Chapter 6
Obsidian Provenance Studies on Kamchatka Peninsula (Far Eastern Russia): 2003–9 Results

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Abstract: *The results of obsidian provenance research on the Kamchatka Peninsula based on extensive study of the chemical composition of volcanic glasses from both 'geological' sources and archaeological sites are presented. At least 16 geochemical groups reflecting different sources of obsidian have been identified for Kamchatka using Instrumental Neutron Activation Analysis. Seven sources of archaeological obsidian have been linked to specific geologic outcrops, with the distances between sites and obsidian sources up to 550km. At least seven geochemical groups based only on artefact analysis are also described. The use of multiple obsidian sources was a common pattern during the Palaeolithic, Neolithic, and Palaeometal periods of Kamchatkan prehistory.*

Keywords: *Obsidian, Source Identification, Palaeolithic, Neolithic, Kamchatka Peninsula, Russian Far East*

Introduction

Studies of the geochemistry of waterless volcanic glasses (i.e., obsidians) and sources of archaeological obsidian in the Russian Far East have been ongoing since the early 1990s, and the results were recently summarised (Kuzmin 2006; see also Kuzmin, this volume). Until the early 2000s, most areas under investigation were located in the southern part of the region, namely the Primorye (Maritime) Province, the Amur River basin, and Sakhalin Island. In the northern part of the Russian Far East, the Kamchatka Peninsula remains one of the most promising areas for obsidian provenance studies due to the abundance of volcanic glass sources and the extensive use of obsidian by prehistoric people. However, it was not until 2003 that systematic studies of obsidian geochemistry were initiated (Glascock *et al.* 2006a, 2006b; Kuzmin *et al.* 2006; Popov *et al.* 2005a; Speakman *et al.* 2005).

Summarised here are the results from the research undertaken on the geochemistry of obsidian from the Kamchatka Peninsula since 2003. Compared to earlier investigations (Glascock *et al.* 2006b; Speakman *et al.* 2005), data presented in this study are more comprehensive as a consequence of a larger dataset. Data described in this chapter contribute to a more detailed study of Kamchatkan prehistory, an area important in terms of its relationship with the peopling of the New World at the end of Pleistocene and in the Holocene, especially with regard to Alaska and the Aleutian Islands.

General Patterns of Geology and Archaeology of Kamchatka

The Kamchatka Peninsula, situated in the Northwestern Pacific, stretches approximately 1200km in a SSW–NNE direction with a maximum width of about 400km. The territory of Kamchatka covers about 370,000km^2 and is flanked by the Bering Sea in the east, the Sea of Okhotsk in the west, and the open Pacific Ocean in the south (Figure 6.1, A). The main geomorphic features of the Kamchatka Peninsula are two major mountain ranges, Central and Eastern, with a sedimentary basin between them occupied by the Kamchatka River drainage; mountains of the southern region; and lowlands on the western coast (Suslov 1961, 380–384; Ivanov 2002, 431–433) (Figure 6.1, A). The highest peak in the Central Range [*Sredinny Khrebet*, see The Times Atlas 1989] is Ichinsky Volcano [*Ichinskaya Sopka*] (3607m above sea level; hereafter – a.s.l.); and in the Eastern Range the highest point is the volcanic cone of Klyuchevskaya Sopka (4688m a.s.l.). It should be noted that the summits' heights and size of Kamchatka are to some extent different in Russian and US sources; for the purposes of this paper Russian dictionaries and atlases (Gorkin 1998; Sveshnikov and Krayukhin 2004; Topchiyan 1998) were used.

The Central Range includes a chain of extinct volcanoes located between 53° and 60° N. Among the highest summits are Khangar (2000m a.s.l.), Alnei (2598m a.s.l.), Shishel (2525m a.s.l.), Ostraya (2552m a.s.l.), Khuvkhoitun (2613m a.s.l.), Tylele (2234m a.s.l.), and Budakhanda (1707m a.s.l.). The Eastern Range consists of several ridges, Ganalsky, Valaginsky, Tumrok, Kumroch, and Gamchen; it also has separate high volcanic cones such as Avachinskaya Sopka (2741m a.s.l.), Koryakskaya Sopka (3456m a.s.l.), Zhupanovskaya Sopka (2923m a.s.l.), Krasheninnikov Volcano (1856m a.s.l.), Kronotskaya Sopka (3521m a.s.l.), Tolbachikskaya Sopka (3672m a.s.l.), and Shiveluch Volcano (3307m a.s.l.). The southern part of Kamchatka (south of 53° N) is represented by high plateaus and short ridges like Balaganchik, with volcanic cones situated between them. The highest summits are Mutnovskaya Sopka (2322m a.s.l.), Khodutka Volcano (2089m a.s.l.), Opala Volcano (2460m a.s.l.), Zheltovskaya Sopka (1957m a.s.l.), and Kambalnaya Sopka (2161m a.s.l.).

Tectonically, Kamchatka is located on the boundary between the Pacific and Eurasian plates (e.g., Khain 1994) which is one of the most active volcanic arcs in the world.

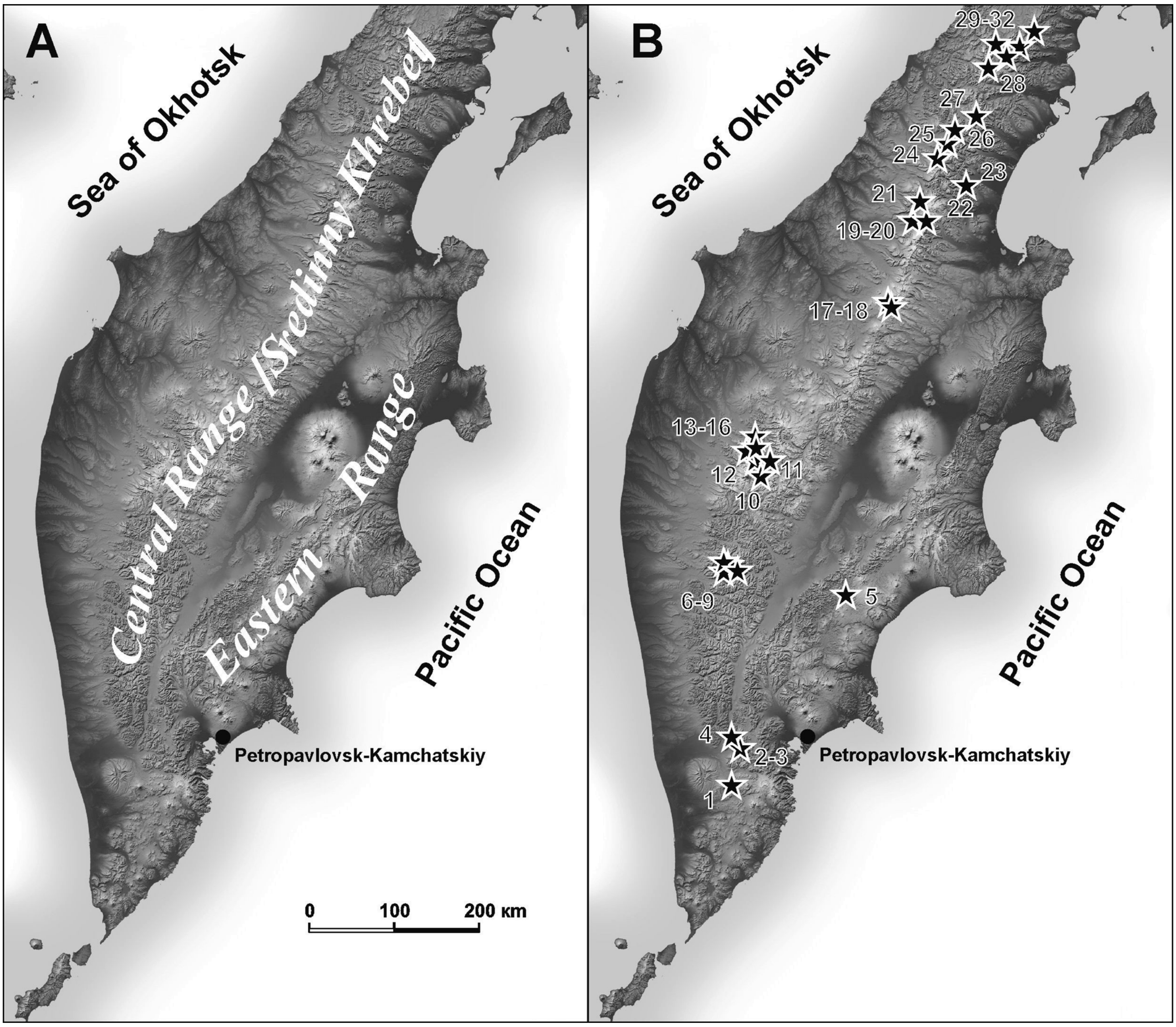

Figure 6.1. Major geomorphic features and obsidian sources at Kamchatka. A: Major mountain ranges. B: Main obsidian sources indicated by star signs (after Otchet 1992, modified). Sources: 1 – Tolmachev Dol (Chasha Maar); 2 – Nachiki Stream; 3 – Taburetka River; 4 – Nachiki (Shapochka Summit); 5 – Karimsky Volcano; 6 – Khangar Volcano (Southern); 7 – Khangar Volcano (Central); 8 – Khangar Volcano (Eastern); 9 – Khangar Volcano (Northern); 10 – Gigigilen; 11 – Payalpan; 12 – Maly Payalpan; 13 – Nosichan; 14 – Polyarnaya Summit; 15 – Tynya Summit; 16 – Belogolovaya Vtoraya River; 17 – Kunkhilok; 18 – Sedanka; 19 – Itkavayam (Southern); 20 – Itkavayam (Northern); 21 – Kevenei (Northern); 22 – Kevenei (Western); 23 – Levye Nachiki; 24 – Levoe Khailuli Plateau; 25 – Maryavaam; 26 – Palana (southern) and Korkavayam; 27 – Palana 1; 28 – Posledny Stream; 29 – Vanyavaam; 30 – Kichiga River, right side; 31 – Belaya River Headwaters; 32 – Kichiga River, left side

As a result, 28 active volcanoes are known on Kamchatka (Fedotov and Masurenkov 1991). Most of the Kamchatkan terrain consists of Cenozoic volcanic rocks, with some sedimentary and volcanic-sedimentary formations (Khain 1994). General petrological information about the volcanic rocks of Kamchatka is available from multiple sources (e.g., Leonov and Grib 2004; Popolitov and Volynets 1982; Volynets *et al.* 1990). Geochemical studies of acidic volcanic rocks on Kamchatka, related to investigations of the genesis of the island arc's acidic magmas, have been performed (Pampura *et al.* 1979; Popolitov and Volynets 1981). Volcanic glasses (obsidians and perlites) are widely distributed on Kamchatka, and they correspond to dacitic–rhyolitic volcanic complexes of the Neogene–Pleistocene age (Shevchuk 1981).

