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# Initial source evaluation of archaeological obsidian from the Kuril Islands of the Russian Far East using portable XRF

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ABSTRACT

Obsidian artifacts recently have been recovered from 18 archaeological sites on eight islands across the Kuril Island archipelago in the North Pacific Ocean, suggesting a wide-ranging distribution of obsidian throughout the island chain over the last 2,500 years. Although there are no geologic sources of obsidian in the Kurils that are known to have been used prehistorically, sources exist in Hokkaido, Japan, and Kamchatka, Russia, the southern and northern geographic regions respectively from which obsidian may have entered the Kuril Islands. This paper reports on the initial sourcing attempt of Kuril Islands obsidian through the analysis of 131 obsidian artifacts. Data from this research were generated through the application of portable XRF technology, and are used to address research questions concerning prehistoric mobility, exchange, and social networking in the Kuril Islands.



## 1. Introduction

During the past decade, a number of studies have detailed the obsidian sources and prehistoric obsidian use in northeast Asia including Japan, Kamchatka, Sakhalin Island and Primorye (Russian Far East) (Doelman et al., 2008; Glascock et al., 2000, 2006; Kuzmin, 2006a, b; Kuzmin et al., 1999, 2000, 2002, 2008; Speakman et al., 2005). This previous research has documented networks of obsidian exchange and transport in the region since the Late Paleolithic (ca. 20,000 BP) that extended up to 1000 km. The Kuril Islands in the North Pacific Ocean (Fig. 1) represent an area where to date relatively little archaeological research has been conducted, but which is important for understanding the overall scope of obsidian procurement and use in northeast Asia.

This paper reports on research conducted to identify the sources of archaeological obsidian recovered from the Kuril Islands. Although artifact assemblages from sites across the island chain include stone tools and flakes made from obsidian and a variety of other raw materials, obsidian native to the Kuril Islands is not known to have been used prehistorically (Fitzhugh et al., 2004). This raises a number of questions about how obsidian was obtained and utilized by Kuril Island marine-adapted hunter–gatherers, and the connections that these people had with social networks in other parts of northeast Asia. Data reported here contribute new information to archaeological obsidian studies in northeast Asia, and provide a basis for further research in the Kuril Islands.

## 2. Geographical and geological background

The Kuril archipelago is an active volcanic island arc spanning the Okhotsk Sea–Pacific Ocean boundary from northern Japan to southern Kamchatka. The Kuril Islands vary in size from 5 km$^2$ to 3200 km$^2$, and the southern group (Kunashir, Iturup, and Urup Islands) and northern group (Onekotan, Paramushir and Shumshu Islands) tend to be larger than the more geographically isolated central group (Chirpoi, Simushir, and Shiashkotan Islands).

The Kuril Islands are located on the arc-trench tectonic system at the edge of the boundary between the Okhotsk and Pacific Plates and are affected by the subduction of the Pacific Plate underneath the Okhotsk Plate. The islands are comprised of 160 Quaternary terrestrial and 89 submarine volcanoes formed by the active arc volcanism, built on a Cretaceous to Neogene basement (Fitzhugh et al., 2002; Gorshkov, 1970; Nemoto and Sasa, 1960). Thirty-two of these volcanoes are known to have erupted during the past 300 years, 19 have erupted since 1945 (Ishizuka, 2001). Tephra layers throughout the islands indicate that prehistoric volcanic activity was a regular occurrence. A cultural layer at the Ainu Bay 2 archaeological site on Matua Island in the central Kuril Islands was

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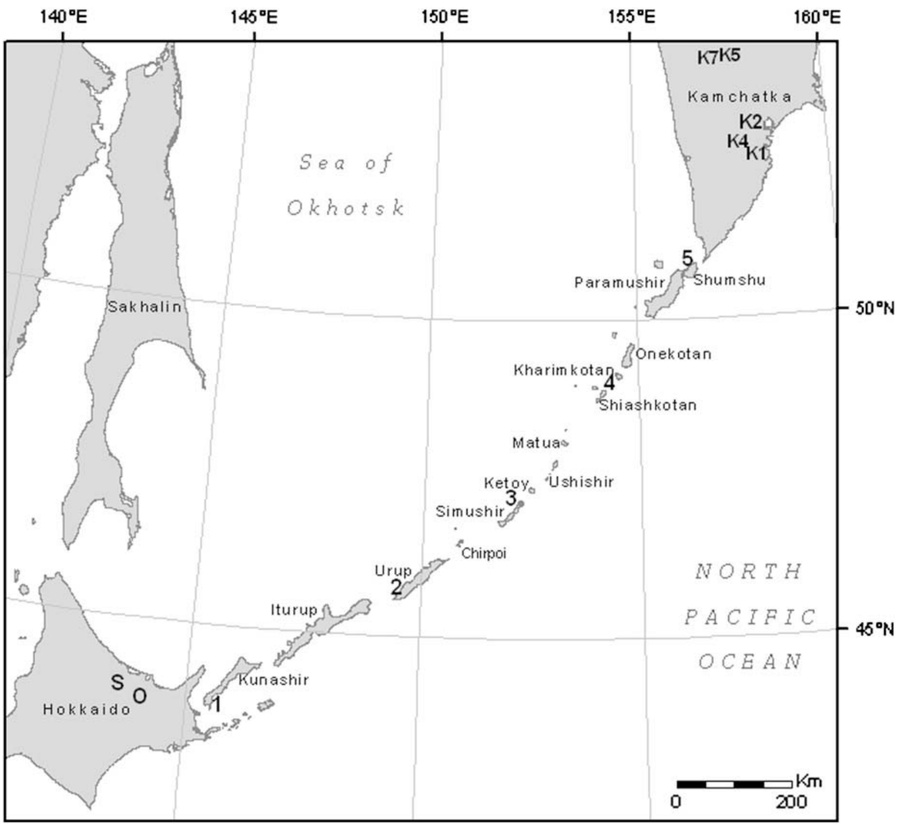


