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The identification of archaeological obsidian sources on Kamchatka Peninsula (Russian Far East) using geochemical and geological data: Current progress

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ABSTRACT

The current state-of-the-art of provenance studies for archaeological obsidian on Kamchatka Peninsula is presented. Prehistoric people widely used obsidian as a raw material for making tools, and acquired it from several primary sources. The exact position of seven sources allowed us to understand the general features of obsidian geochemistry and tectonic position of obsidian-bearing volcanic formations. This also made it possible to suggest the localization of seven still unknown sources for archaeological obsidian on Kamchatka. Verification of our preliminary conclusions can be made by fieldwork in selected areas.

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1. Introduction

Nowadays, research on obsidian provenance is integral to the study of human–environment interaction, especially in terms of lithic raw material resources (e.g., Shackley, 2008). In Northeast Asia, covering Japan, the Russian Far East, Korea, and Northeast China (or Manchuria), the number of research groups working in the field of archaeological obsidian sources has increased dramatically since the 1990s. As a result, there are several edited volumes with data generated since the early 2000s (Kuzmin and Popov, 2000; Kuzmin and Glascock, 2010; Ono et al., 2014). The Kamchatka Peninsula in the northern part of the Russian Far East is one of the promising regions due to the large number of primary obsidian sources and the extensive use of this raw material in prehistory (e.g., Kuzmin et al., 2008; Grebennikov et al., 2010, 2014).

However, Kamchatka remains less studied when compared to the neighboring parts of Northeast Asia, mainly due to the difficult terrain. This calls for particular attention to this region using all available data, mainly from the geology and geochemistry of volcanic rocks. This paper presents the current understanding of the peculiarities of the geochemistry and chronology of archaeological obsidians on Kamchatka.

2. Material and methods

Obsidian was widely used by prehistoric populations of Kamchatka, and this was one of the major kinds of raw material for toolmaking (Dikov, 1996, 2003). Most of sites considered in this paper belong to Neolithic and Paleometal stages of Kamchatkan prehistory dated to ca. 6000–300 BP (Grebennikov et al., 2010; Kuzmin et al., 2008; see also Kuzmin, 2000).

Since the early 2000s, our team has collected about 500 samples of Kamchatkan obsidian, from both archaeological and geological contexts. All specimens were tested by Neutron Activation Analysis (NAA) at the Research Reactor Center, University of Missouri (MURR), in Columbia, MO, USA (Grebennikov et al., 2010). At first, the concentrations of seven short-lived elements (Al, Ba, Cl, Dy, K, Mn, and Na) were established for all samples using only short irradiation. Afterwards, long irradiation for 162 specimens allowed us to measure an additional 21 medium and long-lived elements (La, Lu, Nd, Sm, U, Yb, Ce, Co, Cs, Eu, Fe, Hf, Rb, Sb, Sc, Sr, Ta, Tb, Th,

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Zn, and Zr). Statistical grouping of the data obtained was performed using the methodology developed by Glascock et al. (1998), which was successfully employed in other parts of the Russian Far East since the 1990s (e.g., Kuzmin et al., 2002a, 2002b; Kuzmin and Glascock, 2007; Glascock et al., 2011).

As a result, 16 geochemical groups of obsidian were established (Fig. 1). Each group reflects the composition of an individual obsidian source, with its unique geochemical signature. Fourteen out of 16 groups are identified among archaeological specimens, and seven of these groups also have geological source samples; two groups are known only from geological sources (Grebennikov et al., 2010).

These data allow us to identify the primary obsidian localities used by the ancient populations of Kamchatka. When we have samples from both the primary source and the prehistoric site, it is possible to find out from where obsidian was acquired. There are seven locales with high quality obsidian from which prehistoric people collected valuable raw material. Data on the locations of these obsidian sources (labeled as "known") made it possible to understand the general peculiarities of their geochemical composition in relation to the major tectonic zones of the region (Grebennikov et al., 2010). Based on these data, we separated the obsidian geochemical groups into three major geographic clusters: 1) Central Range; 2) Eastern Range; and 3) southern Kamchatka (Fig. 1). Each of them is characterized by its own history of volcanism (Grebennikov et al., 2014).

The locations of seven other sources (labeled as "unknown") remains unclear. Keeping in mind that there are at least 30 well-known obsidian locales on Kamchatka (e.g., Grebennikov et al., 2010), this is not surprising. Our team was so far able to obtain reference samples from about 27% of them (Grebennikov et al., 2014: 96). A similar situation exists in Alaska where only a small portion of sources for archaeological obsidian has been pinpointed (e.g., Reuther et al., 2011). Nevertheless, data on the geochemical zoning of known Kamchatkan sources, as established by our team (see Grebennikov et al., 2014), are now crucial in order to suggest the approximate location of unknown ones.

Judging from the geographic distribution of archaeological sites with obsidian from known sources, it is possible to assume the spatial position of primary localities in relation to prehistoric sites. For the most widely used groups KAM-03 (Itkavayam) and KAM-05 (Payalpan), archaeological sites are usually situated around the sources (Fig. 2). In some cases, however, sites are located quite far away from them, with distances of up to 500–600 km (Grebennikov et al., 2010). These spatial patterns can be used to suggest the position of unknown obsidian sources.

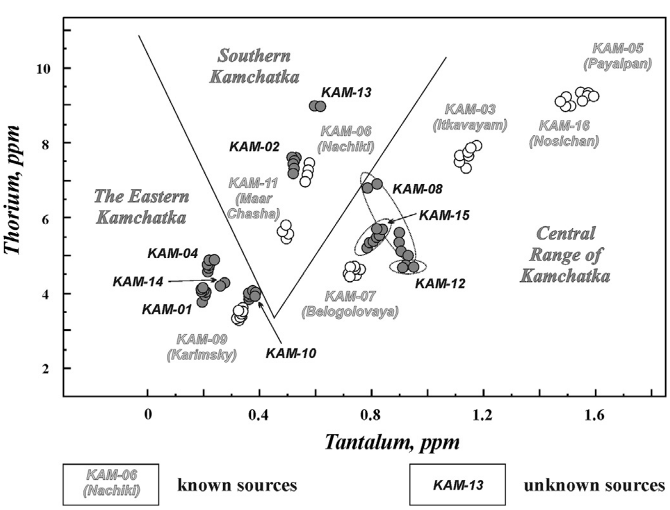

Fig. 1. Geochemical groups of Kamchatkan obsidian (after Grebennikov et al., 2014; modified).