Today, about 30 sources of high and medium quality obsidian are known on Kamchatka (Otchet 1992; Rozenktrants 1981; Shevchuk 1981) (Figure 6.1, B). In the Central Kamchatkan volcanic belt, corresponding to the Central Range, obsidian-parent volcanic formations are dated to the Oligocene–Neogene. In the Eastern Kamchatkan volcanic belt (Eastern Range), obsidian is known mainly among the Pleistocene rocks (Khain 1994). In southern Kamchatka, obsidian-bearing rocks are dated to the Pliocene–Pleistocene. Volcanic glasses on Kamchatka occur in extrusive domes, lava and pyroclastic flows, and are also found in pyroclastic rocks (tephras and pumice tuffa) in the form of fragments. According to their chemical composition, the volcanic glasses correspond to dacites and rhyolites.

The largest number of obsidian sources on Kamchatka is found in the Central Range (Figure 6.1, B). Sources tend to be located at the higher elevations and occur as open-air scatters of colluvial origin on the mountain plateaus covered with tundra. Obsidian is present in blocks and big chunks. In the central part of the Eastern Range, several volcanic glass localities are found; and they are correlated with the Pleistocene phase of the acidic ignimbrite volcanism. South of the city of Petropavlovsk-Kamchatskiy, several volcanic glass sources of the Pliocene–Pleistocene age and rhyolitic composition were discovered.

The first natural science explorers on Kamchatka recorded obsidian sources in the mid-eighteenth century AD (e.g., Krasheninnikov 1972). To modern archaeologists, obsidian as a raw material was known in the prehistoric complexes of Kamchatka since at least the beginning of the twentieth century (e.g., Jochelson 1928), and its significance became more evident in the early 1960s when excavations of the Ushki site cluster began along with reconnaissance of the whole peninsula (Dikov 1965, 1968). Continued studies of the Kamchatkan archaeology (e.g., Dikova 1983; Ponomarenko 1985, 2000; Ptashinsky 2002) confirm the abundance of obsidian in the prehistoric assemblages. Since the early 1900s, obsidian artefacts have been discovered at more than 800 archaeological sites throughout Kamchatka. It was found that obsidian is prevalent in assemblages from the central and southern parts of Kamchatka in up to 96% of the total amount of raw material used (Glascock *et al.* 2006b). In northern Kamchatka, the use of obsidian for tool manufacture in prehistory was less common.

On the Kamchatka Peninsula, three main prehistoric stages, Palaeolithic, Neolithic, and Palaeometal (or Early Iron Age in some sources), have been established (e.g., Dikov 2003, 2004; Ponomarenko 2005). The Upper Palaeolithic is best represented by the two lowermost layers, 6 and 7, of the Ushki site cluster in the Kamchatka River Valley (Dikov 1996). The age of layer 7 of the Ushki, based on radiocarbon (hereafter – ^{14}C) dates is estimated as ca. 14,300–10,400 BP (Dikov 1996), or perhaps as ca. 11,300–10,000 BP according to the latest research (Goebel *et al.* 2003); and the age of layer 6 is ca. 11,100–10,000 BP. The newly discovered site Anavgai 2 with microblades is dated to ca. 10,900 BP (Ptashinsky 2009). The Neolithic period emerged on Kamchatka during the Middle Holocene, ca. 6000–5000 BP, and continued until ca. 1500 BP (Kuzmin 2000). A particular feature of Kamchatkan Neolithic is the very rare occurrence of pottery (e.g., Dikov 2003; Kuzmin 2000; Ponomarenko 2005). There are up to 100–150 Neolithic sites known on Kamchatka according to surveys (Ponomarenko 2005; Ptashinsky 2003), but only about ten of them are well-excavated and ^{14}C-dated. The Palaeometal stage (ca. 1500–300 BP) succeeds the Neolithic, although wide use of stone raw materials continued to exist until the contact with colonising Russian Cossacks during the late seventeenth – early eighteenth centuries AD. The number of sites attributed to the Palaeometal is in the several hundreds (Dikov 2003; Ponomarenko 1985, 1991, 1993, 1997, 2000; Ptashinsky 1989, 1999, 2002).

Materials and Methods

To achieve the primary aim of this study, 444 obsidian artefacts were collected from 45 archaeological sites and site clusters on Kamchatka (Table 6.1). The sites range in age from the late Upper Palaeolithic to the Palaeometal. Sixty-three samples of high quality volcanic glass also were obtained from 'geological' outcrops located throughout the Kamchatka Peninsula.

Geochemical studies of volcanic glasses were conducted using Instrumental Neutron Activation Analysis (hereafter – INAA; e.g., Glascock *et al.* 1998, 2007). INAA remains one of the most advanced methods to study the chemical composition of volcanic glasses, with sensitivity limits for most elements in the parts-per-million (ppm). The advantage of INAA is that one can use small samples (starting from a few milligrams) to measure more than 25 chemical elements, including the rare earth ones, to reveal a unique "geochemical fingerprint" for individual volcanic glass sources. For this study, INAA was performed at the University of Missouri Research Reactor (MURR).

A total of 507 obsidian samples from Kamchatka were submitted to MURR. Two analytical procedures were employed to measure the elemental concentrations. All of the samples first underwent a procedure that used a short irradiation and short decay to measure seven short-lived elements (Al, Ba, Cl, Dy, K, Mn, and Na). Based on these results, the preliminary geochemical groups were established. After that, a total of 162 samples were selected for the second procedure (i.e., a long irradiation). Samples selected for the long irradiation included those assigned to geochemical groups with small number of samples and also individual samples that failed to match any established geochemical group. The long irradiation procedure allows measurement of 22 medium and long-lived elements (Ba, La, Lu, Nd, Sm, U, Yb, Ce, Co, Cs, Eu, Fe, Hf, Rb, Sb, Sc, Sr, Ta, Tb, Th, Zn, and Zr). Statistical groupings, based on examination of bivariative and three-dimension plots, and cluster and discriminant classification analyses, were achieved with the help of GAUSS software (available from MURR) to indicate within a 95% degree of probability the major geochemical groups reflecting the sources of obsidian (Glascock *et al.* 1998).

Results and Discussion

Geochemistry of Kamchatkan Volcanic Glass: The 2009 State-of-the-Art

According to the chemical compositions determined in this study, the acidic volcanic glasses on Kamchatka belong to metaluminous and peraluminous rhyodacites and rhyolites of calc-alcali and subalcali types, and have a variable K/Na ratio. The SiO_2 content in volcanic glasses is from 72.65% to 75.84% weight. Volcanic glasses differ by content according to the amount of large-ion lithophilic elements (Rb, Ba, and Sr), high field strength elements (Y, Ta, Zr, Hf, Nb, and Th), and rare-earth elements, and also the K/Na, Rb/Sr, La/Yb, and Nb/Zr ratios. On the Hf–Rb–Ta diagram

Table 6.1. Archaeological sites and site clusters of the Kamchatka studied for the obsidian sources in 2003-7

Site No.	*Site/Cluster Name*	*Type of Site*	*Archaeological Age*
1	Lopatka Cape	Surface	Neolithic
2	Ozernovsky 1–4	Surface	Neolithic
3	Ozernaya River 1–2	Surface	Neolithic
4	Kurilskoe Lake	Surface	Neolithic
5	Kekhta River	Surface	Neolithic
6	Ust-Kovran	Cultural layer	Palaeometal
7	Kulki	Cultural layer	Neolithic
8	Palana-airport	Cultural layer	Neolithic
9	Anadyrka 1	Cultural layer	Palaeometal
10	Inchegitun 1	Cultural layer	Palaeometal
11	Chimei	Cultural layer	Palaeometal
12	Galgan 1	Cultural layer	Palaeometal
13	Zeleny Kholm	Cultural layer	Palaeometal
14	Pakhachi	Surface	Neolithic
15	Vaimintagin	Surface	Palaeometal
16	Nerpichye Lake	Surface	Palaeometal
17	Kozlov Cape	Surface	Palaeometal
18	Lisy	Surface	Palaeometal
19	Zhupanovo (Cape Pamyatnik)	Cultural layer	Palaeometal
20	Kopyto 1 (Zhupanovo River mouth)	Cultural layer	Palaeometal
21	Avacha; Avacha River, lower stream; Avacha River, animal farm	Cultural layer	Neolithic
22	ASK (Avacha 9); Severnye Koryaki Airport	Cultural layer	Neolithic
23	Plotnikova River (Nachiki Lake)	Surface	Neolithic
24	Lake Sokoch	Cultural layer	Neolithic
25	Viluchinsk 1–5; Sarannya Bay; Turpanka Bay	Surface	Palaeometal
26	Veselaya River (tributary of the Mutnaya R.)	Surface	Neolithic
27	Anavgai	Surface	Final Palaeolithic – Neolithic
28	Esso	Surface	Neolithic
29	Bolshoi Kamen	Cultural layer	Palaeometal
30	Karimshina River	Surface	Palaeometal
31	Elisovo 1–5; Nikolaevka	Surface	Palaeometal
32	Ilmagan	Surface	Neolithic
33	Kluchi	Cultural layer	Neolithic
34	Nikolka	Cultural layer	Neolithic
35	Siyushk	Cultural layer	Paleometal
36	Kozyrevsk	Cultural layer	Neolithic
37	Penzhina	Surface	Paleometal
38	Ushki 1, 2, 5	Cultural layer	Upper Palaeolithic – Neolithic
39	Kirpichnoe	Cultural layer	Neolithic
40	Zastoichik	Cultural layer	Neolithic
41	Lake Domashnee	Cultural layer	Neolithic
42	Kamaki	Cultural layer	Neolithic
43	Lopatka	Surface	Neolithic
44	Yavino 2	Surface	Palaeometal
45	Doyarki	Cultural layer	Neolithic

(Figure 6.2), the composition of volcanic glasses from the Central Range, Eastern Range, and the southern part of the peninsula are distinct; and the fields do not overlap.

