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Obsidian provenance for prehistoric complexes in the Amur River basin (Russian Far East)

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ABSTRACT

The sources of high quality volcanic glass (obsidian) for archaeological complexes in the Amur River basin of the Russian Far East have been established, based on geochemical analyses by neutron activation and X-ray fluorescence of both 'geological' (primary sources) and 'archaeological' (artifacts from the Neolithic and Early Iron Age cultural complexes) specimens. A major obsidian source identified as the Obluchie Plateau, located in the middle course of the Amur River, was found to be responsible for supplying the entire middle and lower parts of the Amur River basin during prehistory. The source has been carefully studied and sampled for the first time. Minor use of three other sources was established for the lower part of the Amur River basin. Obsidian from the Basaltic Plateau source, located in the neighboring Primorye (Maritime) Province, was found at two sites of the Initial Neolithic (dated to ca. 11,000–12,500 BP). At two other sites from the same time period, obsidian from a still unknown source called "Samarga" was established. At the Suchu Island site of the Early Neolithic (dated to ca. 7200–8600 BP), obsidian from the 'remote' source of Shirataki (Shirataki-A sub-source) on Hokkaido Island (Japan) was identified. The range of obsidian transport in the Amur River basin was from 50 to 750 km within the basin, and from 550 to 850 km in relation to the 'remote' sources at the Basaltic Plateau and Shirataki-A located outside the Amur River valley. The long-distance transport/exchange of obsidian in the Amur River basin in prehistory has now been securely established.

1. Introduction

Obsidian (i.e. waterless volcanic glass; see Bates and Jackson, 1984, 352) was widely used throughout prehistoric Northeast Asia, including Japan, Korea, Russian Far East, and Northeast China, as raw material for tool manufacture (Kuzmin and Glascock, 2010). Because identification of obsidian source(s) gives direct evidence for human contact, exchange, and migration (e.g., Cann, 1983; Williams-Thorpe, 1995), studies of both 'geological' and 'archaeological' obsidians were initiated in the Russian Far East in the early 1990s (e.g., Kuzmin et al., 1999; Kuzmin and Glascock, 2001; Kuzmin and Popov, 2000). The main territories under investigation were the Primorye [Maritime] Province and Sakhalin Island (Kuzmin and Glascock, 2007; Kuzmin et al., 2002a, 2002b). Now, the main patterns of obsidian exploitation in prehistory of the region have been established (Kuzmin, 2006a, 2010).

The Amur River basin (within the territory of Russian Federation, see Fig. 1) was a long-neglected part of the Russian Far East, despite the fact that obsidian artifacts were found in the Neolithic and Paleometal cultural complexes since the 1960s (e.g., Derevianko, 1970, 2000; Okladnikov et al., 1971; Konopatski, 1993; Lapshina, 1999). Until the late 1990s, no instrumental geochemical analysis (sensu Glascock et al., 1998) was applied to obsidian artifacts from the Amur River basin, and this paper is the first systematic work on the identification of sources of archaeological obsidian from this region.

2. Material and methods

2.1. Prehistoric archaeological complexes of the Amur River basin

The Amur River valley within the Russian Far East is divided into two parts. A middle course which extends roughly from the

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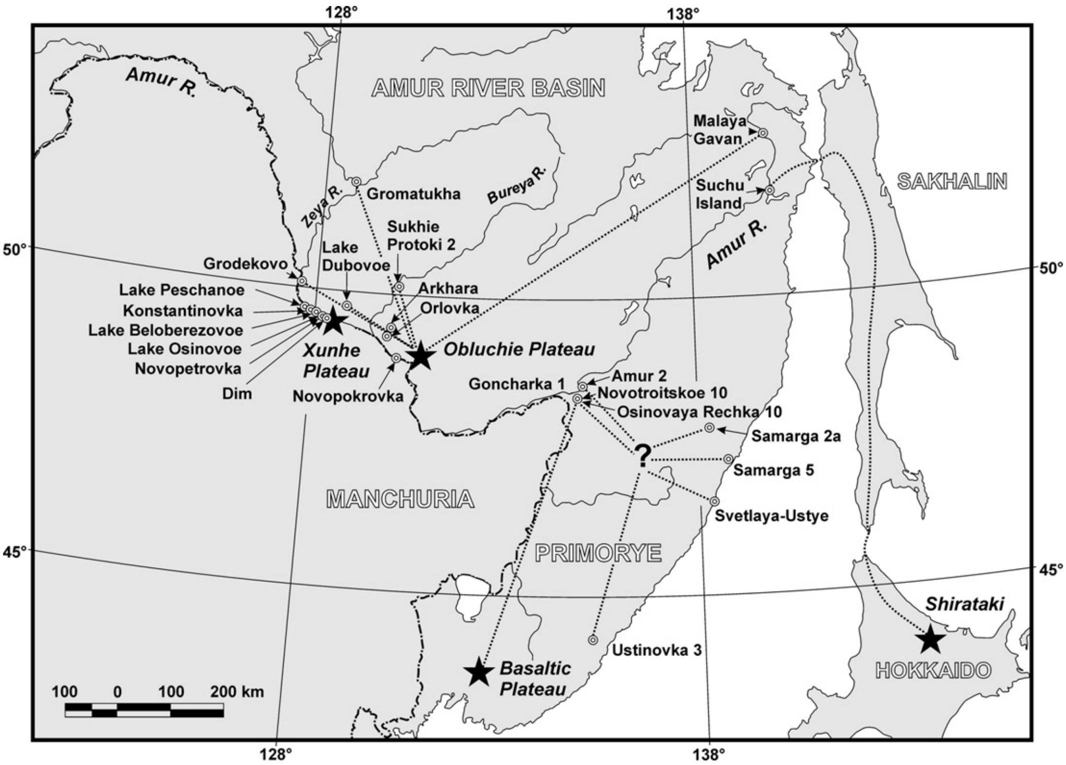

Fig. 1. Distribution of archaeological sites and obsidian sources in the Amur River basin.

confluence of Amur and Zeya rivers to the joining of Amur and Ussuri rivers, and a lower course extending from the confluence of Amur and Ussuri to the mouth of Amur River (Fig. 1). In total, obsidian artifacts from 19 sites belonging to the Neolithic and Paleometal (Early Iron Age) cultural complexes in the Amur basin were analyzed for the purpose of this study (Fig. 1; Table 1). There are also numerous Upper Paleolithic sites in the Amur River basin (Derevianko et al., 2006) but no obsidian artifacts were found at them.

