

Obsidian use at the Ushki Lake complex, Kamchatka Peninsula (Northeastern Siberia): implications for terminal Pleistocene and early Holocene human migrations in Beringia

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Abstract

A study of the movement of people within Northeast Asia at the end of the Pleistocene is critical for understanding how and when some of the first human populations entered North America. Chemical source studies of obsidian may provide the evidence necessary to document people's migrations between these regions. Sixty two obsidian artifacts from the late Pleistocene and Holocene Ushki Lake sites in Kamchatka Peninsula were analyzed by instrumental neutron activation analysis (INAA). Data generated demonstrate that multiple obsidian sources throughout Kamchatka were exploited by the inhabitants of Ushki Lake, and allow us to document long-distance population movements during the late Pleistocene and Holocene. It is reasonable to expect that obsidian from Kamchatka might have been transported to Alaska. This is true for the Chukotka region of Northeastern Siberia; obsidian from Chukotka has been found in late Holocene archaeological sites in Alaska. Ultimately, an expanded study that includes all areas of Northeast Asia and Alaska may provide the data necessary to document the earliest movements of people in these regions.

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1. Introduction

The issue of prehistoric human migrations in Beringia, a vast region between the Lena River in Northeastern Siberia and the Mackenzie River in northernmost North America (Hopkins et al., 1982; West, 1996), is of special importance for studies related to the peopling of the Americas and human adaptations to arctic environments. For decades, archaeologists have looked

to Beringia as the probable and logical origin of the first Americans. Although much research has focused on the search for archaeological sites in Beringia that might be antecedents of the North American Clovis complex (dated to ca. 11,500–10,900 BP)—the earliest undisputed archaeological complex in North America—archaeologists have failed to determine an unambiguous pre-13,000 BP connection between the Old World and the Americas.

Despite the inability to identify a clear link between Siberia and North America, the Ushki Lake sites located in central part of Kamchatka Peninsula (56°15' northern latitude,

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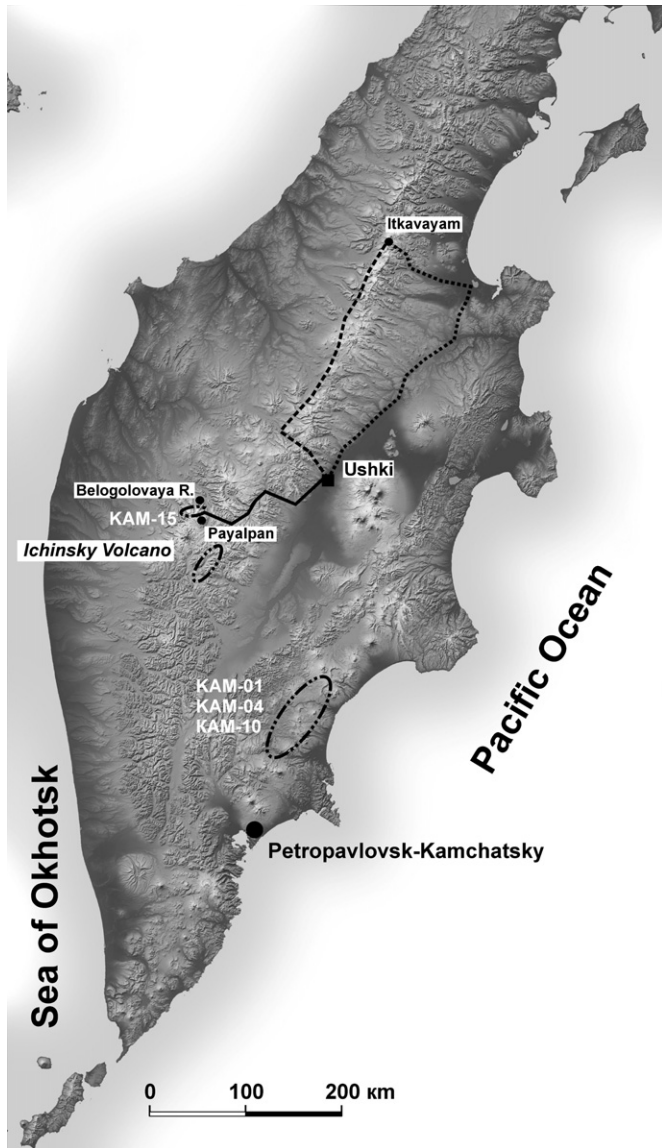


Fig. 1. Locations of Ushki cluster and obsidian sources used by its inhabitants at Kamchatka. Dashed line denotes probable route to the Itkavayam source by watershed, and dotted line—by river valleys; solid line is the probable route to the Belogolovaya River and Payalpan sources. Ellipses of dashed and dotted lines represent possible location of unknown sources.