The distribution of rare earth elements in volcanic glasses normalised by the primitive mantle provide evidence with regard to the depletion of all groups by heavy rare earth elements in relation to comparatively light elements, with a sharp decrease from La to Eu, and a steady increase from Eu to Lu. The clear Eu anomaly (in addition to obsidians from the Khangar Volcano, some of the Payalpan localities, and the Chasha Maar) is evident for volcanic glasses of Kamchatka. Based on Pierce's bivariant diagrams Nb–Y, Ta–Yb, Rb–(Y+Nb), and Rb–(Yb+Ta), these glasses belong to granitoids of volcanic arcs. The KAM-2 geochemical group of archaeological obsidian is the only exception; and

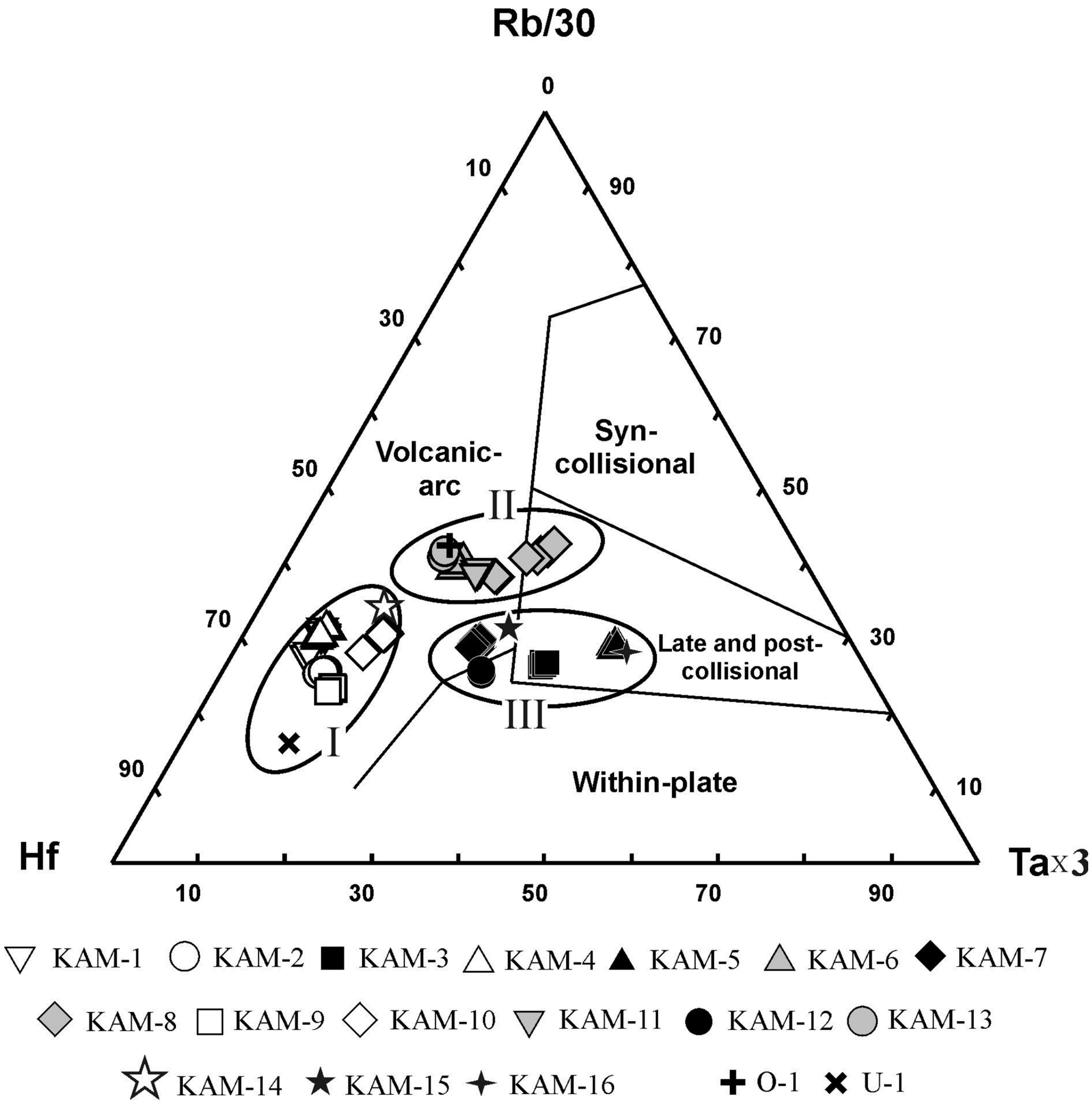

Figure 6.2. The Hf–Rb/30 – Ta×30 discrimination diagram for obsidian source samples and artefacts from Kamchatka (after Popov et al. 2007, with additions) showing the fields for volcanic arc granites, within-plate granites, syn-collisional granites, and late- and post-collisional granites. I – volcanic glasses from Eastern Kamchatka; II – volcanic glasses from Southern Kamchatka; III – volcanic glasses from Central Ridge; O–1 - obsidian from Opala Volcano; U–1 - perlite from Uzon Caldera. Site numbers correspond to those in Table 6.1. The plotting coordinates are from Harris et al. (1986)

it corresponds to an intraplate granite. For this group, the high concentrations of potassium (K), high field strength elements, rare earth elements, and low values of Nb/Zr ratio are considered typical. Volcanic glasses from the KAM-2 group correspond to the Eastern Volcanic Zone (Eastern Range). Volcanic glasses of Eastern Kamchatka (Uzon Caldera; Odnoboky Volcano in Karimsky Volcanic Centre) are characterised by minimal Nb/Zr values. The Nb/Zr ratio increases in the western part of Southern Kamchatkan Volcanic Zone (Shapochka and Opala volcanoes, Chasha Maar, and Yagodnaya Summit) and in Central Range (Payalpan group of volcanic glasses; Khangar and Obsidianovy volcanoes).

Based on the dataset, a total of 16 geochemical groups (KAM-01 through KAM-16) of obsidian were identified from the analysis of 407 specimens. An additional 37 obsidian samples were unassigned or ungrouped, and may be considered outliers and/or unknown sources. The groups and the number of samples in each are as follows:

Groups	**Number of archaeological (geological) samples**
KAM-01	113 (0)
KAM-02	46 (0)
KAM-03	34 (4)
KAM-04	28 (0)

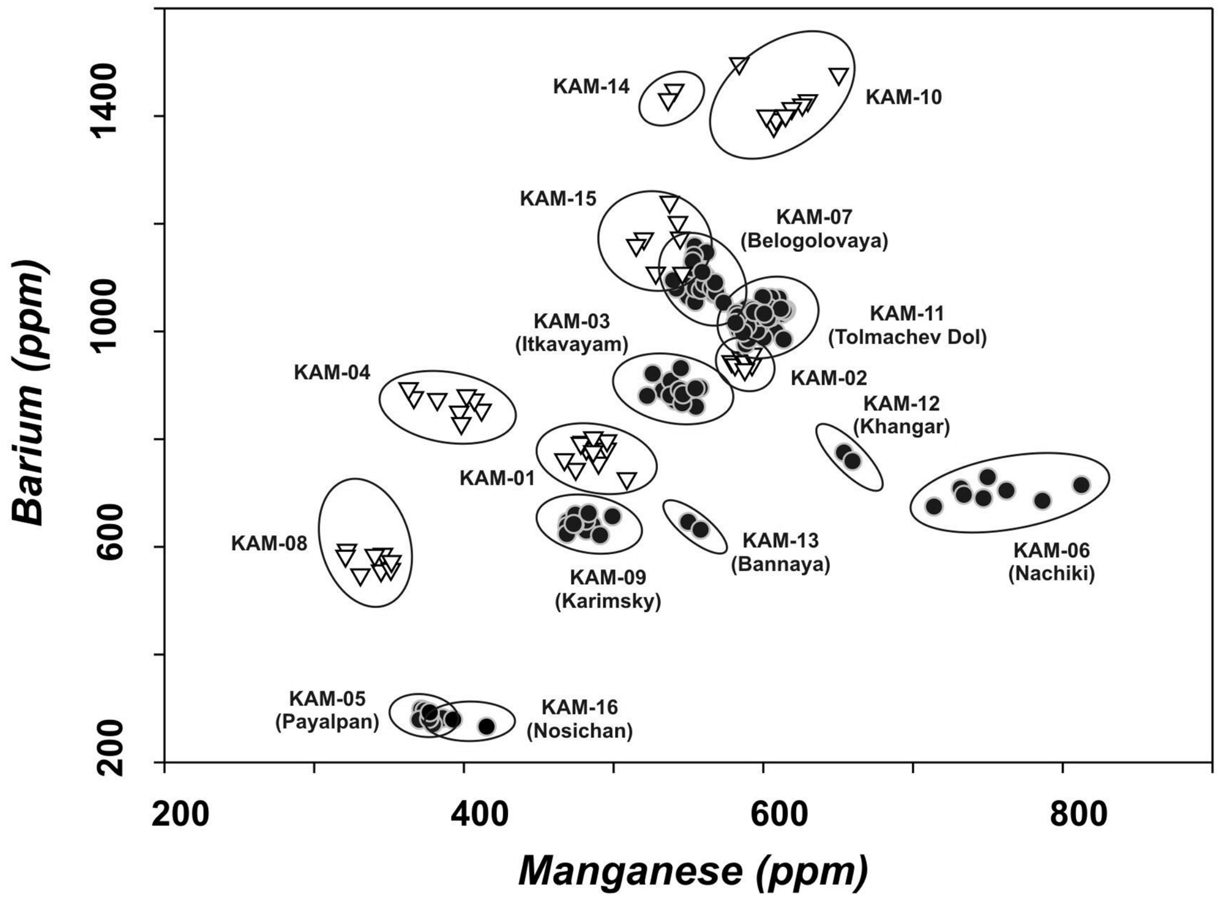

Figure 6.3. Bivariative plot of Mn vs. Ba concentrations for obsidian source samples and artefacts from Kamchatka analysed by INAA and geochemical group names (ellipses represent 95% confidence interval for group membership)