**Fig. 1.** Map of study area where obsidian artifacts from the Kuril Islands were recovered, including archaeological sites and obsidian source group locations mentioned in the text. Archaeological sites: (1) Rikorda, Kunashir Island; (2) Ainu Creek, Urup Island; (3) Vodopodnaya 2, Simushir Island; (4) Drobnyye, Shiashkotan Island; (5) Baikova, Shumshu Island. Obsidian source groups: (O) Oketo group; (S) Shirataki group; (K1) Kamchatka-1 group; (K2) Kamchatka-2 group; (K4) Kamchatka-4 group; (K5) Kamchatka-5 group; (K7) Kamchatka-7 group. Note that the locations of Kamchatka-1, Kamchatka-2, and Kamchatka-4 are a best approximation of where these sources are suspected to be located. Even if the locations are incorrect, these groups almost certainly occur in the southern portion of the peninsula.

buried 100 cm below the surface and under 10 tephra layers (Fitzhugh et al., 2002). The geology of this region includes various rock types, such as obsidian, andesite, chert and siliceous tuffs of varying colors that were available to the prehistoric inhabitants of the Kuril Islands (Izuho and Sato, 2007).

## 3. Archaeological background

Compared with Hokkaido to the south and Kamchatka to the north, relatively little archaeological research has been conducted in the Kuril Islands. Archaeological investigations during the past 70 years have identified a number of prehistoric sites in the chain, with the heaviest concentrations of settlement on the southern islands of Kunashir, Iturup, and Urup and a smaller concentration on the northern islands of Shumshu and Paramushir (Baba, 1937, 1939; Baba and Oka, 1938; Befu and Chard, 1964; Kodama, 1948; Shubin, 1994, 2001; Vasilevsky and Shubina, 2006; Zaitseva et al., 1993). The distribution of archaeological sites is the product of a historical research focus on the extreme southern and northern ends of the Kuril Island chain by Japanese and Russian archaeologists, and the most detailed testing of sites is concentrated in the southernmost islands. Recent archaeological work in the Kuril Islands as part of the International Kuril Island Project (IKIP) in 2000 and the Kuril Biocomplexity Project (KBP) in 2006 and 2007 provided new data and the means to synthesize the archaeology of the entire island chain into a coherent regional framework for the first time (Fitzhugh et al., 2002).

Although the northern and southern Kuril Islands were connected to mainland areas during the last glacial period (ca. 18,000 BP), the earliest evidence of human occupation in the most southern Kuril Islands dates to ca. 7000 BP, probably by the Jomon hunter–gatherers who lived throughout the Japanese Archipelago from ca. 16,000 to 2500 BP. Very little information currently exists for this period; some researchers have labeled it the "Early Neolithic" of the southern Kuril Islands (Kuzmin et al., 1998; Vasilevsky and Shubina, 2006; Zaitseva et al., 1993). These early groups likely lived in small and highly mobile populations subsisting primarily by terrestrial hunting and gathering, which was supplemented with fish and shellfish (Dikov, 1996; Imamura, 1996; Kikuchi, 1999; Kimura, 1999; Okada, 1998).

Consistent occupation in the southern Kurils began ca. 4000 BP (Zaitseva et al., 1993), and between ca. 2500 and 1300 BP an increasingly maritime-focused Jomon/Epi-Jomon people moved north out of Hokkaido into the remote central Kuril Islands (Fitzhugh et al., 2002; Kikuchi, 1999; Niimi, 1994; Tezuka and Fitzhugh, 2004; Yamaura, 1998; Yamaura and Ushiro, 1999; Vasilevsky and Shubina, 2006). Around 1300 BP the intensively marine-oriented Okhotsk culture expanded from the Russian mainland and Sakhalin Island through Hokkaido (Kikuchi, 1999, Otaishi, 1994), and established substantial colonies throughout the length of the Kuril Island chain. After ca. 800 BP, the Okhotsk people were replaced on Hokkaido and in the Kuril Islands by Ainu settlements (Fitzhugh and Dubreuil, 1999). The Ainu engaged in terrestrial/maritime foraging for subsistence resources and eventually developed trade relationships with European and American explorers and trading companies (Krasheninnikov, 1972; Shubin, 1994; Stephan, 1974; Vysokov, 1996).

