



# Provenance analysis of obsidian artifacts from the Indigirka River basin (Northeast Siberia) and the long-distance exchange of raw material in prehistoric Siberian Arctic

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## ABSTRACT

For the first time, an obsidian provenance study is performed for artifacts from the Indigirka River basin (Northeast Siberia). The non-destructive ED-XRF analysis of seven obsidian items from the Buolumuna-Taasa site, dated to the Neolithic (ca. 5000–1000 cal BC), shows that all of them originated from the Lake Krasnoe source, situated ca. 1300 km away. This is a remarkable example of super-long-distance transport / exchange of obsidian in prehistory of Siberian Arctic, and it testifies in favor of extensive contacts of ancient population in Northeast Siberia since the Mesolithic, ca. 6900 cal BC, or even earlier.

## 1. Introduction

Investigations of the primary sources for archaeological obsidian began in the 1960s in the Mediterranean region (Cann and Renfrew, 1964), and quickly spread to other parts of the globe (see, for example: Glascock, 2002; Summerhayes, 2009; Ambrose, 2012). It resulted in understanding not only the patterns of lithic resource exploitation but also the peculiarities of human movements and contacts in antiquity. The importance of this kind of research was emphasized by Williams-Thorpe (1995) who noticed that traditional archaeological approach was unable to reconstruct the contact zones and exchange networks which existed in prehistory.

Obsidian provenance studies in eastern Russia were initiated quite late, only in the early 1990s (e.g. Shackley et al., 1996; Kuzmin et al., 2002a, Kuzmin et al., 2002b), and resulted in the establishment of the main patterns of raw material acquisition and exchange in prehistory for the southern Russian Far East (including Maritime and Amur provinces, Sakhalin Island, and Kurile Islands) and neighboring regions of Northeast Asia (Hokkaido Island of Japan, Korean Peninsula, and

Northeast China) (e.g. Kuzmin, 2010, 2014, 2017). It was shown that obsidian was an important commodity traded / exchanged since the Upper Paleolithic (ca. 28,000 years ago) over long distances, often exceed 600–700 km in a straight line.

Obsidian is also known at prehistoric sites further north—in Northeast Siberia (see Shahgedanova et al., 2002; Suslov, 1961)—covers basins of the Kolyma, Indigirka, and Yana rivers, coastal lowlands of the Arctic Ocean, the insular High Arctic, Koryak Uplands, and Chukotka region (Fig. 1). Here obsidian provenance studies began only in 2009, and the first results were recently released (Grebennikov et al., 2018; Kuzmin, 2019a; Kuzmin et al., 2018; Pitulko et al., 2019). The largest concentration of obsidian artifacts is detected in the Chukotka region (see Dikov, 1997; Kiryak, 2010); towards the west of it, in the basins of Kolyma and Indigirka rivers, obsidian is quite rare. Until recently, the investigations of obsidian provenance were done only in the Kolyma River basin (Kuzmin et al., 2018). In this paper, we report the results of analysis for obsidian artifacts from the westernmost occurrence in mainland Siberia – in the Indigirka River basin, and discuss its impact on understanding the patterns of prehistoric raw material

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Fig. 1. Archaeological sites in Northeast Siberia and Alaska and obsidian sources in Northeast Siberia under consideration. 1 – the Lake Krasnoe obsidian source; 2 – possible obsidian source in the Berezovka River basin; 3 – the most remote archaeological sites in Northeast Siberia with obsidian from the Lake Krasnoe source; 4 – Boulumuna-Taasa site.

exchange and transportation in Northeast Siberia.

## 2. Material and methods

Obsidian is very rare in prehistoric complexes west of the Kolyma River, and only a handful of sites in the Indigirka River basin contain artifacts made of this raw material. It was initially discovered by [Everstov \(1979\)](#); see also [Fedoseeva, 1980, p. 150](#)) at the Belaya Gora site in the middle course of the Indigirka River. Unfortunately, obsidian from this site is not currently available for analysis.