160°00' eastern longitude; Fig. 1) have intrigued archaeologists for the last 30 years because initial dates obtained from the lowest levels of these sites suggested an occupation as early as 14,300 BP (Dikov, 1996, 2003, 2004). As a result of these early dates, it was argued that Ushki Lake (and/or Kamchatka) served as a 'jumping off point' for the colonization of North America (Dikov, 2003, 2004). This idea was recently called into question by T. Goebel and colleagues who obtained and radiocarbon dated additional material from the earliest components of the Ushki 1 and Ushki 5 sites (Goebel et al., 2003). Contrary to N.N. Dikov's early dates, Goebel et al.'s (2003) research suggested that the Ushki Lake sites were in fact younger than previously reported (Dikov, 2003, 2004), and therefore no older than the earliest archaeological

sites in Alaska (ca. 11,800 BP; e.g., Bever, 2006). Although T. Goebel et al.'s results serves to effectively eliminate the first inhabitants of Ushki Lake as possible Clovis progenitors, their research does not preclude the possibility that earlier sites may exist in Kamchatka and/or other nearby parts of Beringia, nor does it exclude the possibility that a close affinity may exist with the earliest inhabitants of Alaska. The Ushki Lake sites therefore continue to figure prominently in research focused on the settlement of the Americas, and the sites are considered to be among the best-studied terminal Pleistocene complexes in western Beringia (Goebel et al., 2003; Kiryak (Dikova), 2005). Rich artifact assemblages, decorative art, burials, and large dwellings make Ushki an extraordinary phenomenon for understanding the terminal Pleistocene and Holocene archaeology of Siberia and Eurasia.

Although significant progress in the investigation of human paleoecology in Beringia has occurred during the past several decades (e.g., West, 1996), some aspects of prehistoric adaptations remain poorly studied and the ranges and directions of human migrations during the late Pleistocene and the Holocene remain virtually unknown. In this research, we begin to address issues concerning the movement of people within Beringia using data generated from the analyses of obsidian—a volcanic glass widely used by prehistoric people to manufacture stone tools. Given that each geologic source of obsidian has a unique chemical 'fingerprint', obsidian provenance studies provide direct information about raw material procurement patterns, and by extension, the movement of people (Glascok, 2002; Glascok et al., 1998; Shackley, 1998, 2005).

Obsidian as a raw material for tool manufacture has been known in Kamchatka since the time when the first natural scientists explored Northeastern Siberia during the mid-eighteenth century (Krashennikov, 1949; Steller, 1999), and descriptions of some obsidian sources exist in Russian geological literature (Shevchuk, 1981; Rozenkrantz, 1981). A catalog of obsidian sources at Kamchatka has been compiled using data collected by the Geological Survey of Russia (Otchet, 1992). However, the geochemistry of Kamchatkan obsidian remained unknown until the early 2000s when initial research conducted by our research team began to address this 'gap' in knowledge about the prehistoric subsistence in western Beringia (Speakman et al., 2005; Glascok et al., 2006). Using data generated from our research in Kamchatka, we are now in a position to make some preliminary conclusions about the sources of volcanic glass used in prehistory, and we can begin to focus on the impact of this type of study on the broader issue of human migrations in Beringia.

2. The Ushki Lake cluster at Kamchatka: archaeological and geological settings

The Ushki site cluster is unique in western Beringia because it is the only place on the Kamchatka Peninsula known to contain evidence of a terminal Pleistocene human occupation (e.g., West, 1996; Michael, 1984; Alexeev, 1994; Vasil'evskiy, 1998). The record of human presence at Ushki began at least as early as the terminal Pleistocene

(ca. 14,000–11,300 BP), and continued throughout most of the Holocene (until ca. 800 BP) (Dikov, 2003, 2004; Goebel et al., 2003). The site cluster consists of five locales—Ushki 1, 2, 3, 4, and 5—situated along the Ushki Lake shore (Dikov, 2003; Dikov and Titov, 1984). According to Dikov (1996, 2004), cultural Levels 7 through 1 at the different locales can be correlated laterally, and therefore level numbers are uniform across the entire cluster.

The Ushki components are situated along the coastline of large oxbow Ushki Lake in the middle stream of the Kamchatka River, about 200 km from its mouth on the open coast of the Pacific Ocean. The elevation of the sites above the lake's water level are quite low, about 2–4 m. The general view about the genesis of culture-bearing sediments is that they were created by aeolian processes. Fluvio-glacial activity during the melting of ice covers the neighboring glaciation center of the Kluchevskoy Volcano and is responsible for formation of the lower Ushki levels according to the first generation of studies (Dikov and Titov, 1984). Later this view was revised, and the base is now considered to have an alluvial origin (Dikov and Ivanov, 1990; Goebel et al., 2003). The sediment matrix is interbedded with volcanic ash layers that originate from large eruptions of the Kluchevskoy and Kizimen volcanoes in northern part of Kamchatka (Fedotov and Masurenkov, 1991). Paleoenvironmental data for the Ushki region are limited. Pollen analyses of sediments from the various components (Dikov, 1996; Lozhkin et al., 2004) indicate a treeless barren tundra and shrub-moss tundra for Levels 7–5; and birch-alder and birch-larch forests for Levels 4–1.