Obsidian artifacts discussed herein were obtained from Kuril Islands contexts that span the Epi-Jomon and Okhotsk cultural periods—roughly 1750 years from ca. 2500 to 750 BP. Although few studies of Kuril Island lithic assemblages have been published, it was initially believed that patterns of raw material distribution demonstrated that the islands were sufficiently isolated to constrain the spread of non-local raw materials throughout the island chain via mobility or exchange (Fitzhugh et al., 2004). In contrast, our data demonstrate that non-local obsidian was transported, almost exclusively, among the islands from significantly long distances, suggesting far-reaching and complex social networks within which obsidian procurement was embedded.

## 4. Materials and methods

The obsidian artifact samples analyzed in this study were collected during the International Kuril Island Project (IKIP) expedition in 2000, the Kuril Biocomplexity Project (KBP) 2006 summer field season, and through independent work in the southern Kuril Islands led by Russian archaeologist Olga Shubina. A total of 459 obsidian flakes were obtained via surface collection and test-pit excavation from 18 different archaeological sites on eight islands spanning the southern, central, and northern parts of the Kuril Island chain including Kunashir, Iturup, Urup, Chirpoi, Simushir, Shiashkotan, Paramushir, and Shumshu Islands. From the KBP 2006 field season alone, 438 obsidian artifacts were collected, representing ca. 8% of the total lithic flake assemblage ($n = 5358$). Out of the total obsidian sample from the Kuril Islands, 131 pieces of flake debitage primarily from biface tool production, were analyzed at the Smithsonian Institution's Museum Conservation Institute using a Bruker AXS Tracer III-V handheld X-ray fluorescence spectrometer (XRF). Obsidian flakes were chosen for analysis based on their size (roughly 5 mm in diameter) and morphology (with a flat ventral or dorsal face). Samples that were too small to analyze by XRF and those that could not be assigned to known Hokkaido and/or Kamchatka sources, subsequently were analyzed by laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) at the Museum Conservation Institute and compared to published neutron activation analysis (NAA) data for northeast Asian obsidian (e.g., Glascock et al., 2006; Kuzmin et al., 2000, 2002; Speakman et al., 2005).

Until relatively recently, XRF-based research was for the most part limited to dedicated laboratories. However, as a result of recent advances in XRF instrumentation, it is now possible to purchase (or build) at modest cost, small, portable, high-resolution XRF instruments with thermoelectrically-cooled detectors (that alleviate the need for liquid nitrogen). Dubbed portable XRF (PXRF), field-portable XRF (FPXRF), or handheld XRF, such instrumentation has been used extensively in geology (e.g., Potts et al., 1995, 1997b), but relatively few published archaeological applications exist (but see Emery and Morgenstein, 2007; Morgenstein and Redmount, 2005; Pantazis et al., 2002; Potts et al., 1997a; Williams-Thorpe et al., 1999, 2003). Additionally, until very recently most portable XRF instruments used radioactive isotopes as the excitation source which complicated transportation of the equipment given state, federal, and international regulations governing the movement of radioactive materials—especially following the events of September 2001. Technological advances during the last several years in miniature X-ray tubes have all but alleviated the use of radioactive sources. When considered together, the development of miniature X-ray tubes, thermoelectrically-cooled detectors, and portable computers have greatly enhanced the potential of PXRF for archaeological research. Applications that are ideally suited for this analytical technique include the analyses of some metals and ceramics, and the source identification of archaeological obsidian (e.g., Aldenderfer et al., 2008; Cecil et al., 2007; Craig et al., 2007; Speakman et al., 2007).

In provenance studies, non-destructive analytical techniques are preferable to destructive methods provided that the analytical approach allows sufficient resolution to accurately characterize and assign samples to specific geologic sources. And, *in situ* non-destructive analyses are clearly preferable for museum and other protected and/or sensitive collections. This is especially true if the objects in question are in the process of (or subject to) repatriation. Portable analytical methods also are preferable in international research contexts where it is oftentimes difficult to obtain export permits for artifacts, or in field laboratories, such as the ship that serves as the base of operations for the Kuril Biocomplexity Project. Given current trends in archaeology and museum conservation, non-intrusive and minimally invasive analyses of cultural materials and/or the ability to analyze artifacts, non-destructively, in the field or in museums is an obvious advantage of PXRF. Non-destructive analyses conducted on-site are more conducive to obtaining permission to conduct such analyses given that collections managers need not be concerned about objects being lost or damaged during transit – not to mention that paperwork for conducting on-site analyses typically is negligible. In countries where obtaining export permits for artifact analyses are time consuming, costly, and difficult, if not impossible, to obtain, the analyses of objects by PXRF will alleviate some of these problems while providing high-resolution multi-element data at a low analytical cost.