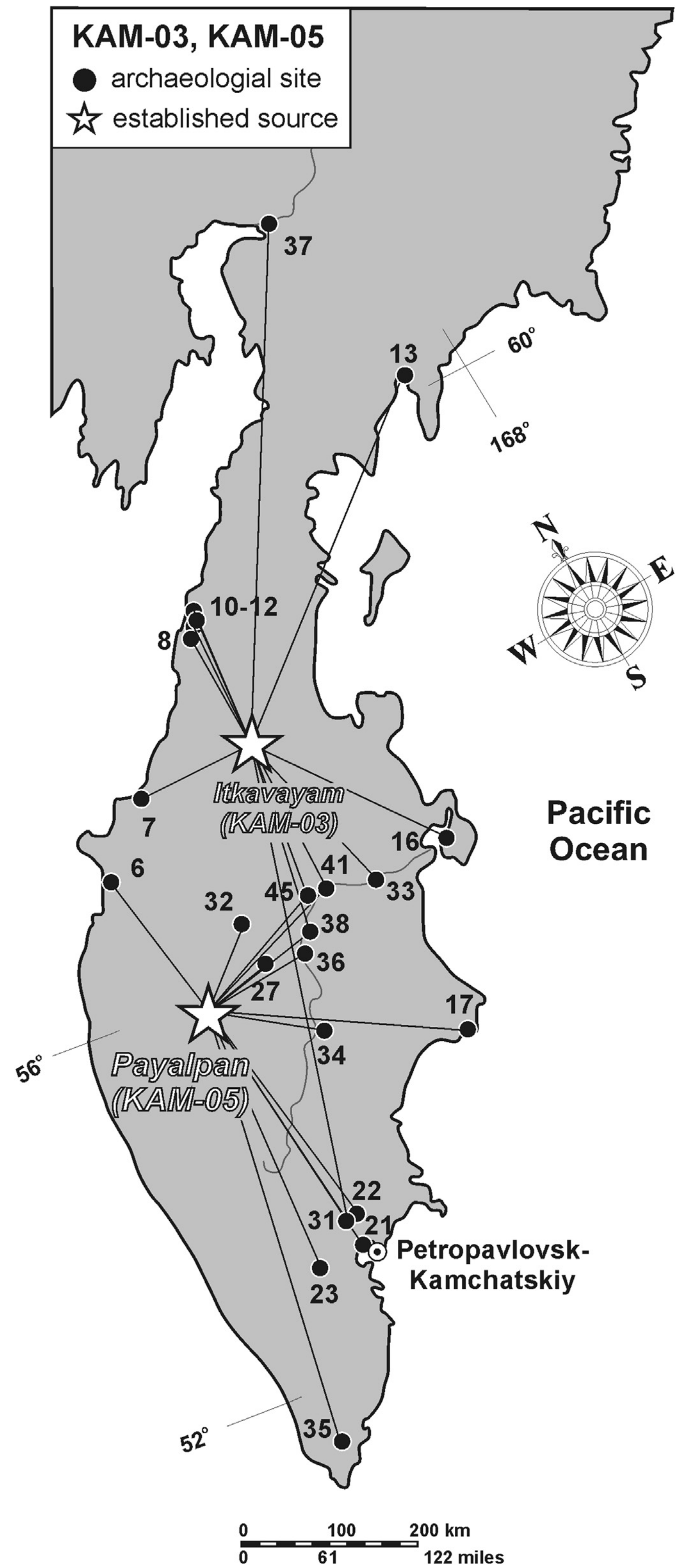

Fig. 2. Distribution of obsidian from two primary sources, KAM-03 (Itkavayam) and KAM-05 (Payalpan), in archaeological sites on Kamchatka. In Figs. 2–9, site numbers correspond to those in Grebennikov et al. (2010).

At this stage, we have data for seven groups with clearly different geochemical signatures (KAM-01, 02, 04, 08, 10, 14, and 15) only from archaeological sites (Fig. 1, Table 1; see also Grebennikov et al., 2014). The number of artifacts at each site belonging to these geochemical groups is indicated in Table 2. The first attempt to determine the possible locations of these unknown sources was conducted by Grebennikov et al. (2014). Today, we can move forward using the latest information about the geographic position of sites, the geochemical peculiarities of Kamchatkan volcanic rocks, and the absolute ages of some obsidian sources.

3. Localization of unknown sources for archaeological obsidian on Kamchatka: current progress

3.1. KAM-01 group

This is one of the most numerous obsidian geochemical groups (Tables 1–2). Artifacts of the KAM-01 group are widely distributed on Kamchatka, with the largest concentration of sites in the southern part of the region (Fig. 3). The KAM-01 group has a Nb/Zr ratio of around 0.04, which is typical for volcanic rocks of the Eastern Kamchatkan Volcanic Belt. According to tectonic zoning, the primary source of this obsidian is most likely situated in the Eastern Range. The age determination of the KAM-01 obsidian gave a value of ca. 1.94 Ma (Grebennikov et al., 2014). This is similar to the time of powerful eruptions in the southernmost part of the Eastern Range (Bindeman et al., 2010).

The most probable candidate for this source is the Karymshina Caldera (Leonov and Rogozin, 2010; see Fig. 3). If so, the maximal distance from this suggested source to the utilization site is ca. 720 km (Fig. 3), and this is within the range of long-distance exchange of obsidian in Northeast Asia (e.g., Kuzmin, 2013). Future field surveys will hopefully identify this source.