Cultural material at Ushki is found in seven distinct levels (Dikov, 1996, 2003; Goebel et al., 2003). Level 7, the earliest occupation of the site, was ¹⁴C-dated by Dikov (1996, 2003, 2004) to ca. 14,300–13,600 BP. Results obtained by Goebel et al. (2003) suggest a younger age for Level 7 of about 11,300–10,700 BP, and an age for the underlying non-cultural level (e.g., no evidence of artifacts) of ca. 11,900–11,200 BP. Level 6 was dated by Dikov (1996) as ca. 10,900–10,400 BP, and by Goebel et al. (2003) as ca. 11,100–10,200 BP. The ¹⁴C age of Level 5 is ca. 9000 BP (Dikov, 2003). Level 4 has two ¹⁴C dates of ca. 4200 BP and ca. 3100 BP; Level 3 has no ¹⁴C age determinations, and Levels 2 and 1 are ¹⁴C-dated to ca. 2400–1100 BP and ca. 700–200 BP, respectively (Dikov, 2003).

From the perspective of the stone tool assemblage, Levels 7 and 6 are very different from the upper levels. Although microblades and wedge-shaped cores are evident in the assemblage associated with Level 6, Level 7 lacks these tools. Level 7 is particularly renowned for the discovery of 'stemmed' projectile points that appear to be unique to Siberia and the Russian Far East (Dikov, 1996). Bifacial tools, knives, scrapers, and burins also are typical of the Level 7 assemblage. Some stone adornments such as pendants and beads have also been found. In Level 6, the major tool types are microblades, burins, bifaces, and scrapers (Dikov, 1996). Several stone pendants also were unearthed from Level 6. Remains of shallow dwellings were found in Levels 7 and 6. In Level 6, at least two burials (dog and human) are known. It is possible that

Level 7 also has a human interment (Dikov, 2003). The stone tool inventory for Level 5 is similar to that of Level 6. Details of the Levels 6 and 7 artifact assemblage are discussed in several publications by Dikov (1996, 2003, 2004).

The Holocene cultural Levels 4, 3, and 2 contain prismatic and conical cores and a stone tool assemblage that include knife-like blades, leaf-shaped biface-knives, burins, scrapers, small projectile points (especially rhomboid, stemmed, and three-edged file-like shapes), borers, and burins (Dikov, 2003). During the late Holocene (Level 2), polished-edge adzes emerged, but pottery, which occurs in other contexts in Kamchatka, is absent from the late Holocene components of the Ushki sites. Level 1 belongs to the Middle Kamchatkan [Nikul'skaia] variant of the Late Prehistoric Old Itel'men [Drevneitel'menskaya] culture. The primary tool types include: adzes; axes; narrow leaf-shaped and stemmed points; stemmed and polished knives; and scrapers (Dikov, 2003).

According to Dikov (2004), artifacts from Ushki Levels 6, 5, 4, 3, and 2 resemble other documented prehistoric complexes in Northeastern Siberia and neighboring regions, including northwestern North America. Level 7, however, has no analogs in Siberia (Dikov, 2004; Powers, 1973). Although Dikov (2004) considered the Level 7 'stemmed' points associated with the Paleo-Indian complexes in western North America, Goebel et al.'s (2003) examination of these points indicated they are much smaller and thinner than their North American counterparts, and morphologically appear to be more similar to notched points than stemmed points.

3. Materials and methods

Obsidian samples for analysis were selected from the Ushki cluster archaeological collections, excavated by N.N. Dikov from the mid-1960s until his death in 1996. These collections are curated in the depository of the Northeastern Multidisciplinary Research Institute, Far Eastern Branch of the Russian Academy of Sciences, in Magadan. In September 2005, small flakes (usually about 1–2 cm long and up to 1 cm wide) were sampled from the Ushki collection; they may be classified as debitage created during the manufacture of prepared cores. No cortex was observed on either flakes selected for chemical analysis or the cores and tools in the collection. Given that our analytical technique, neutron activation analysis, is destructive, debitage was the focus of our study because it is less valuable (from a museum conservation perspective) and it is highly representative of the Ushki collection.

In total, 62 obsidian specimens were selected for analysis (Table 1), primarily from the Ushki-1 site ($n = 48$), and also from the Ushki-2 and Ushki-5 sites (6 and 8 artifacts, respectively). Nineteen samples associated with cultural Level 7, and 14 artifacts each from Level 6 and Level 4 also were analyzed. We obtained a few artifacts (from one to four samples) from Levels 5, 3, 2, and 1 (Table 1). Three samples from the Ushki-1 site not assigned to a specific cultural level by Dikov are treated separately, as indicated in Tables 1 and 3.