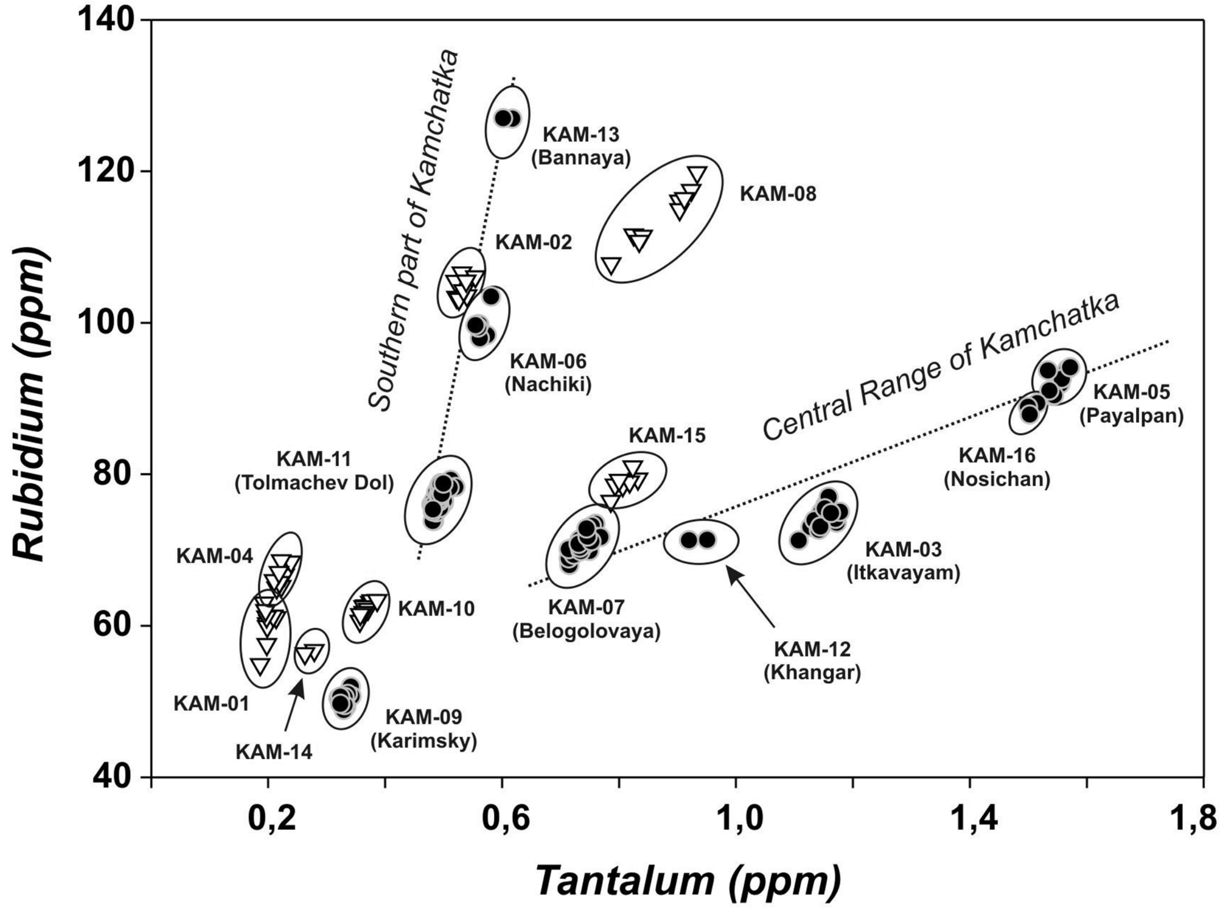

Figure 6.4. Bivariative plot of Ta vs. Rb concentrations discriminating geochemical groups of Kamchatkan obsidian (ellipses indicate 95% confidence level)

KAM-05	38 (2)
KAM-06	17 (2)
KAM-07	14 (0)
KAM-09	13 (11)
KAM-10	52 (0)
KAM-11	34 (30)
KAM-12	2 (2)
KAM-13	2 (2)
KAM-14	2 (0)
KAM-15	9 (0)
KAM-16	3 (2)
Unassigned/ungrouped	37 (10)
Total number of specimens	**444 (63)**

Bivariate plots of Ba versus Mn, and Rb versus Ta are shown in Figures 6.3 and 6.4, respectively. These plots illustrate the major geochemical groups in the dataset as of December 2008. Ba and Mn are particularly useful as discriminating elements because as large ions they are incompatible with crystallising solids; as magmas evolve the concentrations of incompatible elements will be different for each source. Figure 6.4 depicts the geographic position of obsidian sources in relationship to main volcanic belts of Kamchatka.

In Table 6.2, the means and standard deviations for the 16 source groups identified from the INAA data are summarised; unassigned/ungrouped samples are not included in Table 6.2 and are not depicted on Figures 6.3–6.4. The number of samples used to establish group statistics for Table 6.2 is much less than the total number of specimens analysed; this is due to the fact that only samples with determination of all 28 elements measured by the short and long irradiation were used to calculate mean values.

It was determined that (1) seven groups contained both archaeological and geological obsidians; (2) seven groups had only archaeological samples; and (3) two groups of geological obsidians had no matches with any archaeological specimens analysed thus far. Four compositional groups were directly attributed to 'geological' sources in the Central Range with precisely known locations: KAM-03 (Itkavayam), KAM-05 (Payalpan), KAM-07 (Belogolovaya Vtoraya River), and KAM-16 (Nosichan). One group, KAM-09 (Karimsky), was identified in the Akademii Nauk Caldera, part of the Karimsky Volcanic Centre in the Eastern Range. Two sources were identified in southern Kamchatka, groups KAM-06 (Nachiki) and KAM-11 (Tolmachev Dol) (Figure 6.4). Based on the results, the major sources of archaeological obsidian can be identified. This information is crucial to understanding the main patterns of raw material exploitation during the prehistory of Kamchatka.

Chemical data based on the variation of trace element compositions for volcanic glasses confirmed the geochemical zonal structure across the Kamchatkan Volcanic Arc which were established earlier (Churikova *et al.* 2001; Ishikawa *et al.* 2001; Popolitov and Volynets 1981; Volynets *et al.* 1987a, 1987b). The nature of this zonal pattern is related to a steep retreat of the subduction zone to the east, and the riftogenesis process and alkali volcanism of intraplate type in the western part of the Central Range. Rhyolites are characterised by the same geochemical peculiarities as basalts in the Neogene–Pleistocene volcanic series of Kamchatka.

Sources of Archaeological Obsidian at Kamchatka: The 2009 Status

Seven archaeological obsidian sources and the sites associated with them are presented in Table 6.3. In comparison to earlier studies (Glascock *et al.* 2006a, 2006b; Speakman *et al.* 2005), one new source is identified, Nosichan (KAM-16) in the Ichinsky Volcano region. Also, for several sources the number of related archaeological sites increased significantly. For example, the KAM-03 source now has 14 associated sites where before there were only eight sites where obsidian from this source was detected. The KAM-05 source has 17 associated sites versus ten in previous studies. The KAM-07 source obsidian is identified at ten localities compared to three sites as reported in Glascock *et al.* (2006b).

The KAM-03 source (Figure 6.5) is located near the headwaters of the Itkavayam River drainage basin on the western slope of the Central Range. The geographic coordinates are 58°05´ N and 160°46´ E. Volcanic glass from the KAM-03 source constitutes the cone of the small Obsidianovy Volcano which is probably not older than approximately 150,000 years. Obsidian is part of the lava flow, and occurs in layers of massive and striped volcanic glass of black and white colours about 0.4–15m thick. According to the chemical composition, the obsidian is rhyolitic.

In the vicinity of the Ichinsky Volcano, situated on the western slope of the Central Range, there are at least 11 distinct volcanic glass sources (Belogolovaya Vtoraya River, Tynya, Polyarnaya, Nosichan, Payalpan, Maly Payalpan, Galdavit, Studeny, Zemnoy Creek, Zemnoy Summit, and Gigigilen) based on data generated by the Geological Survey of Russia (Otchet 1992). Three of these—KAM-05 (Payalpan) (Figure 6.6), KAM-07 (Belogolovaya River) (Figure 6.7), and KAM-16 (Nosichan) (Figure 6.8) – are identified as sources of archaeological obsidian. Their coordinates are: 55°48´ N, 157°54´ E (KAM-05 and KAM-16); and 55°52´ N, 157°37´ E (KAM-07). The volcanic glass corresponds mainly to the dacite–rhyolite rocks of the upper part of Alnei Group (late Miocene) (Sheimovich and Patoka 2000). Some sources, such as Belogolovaya Vtoraya River, may have been created approximately 2,500,000 years ago.

The KAM-05 source is located on the western slope of Maly Payalpan Volcano and represents a lava flow originating from the intrusive dome. The flow is about 100m long and 5m thick. The obsidian has a black colour with dark-grey stripes, often subtranslucent. Based on chemical composition, the KAM-05 volcanic glass is rhyolitic. The KAM-07 source is situated in the headwaters of the Belogolovaya Vtoraya River, on the northern part of

Table 6.2. Concentration of elements (ppm) measured by INAA in obsidian samples from Kamchatka

Groups	***KAM-01***		***KAM-02***		***KAM-03***		***KAM-04***		***KAM-05***		***KAM-06***		***KAM-07***		***KAM-08***	
	(n = 12)		***(n = 8)***		***(n = 15)***		***(n = 8)***		***(n = 9)***		***(n = 8)***		***(n = 24)***		***(n = 9)***	
Element	***Mean***	***S.D.***	***Mean***	***S.D.***	***Mean***	***S.D.***	***Mean***	***S.D.***	***Mean***	***S.D.***	***Mean***	***S.D.***	***Mean***	***S.D.***	***Mean***	***S.D.***
Ba	773	24	945	10	890	19	867	21	289	18	700	17	1093	28	645	216
La	11.5	0.2	27.0	0.4	16.8	0.4	12.9	0.2	24.2	0.5	22.8	0.3	18.7	0.4	15.9	2.5
Lu	0.290	0.016	0.778	0.006	0.320	0.026	0.341	0.007	0.265	0.030	0.294	0.005	0.194	0.018	0.277	0.017
Nd	9.5	1.2	30.9	1.5	14.9	6.5	11.6	1.2	14.2	0.7	17.8	1.5	12.6	1.2	14.1	2.3
Sm	2.24	0.40	7.50	0.08	2.78	0.10	2.78	0.56	2.48	0.05	3.57	0.72	2.16	0.08	3.20	0.23
U	1.52	0.35	2.95	0.18	4.10	0.28	1.72	0.52	4.47	0.31	2.77	0.11	2.54	0.22	3.05	0.29
Yb	1.77	0.14	5.18	0.14	1.80	0.11	2.11	0.07	1.35	0.03	1.85	0.12	1.09	0.06	1.51	0.09
Ce	23.4	0.7	61.6	1.2	34.1	0.9	26.9	0.6	44.0	1.5	45.4	0.9	34.0	0.8	33.8	4.9
Co	1.290	0.118	0.595	0.016	0.351	0.012	1.029	0.081	0.163	0.031	0.223	0.024	0.954	0.110	0.909	0.158
Cs	3.54	0.09	4.74	0.07	3.23	0.08	4.40	0.15	2.26	0.05	4.58	0.07	1.26	0.02	10.39	0.81
Eu	0.473	0.044	1.006	0.015	0.455	0.017	0.491	0.011	0.296	0.007	0.499	0.010	0.513	0.011	0.502	0.041
Fe	10,777	367	13,489	181	5761	151	9586	404	4146	99	5272	128	8548	418	9285	810
Hf	4.06	0.11	8.66	0.14	3.50	0.08	4.41	0.09	2.95	0.08	3.39	0.11	3.44	0.08	3.01	0.36
Rb	60.0	2.2	104.8	1.3	74.2	1.5	66.6	1.4	92.2	1.5	99.8	1.6	70.8	1.4	114.0	3.8
Sb	1.28	0.13	1.01	0.10	0.41	0.03	1.73	0.22	0.41	0.02	0.50	0.05	0.12	0.01	0.24	0.02
Sc	3.03	0.52	7.48	0.11	1.99	0.04	3.26	0.14	1.72	0.04	2.02	0.03	1.82	0.05	3.26	0.07
Sr	206	20	84	41	111	17	157	7	53	6	77	10	354	54	153	18
Ta	0.20	0.01	0.53	0.01	1.15	0.02	0.22	0.01	1.56	0.04	0.56	0.01	0.74	0.02	0.87	0.05
Tb	0.31	0.03	1.23	0.03	0.37	0.01	0.39	0.01	0.29	0.01	0.39	0.01	0.22	0.01	0.47	0.03
Th	3.98	0.14	7.43	0.11	7.62	0.17	4.71	0.13	9.27	0.05	7.14	0.13	4.65	0.11	5.72	0.79
Zn	34.8	2.4	65.4	3.1	34.1	2.1	35.1	2.7	24.5	3.7	32.3	1.0	34.3	4.4	44.1	5.6
Zr	131	9	282	10	126	6	145	8	97	5	114	6	133	10	106	16
Al	70,756	2369	71,637	2724	70,995	2881	67,649	4003	66,722	2640	69,736	2802	75,867	2000	75,412	2186
Cl	376	73	686	105	112	23	356	24	239	42	409	29	238	79	37	20
Dy	1.84	0.38	7.78	0.47	2.24	0.28	2.71	0.22	1.64	0.16	2.25	0.21	1.09	0.26	2.68	0.35
K	26,219	3215	41,885	2051	31,992	1708	27,542	1536	39,407	1594	37,643	2011	32,521	1987	31,665	437
Mn	486	11	587	5	542	10	391	18	377	5	755	32	558	8	339	12
Na	30,867	971	32,292	357	32,134	411	29,473	707	28,142	773	30,858	338	31,966	703	30,404	690