One of the few localities from where we were able to obtain obsidian is the Boulumuna-Taasa site. It is situated in middle part of the Indigirka River basin, 11.5 km SW of the Belaya Gora town, on the terrace of the Indigirka River 10–15 m above the water level; geographic coordinates are 68° 28' 08" N, 145° 58' 51" E ([Fig. 1](#)). The site was discovered in 1980 ([Everstov, 1981](#)), and test excavations (12 m<sup>2</sup>) were conducted in 1980 and 2002. As a result, lithic artifacts, pottery, and some burnt animal bones were unearthed. Among the stone artifacts, there were fragmented knife, polished tool, four points, and seven knife-like blades; three arrowheads; four end scrapers; three complete knives; four insets; grinding stones; and four cores. Pottery was represented by fragments with net and cord design, and it became clear that items of two cultural complexes, Syalakh and Belkachi (see [Alekseyev and Dyakonov, 2009](#)), are mixed in the cultural layer.

The latest small-scale excavations (4 m<sup>2</sup>) at the Boulumuna-Taasa site were conducted in 2016–2017 by V.M. Dyakonov. Seventy five lithics, 37 potsherds (with waffle, cord, and smooth designs), and four animal bones were found, including seven black obsidian items ([Fig. 2](#)). Stone artifacts are represented by following categories: flakes (n = 40),

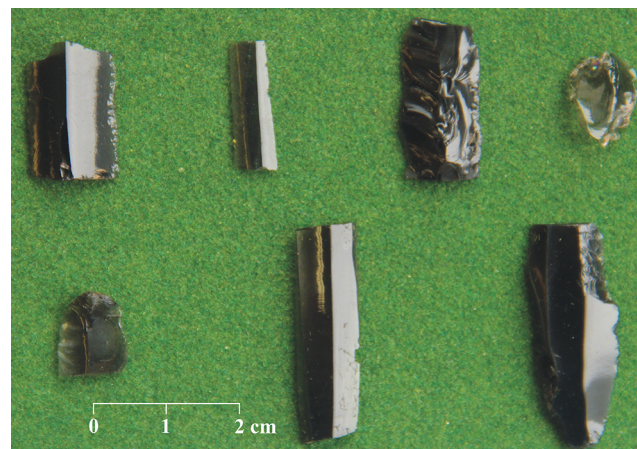


Fig. 2. Obsidian artifacts from the Boulumuna-Taasa site analyzed by ED-XRF.

two made of obsidian; blades (n = 31), two made of obsidian; insets on blade (n = 2) and a burin-like tool, all made of obsidian; and a scraper. The most common lithic raw materials at the Boulumuna-Taasa site are flint, silicified schist and chalcedony.

According to typology of stone artifacts and pottery, the Boulumuna-Taasa site belongs to the Neolithic epoch. Remains of all three major archaeological complexes of the Arctic Neolithic—Syalakh, Belkachi, and Ymyyakhtakh—were found. Unfortunately, due to mixture of artifacts of different complexes, it was impossible to sub-divide the cultural layer into separate stratigraphic units, and we treat the site as a palimpsest. Based on general cultural chronology of northern

Yakutia (Alekseyev and Dyakonov, 2009; Pitulko and Pavlova, 2016; Kuzmin et al., 2018), the age of site can be established within the fifth – second millennia BC (ca. 5000–1000 cal BC; or ca. 6500–3000 BP).

Due to extreme rarity of obsidian in Northeast Siberia west of the Kolyma River (Kuzmin et al., 2018; Pitulko et al., 2019), we decided to analyze all seven obsidian artifacts from the Buolumuna-Taasa site by non-destructive geochemical method, in order to establish their provenance. The Energy Dispersive X-ray Fluorescence (ED–XRF) analysis was performed at the Archaeometry Laboratory, Research Reactor Center, University of Missouri (MURR) at Columbia, MO, USA. A few of the artifacts were below the traditional size and thickness recommended for ED–XRF but none were so small that they could not be analyzed reasonably.

Measurements were performed using a ThermoScientific ARL Quantx ED–XRF spectrometer. The instrument has a rhodium-based X-ray tube and thermoelectrically-cooled silicon-drift detector (SDD). The tube was operated at 35 kV and current was automatically adjusted to a fixed 30% dead time. The samples were counted for two minutes each permitting measurements for the following elements: Mn, Fe, Zn, Rb, Sr, Y, Zr, Nb, and Th. Normalization to the Compton scattering peak was used to account for differences in sample size and thickness. The Quantx ED–XRF spectrometer was calibrated for obsidian by measuring a set of 40 very well-characterized obsidian source samples previously analyzed by Neutron Activation Analysis (NAA), Inductively Coupled Plasma – Mass Spectrometry (ICP–MS), and XRF methods.