In the Middle Amur region, Gromatukha complex (Derevianko, 2004, 464–465) may be associated with the Initial Neolithic with ^{14}C age of ca. 11,600–12,400 BP (Kuzmin, 2006b; Nesterov et al., 2006). The assemblage of artifacts is characterized by bifacial stone tools and pottery with crude surface decorations made with grass (Derevianko, 2004). The Novopetrovka complex (Derevianko, 2004, 464) can be attributed to the Middle Neolithic, with ^{14}C dates of ca. 7900–8000 BP (Nesterov et al., 2005). The stone inventory is represented by blade tools, and the pottery was decorated by applying rollers. The Late Neolithic comprises the Osinovoe Ozero [Osinoozerskaia] cultural complex (Derevianko, 2004, 465), dated to ca. 3300–4300 BP (Nesterov et al., 2005; Kuzmin, 2006b), with artifacts present as bifacial flake stone tools and pottery decorated by stick rollers. As for the Paleometal complexes, obsidian was detected at the single site of Sukhie Protoki 2 which has been dated to ca. 2600–2900 BP (Nesterov and Kuzmin, 1999; Derevianko, 2000, 97).

Table 1
Archaeological sites in the Amur River basin with obsidian artifacts, analyzed in this study.

Site Name	Localization	Site Age	Source[a]
Gromatukha	Middle Amur, Zeya River basin	Initial–Early Neolithic	[1]
Grodekovo	Middle Amur, Zeya–Bureya Plain	Initial–Early Neolithic	[2]
Novopetrovka	Middle Amur, Zeya–Bureya Plain	Middle–Late Neolithic	[1]
Konstantinovka	Middle Amur, Zeya–Bureya Plain	Late Neolithic	[3]
Lake Beloberezovoe	Middle Amur, Zeya–Bureya Plain	Late Neolithic	[3]
Lake Dubovoe	Middle Amur, Zeya–Bureya Plain	Late Neolithic	[3]
Lake Peschanoe	Middle Amur, Zeya–Bureya Plain	Late Neolithic	[3]
Dim	Middle Amur, Zeya–Bureya Plain	Late Neolithic	[3]
Orlovka	Middle Amur, Zeya–Bureya Plain	Late Neolithic	[3]
Arkhara	Middle Amur, Zeya–Bureya Plain	Late Neolithic	[3]
Novopokrovka	Middle Amur, Zeya–Bureya Plain	Late Neolithic	[3]
Osinovoe Ozero	Middle Amur, Zeya–Bureya Plain	Late Neolithic	[1]
Sukhie Protoki 2	Middle Amur, Bureya River basin	Early Iron Age	[4]
Goncharka 1	Lower Amur	Initial Neolithic	[5]
Osinovaya Rechka 10	Lower Amur	Initial Neolithic	[5]
Amur 2	Lower Amur	Initial Neolithic	[5]
Novotroitskoe 10	Lower Amur	Initial Neolithic	[5]
Suchu Island	Lower Amur	Early Neolithic	[6]
Malaya Gavan	Lower Amur	Late Neolithic	[7]

[a] Numbers correspond to these sources: [1] – Derevianko (2004); [2] – Sapunov et al. (2000); [3] – this study; [4] – Derevianko (2000); [5] – Shewkomud and Kuzmin (2009); [6] – Derevianko et al. (2003); [7] – Konopatski (1993).

In the Lower Amur River basin, several Neolithic complexes are known (see Derevianko and Medvedev, 2006). As for sites with obsidian artifacts (Goncharka 1, Osinovaya Rechka 10, Amur 2, and Novotroitskoe 10), they belong to the Osipovka cultural complex of the Initial Neolithic (Shewkomud, 2005) and are dated to ca. 9900–12,500 BP (Kuzmin, 2006b; Shewkomud and Kuzmin, 2009). The Suchu Island cluster has several cultural components, including the Early, Middle, and Late Neolithic (Derevianko and Medvedev, 2006). Obsidian was found in dwelling belonging to the Early Neolithic (Mariinsk) culture. The Mariinsk complex is dated to ca. 7200–8600 BP (Derevianko et al., 2003, 396–397; see also Kuzmin, 2006c, 25).

2.2. *Geology of basaltic plateaus in the Amur River basin: brief description*

The basaltic volcanism in the Amur River basin originates from deep-seated faults oriented along a northeasterly direction. In the middle course of the Amur River, basaltic volcanic fields are located on the right (Xunhe Plateau) and left (Obluchie [Obluch'ye] Plateau) banks (Fig. 1). The Obluchie Plateau is a part of larger region called the Lesser Khingan [Xiao Hinggan] Mountains located north of the Amur River. Further northeast, it joins the Bureya [Bureiskiy] Range (see Suslov, 1961, 326–328). The area under study is located in the basins of the Khingan and Mutnaya rivers (Fig. 2). The total area covered by basalt is ca. 1500 km^2. The surface of the plateau is generally flat, with elevations ranging 500–700 m above sea level (hereafter – a.s.l.). In the central part of plateau, there are summits up to ca. 670 m a.s.l. such as the Udurchukan Mountain. The thickness of basalt flows in the central plateau is up to 100–130 m. The headwaters of the Khingan, Uril, Udurchukan, and Mutnaya rivers cut through the basaltic flows (Fig. 2). The depth of the valleys is about 150 m. Most of the river floodplains are bogged-up, besides the section of the Khingan River between the town of Obluchie and the confluence of the Pravy Khingan and Levy Khingan rivers where pebble banks have developed along the channel (Fig. 2). The age of the basalts and basaltic andesites as determined by K/Ar dating is 18.6–22.6 Myr old (Derbeko and Koshkov, 2001).

The Obluchie Plateau region was surveyed during the summer of 2004 (Popov et al., 2006). Eroded lava flows along the watershed of the Khingan, Mutnaya, and Uril rivers were carefully studied (Fig. 2). Volcanic glass belongs to the hyaloclastites in the lower parts of basalt flows, and it corresponds to the beginning of volcanic activity. Hyaloclastite is clastic glassy rock created during the interaction between the lava and water which results in rapid hardening with the formation of a crust and fragmentation of glassy crusts during contact with water. The hyaloclastites are associated with pillow lavas of basaltic andesite and are intercalated with them (Fig. 3, a). On the right bank of the Kundurka River, a primary source of volcanic glass was found in a road cut (geographic coordinates 49°11′ N, 130°44′ E). The exposure is 100 m long and 7 m high in the central part and 4 m on the sides. It consists of a mixture of pillow lavas of andesitic basalts and hyaloclastites (Fig. 3, a).