Table 6.2. Concentration of elements (ppm) measured by INAA in obsidian samples from Kamchatka (end)

Groups	KAM-09		KAM-10		KAM-11		KAM-12		KAM-13		KAM-14		KAM-15		KAM-16	
	(n = 18)		(n = 11)		(n = 34)		(n = 2)		(n = 2)		(n = 2)		(n = 7)		(n = 3)	
Element	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Ba	650	16	1391	100	1024	24	767	11	639	10	1439	12	1167	48	279	13
La	15.3	0.2	19.2	3.5	18.4	0.3	20.6	0.1	23.3	0.2	13.8	0.2	20.3	0.5	24.2	0.1
Lu	0.432	0.018	0.292	0.034	0.214	0.012	0.271	0.005	0.357	0.003	0.222	0.021	0.234	0.025	0.297	0.026
Nd	16.5	1.2	16.4	3.4	12.8	1.8	17.1	0.2	20.5	0.3	12.0	2.8	13.7	0.9	13.3	0.1
Sm	3.69	0.10	3.10	0.48	2.29	0.21	3.01	0.02	3.82	0.00	2.11	0.04	2.33	0.11	2.45	0.02
U	1.99	0.22	2.26	0.52	2.46	0.15	2.95	0.29	3.40	0.21	2.93	0.27	2.72	0.16	4.46	0.03
Yb	2.89	0.04	1.75	0.16	1.26	0.07	1.77	0.04	2.37	0.03	1.12	0.03	1.16	0.14	1.38	0.03
Ce	34.5	1.0	37.1	3.3	33.9	0.9	41.1	0.1	48.7	0.4	27.4	0.1	37.0	1.1	42.0	0.3
Co	0.724	0.150	0.563	0.101	0.264	0.098	0.235	0.004	0.197	0.038	0.336	0.036	0.361	0.029	0.171	0.034
Cs	1.74	0.03	1.68	0.13	2.66	0.06	1.69	0.00	5.67	0.03	2.80	0.01	1.44	0.02	2.20	0.00
Eu	0.594	0.013	0.611	0.037	0.458	0.012	0.661	0.008	0.46	0.001	0.4	0.002	0.498	0.011	0.294	0.004
Fe	9397	326	7758	291	5441	251	7358	256	5337	0	5491	76	6411	156	4069	96
Hf	4.63	0.07	3.68	0.22	2.53	0.06	4.19	0.08	4.24	0.10	2.59	0.30	3.28	0.12	2.90	0.06
Rb	50.4	0.8	63.1	2.9	76.9	1.4	71.3	0.0	127.0	0.0	56.5	0.3	78.9	1.4	88.7	0.8
Sb	0.39	0.05	0.41	0.11	0.36	0.02	0.24	0.00	0.71	0.01	2.16	0.02	0.14	0.01	0.36	0.02
Sc	3.10	0.12	2.11	0.11	1.52	0.10	1.55	0.03	2.38	0.01	1.72	0.01	1.49	0.04	1.71	0.04
Sr	119	20	282	21	216	24	205	4	39	0	219	25	276	25	47	5
Ta	0.33	0.01	0.40	0.11	0.49	0.01	0.94	0.02	0.61	0.01	0.27	0.01	0.81	0.02	1.51	0.01
Tb	0.60	0.02	0.37	0.04	0.26	0.01	0.36	0.01	0.46	0.00	0.22	0.02	0.24	0.01	0.28	0.01
Th	3.43	0.07	4.01	0.25	5.60	0.10	4.69	0.02	8.97	0.02	4.24	0.04	5.41	0.18	9.08	0.02
Zn	35.3	2.6	37.6	3.0	34.0	3.2	45.4	1.9	34.8	0.4	28.9	1.3	31.1	2.0	20.7	0.2
Zr	145	11	134	12	89	5	151	7	141	5	107	15	120	6	98	4
Al	69,299	2750	70,841	4079	70,320	2519	74,444	2946	66,621	257	66,800	1445	74,550	4352	72,595	3467
Cl	756	136	253	33	355	74	363	9	533	31	215	18	254	20	254	20
Dy	3.89	0.39	2.11	0.46	1.49	0.28	1.78	0.42	2.83	0.11	1.09	0.08	1.37	0.33	1.73	0.26
K	28,103	1774	31,381	1494	30,701	2051	28,277	681	39,995	481	29,760	97	33,121	1478	38,202	2921
Mn	481	10	610	22	599	10	657	4	554	6	539	3	534	12	395	19
Na	32,978	597	29,334	1893	29,489	393	36,401	314	29,709	100	27,945	112	30,424	699	29,830	1805

Table 6.3. Sources of archaeological obsidian at Kamchatka and distance from sources to sites

Source Name (Group No.)	***Site No.****	***Site Name***	***Number of samples***	***Distance from source (km)***
Itkavayam (KAM-03)	7	Kulki	1	170
	8	Palana-airport	3	100
	10	Inchegitun 1	5	120
	11	Chimei	2	140
	12	Galgan 1	7	90
	13	Zeleny Kholm	1	450
	16	Lake Nerpichye	1	220
	31	Elisovo 2	1	560
	33	Kluchi	1	210
	37	Penzhina	1	490
	38	Ushki 1	4	230
	38	Ushki 2	1	230
	41	Lake Domashnee	1	200
	45	Doyarki	1	220
Payalpan (KAM-05)	6	Ust-Kovran	1	170
	17	Kozlov Cape	1	280
	21	Avacha	1	315
	21	Avacha River, lower stream	1	310
	22	ASK (Avacha 9)	3	280
	23	Plotnikova River (Lake Nachiki)	1	310
	27	Anavgai	2	70
	31	Elisovo 2	1	290
	31	Elisovo 5	1	290
	32	Ilmagan	5	90
	34	Nikolka	1	140
	35	Siyushk	1	530
	36	Kozyrevsk	1	125
	38	Ushki 1	13	135
	38	Ushki 5	1	135
	41	Lake Domashnee	1	170
	45	Doyarki	1	160
Nachiki (KAM-06)	21	Avacha River, animal farm	1	50
	23	Plotnikova River (Lake Nachiki)	13	5
	24	Sokoch Lake	1	25
Belogolovaya Vtoraya River (KAM-07)	2	Ozernovsky 1	1	470
	2	Ozernovsky 2	1	470
	22	ASK (Avacha 9)	1	260
	33	Kluchi	1	190
	35	Siyushk	1	530
	36	Kozyrevsk	2	120
	38	Ushki 1	7	130
	40	Zastoichik	1	160
	41	Lake Domashnee	2	170
	42	Kamaki	1	230
Karimsky (KAM-09)	20	Kopyto 1 (Zhupanova River mouth)	2	40
Tolmachev Dol (KAM-11)	24	Lake Sokoch	2	60
	25	Viluchinsk 2	2	65
Nosichan (KAM-16)	22	ASK (Avacha 9)	1	260

*Site Nos. correspond to those on Figures 6.5–6.11.