3.2. KAM-02 group

This group is also widely distributed in the southern and central parts of Kamchatka (Fig. 4, Tables 1–2). The geochemical data are not as clear as with KAM-01, but we have correlated the composition of the KAM-02 group with existing obsidian sources in both southern Kamchatka and the Eastern Range (Grebennikov et al., 2014: 103–104; see Fig. 1). At this stage of research, we suggest that the Bakening Volcano at the junction of the Central Range and Eastern Range, with its late Pliocene – early Pleistocene subalkali rocks (see Dorendorf et al., 2000), could be the possible primary source for the KAM-02 group.

The Bakening Volcano is situated in the headwaters of the Srednaya Avacha River. Several archaeological sites with obsidian of the KAM-02 group are located at the mouth of the Avacha River which originates at the confluence of the Srednaya Avacha and Levaya Avacha rivers (Fig. 4). In this area, obsidian nodules were recorded in rocks constituting monogenic rhyodacite volcanic domes (Dorendorf et al., 2000). Future fieldwork will target this specific location.

3.3. KAM-04 group

Archaeological sites with obsidian artifacts belonging to this group are located mainly in southern Kamchatka (Fig. 5, Table 1). The geochemical data and tectonic zoning indicate that the primary source is situated somewhere in the Eastern Range (Fig. 1). The most likely candidate for the primary locality is the Uzon Caldera. Here, south of Lake Kronotskoye (geographic coordinates are 54°28′ N, 160°04′ E), at the elevation of 1000 m in the area of white pumices, glassy andesites, and dacites, an outcrop of volcanic

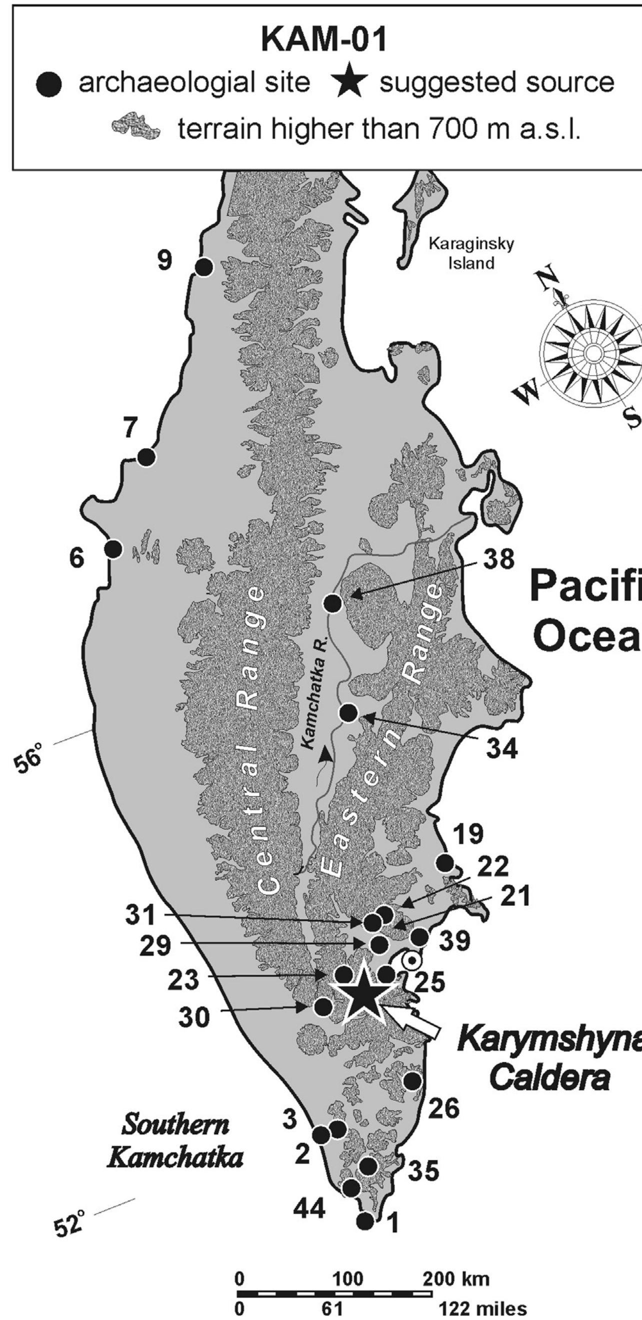

Fig. 3. Distribution of archaeological sites of the KAM-01 group, and its possible primary source.

glasses with features typical for the KAM-02 group is known (Otchet, 1992). The obsidian is of black color, practically not translucent in thin section. Fieldwork in this region is therefore necessary to obtain samples of obsidian.

3.4. KAM-08 group

This group was detected at three sites in northern Kamchatka (Fig. 6, Table 1). According to the geochemical data, absolute age, and tectonic zoning (Grebennikov et al., 2014), the KAM-08 group belongs to the Central Range (Fig. 1). It is most likely that the primary source is located somewhere in the northern part of this region (Fig. 6). The Itkavayam cluster could be one of candidates