In order to find the most probable match to the primary locale(s) of obsidian, the geochemical data on the sources from Chukotka and Kamchatka regions previously studied by our group were used for comparison (Grebennikov and Kuzmin, 2017; Grebennikov et al., 2010, 2014, 2018). We employed the approach developed by Glascock et al. (1998), described in detail in our previous publications (e.g. Kuzmin and Glascock, 2007, 2014; Kuzmin et al., 2002a, 2002b, 2013). Briefly, the procedure is the following. All specimens from primary sources were previously tested by NAA at the MURR, and a comprehensive geochemical “signatures”, based on the composition of 28 elements, were established (e.g. Grebennikov and Kuzmin, 2017; Grebennikov et al., 2018). Afterwards, it was possible to use the smaller number of elements measured by XRF to identify the obsidian source. Statistical grouping, based on bivariate plots, and cluster and discriminant classification analyses, was performed by using the GAUSS software (available from the MURR on request), to indicate the obsidian sources with greater than 90% probability.

### 3. Results and discussion

The element contents and ratios for analyzed artifacts are presented in Table 1. Due to the normalization procedure used to estimate the amount of sample exposed to X-rays, many of the absolute concentrations for small/thin samples have incorrect absolute values. To reduce this problem, the concentration data for the most useful elements (Rb and Y) were converted to ratios by dividing by the concentration of Zr (Fig. 3, B).

The process of assigning sources actually involves eliminating the

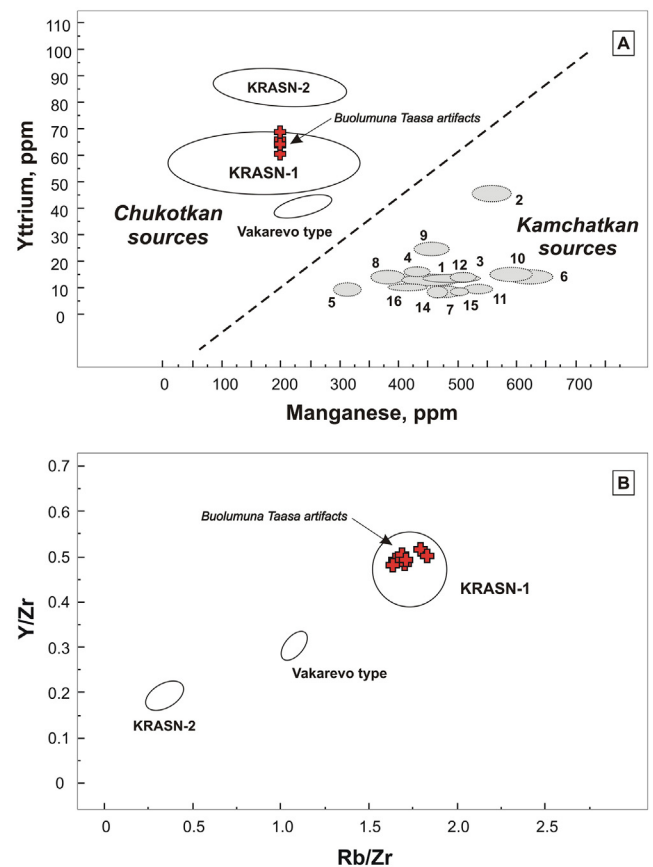


Fig. 3. Scatterplots for obsidian artifacts from Buolumuna-Taasa site (red crosses) compared to obsidian sources in Chukotka and Kamchatka (source ellipses are shown at the 90% confidence interval): A – Mn vs. Y (Kamchatkan sources Nos. 1–16 are KAM-1 through KAM-16; see Grebennikov & Kuzmin, 2017); B – Rb/Zr vs. Y/Zr ratios for Chukotkan sources.

locales that clearly do not match the artifacts and then selecting the best matching source from the remainder. Scatterplots (Fig. 3) illustrate how the artifacts in this investigation were assigned to particular source. The regional sources considered were Cape Medvezhiy (KRASN-1) and Cape Ribachiy (KRASN-2), both in the Lake Krasnoe of Chukotka region (Grebennikov et al., 2018). The results show that all of artifacts from Buolumuna-Taasa came from the locality known as Cape Medvezhiy (KRASN-1). None of other possible sources—on Kamchatka Peninsula (KAM-1 – KAM-16) (see Grebennikov and Kuzmin, 2017) and the Vakarevo on Chukotka (with unknown precise position; see Grebennikov et al., 2018)—fit the geochemical composition of the Buolumuna-Taasa artifacts (Fig. 3, A–B).