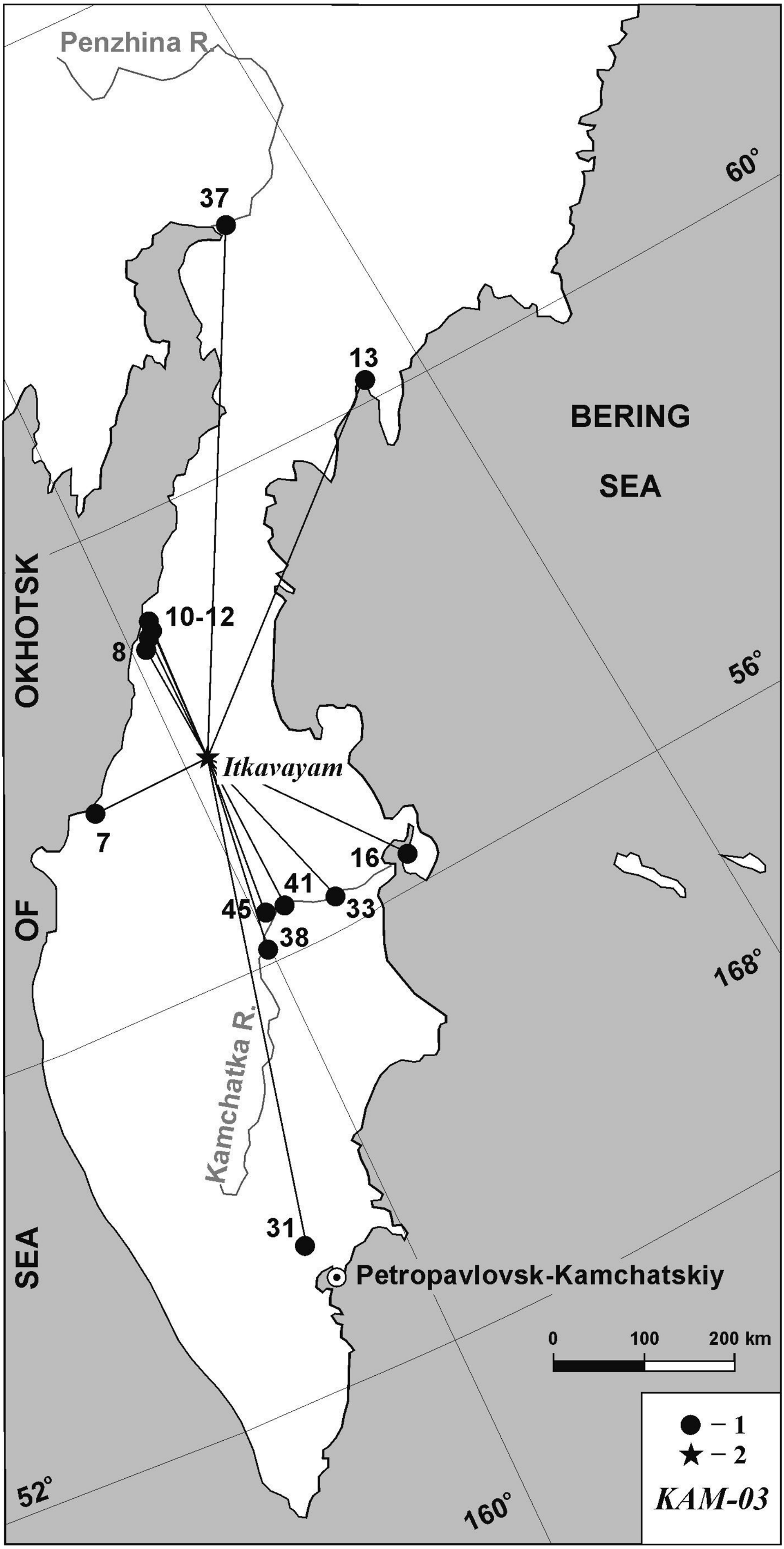

Figure 6.5. The KAM-03 (Itkavayam) obsidian source and associated archaeological sites (on Figures 6.5–6.11, site numbers correspond to those in Table 6.1)

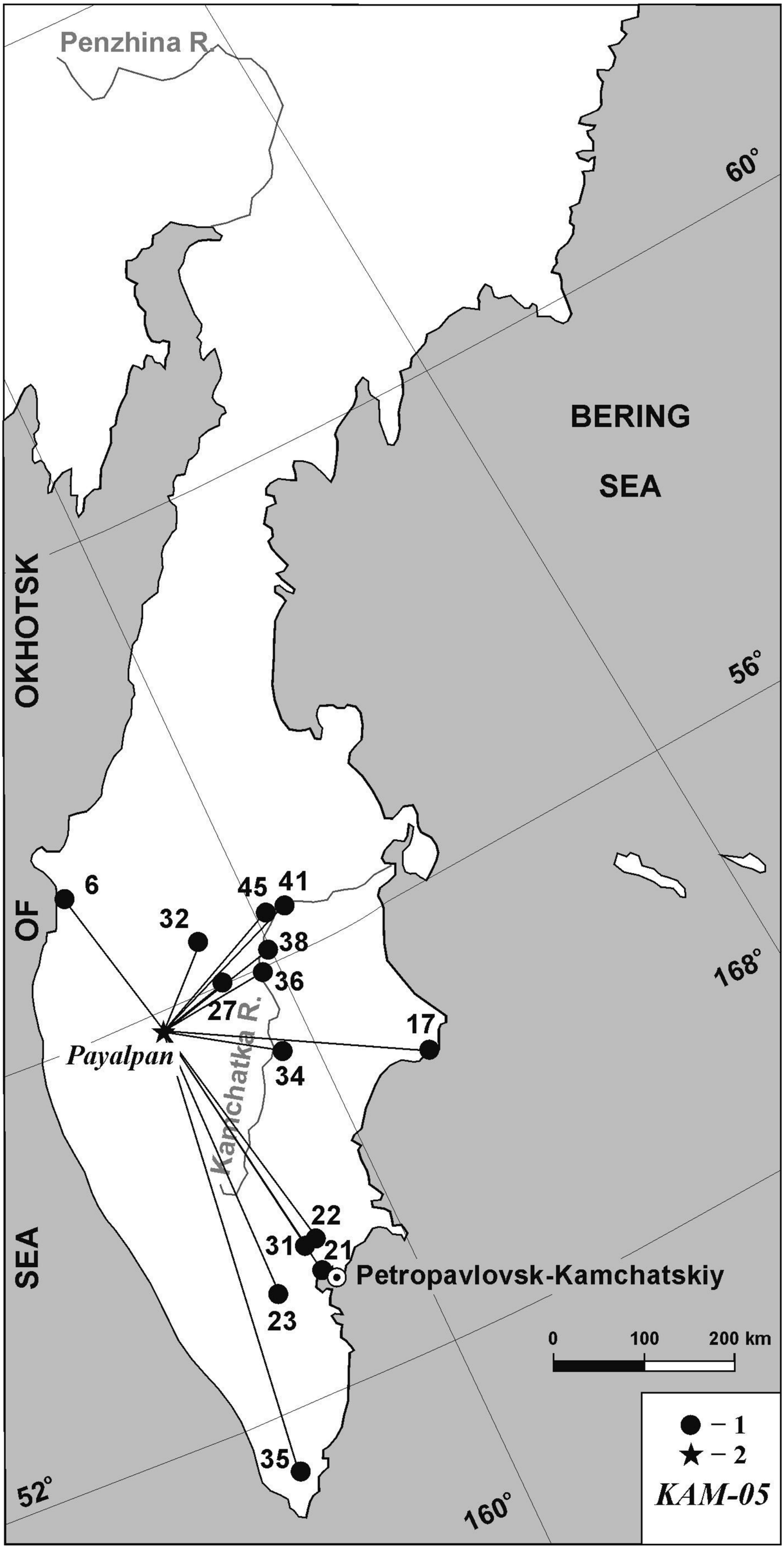

Figure 6.6. The KAM-05 (Payalpan) obsidian source and associated archaeological sites

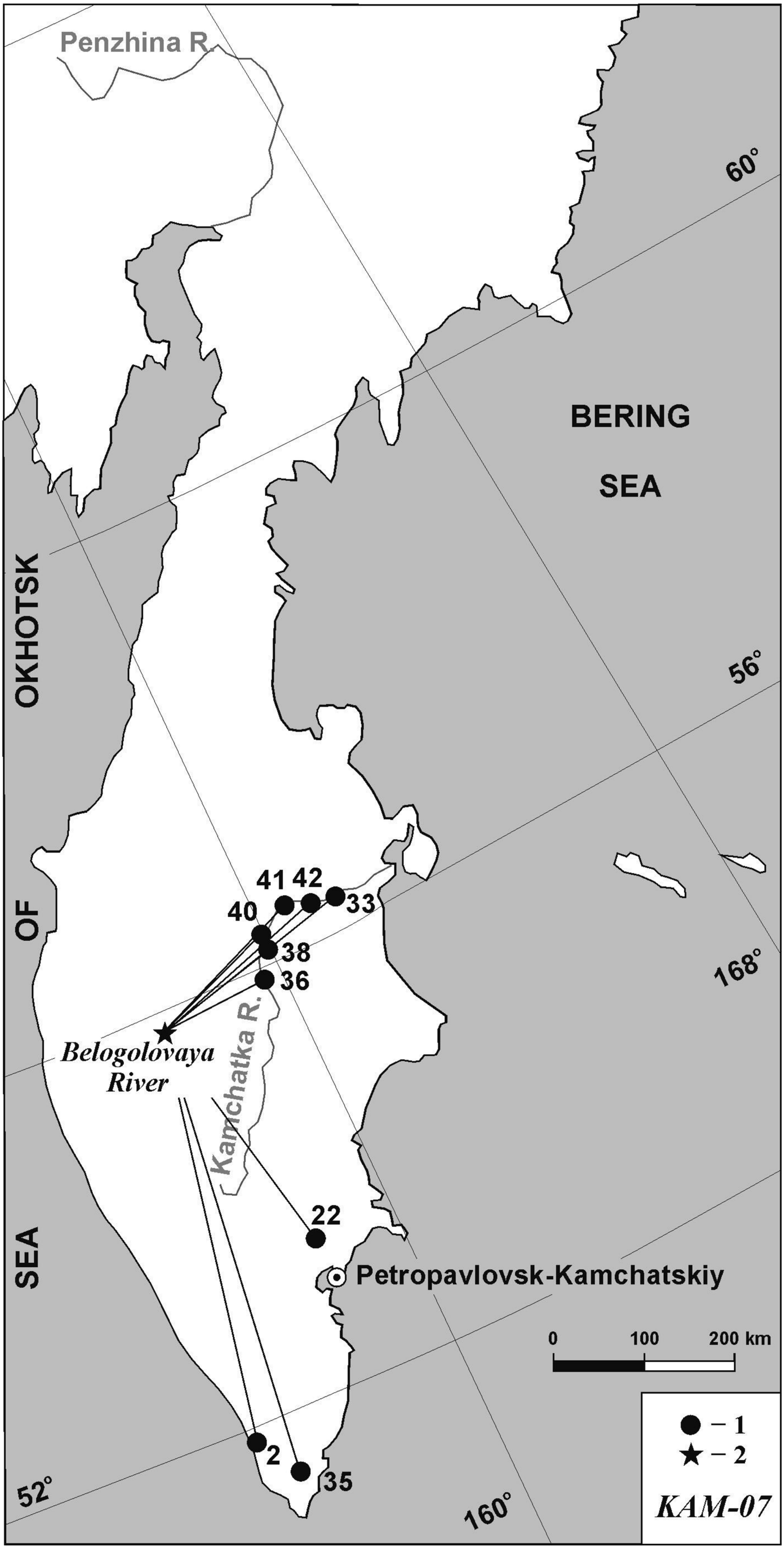

Figure 6.7. The KAM-07 (Belogolovaya Vtoraya River) obsidian source and associated archaeological sites