Table 1
Frequency of obsidian from different sources at the Ushki site cluster (in %, rounded to nearest whole number)

Levels (no. of samples)	KAM-01	KAM-03	KAM-04	KAM-05	KAM-07	KAM-10	KAM-14	KAM-15
Unassigned (3)				33		34		33
Level 1 (4)		25		25	25	25		
Level 2 (1)						100		
Level 3 (3)		33				67		
Level 4 (14)			7	7	7	57	7	15
Level 5 (4)				25	25	50		
Level 6 (14)				22	22	42		14
Level 7 (19)	5	18		35	6	24		12

An exact accounting of the amount of obsidian recovered from the Ushki cultural levels is difficult to determine. Our estimates, derived from Dikov (2003, 2004), is that Level 7 obsidian represents about 8.3% of the excavated material; Level 6 represents about 3.5%. However, according to A.V. Ptashinsky's observations of the excavations in the 1970s, the total amount of obsidian from Level 7 could be as high as 15–20%, and in Level 6 as high as 50–60%. The exact amount of obsidian in Levels 5, 4, and 2 also remains unknown, and we estimate it to be about 5–10% of the total material for that level. In Level 3, obsidian is the predominant lithic material and represents about 70% of the total assemblage for that level. Approximately 10% of the artifacts recovered from Level 1 are obsidian.

Geochemical study was conducted by instrumental neutron activation analysis (INAA). Using this analytical technique, we determined the concentrations of seven short-lived elements (Al, Ba, Cl, Dy, K, Mn, and Na) in all the samples. In most cases, Ba, Mn, and Dy are sufficient for source determination of most Kamchatka obsidian (as well as obsidian from other areas of Northeast Asia and Alaska). A second, more comprehensive analysis was undertaken on ambiguous samples and those that could not be readily assigned to known compositional groups (e.g., groups KAM-14 and KAM-15). The second analysis permitted the measurement of six medium half-life elements (La, Lu, Nd, Sm, U, and Yb) and 15 long-lived elements (Ce, Co, Cs, Eu, Fe, Hf, Rb, Sb, Sc, Sr, Ta, Tb, Th, Zn, and Zr).

Geochemical groups were identified on the basis of their inherent patterning in bivariate and multivariate space (Table 2). In this particular case, group assignments were obtained by comparing the new artifact analyses against compositional groups identified in earlier study of geologic source samples and artifacts from Kamchatka (Speakman et al., 2005; Glascock et al., 2006). Details of the statistical procedures are described in Glascock et al. (1998).

4. Results

As a result of our geochemical studies of volcanic glass from all cultural levels of the Ushki cluster, eight compositional groups were identified (Fig. 2; Tables 1–3). These groups represent geographically discrete obsidian sources that were exploited by the people who lived at the Ushki sites throughout the terminal Pleistocene and the Holocene. All

samples, except for a single specimen from Level 7 (labeled as “Unknown Source” in Fig. 2), were assigned to either previously identified geochemical groups (Speakman et al., 2005; Glascock et al., 2006) or newly established groups (KAM-14 and KAM-15; Fig. 2; Tables 1 and 3).

Three compositional groups are directly attributable to geologic sources of obsidian with precisely known location—KAM-03 (Itkavayam), KAM-05 (Payalpan), and KAM-07 (Belogolovaya River) (Glascock et al., 2006) (Table 3). Two of these sources, KAM-05 and KAM-07, are situated along Ichinsky Volcano on western slope of the Middle [Sredinny] Range of Kamchatka Peninsula (Fig. 1). According to published reports, at least 11 distinct obsidian sources are known to exist the vicinity of Ichinsky Volcano (Otchet, 1992).

The KAM-03 source is located in the headwaters of the Itkavayam River drainage, part of the Kutina River basin (western slope of the Middle Range) (Fig. 1). The geographic coordinates of the KAM-03 source are 58°05' N, and 160°46' E. Volcanic glass of the KAM-03 source originates from the cone of the small Obsidianovy Volcano which is probably not older than about 130,000–150,000 years. Obsidian from this source is associated with lava flows, and occurs in layers about 0.4–15 m thick. The source itself is a flow of massive and striped volcanic glass of black and reddish-brown colors. According to composition data, the obsidian is rhyolitic. The distance from this source to the Ushki cluster is about 200 km straight-line distance, and about 250–300 km by the most probable transit routes following either watersheds or major river valleys (Fig. 1).

The KAM-05 and KAM-07 sources are part of the Ichinskaya Source Group (Fig. 1). Their respective coordinates are 55°48' N, 157°54' E (KAM-05), and 55°52' N, 157°37' E (KAM-07). The volcanic glass corresponds to the dacite-rhyolite rocks of the upper part of Alnei series (late Miocene) (Sheimovich and Patoka, 2000). Some of the sources, such as those found in Belogolovaya River (KAM-07), may have been formed about 2,500,000 years ago.