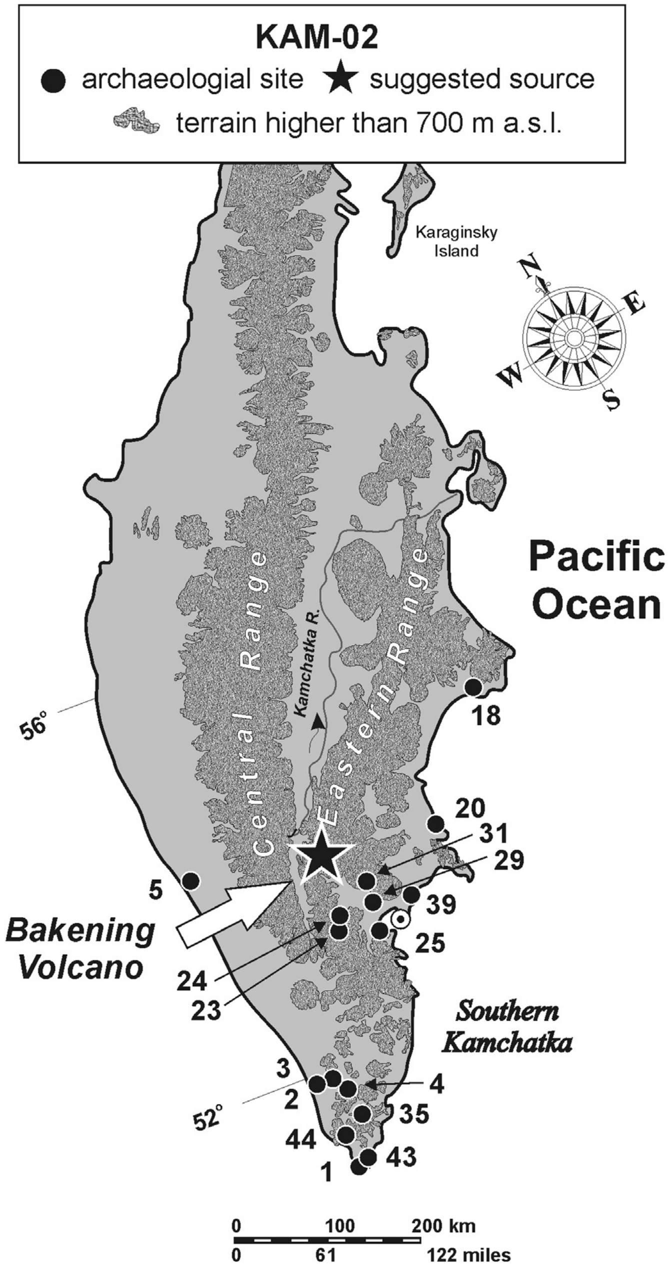

Fig. 4. Distribution of archaeological sites of the KAM-02 group, and its possible primary source.

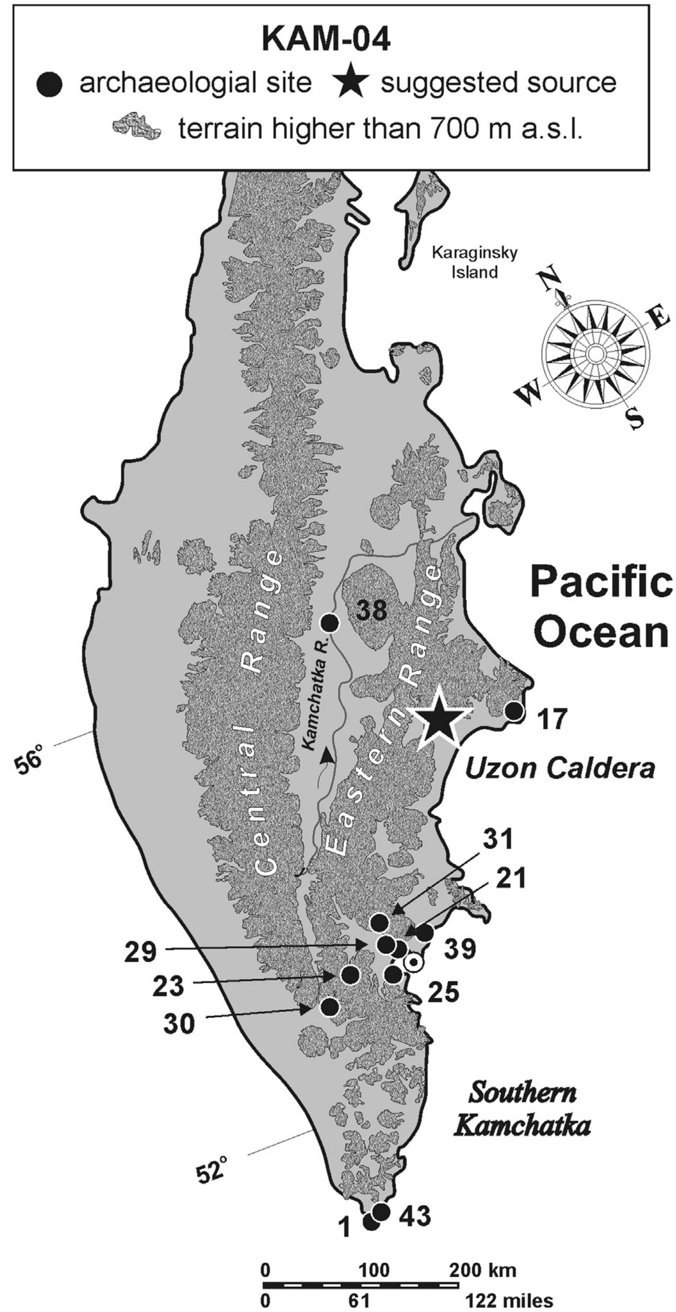

Fig. 5. Distribution of archaeological sites of the KAM-04 group, and its possible primary source.

because there are at least two sources of obsidian, Itkavayam (southern) and Itkavayam (northern), for which we have reference samples (Grebennikov et al., 2010). Obsidian from the Itkavayam cluster reached the northernmost part of Kamchatka at the Penzhina site (Fig. 2, No. 37; see Grebennikov et al., 2010).

Another possibility is that the primary locale is situated further north, at the watershed between the Sea of Okhotsk and the Pacific Ocean, on the Kamchatka Isthmus (Fig. 6), where several obsidian sources are known from inventory (Otchet, 1992; see also Grebennikov et al., 2010). There are two potential clusters of obsidian sources in this region. One is situated in the headwaters of the Palana River (Fig. 6, No. 1) where several localities with high quality volcanic glass are known. They are associated with rocks of the Alnei Series (late Miocene) (see Grebennikov et al., 2014: 97). The second cluster is located in the basins of the Belaya and Kichiga rivers (Fig. 6, No. 2). Here, several obsidian sources also belong to the Alnei Series.

It should be kept in mind that the Kamchatka Isthmus is an extremely remote area (accessible only by helicopter), and great effort is needed to access these sources.