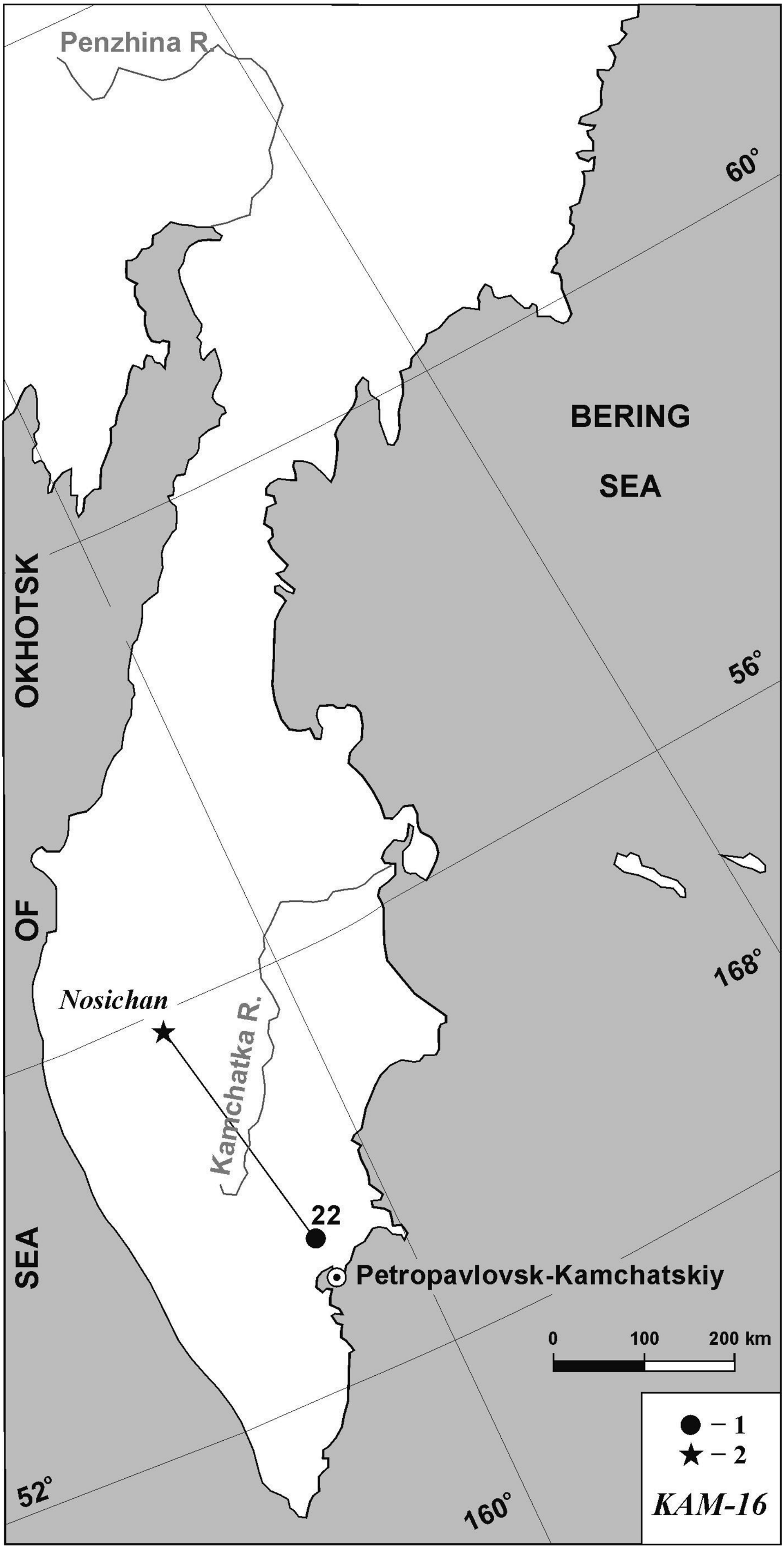

Figure 6.8. The KAM-16 (Nosichan) obsidian source and associated archaeological site

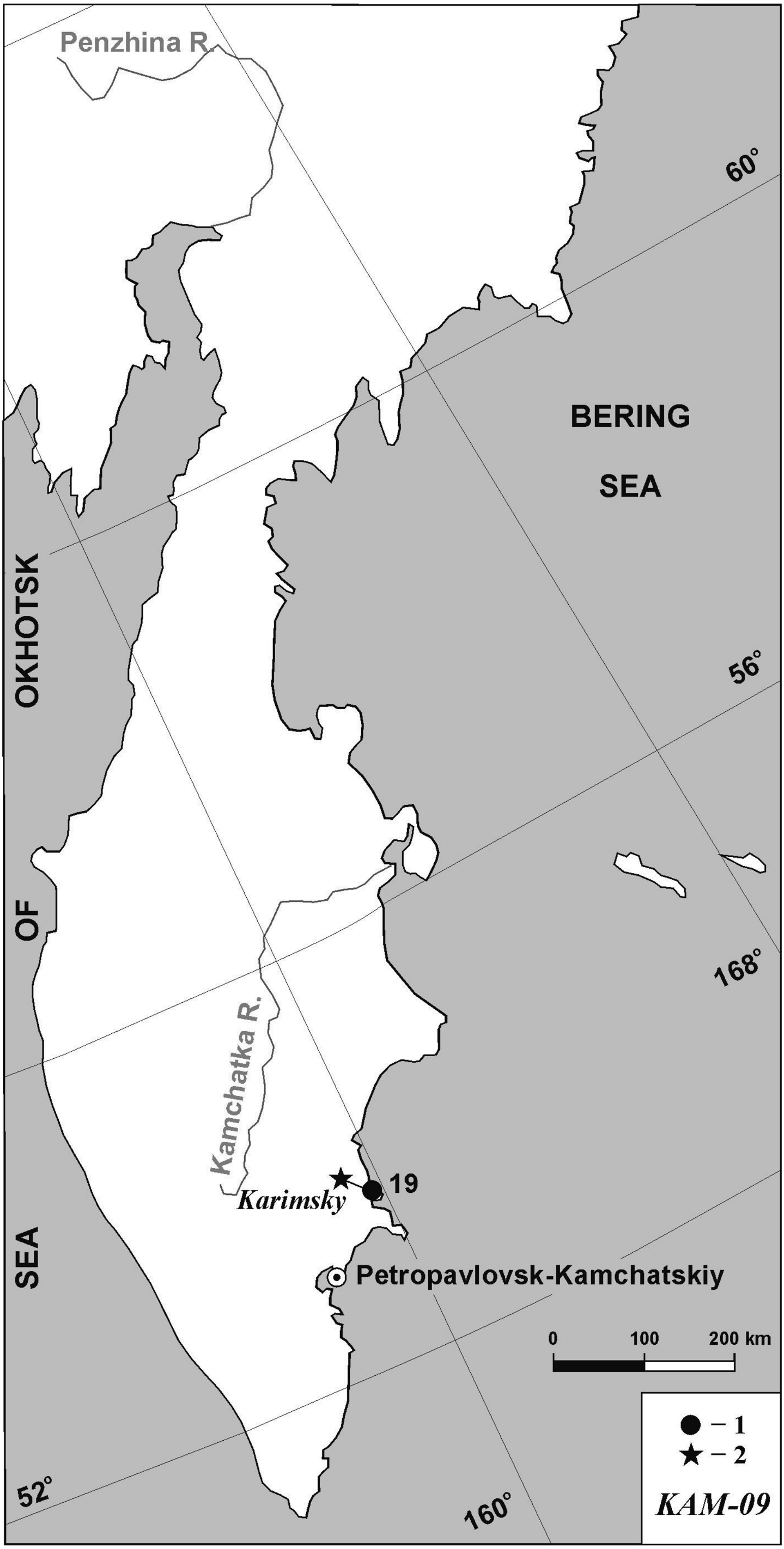

Figure 6.9. The KAM-09 (Karimsky Volcano) obsidian source and associated archaeological site

Tynya Ridge near the summits of Bystraya (1304m a.s.l.) and Tynya (1429m a.s.l.). Volcanic glass from this source is associated with rhyolitic extrusive domes and lava flows. The colours of the obsidian are black and dark-reddish, sometimes dark-gray and blue-grayish; the structures are massive and clastic. Some of the black obsidian pieces are semitransparent. The KAM-16 source is located near the Nosichan River, a tributary of the Belogolovaya Vtoraya River. Three small colluvial taluses and one bedrock outcrop were discovered. The KAM-16 source corresponds to the middle Pleistocene rhyolitic extrusive domes.

In the Eastern Range, the single obsidian source KAM-09 associated with prehistoric sites is in the Karimsky Volcanic Centre (coordinates 54°30´ N, 159°26´ E) (Figure 6.9). During the later stages of the development of this volcanic structure during the late Pleistocene and the Holocene, two calderas were created, Akademii Nauk and Karimskaya (e.g., Erlikh 1972). This source is composed of pumice tuffa, volcanic bombs, and lapilli, of rhyolithic and dacitic composition. High quality volcanic glass is found on the lake shore of the Akademii Nauk Caldera.

In the southern part of Kamchatka two sources of archaeological obsidian, KAM-06 and KAM-11, were identified. The KAM-06 source (Figure 6.10) originates from the eastern slope of Shapochka Summit in the Lake Nachiki area; geographic coordinates are 53°01´ N, 157°43´ E. Black obsidians are embedded into layers of volcanic glass, a marginal part of the rhyolitic extrusion. The KAM-11 source (coordinates 52°37´ N, 157°33´ E) is situated around the Chasha Maar in the central part of the Tolmachev Dol basaltic plateau (Figure 6.11). It was created by a catastrophic explosion around 5300 BP when tephra covered a territory about 15,000km^2, mainly toward the northeast of the Tolmachev Dol Plateau (Melekestsev *et al.* 1996; Dirksen *et al.* 2002). Volcanic products vary from pumice to waterless volcanic glass of grayish colour. The composition of volcanic glass from Tolmachev Dol source is rhyolitic.

Archaeological Obsidian Sources on Kamchatka Yet to Be Identified

In addition to 'geological' sources of archaeological obsidian which were identified, there are at least seven geochemical groups represented only by prehistoric artefacts; and the sources of these have yet to be located. Due to the large number of obsidian sources at Kamchatka, more research is needed to correlate the volcanic glass from archaeological assemblages with sources of obsidian. However, geochemical data and position of archeological sites suggests possible geographic locations for the unknown sources.