The KAM-05 source is located on the western slope of Maly Payalpan Volcano, and is represented by a lava flow that originates at the intrusive dome. The flow is about 100 m long and 5 m thick. The obsidian is black in color with dark-gray stripes, and often transparent in thick-edge. Based on chemical composition, the KAM-05 volcanic glass is rhyolitic. The distance between this source and the Ushki sites is about 190 km.

Table 2
Mean elemental composition and standard deviations [SD] (in parts per million, except where note otherwise) for the geochemical groups identified at the Ushki sites (based on the larger Kamchatka database for which 28 elements were measured; see Glascock et al., 2006)

Element	KAM-01		KAM-03		KAM-04		KAM-05		KAM-07		KAM-10		KAM-14		KAM-15	
	<i>n</i> = 12		<i>n</i> = 15		<i>n</i> = 8		<i>n</i> = 9		<i>n</i> = 24		<i>n</i> = 11		<i>n</i> = 2		<i>n</i> = 7	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Ba	773	24	890	19	867	21	289	18	1093	28	1391	100	1439	12	1167	48
La	11.5	0.2	16.8	0.4	12.9	0.2	24.2	0.5	18.7	0.4	19.2	3.5	13.8	0.2	20.3	0.5
Lu	0.290	0.016	0.320	0.026	0.341	0.007	0.265	0.030	0.194	0.018	0.292	0.034	0.222	0.021	0.234	0.025
Nd	9.5	1.2	14.9	6.5	11.6	1.2	14.2	0.7	12.6	1.2	16.4	3.4	12.0	2.8	13.7	0.9
Sm	2.24	0.40	2.78	0.10	2.78	0.56	2.48	0.05	2.16	0.08	3.10	0.48	2.11	0.04	2.33	0.11
U	1.52	0.35	4.10	0.28	1.72	0.52	4.47	0.31	2.54	0.22	2.26	0.52	2.93	0.27	2.72	0.16
Yb	1.77	0.14	1.80	0.11	2.11	0.07	1.35	0.03	1.09	0.06	1.75	0.16	1.12	0.03	1.16	0.14
Ce	23.4	0.7	34.1	0.9	26.9	0.6	44.0	1.5	34.0	0.8	37.1	3.3	27.4	0.1	37.0	1.1
Co	1.290	0.118	0.351	0.012	1.029	0.081	0.163	0.031	0.954	0.110	0.563	0.101	0.336	0.036	0.361	0.029
Cs	3.54	0.09	3.23	0.08	4.40	0.15	2.26	0.05	1.26	0.02	1.68	0.13	2.80	0.01	1.44	0.02
Eu	0.473	0.044	0.455	0.017	0.491	0.011	0.296	0.007	0.513	0.011	0.611	0.04	0.4	0	0.498	0.011
Fe (%)	1.08	0.04	0.58	0.02	0.96	0.04	0.41	0.01	0.85	0.04	0.78	0.03	0.55	0.01	0.64	0.02
Hf	4.06	0.11	3.50	0.08	4.41	0.09	2.95	0.08	3.44	0.08	3.68	0.22	2.59	0.30	3.28	0.12
Rb	60.0	2.2	74.2	1.5	66.6	1.4	92.2	1.5	70.8	1.4	63.1	2.9	56.5	0.3	78.9	1.4
Sb	1.28	0.13	0.41	0.03	1.73	0.22	0.41	0.02	0.12	0.01	0.41	0.11	2.16	0.02	0.14	0.01
Sc	3.03	0.52	1.99	0.04	3.26	0.14	1.72	0.04	1.82	0.05	2.11	0.11	1.72	0.01	1.49	0.04
Sr	206	20	111	17	157	7	53	6	354	54	282	21	219	25	276	25
Ta	0.20	0.01	1.15	0.02	0.22	0.01	1.56	0.04	0.74	0.02	0.40	0.11	0.27	0.01	0.81	0.02
Tb	0.31	0.03	0.37	0.01	0.39	0.01	0.29	0.01	0.22	0.01	0.37	0.04	0.22	0.02	0.24	0.01
Th	3.98	0.14	7.62	0.17	4.71	0.13	9.27	0.05	4.65	0.11	4.01	0.25	4.24	0.04	5.41	0.18
Zn	34.8	2.4	34.1	2.1	35.1	2.7	24.5	3.7	34.3	4.4	37.6	3.0	28.9	1.3	31.1	2.0
Zr	131	9	126	6	145	8	97	5	133	10	134	12	107	15	120	6
Al (%)	7.08	0.24	7.10	0.29	6.76	0.40	6.67	0.26	7.59	0.20	7.08	0.41	6.68	0.14	7.46	0.44
Cl	376	73	112	23	356	24	239	42	238	79	253	33	215	18	254	20
Dy	1.84	0.38	2.24	0.28	2.71	0.22	1.64	0.16	1.09	0.26	2.11	0.46	1.09	0.08	1.37	0.33
K (%)	2.62	0.32	3.20	0.17	2.75	0.15	3.94	0.16	3.25	0.20	3.14	0.15	2.98	0.01	3.31	0.15
Mn	486	11	542	10	391	18	377	5	558	8	610	22	539	3	534	12
Na (%)	3.09	0.10	3.21	0.04	2.95	0.07	2.81	0.08	3.20	0.07	2.93	0.19	2.79	0.01	3.04	0.07