The pillow lavas in Obluchie Plateau region are intercalated with psephitic hyaloclastites of desquamation and granulation types, which fill out the space between pillows. Volcanic glass is found in two forms: 1) as a hardened crust of pillow lavas; and 2) as numerous fragments in a hyaloclastic matrix redeposited from pillow lavas (Fig. 3, b). The glass has black and dark gray colors and is 0.5–5 cm in size. The amount of volcanic glass in the matrix is 15–20% by volume. Above the pillow lavas, massive and porous basalts are observed (Fig. 3, a). Six samples of volcanic glass were collected for geochemical analysis from this primary outcrop.

A secondary source of volcanic glass was found in the Khingan River valley, upstream from the town of Obluchie (Fig. 2). On the spits located along the river channel, rounded pebbles of black and dark

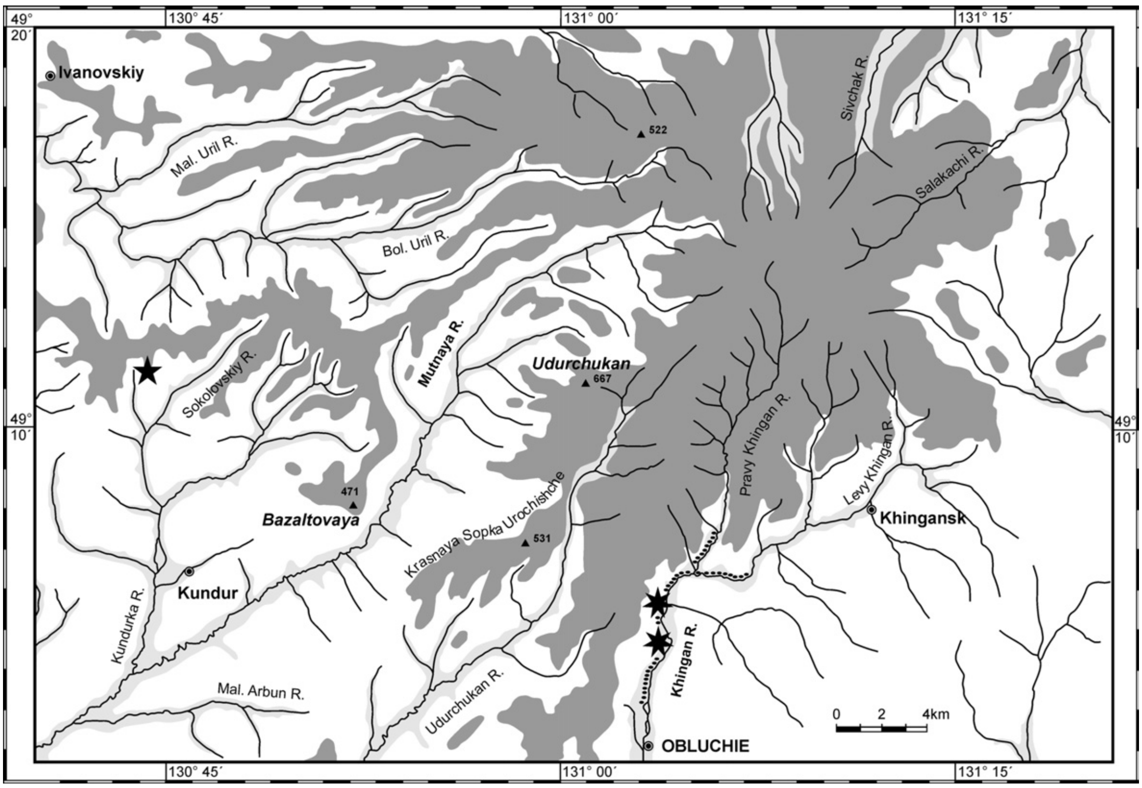

Fig. 2. Map of Obluchie Plateau and sampling localities with volcanic glass. Star indicates primary source of volcanic glass in the Kundurka River basin; diamonds and dots indicate locations for sampling of obsidian pebbles on the bank of Khingan River (diamonds) and distribution of obsidian pebbles in the river channel (dots).

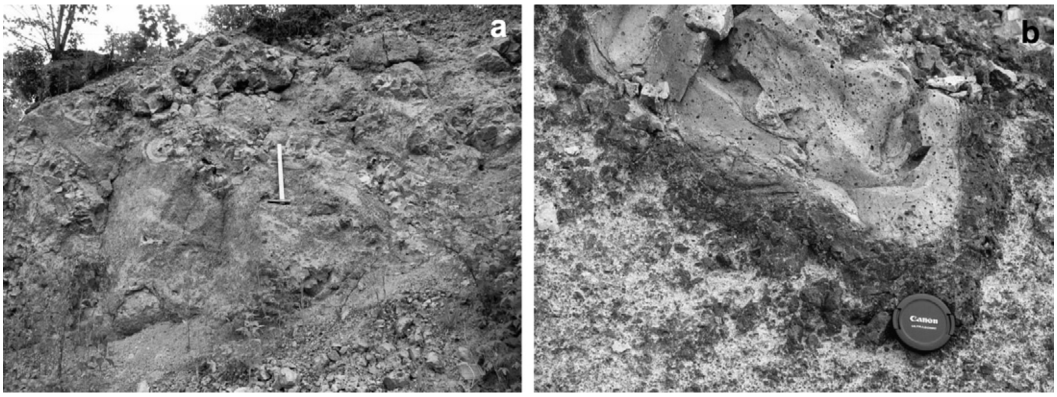

Fig. 3. The outcrop of the Obluchie Plateau pillow lavas in the Kundurka River basin: a – general view; b – close view (black matter is volcanic glass).

gray volcanic glass ranging up to 7–8 cm in diameter were found. The right-hand tributaries of the Khingan River erode the Obluchie Plateau and bring into the main valley blocks of basalts and hyaloclastites containing volcanic glass. Six samples of volcanic glass pebbles were collected from the river banks for geochemical analysis.

At modern state of research, it is hard to say for certain where the obsidian source used by ancient humans was located, but it is possible to assume that it still was situated in the vicinity of the town of Obluchie, not too far from the finds of secondary sources located in the Khingan River channel. However, this uncertainty makes our conclusions about the transportation distance to some extent tentative. Future in-depth study can give more precise information. On the other hand, we do not expect major changes in our results.