In the 1930s, some information on the presence of primary locality with obsidian in the Kolyma River basin was published by Wakar (1934). He described obsidian in the basin of Berezovka River, tributary of the Kolyma River (see Fig. 1). According to his information, obsidian

Table 1  
Concentrations of elements (parts-per-million, ppm) in obsidian artifacts from Buolumuna Taasa site.

Sample ID <sup>†</sup>	Mn	Fe	Zn	Rb	Sr	Y	Zr	Nb	Th	Rb/Zr	Y/Zr
KU1304	199.7	7128.9	54.3	230.4	3.0	64.9	134.8	8.5	21.8	1.71	0.48
KU1305	199.7	6471.5	46.6	214.0	2.5	63.5	129.4	8.7	20.6	1.65	0.49
KU1306	199.7	7897.8	59.1	239.0	2.7	68.4	132.8	8.4	21.7	1.80	0.52
KU1307	199.7	6742.2	48.0	221.8	2.2	65.7	130.9	9.0	19.9	1.69	0.50
KU1308	199.7	8811.7	67.8	250.8	2.9	68.7	137.0	9.1	23.2	1.83	0.50
KU1309	199.7	6173.5	41.9	205.4	2.4	60.3	125.3	8.9	17.7	1.64	0.48
KU1310	199.7	7268.0	51.1	223.0	3.3	64.1	130.1	7.4	19.0	1.71	0.49

<sup>†</sup> Correspond to those in the MURR database.



constitutes part of liparite (rhyolite) dike. However, it is not clear what kind of rock was found: pure obsidian suitable for making tools or perlite with non-homogenous texture. According to microscopic examination (Wakar, 1934, pp. 5–7), green volcanic glass has inclusions of crystals up to 1 mm in diameter; this is more typical for perlite rather than for obsidian. The water content in volcanic glass is 1.40–7.16 wt%, again more common in perlites than in obsidians. Perlite-like volcanic glasses with relatively high content of water (up to 6.0 wt%) are found in several places in Northeast Siberia (Nasedkin, 1983) but because of its low quality—brittle texture without sharp conchoidal fracture—it was never used by prehistoric people. Numerous dikes of perlite are described in the Northeast Siberia by Nasedkin (1983) but none of them contain waterless volcanic glass. Also, the small size of liparite dikes with “obsidian” (only 4–5 m long, and 1.5–2 m wide) and possible inaccessibility to them by ancient people because these rocks were not exposed in prehistory and no obsidian pebbles could be found in the river channel, resulted in absence of this volcanic glass in prehistoric lithic assemblages.

The important part of our conclusion about the Lake Krasnoe source as main supplier of obsidian for entire Northeast Siberia is that all the analyses used in this and related studies (see Kuzmin et al., 2008, 2018; Grebennikov and Kuzmin, 2017; Grebennikov et al., 2010, 2014, 2018; Pitulko et al., 2019) were performed at the same laboratory (MURR), with the same analytical standards and reference samples. This issue became now crucial when data produced by different laboratories are not compatible due to several reasons (see Suda et al., 2018). This is especially true in cases of application of semi-quantitative ED-XRF analysis, which on the one hand is non-destructive but on the other hand can generate unreliable data. Therefore, the cross-analysis of obsidian samples by different methods is now recommended (e.g. Orange et al., 2017; Kasztovszky et al., 2018). In our case, use of both NAA and XRF methods give us confidence that our results are reliable.

The distance between the primary obsidian source on the Lake Krasnoe and the Boulumuna-Taasa site is 1330 km as crow flies (Fig. 1). This is a case of one of the longest transportation of obsidian in mainland Northeast Asia in general (Kuzmin, 2017, pp. 6–7), and in Northeast Siberia in particular. Only the Zhokhov site in the Siberian High Arctic has record of longer transport of raw material, ca. 1500 km in straight line and ca. 2000 km considering the coastline at ca. 8900–8600 cal BP (Pitulko et al., 2019).