Table 3
Summary of obsidian sources for the Ushki site cluster, Kamchatka Peninsula (Northeastern Siberia)

Levels (ages)	KAM-01 (unknown)	KAM-03 (Itkavayam)	KAM-04 (unknown)	KAM-05 (Payalpan)	KAM-07 (Belogolovaya River)	KAM-10 (unknown)	KAM-14 (unknown)	KAM-15 (unknown)	Unknown Source	No. of sources
Unassigned				+		+		+		3
Level 1 (700–200 BP)		+		+	+	+				4
Level 2 (2400–1000 BP)						+				1
Level 3 (no age determinations)		+				+				2
Level 4 (4200–3100 BP)			+	+	+	+	+	+		6
Level 5 (9000 BP)				+	+	+				3
Level 6 (combined) (11,100–10,200 BP)				+	+	+		+		4
Level 7 (14,300–10,700 BP)	+	+		+	+	+		+	+	7
Frequency of source in cultural Levels 1–7	1	3	1	5	5	7	1	3	1	

The KAM-07 source, which we refer to here as the Belogolovaya River, is situated near the headwaters of the Belogolovaya Vtoraya River, on the northern part of Tynua Ridge near the summits of Bystraya (1304 m above the sea level) and Tynua (1429 m). Volcanic glass from this source is associated with extrusive domes and lava flows. The colors of this obsidian range from black to a dark-reddish brown, and sometimes occurs in dark-gray and blue-grayish colors; the structures are massive and clastic. Some of the black obsidians are semi-transparent. The distance between this source and the Ushki cluster is about 180 km.

As a consequence of the early nature of our ‘geological’ obsidian research in Kamchatka, we cannot state precisely where the geologic sources for the remaining five groups of obsidian (KAM-01, KAM-04, KAM-10, KAM-14, and KAM-15) are

located. However, we can speculate about the origin of a few sources based on the spatial distribution of archaeological specimens assigned to these groups and their frequency at other sites throughout Kamchatka (Glascok et al., 2006). The unknown sources may be discussed as two separate clusters based on our estimation of their geological origin; one that includes KAM-01, KAM-04, and KAM-10 groups, and the second which includes KAM-14 and KAM-15 (Figs. 1 and 2).

The KAM-01 group is represented at Ushki by a single sample from Level 7. About 100 archaeological obsidian samples from 32 sites belong to this geochemical group, and artifacts from this source are widely distributed throughout all of Kamchatka (Glascok et al., 2006). A single sample attributed to KAM-04 was identified from cultural Level 4. An additional 21 specimens are known from 11 sites in central and southern

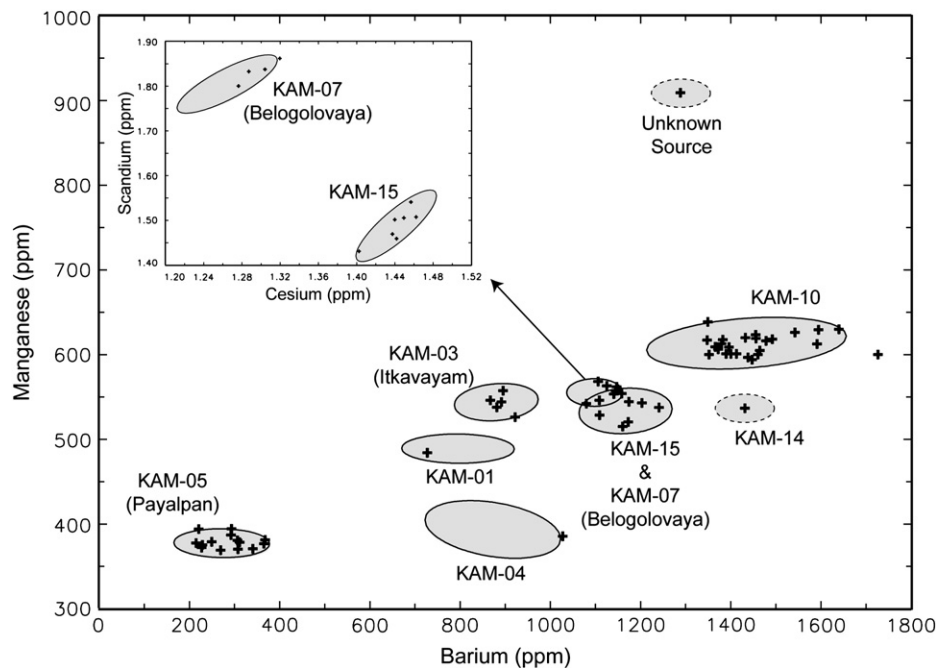


Fig. 2. Bivariate plot of barium and manganese concentration illustrating the Ushki artifacts (+) relative to the 95% confidence ellipses determined for relevant Kamchatka geochemical reference groups. Inset: A bivariate plot of scandium and cesium concentrations showing the unambiguous separation of the KAM-07 and KAM-15 groups. Dashed ellipses indicate an insufficient number of analyzed samples exist to calculate confidence ellipses.