2.3. Obsidian artifacts in the Amur River basin

The artifacts are made of high quality volcanic glass, mainly of black and dark gray colors, with conchoidal fracture, typical striation, and vitreous luster (sometimes with a dull surface of spall). The glass is not transparent in thin section. It contains small (up to 1 mm in diameter) gas cavities or phenocrysts of pyroxene and plagioclase. Some artifacts with numerous small grains (embryos) of minerals have typical tubercular surface of spall. The initial surfaces of the artifacts have a peculiar shard structure which testifies in favor of their origin from hyaloclastites. It should be noted that the majority of artifacts are made from rounded pebble material. For the purposes of this study, 35 obsidian artifacts were analyzed.

The amount of obsidian in prehistoric assemblages of the Amur River basin is quite small, typically around 1% or less. In rare cases it exceeds this amount with up to 4–14% (Petrov et al., 2004). For example, among the 3772 artifacts at the Khummi site in the Lower Amur basin (dated to ca. 10,400–13,200 BP), only two cores (0.05% of total assemblage) are made of obsidian (Lapshina, 1999). In the Excavation Pit 12 at Suchu Island, five obsidian artifacts were found (Derevianko et al., 2003, 197–247), and the total number of stone items is 3420. Thus, obsidian raw material constitutes only 0.14%. In the Dwelling 26 at Suchu Island, two obsidian artifacts were recovered out of a total number of 1620 items (Derevianko et al., 2003). This makes the share of obsidian 0.12%. Samples KU1026–1030 from Pit 12 (see Appendix 3) are curated by the Museum of History and Culture of Siberian and Far Eastern Nations, Institute of Archaeology and Ethnography, Novosibirsk (Russia).

2.4. Analytical methods

For determination of obsidian sources, two analytical methods were used: 1) Neutron activation analysis (NAA); and 2) X-ray fluorescence (XRF) analysis. In addition, for some of the samples major oxides and loss on ignition were determined.

NAA is a technique relying on nuclear reactions between the elements in the sample and neutrons from a nuclear reactor. The technique offers high accuracy and precision, but it requires that a portion of the sample be destroyed by making it radioactive. In this study, two different NAA procedures were used by the Archaeometry Laboratory at the University of Missouri Research Reactor (MURR). One to measure short-lived elements, and the second to measure long-lived elements. Samples weighing 100 mg in polyvials were irradiated for 5 s using a neutron flux of 8×10^{13} n cm^{-2} s^{-1}. Following irradiation, the samples and standards were allowed to decay for 25 min before the start of a 12-min counting period. The elements possible from a short irradiation are Al, Na, Cl, K, Mn, Ba, and Dy. By ratioing the count-rates from unknowns relative to known standards, absolute concentrations were determined.

If the data obtained for short-lived elements are inadequate to determine the specific source, a long-irradiation procedure was performed. In this case, samples weighing about 200 mg were encapsulated in high-purity quartz vials. The samples and standards were then irradiated for 60 h in a neutron flux of 5×10^{13} n cm^{-2} s^{-1} before conducting the first of two counts. The first count was conducted after seven days of decay to measure the medium-lived elements, including Ba, La, Lu, Nd, Sm, and Yb. After three or four weeks of additional decay, the long-irradiation samples were counted again to measure the long-lived elements, including Ce, Co, Cs, Eu, Fe, Hf, Rb, Sc, Sr, Ta, Tb, Th, Zn and Zr. Often times, the element Ba from the medium-lived measurement is more reliable than that possible following the short irradiation.

When samples of obsidian must be analyzed non-destructively, the method of energy-dispersive XRF is used. Although XRF is less accurate and precise, it is a very successful research tool for many obsidian studies. In this case, samples were placed in the beam of X-rays emitted by an Elva-X spectrometer and measured for 3 min each. The spectrometer is equipped with an air-cooled tungsten anode and 140 micron Be window. X-rays are measured by a thermoelectrically-cooled Si-PIN detector with a nominal resolution of 180 eV at 6 keV. The X-ray tube is operated at 40 kV with a tube current of 25 μA, and beam dimensions of 4×5 mm. The counting rate is about 6000 counts per second. The most useful elements from XRF are Fe, Zn, Ga, Rb, Sr, Y, Zr and Nb.

A database on obsidian sources in Northeast Asia and Japan was created by analyzing a large number of samples from as many sources as possible and using both the NAA and XRF procedures described above. Through the use of cluster analysis and examination of bivariate plots of the elements (Glascock et al., 1998), chemical groupings of the source samples were established. Table 2 lists the means and standard deviations for the compositional groups of interest to this study. Use of the same analytical procedures on artifacts and comparisons to the source data allows the identification of sources for most artifacts.

All of the artifacts in this study were assigned to one of four different sources (Basaltic Plateau, Obluchie Plateau, Samarga, or Shirataki-A). Appendices 1–3 list the results from NAA and XRF for the artifacts. Giving importance of our results not only for the Amur River basin and neighboring Russian Far East but also for Manchuria (Northeast China), Korea, and Japan, we present original chemical data as appendices, in order to avoid problems encountered in the past with incomplete (if any) recording of primary analytical data for obsidian artifacts from the Russian Far East (see Kuzmin, 2006a, 2010).

3. Results and discussion

3.1. Obsidian from the pillow lavas of the Obluchie Plateau: geochemical characterization

Based on data collected in 2004, geochemical information on volcanic glass from the Obluchie Plateau source was obtained. Two specimens from the channel deposits of the Khingan River turned out to be outliers, and the rest constitute a group called OB (Obluchie Plateau) (Figs. 4–6). This is the geochemical signature for primary source of high quality volcanic glass in the Amur River basin (Table 2). Bulk chemical analysis shows a very low water content, and this volcanic glass can be attributed as obsidian (usually less than 1% weight of water).

3.2. Sources of obsidian artifacts from prehistoric complexes of the Amur River basin

Based on the results of geochemical analysis of the primary and secondary 'geological' localities of volcanic glass in Obluchie Plateau region, the sources of archaeological obsidian in the Amur River basin can be now determined (Table 3; Fig. 1). In the middle course of Amur River, all sites have obsidian from Obluchie Plateau. The distance between the source and sites ranges from 50 to 350 km.