3.5. KAM-10 group

Sites with obsidian belonging to this group are located in the central part of Kamchatka (Fig. 7, Table 1). The geochemical data and tectonic zoning indicate the position of KAM-10 group in the Eastern Range, close to the Karymsky Volcanic Center (Fig. 1). This region contains several obsidian-bearing localities, and it seems

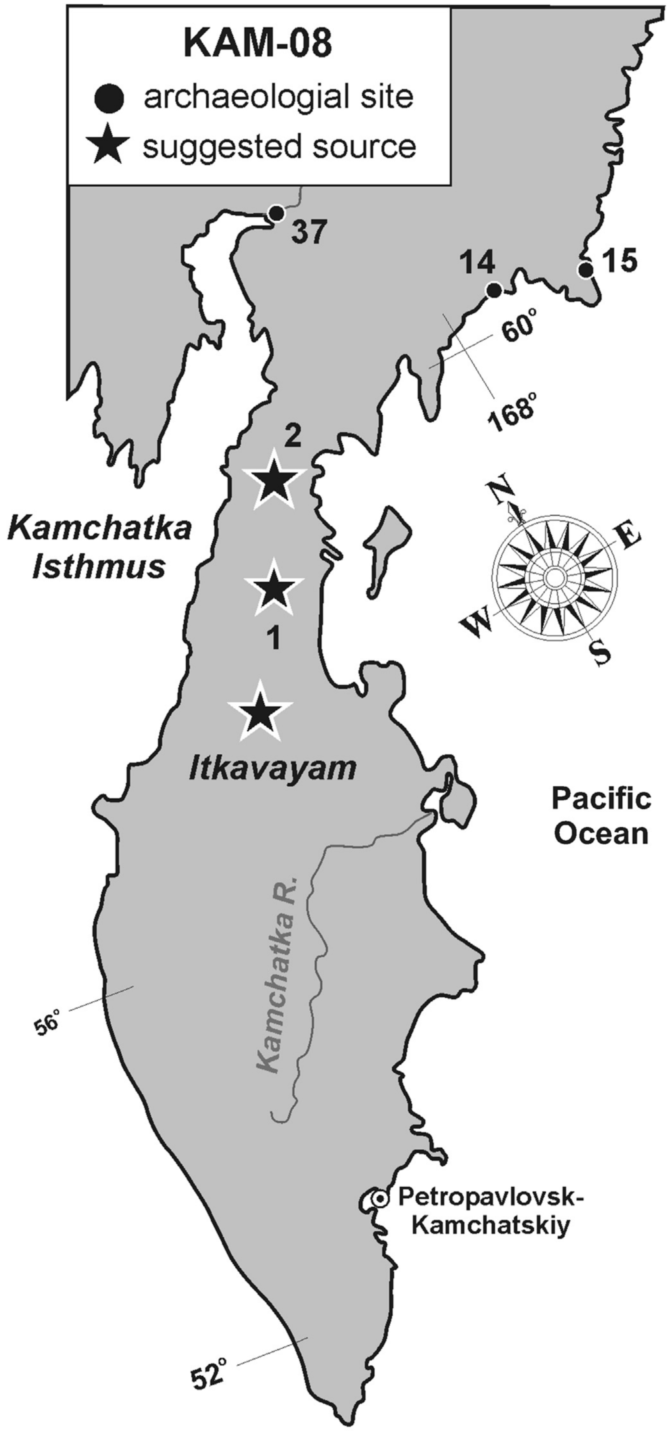

Fig. 6. Distribution of archaeological sites of the KAM-08 group, and its possible primary source. No. 1 – obsidian localities of the Palana River headwaters; No. 2 – obsidian sources in the basins of the Belaya and Kichiga rivers.

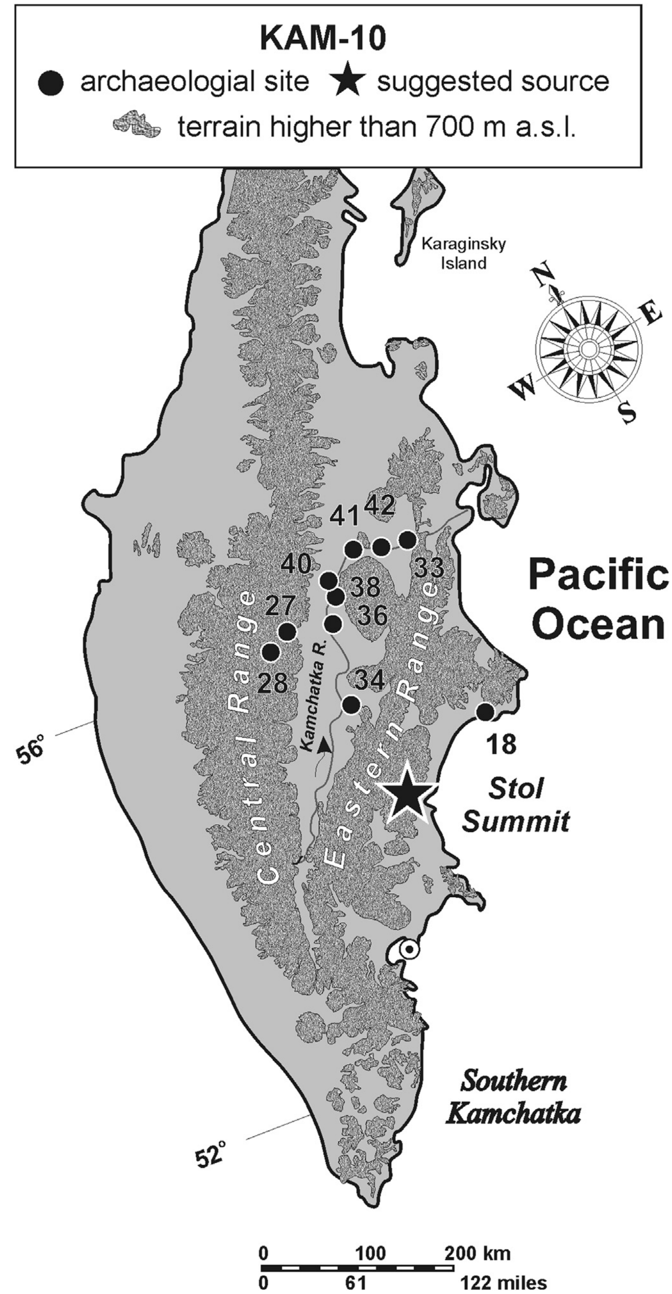

Fig. 7. Distribution of archaeological sites of the KAM-10 group, and its possible primary source.