parts of Kamchatka Peninsula (Glascocks et al., 2006). Both KAM-01 and KAM-04 groups have a Nb/Zr ratio of 0.04, which is characteristic for volcanic rocks of the East Kamchatkan volcanic belt (Ishikawa et al., 2001; Münker et al., 2004). It should be highlighted that sites belong to these groups are in vicinity of Karimsky source (KAM-09 in Glascock et al., 2006) which has similar Nb/Zr ratio.

The KAM-10 group is known to occur at three sites in central Kamchatka (Glascocks et al., 2006); in total, 14 specimens had previously been assigned to this group. At Ushki, 25 samples of attributed to this source were identified. The Nb/Zr ratio is equal to 0.04, and this is typical of the East Kamchatka volcanic region (Ishikawa et al., 2001; Münker et al., 2004; see also above for groups KAM-01 and KAM-04). We assume that the sources of the KAM-01, KAM-04, and KAM-10 groups are situated somewhere in the eastern part of Kamchatka Peninsula (Fig. 1), with a possible distance of about 120–150 km from Ushki.

The KAM-14 and KAM-15 are two new geochemical groups not discussed in our earlier publications (e.g., Glascock et al., 2006). Therefore, it is impossible at this stage of investigation to speculate about the location of their geological sources. Based on our geochemical data, the KAM-15 group has some resemblance to the Belogolovaya River (KAM-07) source (Fig. 2). This attribute can be used to tentatively assume that the location of the KAM-15 source is part of the Ichinskaya Source Group (Fig. 1) located approximately 200 km from Ushki. Additional research is needed to determine which of the Kamchatka volcanic zones the KAM-14 group obsidian may belong.

Finally, there is one sample that is labeled as “Unknown Source” in Fig. 2. This sample was recovered from the earliest component (Level 7) of the Ushki 1 site. Chemically, this sample is so different from other Kamchatka sources, that it is unlikely that the geologic origin for this obsidian is located within Kamchatka—hence our reluctance to refer to this sample as a Kamchatka source as we did for the single specimen that comprises the KAM-14 group. When this sample was compared to the MURR and Smithsonian obsidian databases, which include thousands of analyses of obsidian from other parts of Northeast Asia (e.g., Hokkaido Island, the Kurile Islands, Primorye, Korea, and Chukotka) and Alaska, we were unable to link this sample with any previously analyzed samples. If this artifact is indeed from a non-Kamchatka source, then the origin of this artifact is particularly important for understanding from where the earliest migrants to Kamchatka may have originated, or alternatively who they may have traded with, or where they may have traveled outside of Kamchatka. The identification of this obsidian source is therefore critical to furthering our understanding of the earliest inhabitants of Kamchatka.

5. Discussion

According to our results, multiple obsidian sources were used prehistorically on Kamchatka Peninsula (Tables 1 and 3). During the terminal Pleistocene (Levels 7 and 6), between four

and six individual sources were exploited. During the Holocene (Level 4; note that data for Levels 3, 2, and 1 are insufficient to draw any conclusions), the use of obsidian from up to six sources was identified. KAM-10, KAM-07 (Belogolovaya River), and KAM-05 (Payalpan) were the most actively procured of these sources (Tables 1 and 3). Other sources, such as KAM-03 (Itkavayam) and KAM-15 also are noteworthy—especially given that KAM-15 source is only now beginning to be recognized despite our earlier analyses of several hundred artifacts from Kamchatka (Speakman et al., 2005; Glascock et al., 2006). Some sources, such as KAM-01, KAM-04, and KAM-14, also were used in minor quantities (Table 3).

Because no cortex is observed on surface of analyzed artifacts (flakes) and on flakes and tools in sites' collection (see Section 3), we assume that primary reduction of obsidian occurred at the geologic outcrops. Long-distance transport of obsidian pieces by natural processes, i.e., water is unlikely because the outcrops tend to be small, a few hundred meters in size (Otchet, 1992), and the outcrops incline to be situated high in the mountains where there is no river network. Thus, the possibility of obsidian transportation down-slope by water and/or colluvial processes seems unlikely, as does the procurement of obsidian from secondary (alluvial) sources. No obsidian pebbles suitable for tool manufacture have been observed in the alluvial deposits of drainage basins in the Kamchatka Peninsula where volcanic glass sources are located, as our field observations in 2004–2005 suggest. Therefore, it seems likely that the majority of obsidian used at the Ushki sites was obtained directly from the sources; cores or core-like blanks and debitage recovered from Ushki suggest that significant tool-making and tool-rejuvenation activities occurred at Ushki.