In our study, XRF analyses of the Kuril Islands obsidian artifacts permitted quantification of the following elements: potassium (K), manganese (Mn), iron (Fe), gallium (Ga), thorium (Th), rubidium (Rb), strontium (Sr), yttrium (Y), zirconium (Zr), niobium (Nb). All obsidian samples were analyzed as unmodified samples. The instrument is equipped with a rhodium tube and a SiPIN detector with a resolution of ca. 170 eV FHWM for 5.9 keV X-rays (at 1000 counts per second) in an area of 7 $mm^2$. All analyses were conducted at 40 keV, 15 μA, using a 0.076-mm copper filter and 0.0305 aluminum filter in the X-ray path for a 200-s live-time count. The spot size on this instrument is ca. 4 mm diameter which allows the analysis of smaller artifacts. Peak intensities for the above listed elements were calculated as ratios to the Compton peak of rhodium, and converted to parts-per-million (ppm) using linear regressions derived from the analysis of 15 well characterized obsidian samples that previously had been analyzed by NAA and/or XRF.

Following the XRF analyses, data (Table 1) were compared to a NAA database for northeast Asian obsidian and assigned when possible to extant compositional groups. Because of size constraints and/or ambiguous results, it was not possible to positively assign six samples to previously identified northeast Asian obsidian reference groups. The six unassigned samples subsequently were analyzed by LA-ICP-MS (e.g., Speakman and Neff, 2005; Speakman et al., 2002, 2007). The LA-ICP-MS analyses permitted quantification of about 30 elements, including lanthanide group elements that are particularly useful for direct comparison to extant NAA data (e.g., Glascock et al., 2006; Kuzmin et al., 2000, 2002). It has been demonstrated that bulk compositional data generated for obsidian by XRF analysis are comparable to data generated by NAA and LA-ICP-MS (Gratuze 1997, 1999; Gratuze et al., 2001; Speakman and Neff, 2005; Speakman et al., 2002). While there are differences between the three analytical methods in terms of their precision, specific source groups are accurately differentiated by each of the methods. Additionally, the comparison of analysis results from lab-based XRF and portable XRF instruments has shown consistency in terms of source determination by the different types of XRF instruments (Craig et al., 2007).

**Table 1**
Means and standard deviations for elemental concentrations from obsidian artifacts analyzed in this study.

| Element | Shirataki-A | | Shirataki-B | | Oketo-1 | | Oketo-2 | | Kam-1 | | Kam-2 | | Kam-4 | | Kam-5 | | Kam-7 | | Group-A | | Group-B | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $n = 6$ | | $n = 7$ | | $n = 34$ | | $n = 2$ | | $n = 29$ | | $n = 29$ | | $n = 16$ | | $n = 1$ | | $n = 4$ | | $n = 2$ | | $n = 1$ | |
| | Mean | SD | Mean | SD | Mean | SD | Mean | SD | Mean | SD | Mean | SD | Mean | SD | Mean | SD | Mean | SD | Mean | SD | Mean | SD |
| Mn | 369 | 51 | 353 | 52 | 297 | 56 | 313 | 10 | 507 | 57 | 622 | 82 | 407 | 67 | 254 | – | 530 | 22 | 1013 | 42 | 456 | – |
| Fe | 8489 | 1091 | 7326 | 464 | 7809 | 560 | 9379 | 141 | 12579 | 1399 | 14882 | 2026 | 11457 | 1603 | 3934 | – | 7928 | 474 | 38130 | 1710 | 12014 | – |
| Zn | 56 | 24 | 36 | 14 | 38 | 13 | 39 | 15 | 73 | 32 | 98 | 38 | 65 | 25 | 10 | – | 49 | 11 | 88 | 36 | 61 | – |
| Ga | 16 | 1 | 15 | 1 | 15 | 1 | 14 | 2 | 14 | 1 | 16 | 1 | 14 | 1 | 13 | – | 14 | 1 | 16 | 1 | 15 | – |
| Th | 9 | 1 | 7 | 2 | 9 | 2 | 6 | 3 | 3 | 2 | 7 | 2 | 4 | 2 | 5 | – | 5 | 1 | 9 | 1 | 5 | – |
| Sr | 27 | 2 | 9 | 2 | 63 | 3 | 75 | 2 | 168 | 8 | 70 | 4 | 143 | 12 | 36 | – | 259 | 19 | 213 | 2 | 111 | – |
| Rb | 153 | 12 | 168 | 9 | 135 | 7 | 92 | 1 | 59 | 3 | 107 | 9 | 64 | 5 | 74 | – | 65 | 5 | 23 | 1 | 115 | – |
| Y | 29 | 2 | 33 | 3 | 25 | 1 | 21 | 1 | 15 | 1 | 39 | 2 | 17 | 1 | 14 | – | 14 | 1 | 33 | 1 | 24 | – |
| Zr | 54 | 1 | 44 | 5 | 87 | 4 | 111 | 2 | 138 | 6 | 288 | 12 | 146 | 6 | 54 | – | 132 | 8 | 149 | 6 | 105 | – |
| Nb | 3 | 1 | 4 | 1 | 3 | 1 | 2 | 1 | 1 | 1 | 7 | 1 | 1 | 1 | 8 | – | 7 | 1 | 4 | 2 | 3 | – |