In the Lower Amur River basin, the situation is more complex. The Malaya Gavan site located near the mouth of the Amur also has obsidian from the Obluchie Plateau source. The distance between the site and source is about 750 km (Fig. 1). At two Initial Neolithic sites, Osinovaya Rechka 10 and Novotroitskoe 10, obsidian from Basaltic Plateau source in Primorye was discovered. These sites and the source of their obsidian are about 550 km apart (Fig. 1). At two other sites from the same period, Goncharka 1 and Amur 2, obsidian from a still unknown source called "Samarga" (see Kuzmin et al., 2002a) was identified. It is important to note that these sites received obsidian from the south, i.e. the Primorye region, and this testifies in favor of connection between the Lower Amur River basin and territories south of it in quite early times, at least beginning at ca. 12,500 BP.

At the Suchu Island site located near the mouth of Amur River, obsidian from the well-known source of Shirataki-A on Hokkaido Island (Japan) was identified, with a distance of at least 850 km from the site (see below). Five samples of black obsidian from Excavation Pit 12 (Derevianko et al., 2003, 105–374) belonging to the Early Neolithic Mariinsk complex were analyzed, and all of them are from the Shirataki-A source subgroup. Due to importance of this fact, full geochemical data are presented (see Appendix 3).

In the lowermost part of the Amur River, use of 'exotic' obsidian from the Shirataki-A source on Hokkaido Island (see Kuzmin et al., 2002b) is an important discovery. It has been suggested by Kimura (1995, 1998) who calls the way of volcanic glass transportation from Hokkaido to the mouth of Amur River an 'obsidian path', and it was from Hokkaido via Sakhalin Island to the lower part of Amur River basin. Kimura's (1995, 1998) conclusion was based mainly on general assumption from a limited amount of analytical data for the

Table 2
Means and standard deviations for element concentrations (in parts-per-million, ppm; unless otherwise indicated) measured in source samples in the Amur River basin and neighboring regions (after Kuzmin and Glascock, 2007; Kuzmin et al., 2002a, 2002b; this study), using NAA and XRF data.

Element	Obluchie Plateau	Basaltic Plateau	Samarga	Shirataki-A
NAA	(*n* = 9)	(*n* = 39)	(*n* = 5)[a]	(*n* = 8)
Na (%)	2.84 ± 0.05	2.35 ± 0.1	2.92 ± 0.10	2.88 ± 0.06
Al (%)	7.92 ± 0.28	7.90 ± 0.39	7.22 ± 0.24	6.75 ± 0.26
Cl	75 ± 26	91 ± 38	349 ± 29	540 ± 127
K (%)	1.08 ± 0.12	0.41 ± 0.14	2.98 ± 0.22	3.73 ± 0.13
Sc	11.8 ± 0.6	18.0 ± 1.0	2.82 ± 0.05	2.67 ± 0.02
Mn	967 ± 17	1108 ± 47	525 ± 4	384 ± 6
Fe (%)	6.39 ± 0.23	7.22 ± 0.24	0.97 ± 0.17	0.79 ± 0.19
Co	30.8 ± 0.7	37.7 ± 1.3	1.39 ± 0.03	0.13 ± 0.01
Zn	125 ± 3	126 ± 21	32 ± 5	39 ± 4
Rb	29 ± 3	12 ± 3	102 ± 2	151 ± 2
Sr	470 ± 77	392 ± 93	250 ± 17	28 ± 4
Zr	134 ± 14	97 ± 20	132 ± 3	90 ± 8
Cs	0.37 ± 0.06	0.24 ± 0.07	4.73 ± 0.09	9.64 ± 0.11
Ba	346 ± 55	122 ± 29	533 ± 15	856 ± 7
La	18.1 ± 0.7	6.4 ± 1.1	19.7 ± 0.3	20.1 ± 0.3
Ce	36.4 ± 0.7	14.4 ± 2.1	36.9 ± 0.7	42.9 ± 0.7
Nd	18.6 ± 0.8	9.0 ± 2.0	12.0 ± 0.7	15.9 ± 1.2
Sm	5.13 ± 0.24	3.72 ± 0.29	2.46 ± 0.05	3.99 ± 0.06
Eu	1.61 ± 0.11	1.47 ± 0.07	0.477 ± 0.011	0.279 ± 0.004
Tb	0.64 ± 0.05	0.86 ± 0.27	0.31 ± 0.01	0.63 ± 0.02
Dy	3.51 ± 0.38	3.86 ± 0.40	1.88 ± 0.24	4.39 ± 0.25
Yb	1.14 ± 0.06	1.34 ± 0.10	1.43 ± 0.06	3.00 ± 0.09
Lu	0.16 ± 0.02	0.26 ± 0.05	0.26 ± 0.02	0.46 ± 0.02
Hf	3.46 ± 0.33	2.29 ± 0.17	3.45 ± 0.05	2.80 ± 0.06
Ta	0.65 ± 0.17	0.29 ± 0.08	0.81 ± 0.02	0.54 ± 0.01
Th	1.48 ± 0.26	0.77 ± 0.19	8.85 ± 0.17	11.1 ± 0.1
XRF	(*n* = 8)	(*n* = 8)	(*n* = 3)	(*n* = 5)
Fe (%)	6.14 ± 0.41	6.45 ± 0.19	0.92 ± 0.08	0.70 ± 0.23
Zn	136 ± 14	130 ± 9	35 ± 2	28 ± 3
Ga	16 ± 1	15 ± 1	14 ± 1	16 ± 1
Rb	20 ± 3	12 ± 2	104 ± 3	142 ± 2
Sr	1107 ± 162	540 ± 84	226 ± 9	33 ± 2
Y	22 ± 1	25 ± 1	12 ± 1	25 ± 3
Zr	112 ± 6	87 ± 5	114 ± 4	71 ± 4
Nb	26 ± 2	20 ± 3	7 ± 6	9 ± 1

[a] These are artifacts from unknown source, considered here as 'source samples'.

Sakhalin obsidian (e.g., Vasil'evskiy, 1998, 290) and very inconclusive data on obsidian from the Malaya Gavan site (see Kuzmin and Popov, 2000, 158–159) which were not confirmed by our further investigation of this site (Fig. 4, samples KU0279 and KU0280; see also Kuzmin, 2010, 148–149). Now we have for the first time firm evidence of obsidian transport from the Hokkaido sources to the mainland Russian Far East (Fig. 1). If we assume that it was brought from Hokkaido Island across the La Pérouse [Soya] Strait to Sakhalin Island and further north, and finally across the narrow Nevel'skogo [Mamiya] Strait to the Amur basin, the full length of the route could be up to 900–1000 km. This is the long-distance exchange of obsidian which took place at ca. 7200–8600 BP, as demonstrated by ^{14}C dates from Excavation Pit 12 where the obsidian artifacts were found (Derevianko et al., 2003). Thus, we can now extend the Hokkaido–Sakhalin obsidian exchange network (see Kuzmin and Glascock, 2007; Kuzmin et al., 2002b) to the mainland Northeast Asia.