The distance of obsidian movement during the late Pleistocene at Ushki was up to 200 km and possibly up to 300 km if we assume that people were traveling along major rivers (Fig. 1). The use of the Middle Range watersheds during the terminal Pleistocene, ca. 14,000–10,000 BP, may have been limited due to ice caps and glaciers that covered the higher elevations (Velichko et al., 2002). Most probably, during the terminal Pleistocene humans would have taken routes along the river valleys that were not covered with permanent ice and snow fields. During the Holocene, obsidian was transported to Ushki from distances up to 200–300 km. In other parts of Kamchatka, the distance between the Holocene sites and obsidian sources is up to 500 km (Glascocks et al., 2006).

The earliest inhabitants of the Ushki cluster (Level 7, no later than ca. 11,300 BP) obtained obsidian from multiple raw material sources. At least six localities with high-quality volcanic glass supplied the terminal Pleistocene population of central Kamchatka, and most of them were about 200–300 km distance from the Ushki sites. High concentrations of obsidian outcrops in Kamchatka compared with neighboring continental Northeast Asia (Kuzmin, 2006) enabled prehistoric populations to exploit multiple sources (see also Glascock et al., 2006). People of Kamchatka during the terminal Pleistocene were familiar with obsidian and its sources, and their subsistence strategy to acquire raw material was quite diverse. This pattern is similar to more southern regions of Northeast Asia, such as Primorye

(Maritime) Province of the Russian Far East and Japanese Islands, where multiple obsidian sources located hundreds of kilometers away from habitation sites were used during the late and terminal Pleistocene (Kuzmin et al., 2002a,b; Tsutsumi, 2002).

When we compare the Ushki data with that from neighboring regions of Northeast Asia, one can see that the distances of raw material acquisition are of the same order of magnitude. For example, during the late Pleistocene obsidian from the Paektusan source (on the modern North Korean–Chinese border) is found at sites up to 500–700 km distance (Kuzmin et al., 2002a). In Japan, the distance between the Shirataki and Oketo sources on Hokkaido Island and the late Pleistocene sites that obsidian from these sources was found is as much as 250 km (Kuzmin et al., 2002b), and on the Honshu Island it is up to 300–400 km (Tsutsumi, 2002). During the Holocene, the range of obsidian exchange in Northeast Asia was up to 1000 km (Kuzmin, 2006).

The first comprehensive data concerning obsidian use in Kamchatka allows us to investigate long-distance population movements during the late Pleistocene and Holocene. Given the proximity of Kamchatka to the Bering Strait and the Aleutian Islands, we expect that obsidian from Kamchatka might have reached Alaska, especially if we take into account the most conventional views of intensive and rapid human migrations from Northeastern Siberia to North America and back during the terminal Pleistocene and early Holocene (Hopkins et al., 1982; West, 1996; Hoffecker and Elias, 2003). This is especially true for the Chukotka region of Northeastern Siberia located north of Kamchatka. As geochemical studies of obsidian from Chukotka and Alaska have shown (Cook, 1995) obsidian from a Chukotka source at Krasnoe Lake has been documented in late Holocene archaeological sites in Alaska—a straight-line distance of about 800 km. The existence of long-distance obsidian transportation between Northeast Asia and Alaska makes the study of Kamchatkan obsidian sources and patterns of its use in prehistory an important issue that has direct bearing on the peopling of the New World.

6. Conclusion

The high degree of mobility of the terminal Pleistocene populations of Kamchatka as established in our study may be applied to support the view of human migration from Northeast Asia to North America along the Bering Sea coastline, with probable help of watercraft (see review in Erlandson, 2001). Knowing that at ca. 11,000 BP people in Kamchatka (and purportedly neighboring Chukotka) had adapted to some degree to marine resources, as the finds of anadromous fish bones from Levels 7 (Ponkratova, 2006) and 6 (Dikov, 2003, 2004) at Ushki 1 and 5 sites testify, it is possible to suggest that humans could have moved into Alaska by following the emerging coastline free of continental ice sheets. The existence of coastal sites in Alaska and further south dated to ca. 9000–10,000 BP (Erlandson, 2001), for example On-Your-Knees Cave (Dixon, 1999), suggest that this migration route is quite probable, and also suggests that

obsidian from Kamchatkan and Chukotkan sources could have been transported into northwestern North America during these early migrations.

Obsidian provenance studies in Northeastern Siberia have great potential for identifying long-distance exchange and human migrations during the late Pleistocene and Holocene. The increased pace of this type of research in continental Northeast Asia during the last decade has and will continue to provide unambiguous evidence of the movement and interactions of people in Beringia.

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