## 5. Results

Examination of the XRF and LA-ICP-MS data demonstrates that obsidian sources in Hokkaido and Kamchatka are represented in the Kuril Island obsidian artifact assemblage (Table 2 and Figs. 2 and 3). According to the geochemical groupings, Hokkaido obsidian sources are represented by the Shirataki (43° 55′N, 143° 09′E) and Oketo (43° 42′N, 143° 32′E) volcanoes. Both the Shirataki and Oketo sources are represented by two groups, Shirataki-A and Shirataki-B, and Oketo-1 and Oketo-2 respectively.

Obsidian from the Hokkaido sources represents 37.4% ($n = 49$) of the total Kuril Island sample assemblage that was submitted for analysis, and was found primarily on the southern group of islands, although three samples were recovered from two islands in the central group. The Shirataki-A source is represented by six artifacts from two islands (Kunashir and Urup in the southern group), the Shirataki-B source consists of seven artifacts from four islands (Kunashir and Urup in the southern group, and Chirpoi and Shiashkotan in the central group). The Oketo-1 source consists of 34 artifacts from four islands (Kunashir, Iturup and Urup in the southern group, and Shiashkotan in the central group), whereas the Oketo-2 source is represented by two flakes from Kunashir Island.

Kamchatka obsidian sources are represented by five different geochemical groups: Kamchatka-1, Kamchatka-2, Kamchatka-4, Kamchatka-5, and Kamchatka-7. Due to the incomplete, but ongoing nature of geological obsidian research in Kamchatka by Kuzmin and colleagues (e.g., Kuzmin et al., 2008; Glascock et al., 2007; Speakman et al., 2005), the Kamchatka-1, Kamchatka-2, and Kamchatka-4 groups cannot be assigned to specific geographic locations, though the distribution of artifacts made of obsidian from these groups provides some clues to the source locations (Glascock et al., 2006; Kuzmin et al., 2008). The Kamchatka-1 group is represented by artifacts that are widely scattered across southeastern Kamchatka, and artifacts from the Kamchatka-2 group are found at archaeological sites primarily on the southern part of the peninsula (Glascock et al., 2006). The Kamchatka-4 group is represented by artifacts from the southern and eastern parts of Kamchatka. Artifacts from the Kamchatka-5 group have been recovered from central and eastern Kamchatka (Kuzmin et al., 2008) and represent the Payalpan volcano source. Kamchatka-7 obsidian is believed to be from the Ichinsky volcano near the Payalpan River in central Kamchatka (Kuzmin et al., 2008).

Obsidian from the Kamchatka sources represents 60.3% ($n = 79$) of the sampled assemblage, and is distributed throughout the central and northern island groups. All five of the Kamchatka sources are present in the central group, which is dominated by the Kamchatka-1 and Kamchatka-2 sources. In the northern group, the Kamchatka-1, Kamchatka-2, and Kamchatka-4 sources are represented on Paramushir and Shumshu Islands.

Additionally, several Kuril Island obsidian artifacts could not be assigned to a specific obsidian source at this time. Two obsidian artifacts from Iturup Island were labeled as Group A, and one flake from Kunashir Island was labeled Group B. LA-ICP-MS data generated for these samples were inconclusive. Consequently, these samples will be analyzed by neutron activation analysis (NAA) to determine if they match other sources outside of the immediate geographic region, such as sources in Primorye on the mainland of the Russian Far East.

Although a complete radiocarbon chronology is lacking for the Kuril Islands, a few radiocarbon dates have been obtained for site contexts containing obsidian artifacts that were analyzed in this study (Table 3). These dates currently represent the only dated contexts from which obsidian was recovered, though additional