logical to assume that the primary source is situated within the Karymsky Volcanic Center (Fig. 7). The age of the KAM-10 obsidian, ca. 3.27 Ma (Grebennikov et al., 2014), testifies that the primary source is dated to the late Pliocene. These data allow us to suggest a possible connection between the source and the Pliocene ignimbrite volcanism of the Karymsky Volcanic Center. For example, the ignimbrite strata of the Stol Summit situated at the watershed of the Levaya Zhupanova and Pravaya Zhupanova rivers contain welded tuffs and obsidian fragments dated to ca. 3.71 Ma (Bindeman et al., 2010). More data are therefore needed to confirm a potential connection, with fieldwork in this area.

3.6. KAM-14 group

This is the smallest of the unknown groups, with only two archaeological samples from central Kamchatka: the Ushki cluster and Lake Domashnee site (e.g., Kuzmin et al., 2008) (see Fig. 8, Tables 1–2). Using geochemical and tectonic data, we can place its primary source in the Karymsky Volcanic Center (Fig. 1). Due to its

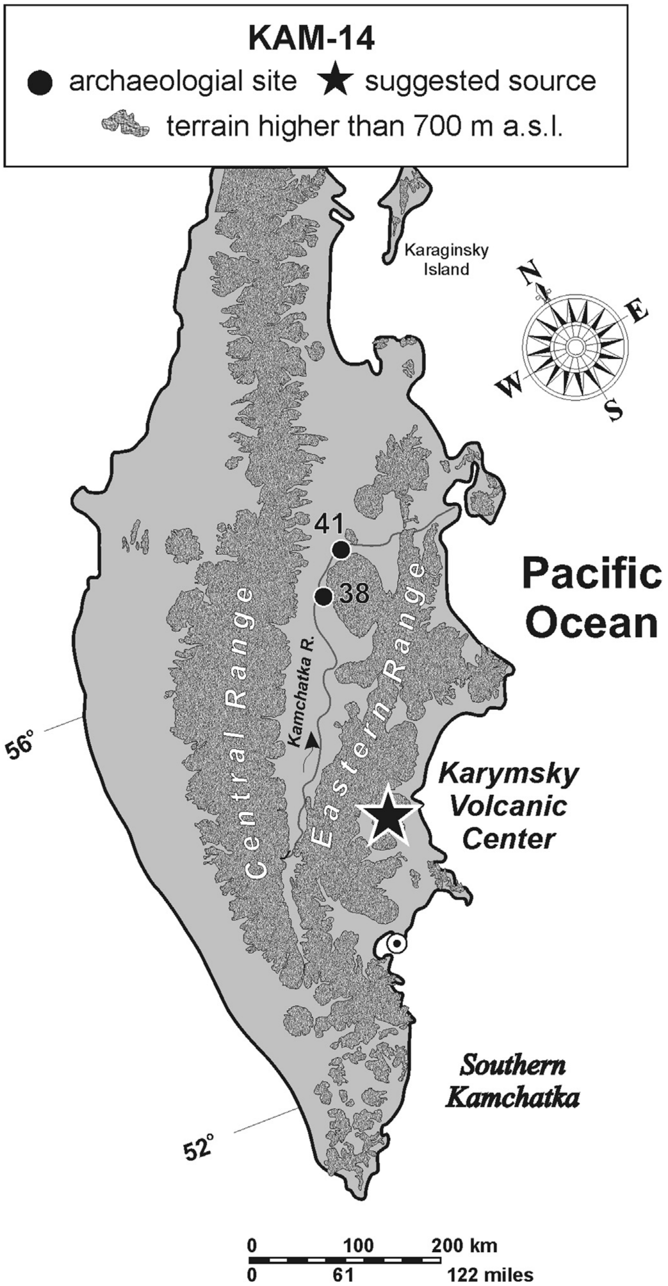

Fig. 8. Distribution of archaeological sites of the KAM-14 group, and its possible primary source.