The use of the 'local' Obluchie Plateau obsidian source during the Neolithic and Early Iron Age, ca. 2600–12,400 BP, is not surprising considering that the river served as the main way of transportation and communication for the fisher-hunter-gatherers of the Amur Basin (Kuzmin, 2006c; Volkov et al., 2006). The range of obsidian exchange in the Late Neolithic was up to 760 km in a straight line or even greater, ca. 1300–1400 km, following the river (Fig. 1). At sites near the confluence of Amur and Ussuri rivers, obsidian from two other sources was exploited, with similar distances between the sources and utilization sites.

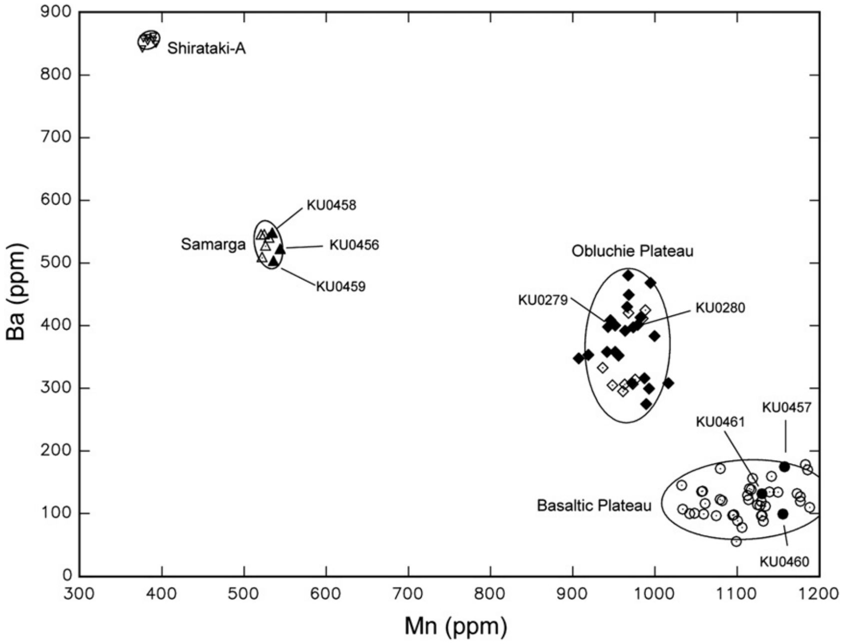

Fig. 4. Bivariate plot of Mn vs. Ba concentrations for obsidian source samples and artifacts analyzed by short-irradiation NAA and source group names (ellipses represent 95% confidence intervals for group membership). Filled symbols are artifacts and their ID Nos.; empty symbols – geological samples. Samarga Group consists of artifacts only (see Section 3.2).

The existence of unknown obsidian source "Samarga" somewhere in the northern Primorye (Kuzmin et al., 2002a) was additionally confirmed by data from Amur River sites. Obsidian from this source is detected at the Early Neolithic – Paleometal sites of northern Primorye (Dyakova and Dyakov, 2000; Kuzmin et al., 2002a), dated to ca. 2000–9300 BP. The search for primary outcrop of this obsidian is a task for the near future.

The role of obsidian as a raw material in the Amur River basin was relatively minor. The main types of rocks used to make tools were sedimentary and metamorphic rocks (silicified aleurolite and tuffa, hornfels, chalcedony, jasper-like rock, and flint) and igneous rocks (basalt, granite, and rhyolite) (e.g., Lapshina, 1999; Sapunov et al., 2000; Derevianko et al., 2003; Shewkomud, 2004; Volkov et al., 2006). However, rare obsidian artifacts can be used as definitive indicator of prehistoric human contacts and/or migrations. Previously, the possibility of contacts between Primorye and Amur River regions in the Middle Neolithic (ca. 5500–6200 BP) was suggested by archaeologists based on similarities in pottery design and

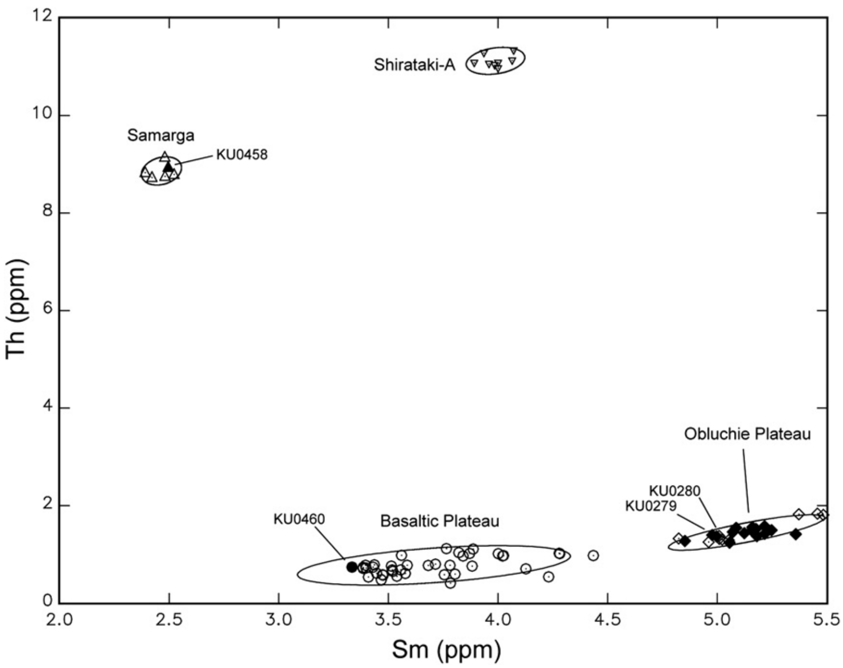

Fig. 5. Bivariate plot of Sm vs. Th concentrations for obsidian source samples and artifacts analyzed by long-irradiation NAA and source group names (ellipses represent 95% confidence intervals for group membership). Filled symbols are artifacts; empty symbols – geological samples.