**Table 2**
Distribution of obsidian artifacts by source from each of the Kuril Islands sampled in this study.

| Source | Southern islands | | | | | | Central islands | | | | | | Northern islands | | | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Kunashir | | Iturup | | Urup | | Chirpoi | | Simushir | | Shiashkotan | | Paramushir | | Shumshu | | | |
| | *N* | % | *N* | % | *N* | % | *N* | % | *N* | % | *N* | % | *N* | % | *N* | % | *N* | % |
| *Hokkaido sources* | | | | | | | | | | | | | | | | | | |
| Shirataki-A | 4 | 15.4 | | | 2 | 13.3 | | | | | | | | | | | 6 | 4.6 |
| Shirataki-B | 2 | 7.7 | | | 3 | 20.0 | 1 | 12.5 | | | 1 | 3.2 | | | | | 7 | 5.3 |
| Oketo-1 | 16 | 61.5 | 7 | 87.5 | 10 | 66.7 | | | | | 1 | 3.2 | | | | | 34 | 26.0 |
| Oketo-2 | 2 | 7.7 | | | | | | | | | | | | | | | 2 | 1.5 |
| Total | 24 | 92.3 | 7 | 87.5 | 15 | 100.0 | 1 | 12.5 | | | 2 | 6.5 | | | | | 49 | 37.4 |
| *Kamchatka sources* | | | | | | | | | | | | | | | | | | |
| Kamchatka-1 | | | | | | | 3 | 37.5 | 4 | 57.1 | 9 | 29.0 | 3 | 15.0 | 10 | 62.5 | 29 | 22.1 |
| Kamchatka-2 | | | | | | | 1 | 12.5 | 2 | 28.6 | 18 | 58.1 | 3 | 15.0 | 5 | 31.3 | 29 | 22.1 |
| Kamchatka-4 | | | | | | | | | | | 1 | 3.2 | 14 | 70.0 | 1 | 6.3 | 16 | 12.2 |
| Kamchatka-5 | | | | | | | | | | | 1 | 3.2 | | | | | 1 | 0.8 |
| Kamchatka-7 | | | | | | | 3 | 37.5 | 1 | 14.3 | | | | | | | 4 | 3.1 |
| Total | | | | | | | 7 | 87.5 | 7 | 100.0 | 29 | 93.5 | 20 | 100.0 | 16 | 100.0 | 79 | 60.3 |
| *Unassigned sources* | | | | | | | | | | | | | | | | | | |
| Group A | 2 | 7.7 | | | | | | | | | | | | | | | 2 | 1.5 |
| Group B | | | 1 | 12.5 | | | | | | | | | | | | | 1 | 0.8 |
| Total | 2 | 7.7 | 1 | 12.5 | | | | | | | | | | | | | 3 | 2.3 |
| Sample total | 26 | 100.0 | 8 | 100.0 | 15 | 100.0 | 8 | 100.0 | 7 | 100.0 | 31 | 100.0 | 20 | 100.0 | 16 | 100.0 | 131 | 100.0 |

radiocarbon samples from obsidian artifact-bearing layers will be submitted for dating through the Kuril Biocomplexity Project. Although these dates do not represent a *direct* dating of the obsidian artifacts, they do provide an initial indication of when the artifacts were made, used, or brought to the site. The Rikorda site on the far southern island of Kunashir contained obsidian artifacts from the Shirataki-B source in excavation levels dated to 2210 BP, from the Oketo-1 source dated to 2250 BP and 2210 BP, and from the Group A unassigned source to 2250 BP. The Ainu Creek site on Urup Island, also part of the southern group, contained obsidian from the Shirataki-A source from contexts dated to 2410 BP and 880 BP, and the Oketo-1 source from stratigraphic layers dated to 2540 BP and 880 BP.

In the central Kuril Islands, the Vodopodnaya 2 site on Simushir Island had obsidian from the Kamchatka-4 source in excavation levels dated to 1600 BP and 1090 BP. The Drobnyye site on Shiashkotan Island contained obsidian from Hokkaido and Kamchatka sources. One obsidian flake from the Shirataki-B source was from an excavation layer dated to 1110 BP; another flake from the Oketo-1 source was from an undated layer. An excavation layer at the Drobnyye site with obsidian from the Kamchatka-1 source was dated to 750 BP; from the Kamchatka-2 source to 1470 BP, 960 BP, and 750 BP; and from the Kamchatka-4 source dated to 1470 BP. One artifact sample from the Kamchatka-5 source was recovered from a currently undated context.

Only one sample was obtained from a dated context in the northern group of Kuril Islands. A flake made of obsidian from the Kamchatka-1 source was recovered from a context at the Baikovo site on Shumshu Island that was dated to 2010 BP.

## 6. Discussion

The Kuril Islands provide an interesting case for characterizing the procurement of non-local stone tool resources such as obsidian.

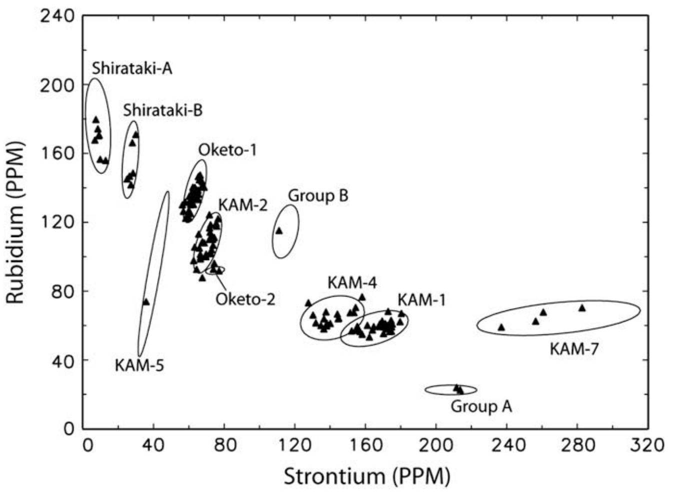


**Fig. 2.** Strontium–rubidium plot of obsidian artifact compositions from the Kuril Islands. The ellipses surrounding each group are drawn at the 95% confidence level. Confidence ellipses were drawn using a minimum of four data points from a larger group of obsidian artifacts, though only the artifacts relevant to this paper are presented here.