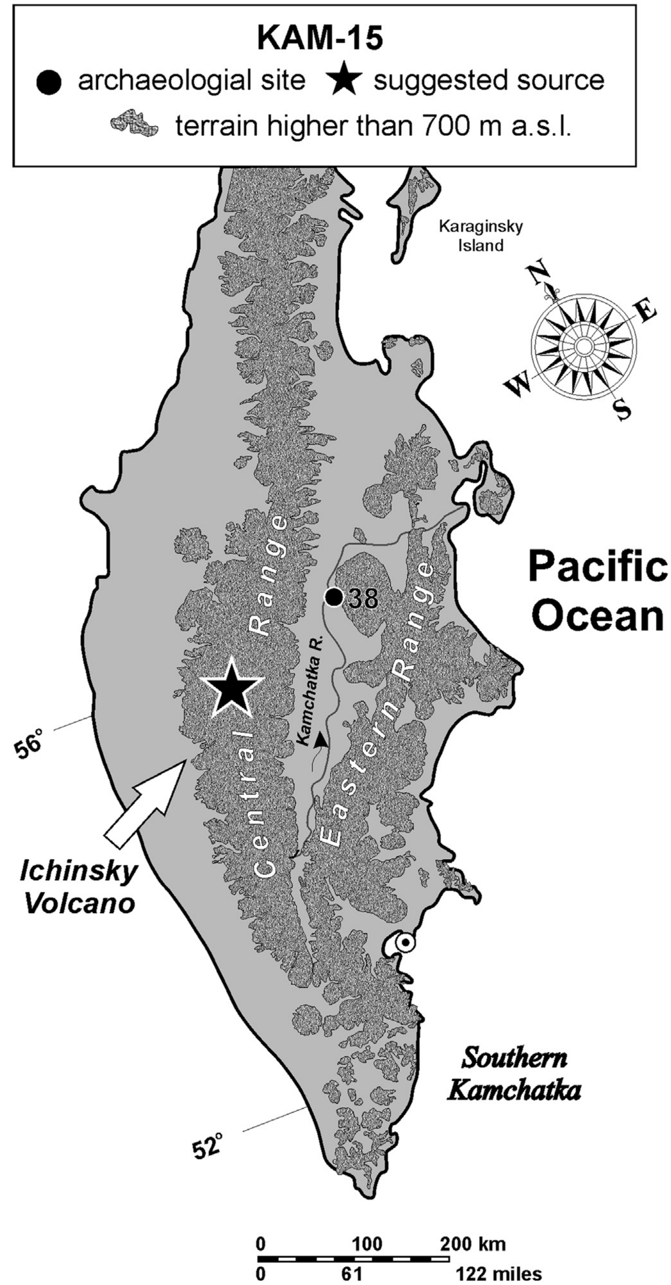

Fig. 9. Distribution of archaeological sites of the KAM-15 group, and its possible primary source.

high potential for the localization of obsidian sources in the Eastern Range, fieldwork in this part of Kamchatka is an urgent need.

3.7. KAM-15 group

This is another small group, with seven samples from the Ushki site group (Fig. 9, Table 1). According to the geochemical composition and general tectonic setting of Kamchatka, the KAM-15 group can be associated with the Central Range (Fig. 1). Based on the close similarity with the Ichinsky cluster of obsidian sources (Grebennikov et al., 2014), we can suggest that the primary locality for the KAM-15 obsidian is situated in this area (Fig. 9). As a matter of fact, in the Ichinsky region there are at least 11 sources of high quality volcanic glass, suitable for making stone tools (Grebennikov et al., 2014: 100). So far, we have been able to obtain specimens from three of them, and there is a high probability that the source of the KAM-15 group is among the non-sampled locales. The Ichinsky cluster is the place with the highest priority for future fieldwork.

3.8. Obsidian in the Ushki cluster: intensive use of multiple sources

In light of the search for the geologic locations of unknown obsidian groups on Kamchatka, it is reasonable to look at the most important archaeological feature in this region, the Ushki site cluster. It was extensively excavated in the 1960s – early 1990s (see Dikov, 1996, 2003), and in the 2000s (Goebel et al., 2003;

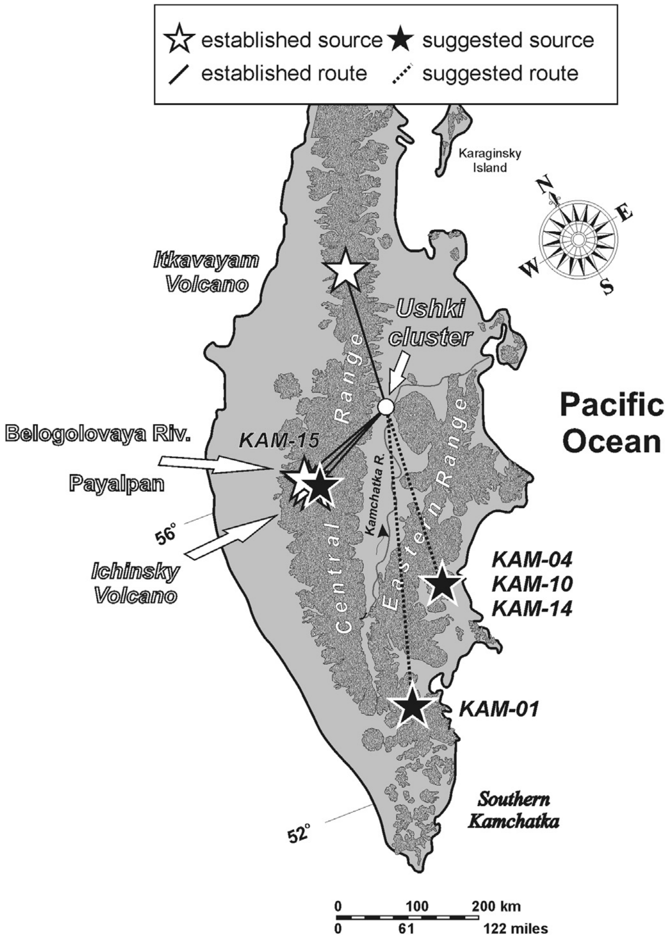

Fig. 10. Established and suggested obsidian sources for the Ushki cluster (after Kuzmin et al., 2008; modified).

Ponkratova, 2007), and obsidian artifacts were analyzed by our team (Kuzmin et al., 2008).

The geochemical composition of 62 artifacts shows that they belong to eight groups (Fig. 10). Three of them can be securely identified as originating from Itkavayam, the Vtoraya Belogolovaya River, and the Payalpan sources in the Ichinsky Volcano area, and there are five unknown sources (KAM-01, 04, 10, 14, and 15). Distances to known sources (as the crow flies) are 130–250 km. If we provisionally accept the localization of unknown sources (see above), they are 240–390 km away from the archaeological sites (Fig. 10). It is also important that these eight sources of archaeological obsidian are situated very far apart, with distances between them around 330–660 km. This is a remarkable phenomenon in the utilization of high quality raw material in the Paleolithic and Neolithic of Northeast Asia. Most probably, since ca. 14,000 BP several large-scale exchange networks existed on Kamchatka, and this is not unique for this region.

4. Conclusions

Upon analysis of all currently available information about the unknown primary sources of archaeological obsidian on Kamchatka, we conclude that they are most probably situated in the Central Range (Bakening Volcano; Ichinsky Volcano; and Kamchatka Isthmus), the Eastern Range (Uzon Caldera and Karymsky Volcanic Center), and Southern Kamchatka (Karymshima Caldera). Fieldwork is needed in these regions in order to verify the source locations. Unfortunately, logistical difficulties have to some extent hampered our previous efforts, and it is clear today that an international expedition to Kamchatka should be organized as soon as possible. In this case, international cooperation with scholars from Japan, Korea, and the USA is very important.