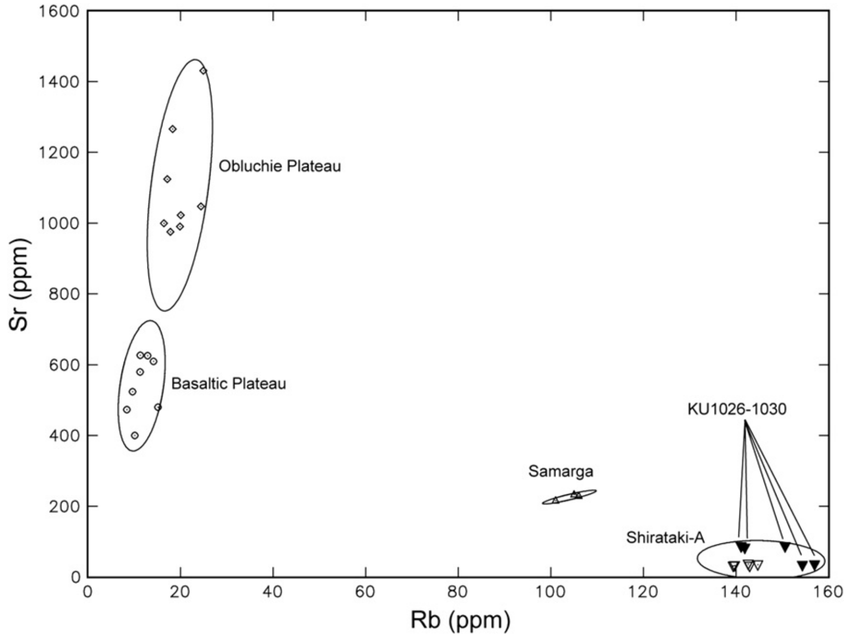

Fig. 6. Bivariate plot of Rb vs. Sr concentrations for obsidian source samples and artifacts analyzed by XRF and source group names (ellipses represent 95% confidence intervals for group membership). Filled symbols are artifacts; empty symbols – geological samples.

decoration (Moreva, 2005; Moreva and Batarshev, 2009). Now, we have evidence of it – obsidian from Basaltic Plateau source brought to the Lower Amur River in the Initial Neolithic (Osinovaya Rechka 10 and Novotroitskoe 10 sites; Table 3). It seems that connections between Amur River basin and Primorye existed for a long time, since at least the beginning of the Neolithic period (ca. 12,500 BP).

No obsidian from two or more sources was detected at the Amur River basin sites (Table 3). However, geographic and cultural proximities for the sites under investigation allow us to suggest that the strategy of obsidian acquisition and use were as complex as in the adjacent territories such as Primorye, Sakhalin Island, and Kamchatka Peninsula where often obsidian from two or more sources was utilized at the same site (Kuzmin and Glascock, 2007; Kuzmin et al., 2002a, 2002b, 2008). This is an important observation which testifies to high degree of adaptation by the forebearers of the Upper Paleolithic, Neolithic, and Paleometal cultures on the Russian Far East to environmental conditions in terms of stone raw material.

Table 3
Sources of archaeological obsidian in the Amur River basin.

Site Name (Number of Artifacts)	Obsidian Sources			
	Obluchie Plateau	Basaltic Plateau	Samarga	Shirataki-A
Gromatukha (1)	+			
Grodekovo (1)	+			
Konstantinovka (1)	+			
Novopetrovka (1)	+			
Lake Beloberozovoe (2)	+			
Lake Dubovoe (1)	+			
Lake Peschanoe (3)	+			
Dim (3)	+			
Orlovka (2)	+			
Arkhara (3)	+			
Novopokrovka (1)	+			
Osinovoe Ozero (2)	+			
Sukhie Protoki 2 (1)	+			
Goncharka 1 (1)			+	
Osinovaya Rechka 10 (1)		+		
Amur 2 (2)			+	
Novotroitskoe 10 (2)		+		
Suchu Island (5)				+
Malaya Gavan (2)	+			

4. Conclusion

In the Amur River basin, obsidian artifacts were used as a commodity to establish the patterns of prehistoric human contacts and exchange. The scarcity of excavated Upper Paleolithic sites does not allow understanding the patterns of obsidian use at that time. The main period of obsidian exploitation in the Amur River basin was the Neolithic, beginning with the earliest stage (ca. 12,400 BP) and until the end of it (ca. 3000 BP). In the Paleometal period, obsidian was rarely used as raw material because of limited introduction of metals (bronze and iron) and dominance of polishing technique which requires another kinds of stone, mainly sedimentary rocks such as silicified aleurolite and schist.

The role of obsidian as raw material in prehistory of the Amur River basin was very minor; however, it was widely exchanged within the region ('local' Obluchie Plateau source) and beyond it ('remote' sources of Basaltic Plateau and Shirataki-A). The range of transport is 50–750 km inside the Amur River basin, and 550–850 km outside of it. These values are of course minimal estimates because people never took the routes as crow flies. As in the neighboring parts of the Russian Far East, the strategy of obsidian acquisition was complex with use of various sources instead of single one closest or easiest to reach.

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Appendix 1

Concentrations of elements in obsidian artifacts of the Amur River basin measured by short-irradiation NAA (in parts-per-million, ppm; unless otherwise indicated).

ID No.*	Na (%)	Al (%)	Cl	K (%)	Mn	Ba	Dy
KU0009A	3.03	7.87	n.d.	0.73	919	353	3.38
KU0009B	3.05	8.32	133	0.86	943	398	3.86
KU0010	3.09	8.43	96	1.15	946	409	4.47
KU0011	3.06	7.99	n.d.	0.96	942	358	3.89
KU0279	3.05	7.67	59	1.05	935	442	3.22
KU0280	3.07	8.19	78	1.01	974	359	3.22
KU0313	3.05	7.94	72	0.70	952	400	2.61
KU0314	2.99	8.09	70	0.98	967	480	3.09
KU0315	3.13	7.90	95	0.93	982	413	3.37
KU0317	3.08	8.78	103	0.99	999	383	3.27
KU0318	3.12	8.37	58	0.72	968	449	2.85
KU0319	3.20	7.92	88	1.04	907	348	2.71
KU0320	3.12	8.35	60	0.79	956	352	3.32
KU0321	3.09	7.92	99	0.84	964	392	2.99
KU0322	3.11	8.26	n.d.	0.76	952	358	3.12
KU0323	3.14	7.81	99	0.86	979	401	3.14
KU0456	3.06	7.30	252	3.22	544	521	2.11
KU0457	2.56	8.82	n.d.	0.17	1158	175	3.45
KU0458	2.98	6.86	240	2.88	534	547	1.82
KU0459	3.01	7.26	231	2.72	536	502	2.35
KU0460	2.49	7.48	n.d.	0.32	1156	99	3.46
KU0461	2.40	7.43	n.d.	0.00	1130	135	3.63
KU0572	3.16	8.00	105	0.80	993	299	3.72
KU0573	3.12	7.69	88	1.07	966	430	3.57
KU0574	3.12	8.51	89	0.84	987	316	3.45
KU0575	3.20	8.10	140	0.82	995	468	3.69
KU0576	3.11	7.86	93	0.78	972	308	3.27
KU0577	3.16	8.84	65	1.11	989	275	3.68
KU0578	3.24	8.29	64	1.01	1016	308	3.04
KU0579	3.07	8.35	72	0.91	973	397	3.08