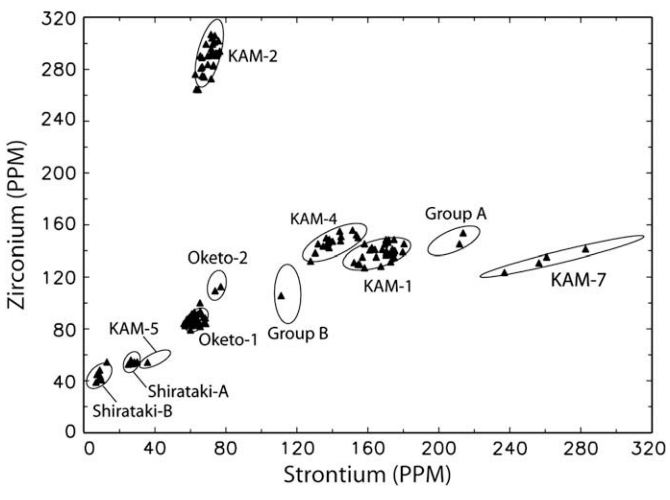


**Fig. 3.** Strontium–zirconium plot of obsidian artifact compositions from the Kuril Islands. The ellipses surrounding each group are drawn at the 95% confidence level. Confidence ellipses were drawn using a minimum of four data points from a larger group of obsidian artifacts, though only the artifacts relevant to this paper are presented here.

**Table 3**
Obsidian artifacts from dated contexts in the Kuril Islands.

| Island/site | Source | No. of samples from dated context | Uncalibrated $^{14}C$ date(s) | Culture period |
|---|---|---|---|---|
| Kunashir/Rikorda | Shirataki-B | 1 | 2210 ± 30 | Epi-Jomon |
| | Oketo-1 | 8 | 2250 ± 25, 2210 ± 30 | Epi-Jomon |
| | Group B | 1 | 2250 ± 25 | Epi-Jomon |
| Urup/Ainu Creek | Shirataki-A | 1 | 2410 ± 30, 880 ± 30 | Epi-Jomon, Okhotsk |
| | Shirataki-B | 3 | 880 ± 30 | |
| | Oketo-1 | 6 | 2540 ± 30, 880 ± 30 | Epi-Jomon, Okhotsk |
| Simushir/ Vodopodnaya 2 | Kamchatka-1 | 2 | 1600 ± 25, 1090 ± 25 | Epi-Jomon, Okhotsk |
| | Kamchatka-2 | 1 | 1090 ± 25 | Okhotsk |
| Shiashkotan/ Drobnyye | Shirataki-B | 1 | 1110 ± 25 | Okhotsk |
| | Kamchatka-1 | 7 | 750 ± 30 | Epi-Jomon, Okhotsk |
| | Kamchatka-2 | 16 | 1470 ± 35, 960 ± 25, 750 ± 30 | Epi-Jomon, Okhotsk |
| | Kamchatka-4 | 1 | 1470 ± 35 | Epi-Jomon |
| Shumshu/Baikova | Kamchatka-1 | 1 | 2010 ± 35 | Epi-Jomon |

Personal relationships between human groups are a social means for circumventing the local subsistence and material resource constraints that are inherent to geographically isolated environments (Mackie, 2001; Rautman, 1993). The presence of non-local obsidian in the Kuril Islands from Hokkaido and Kamchatka sources over a period of almost 2000 years is evidence of a long-term and long-distance network for the transportation and/or trade of obsidian, similar to obsidian networks that existed in other parts of northeast Asia during the late Pleistocene through the Holocene (Glascock et al., 2000; Kuzmin 2006b; Kuzmin et al., 2000, 2002).

The movement of obsidian from Hokkaido is known to have covered large areas of Japan including the Sea of Japan rim area and into the Korean Peninsula (Izuho and Sato, 2007; Kim et al., 2007). It has been demonstrated that a large-scale system for the transport and exchange of obsidian from Hokkaido sources to Sakhalin Island existed since the Upper Paleolithic and continued to operate for almost 20,000 years (Glascock et al., 2000; Kuzmin, 2006a, b; Kuzmin et al., 2000, 2002). By the initial Neolithic, obsidian was being moved from the Shirataki and Oketo sources on Hokkaido to sites on Sakhalin Island up to distances of 1000 km. This movement of material continued after the end of the Last Glacial Maximum (ca. 8000 BP) and the appearance of the 40-km-wide La Perouse Strait between Hokkaido and Sakhalin Island (Glascock et al., 2000; Kuzmin, 2006; Kuzmin et al., 2002).