Summarizing the information presented in this paper, we can say that several sources of high quality volcanic glass on Kamchatka, which were intensively used by prehistoric people, have not yet been located. The continuation of archaeological surveys on Kamchatka in recent years (see Hulse et al., 2011; Pendea et al., 2015) has demonstrated the high potential of obsidian source studies for understanding the human–environment interaction. For example, at four prehistoric sites in the Kamchatka River mouth area, dated to ca. 1100–5300 BP, around 300 obsidian artifacts were recovered (Pendea et al., 2015).

It is now clear that the analysis of geological, geochemical, and chronological data, as employed by our team on Kamchatka, is crucial for understanding the position of obsidian-bearing locales, and for subsequent planning of fieldwork campaigns.

Table 1
Geochemical groups for unknown sources of archaeological obsidian on Kamchatka.

Source group	Number of sites	Number of artifacts	Suggested primary locality
KAM-01	20	113	Karymshyna Caldera
KAM-02	16	45	Bakening Volcano
KAM-04	11	28	Uzon Caldera
KAM-08	3	14	Northern part of Central Range
KAM-10	9	49	Stol Summit[b]
KAM-14	2	2	Karymsky Volcanic Center
KAM-15	1	9	Ichinsky Volcano
Total	37[a]	260	

[a] At 20 sites, obsidian from two or more unknown sources was identified.
[b] In the vicinity of Karymsky Volcanic Center.

Table 2
Amount of artifacts for each unknown group from archaeological sites on Kamchatka (see Table 1).

Site No.	Site/cluster name	Archaeological age	No. of samples and % of each assemblage	Site No.	Site/cluster name	Archaeological age	No. of samples and % of each assemblage
KAM-01				**KAM-02**			
1	Lopatka Cape	Neolithic	1–0.88%	***1***	Lopatka Cape	Neolithic	1–2.22%
2	Ozernovsky 1-4	Neolithic	8–7.08%	***2***	Ozernovsky 1-4	Neolithic	9–20.3%
3	Ozernaya River 1-2	Neolithic	7–6.19%	***3***	Ozernaya River 1-2	Neolithic	2–4.44%
6	Ust-Kovran	Neolithic	4–3.54%	***4***	Kurilskoe Lake	Neolithic	2–4.44%
7	Kulki	Neolithic	1–0.88%	***5***	Kekhta River	Neolithic	1–2.22%
9	Anadyrka 1	Paleometal	1–0.88%	***18***	Lisy Stream	Paleometal	1–2.22%
19	Zhupanovo	Paleometal	1–0.88%	***20***	Kopyto-1	Paleometal	1–2.22%
21	Avacha, Avach River	Neolithic	17–15.06%	***23***	Plotnikova River	Neolithic	12–26.69%
22	Avacha (AN), SKA	Neolithic	7–6.19%	***24***	Sokoch Lake	Neolithic	3–6.66%
23	Plotnikova River	Neolithic	1–0.88%	***25***	Viluchinsk 2	Paleometal	2–4.44%
25	Viluchinsk, Sarannya Bay	Paleometal	23–20.37%	***29***	Bolshoi Kamen	Paleometal	1–2.22%
26	Veselaya River	Neolithic	10–8.85%	***31***	Elisovo 1, Nikolaevka	Paleometal	3–6.66%
29	Bolshoi Kamen	Paleometal	2–1.77%	***35***	Siyushk	Paleometal	1–2.22%
30	Karimshina River	Paleometal	1–0.88%	***39***	Kirpichnoe	Neolithic	1–2.22%
31	Elisovo, Nikolaevka	Paleometal	18–15.95%	***43***	Lopatka	Neolithic	3–6.66%
34	Nikolka	Neolithic	2–1.77%	***44***	Yavino 2	Paleometal	2–4.44%
35	Siyushk	Paleometal	2–1.77%	**KAM-08**			
38	Ushki 1,2,5	Paleolithic – Neolithic	1–0.88%	***14***	Pakhachi	Neolithic	9–64.28%
39	Kirpichnoe	Neolithic	5–4.42%	***15***	Vaimitangin	Paleometal	3–21.43%
44	Yavino 2	Paleometal	2–0.88%	***37***	Penzhina	Paleometal	2–14.29%
KAM-04				**KAM-10**			
1	Lopatka Cape	Neolithic	1–3.57%	***18***	Lisy Stream	Paleometal	1–2.04%
17	Kozlova Cape	Paleometal	1–3.57%	***27***	Anavgai	Paleolithic – Neolithic	4–8.16%
21	Avacha, Avach River	Neolithic	6–21.44%	***28***	Esso	Neolithic	9–18.40%
23	Plotnikova River	Neolithic	1–3.57%	***33***	Kluchi	Neolithic	1–2.04%
25	Viluchinsk	Paleometal	3–10.71%	***34***	Nikolka	Neolithic	2–4.08%
29	Bolshoi Kamen	Paleometal	1–3.57%	***36***	Kozyrevsk	Neolithic	4–8.16%
30	Karimshina River	Paleometal	1–3.57%	***38***	Ushki 1, 2, 5	Paleolithic – Neolithic	25–51.00%
31	Elisovo	Paleometal	10–35.72%	***40***	Zastoichki	Neolithic	1–2.04%
38	Ushki 2	Paleolithic – Neolithic	1–3.57%	***42***	Kamaki	Neolithic	2–4.08%
39	Kirpichnoe	Neolithic	2–7.14%	**KAM-14**			
43	Lopatka	Neolithic	1–3.57%	***38***	Ushki 5	Paleolithic – Neolithic	1–50%
KAM-15				***41***	Domachnee Lake	Neolithic	1–50%
38	Ushki 1, 5	Paleolithic – Neolithic	9–100%				

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