0.24 | 4.10 | 1.04 | 0.45 | 0.27 | 5.18 | 0.05 | 2.78 | 0.74 |
| 14 | Nizovie I, excavations, flake | 5.50 | 0.73 | 4.52 | 0.77 | 2.00 | 0.29 | 1.97 | 0.26 | 4.23 | 1.03 | 0.36 | 0.28 | 3.64 | 0.04 | 2.92 | 0.80 |
| 15 | Nizovie I, excavations, flake | 3.97 | 0.54 | 3.26 | 0.57 | 1.47 | 0.22 | 1.49 | 0.20 | 3.70 | 0.82 | 0.37 | 0.11 | 1.90 | 0.03 | 2.15 | 0.43 |
| 16 | Experimental flake, boulder from the Kraskov Navolok deposit | 2.73 | 0.38 | 2.31 | 0.39 | 1.07 | 0.17 | 1.08 | 0.14 | 3.05 | 0.62 | 0.43 | 0.35 | 5.36 | 0.03 | 1.78 | 0.42 |
| 17 | Experimental flake, bedrock from the Kraskov Navolok deposit | 3.51 | 0.53 | 3.25 | 0.55 | 1.48 | 0.22 | 1.41 | 0.19 | 2.62 | 0.62 | 0.21 | 0.27 | 2.47 | 0.02 | 0.95 | 0.25 |
| 18 | Experimental flake, bedrock from the Kraskov Navolok deposit | 3.54 | 0.49 | 3.04 | 0.52 | 1.34 | 0.20 | 1.34 | 0.17 | 2.56 | 0.59 | 0.24 | 0.28 | 4.32 | 0.02 | 0.93 | 0.28 |
| 19 | Experimental flake, bedrock from the Kraskov Navolok deposit | 3.70 | 0.52 | 3.22 | 0.54 | 1.45 | 0.22 | 1.39 | 0.19 | 2.63 | 0.60 | 0.19 | 0.19 | 2.92 | 0.02 | 0.97 | 0.26 |
| 20 | Experimental flake, boulder from the Kraskov Navolok deposit | 4.59 | 0.66 | 3.79 | 0.65 | 1.81 | 0.26 | 1.73 | 0.24 | 4.06 | 0.84 | 0.28 | 0.17 | 4.86 | 0.04 | 4.22 | 1.20 |