*These Nos. correspond to the following archaeological sites (see Tables 1 and 3): KU0009A and B – Osinovoe Ozero; KU0010 – Gromatukha; KU0011 – Sukhie Protoki; KU0279 and 280 – Malaya Gavan; KU0313 – Konstantinovka; KU0314 and 315 – Lake Beloberozovoe; KU0317 – Lake Dubovoe; KU0318 – Novopetrovka; KU0319, KU0578–579 – Dim; KU0320 – Grodekovo; KU0321–323 – Lake Peschanoe; KU0456 – Goncharka 1; KU0457 – Osinovaya Rechka 10; KU0458 and 459 – Amur 2; KU0460 and 461 – Novotroitskoe 10; KU0572 and 573 – Orlovka; KU0574–576 – Arkhara; and KU0577 – Novopokrovka.

Appendix 2

Concentrations of elements in obsidian artifacts from the Amur River basin measured by long-irradiation NAA (in parts-per-million, ppm; unless otherwise indicated).

ID No.*	Sc	Fe (%)	Co	Zn	Rb	Sr	Zr	Cs	La	Ce	Nd	Sm	Eu	Tb	Yb	Lu	Hf	Ta	Th
KU0009A	12.3	6.43	30.6	138	18.2	785	135	0.30	13.8	29.1	17.2	4.85	1.61	0.65	1.09	0.20	3.29	0.59	1.28
KU0009B	12.4	6.53	31.3	142	25.0	825	141	0.18	15.5	30.8	17.9	5.00	1.66	0.69	1.09	0.19	3.32	0.67	1.37
KU0010	12.5	6.61	31.6	140	23.3	786	88	0.23	15.7	31.9	17.2	4.98	1.68	0.64	1.13	0.20	3.40	0.71	1.40
KU0011	12.8	6.58	31.9	142	19.1	845	136	0.26	14.3	30.2	19.2	5.06	1.67	0.69	1.14	0.19	3.43	0.57	1.24
KU0279	12.6	6.56	32.0	145	28.9	688	127	0.27	15.6	32.4	17.1	4.99	1.67	0.75	1.12	1.16	3.43	0.73	1.36
KU0280	12.5	6.62	32.2	129	22.8	757	110	0.22	15.7	33.0	19.5	5.04	1.69	0.61	1.20	0.14	3.46	0.71	1.37
KU0313	12.7	6.73	32.9	129	23.5	784	122	0.24	15.8	33.0	19.9	5.25	1.73	0.62	1.14	0.17	3.54	0.74	1.50
KU0314	12.6	6.66	32.7	130	24.3	739	147	0.18	16.1	33.3	17.6	5.16	1.70	0.73	1.22	0.18	3.50	0.69	1.56
KU0315	12.8	6.74	33.0	128	28.8	738	123	0.27	16.9	35.4	19.2	5.22	1.71	0.70	1.17	0.17	3.55	0.73	1.58
KU0317	12.6	6.68	33.0	131	23.5	761	149	0.20	16.3	34.1	18.8	5.09	1.68	0.69	1.10	0.18	3.47	0.72	1.54
KU0318	12.9	6.78	33.5	144	23.0	724	112	0.22	16.0	34.0	18.6	5.18	1.75	0.67	1.19	0.17	3.49	0.74	1.52
KU0319	12.4	6.54	32.3	134	22.0	766	156	0.22	15.0	31.8	18.5	5.07	1.70	0.67	1.15	0.17	3.48	0.65	1.46
KU0320	13.0	6.79	33.2	138	22.8	754	128	0.24	14.1	31.0	17.7	5.18	1.70	0.66	1.29	0.17	3.51	0.62	1.37
KU0321	12.8	6.78	33.5	143	24.1	768	126	0.29	15.9	32.8	19.7	5.16	1.73	0.72	1.28	0.15	3.59	0.70	1.49
KU0322	12.6	6.50	32.4	137	25.0	801	114	0.28	15.4	33.4	19.0	5.36	1.72	0.64	1.21	0.16	3.58	0.65	1.41
KU0323	13.0	6.78	33.3	135	22.7	769	139	0.20	15.0	31.7	18.1	5.22	1.73	0.73	1.15	0.20	3.54	0.69	1.42
KU0458	2.8	0.97	1.4	35	103.2	232	133	4.78	19.7	36.5	12.6	2.49	0.48	0.33	1.49	0.24	3.47	0.82	8.94
KU0460	18.7	7.32	38.2	121	12.3	311	91	0.15	5.5	12.4	8.1	3.33	1.38	0.79	1.50	0.20	2.10	0.23	0.74

*For correspondence of these Nos. to archaeological sites (Tables 1 and 3), see footnote to Appendix 1.

Appendix 3

Concentrations of elements in obsidian artifacts from Excavation Pit 12, Suchu Island, measured by XRF (in parts-per-million, ppm; unless otherwise indicated).

ID No.	Museum ID	Artifact type	Mn	Fe (%)	Zn	Ga	Rb	Sr	Y	Zr	Nb
KU1026	A169	Blade (fragment)	273	0.71	34	16	157	35	13	67	14
KU1027	KONI(3)	Blade (fragment)	310	0.71	30	15	154	33	12	65	9
KU1028	48	Point	265	0.70	27	15	141	86	14	98	10
KU1029	50	Point	344	0.70	31	15	142	82	13	98	7
KU1030	–	Point	332	0.74	30	18	151	86	14	102	10

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