The initial movement of obsidian onto the islands of Kunashir, Iturup, and Urup may have coincided with the migration of Epi-Jomon people into the Kurils and the colonization of those islands ca. 2500 BP. Given the geographic proximity of the southern Kuril Islands to Hokkaido, the extension of Hokkaido–Sakhalin obsidian trade/transport networks into the Kurils could be expected. Use of obsidian from the Shirataki-A and Oketo-1 sources at the Ainu Creek site on Urup Island spans the dated occupation of that site, from 2540 to 880 BP, indicating long-term access to obsidian sources on Hokkaido. This access may have been maintained through participation in social networks based on subsistence trade or demographic pressure, such as the need for marriage partners. The transport of obsidian from Hokkaido to and between the southern Kuril Islands also may have necessitated the use of boat technology, as has been suggested for the movement of obsidian from Hokkaido to Sakhalin (Kuzmin, 2006; Kuzmin et al., 2002). Alternatively, extensive stretches of sea ice in the southern Sea of Okhotsk often extend from Hokkaido through the southern Kuril Islands (Schneider and Faro, 1975; Wakatsuchi and Martin, 1990), and may have provided an “ice bridge” during the winter months that could have facilitated the transport of obsidian without the use of boats.

Based on the distribution of obsidian from Hokkaido sources in the Kuril Islands, it appears that the Bussol Strait separating the southern and central Kuril Islands may have been a significant barrier to the transport of significant amounts of obsidian northward into the island chain. The Bussol Strait is the widest strait in the Kuril Island chain, 109 km wide from Urup Island to Simushir Island (30 km between Urup and Chirpoi, and 79 km between Chirpoi and Simushir). The strait has a strong current flowing between the Pacific Ocean and the Sea of Okhotsk, and it is recognized as a biogeographic barrier to the movement of plants and animals from Hokkaido to the central and northern islands (Pietsch et al., 2003). Only three of the 49 pieces of obsidian from Hokkaido sources in this study were found north of the strait, one piece of obsidian from the Shirataki-A source on Chipoi Island, and one piece each from the Shirataki-A and Oketo-1 sources on Shiashkotan Island.

Although networks related to the trade and transport of obsidian from sources in Kamchatka are less well known, it is clear from this initial study that obsidian from Kamchatka sources was used extensively in the central and northern Kuril Islands. Human groups who moved from Hokkaido and the southern Kuril Islands into the central and northern islands may have found it too costly in terms of time, energy, and risk to maintain access to Hokkaido obsidian sources across the Bussol Strait. Securing access to obsidian sources in Kamchatka would have provided a less costly alternative to Hokkaido obsidian and facilitated social connections to the northern mainland. Artifacts from Shiashkotan Island made of obsidian from the Kamchatka-1 and Kamchatka-2 sources were recovered from contexts dated between 1470 and 750 BP, indicating consistent access to Kamchatka sources from the central Kuril Islands for more than 700 years.

## 7. Conclusion

The movement of lithic raw material from its natural source is attributed to three potential mechanisms: procurement directly from the source as part of normal resource extraction activity patterns, procurement through trade/exchange with other groups, or transport in conjunction with the colonization of a new environment (Bamforth, 2002; Rensink et al., 1991). Each of these mechanisms of procurement may account for the presence of non-local obsidian in the Kuril Islands at various locations and points in time, suggesting that different models may be required to fully understand the nature of obsidian access and use across the island chain.

Current evidence from the Kuril Islands demonstrates that the inhabitants of this region maintained access to multiple, non-local sources of obsidian from Hokkaido and Kamchatka for at least 1700 years. Variation in the distribution of obsidian artifacts in archaeological sites across the island chain may be a function of the specific mode of obsidian procurement that was utilized. Factors such as distance from obsidian source to stone tool manufacturing and use sites, and the overall level and patterns of group mobility have been used to infer direct procurement of lithic raw materials versus indirect procurement (e.g., trade/exchange relationships) (Bamforth, 2002; Binford, 1979; Morrow and Jeffries, 1989; Pecora, 2001; Whallon, 2006). Where distances were short and the cost in terms of time and energy of transporting obsidian were low, obsidian raw material may have been obtained directly from the source. This scenario may apply for people living at the extreme southern and northern ends of the island chain, in closer proximity to source locations in Hokkaido and Kamchatka respectively. Where distances were long and the cost of transporting obsidian high (such as in the central Kuril Islands), long-distance exchange relationships may have been relied on for access to non-local obsidian.

The ability to explore issues related to the procurement and use of different obsidian sources requires the identification of discrete source groups (Glascock et al., 1998; Speakman and Neff, 2005). The use of recently advanced PXRF technology to generate obsidian provenance data for the Kuril Island lithic assemblage demonstrates the utility of PXRF instruments for non-destructive artifact analyses. PXRF technology provides a low-cost and flexible, yet analytically accurate and precise method for conducting analysis in a lab, museum, or field setting, greatly expanding the potential application and use of XRF methods.

Finally, although the results presented in this study are based on a small sample size which limits the level of detail that can be assigned to obsidian procurement networks in the Kuril Islands, this is the first study of its kind in this region. Future obsidian provenance research on additional artifacts from the Kuril Islands will continue to build a knowledge base for this little-studied area, and will contribute to the greater understanding of obsidian procurement and use in northeast Asia.

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