The Zhokhov site is located on the small island of the same name, part of the De Long archipelago east of the larger New Siberia Islands (Fig. 1). Obsidian was brought here from Chukotka region as semi-ready forms (cores and blades) (Pitulko et al., 2019). The same pattern is observed for sites in the Kolyma River basin, at the distance from the source of ca. 800–1100 km in a straight line (Fig. 1). It seems logical that people transported ready tools or cores over great distances, well beyond the “supply zone” of ca. 300 km (e.g. Renfrew 1975). When such distance reach ca. 1000 km as the crow flies, it may be called “super-long-distance” exchange of obsidian (Kuzmin, 2019b; Pitulko et al., 2019).

The results of this study along with other data available for Northeast Siberia and Alaska show that the Lake Krasnoe source was the most important supplier of high quality raw material in this part of the world (Fig. 1). As for Alaska, obsidian from the Lake Krasnoe source was identified at several localities: Hillside site, St. Lawrence Island, and Aquilaak 3–3 site near Cape Prince of Wales (Cook, 1995, p. 98); Deering site, Seward Peninsula (Reuther, 2009); and Iyatayet site, Norton Sound (Tremayne, 2015; Tremayne et al., 2018) (Fig. 1).

Besides Alaska (see Rasic, 2016), this obsidian is identified on Chukotka, Koryak Upland, basins of Kolyma and Indigirka rivers, Zhokhov Island, and the northern coast of Okhotsk Sea. The rough estimate of the size of interaction sphere in prehistory of Siberian Arctic is several million square kilometers (Pitulko et al., 2019).

This is a significant conclusion about the scale of human contacts and migrations in Siberian Arctic and beyond it (Alaska) in antiquity,

which was unknown before (Dikov 1997, 2003, 2004; Kiryak, 2010). The earliest solid data known today about the obsidian exchange in Northeast Siberia demonstrate that it was moved from the primary source to faraway utilization site at ca. 6900 cal BC (Zhokhov Island). However, considering the presence of obsidian artifacts at the Orlovka II site in western Chukotka associated with the Upper Paleolithic (Kiryak, 2010), we can suggest that obsidian acquisition and exchange in Northeast Siberia began before the Mesolithic. It is additionally testified by the Ushki cluster on the neighboring Kamchatka region where the earliest cultural complex with obsidian is dated to late Upper Paleolithic, ca. 15,400 cal BC (Kuzmin et al., 2008).

Based on our knowledge, none of ca. 120 obsidian artifacts from the Kolyma River basin, Zhokhov and Boulumuna-Taasa sites, analyzed by our team (see Kuzmin et al., 2018; Pitulko et al., 2019), belong to any other source rather than the Lake Krasnoe. Obsidian from another region in eastern Russia with numerous primary sources—Kamchatka—never reached the territory beyond the Koryak Upland and (possibly) the easternmost Chukotka (Grebennikov et al., 2018).

#### 4. Conclusions

Obsidian at the Boulumuna-Taasa site in the Indigirka River basin was brought from the Lake Krasnoe area in Chukotka. This primary source was the main supplier of high quality volcanic glass in entire Northeast Siberia in the Mesolithic – Neolithic, and possibly in the late Upper Paleolithic. The distances from source to utilization sites vary from a few kilometers to hundreds of kilometers, often exceeding 1000 km in a straight line. The sphere of interaction and contacts in Siberian Arctic in the Mesolithic – Neolithic cover enormously large territory, with estimate of its size as ca. 4,000,000 km<sup>2</sup>. Obsidian was brought to prehistoric sites in Siberian Arctic mainly as ready tools or cores, in order to maximize the effectiveness of transportation efforts. Only by using the obsidian provenance studies it is possible to reconstruct the prehistoric exchange networks and contacts in Northeast Siberia.

#### CRedit authorship contribution statement

**Yaroslav V. Kuzmin:** Conceptualization, Investigation. **Viktor M. Dyakonov:** Data curation, Investigation. **Michael D. Glascock:** Investigation. **Andrei V. Grebennikov:** Investigation

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