The KAM-01 group is widely distributed throughout all of the Kamchatka Peninsula (Figure 6.12) but concentrated mostly in the southeastern part. Artefacts belonging to this group are also identified in the northern Kurile Islands (Phillips and Speakman 2009; see also Phillips, this volume). The KAM-04 Group is situated mostly in the southeastern part of peninsula (Figure 6.13), and also in the northern Kuriles (Phillips and Speakman 2009; see also Phillips, this volume). The KAM-10 group comprises sites located in central and eastern parts of Kamchatka (Figure 6.14). The KAM-14 group consists of sites in central Kamchatka (Figure 6.15). All these groups have Nb/Zr ratios of around 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 noted that sites belonging to these groups are in the vicinity of the Karimsky source (KAM-09) which has similar Nb/Zr ratio. Additionally, the chemical composition of this group is very similar to the KAM-09 group (Figure 6.4). Based on current understanding, it is assumed that the sources of the KAM-01, KAM-04, KAM-10, and KAM-14 groups are situated somewhere in the eastern part of Kamchatka.

The KAM-15 group comprises samples from the Ushki site cluster in central Kamchatka (Figure 6.16) (Kuzmin *et al.* 2008). According to the chemical data, this group has some resemblance to the Belogolovaya Vtoraya River source (KAM-07) (Figure 6.4). This fact can be used to tentatively place the KAM-15 source in the Ichinsky Volcano region. The KAM-02 group is represented by sites located mainly in the southern part of Kamchatka (Figure 6.17) and in the northern Kurile Islands (Phillips and Speakman 2009; see also Phillips, this volume). It has some chemical similarities with the Nachiki source (KAM-06) (Figure 6.4). This suggests a location for the KAM-02 source in southern Kamchatka.

Artefacts from sites in the northern part of Kamchatka constitute the KAM-08 group (Figure 6.18). Chemically, this group is intermediate relative to obsidian from the eastern and southern parts of Kamchatka (Figure 6.4). Therefore, it is difficult at this stage of research to assume a location for the obsidian source associated with this group. However, based on the overall distribution of artefacts assigned to this source, it seems very likely that source is located north of, or on, the Kamchatka Isthmus (narrow part of the peninsula in the north).

In addition to the groups that were comprised only of 'archaeological' obsidian, two geochemical groups contained only geological samples: KAM-12 (Khangar Volcano) and KAM-13 (Bannaya) (Figure 6.19). They have no matches with any artefacts from Kamchatka (Figures 6.3–6.4). It is possible that in the future at some archaeological sites obsidian from these sources will be identified.

Spatial-Temporal Patterns of Obsidian Use in Prehistory of Kamchatka (Preliminary Results)

The spatial distribution of obsidian from the seven known sources (Figures 6.5–6.11; Table 6.3) allows us to establish major patterns of transportation for raw material during Kamchatkan prehistory. The KAM-03 source (Figure 6.5) was widely used by ancient populations, with distance between source and sites up to 560km in a straight line. Similar features are typical for the KAM-05 and KAM-07

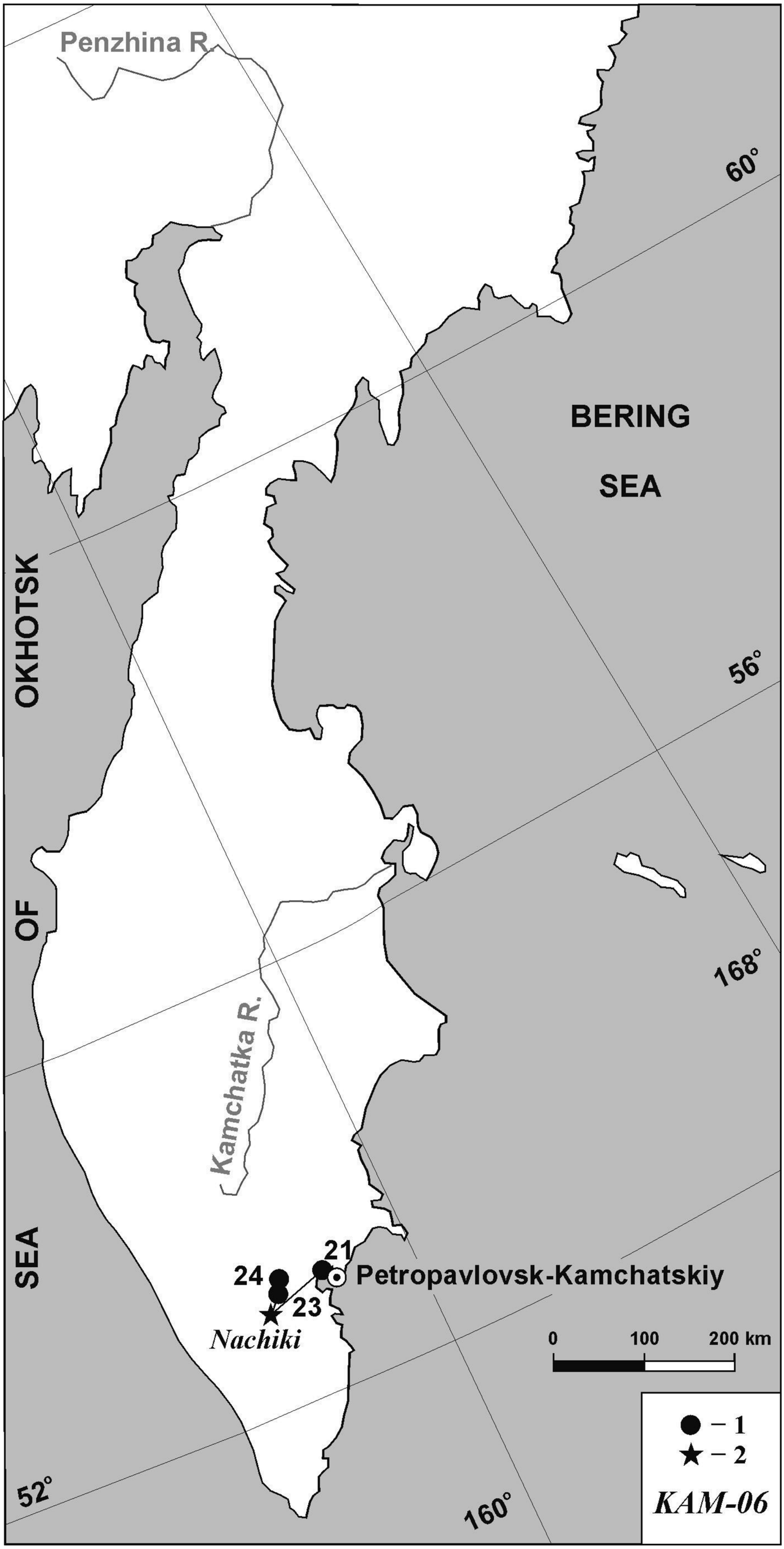

Figure 6.10. The KAM-06 (Nachiki) obsidian source and associated archaeological sites

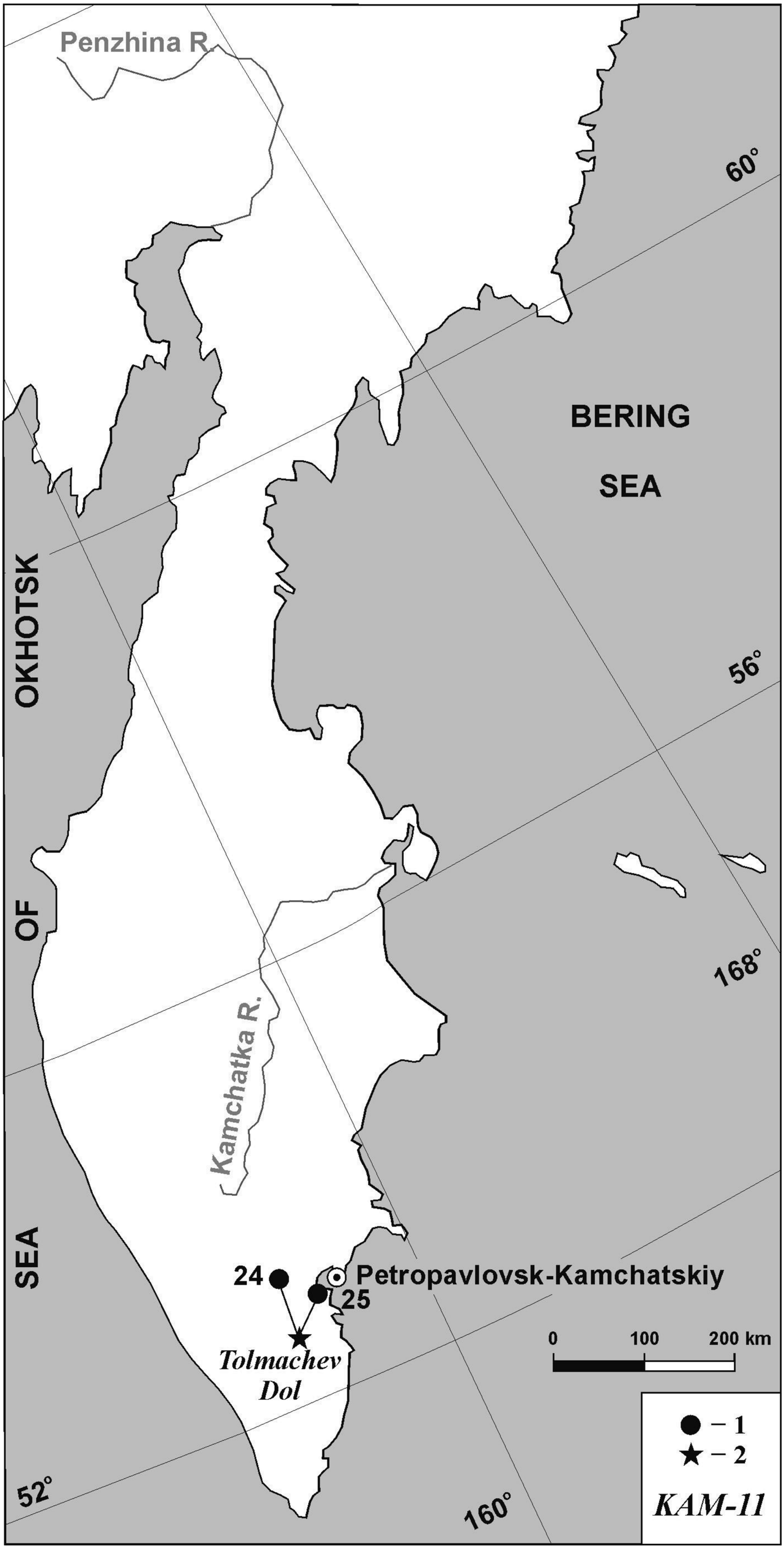

Figure 6.11. The KAM-11 (Tolmachev Dol) obsidian source and associated archaeological sites

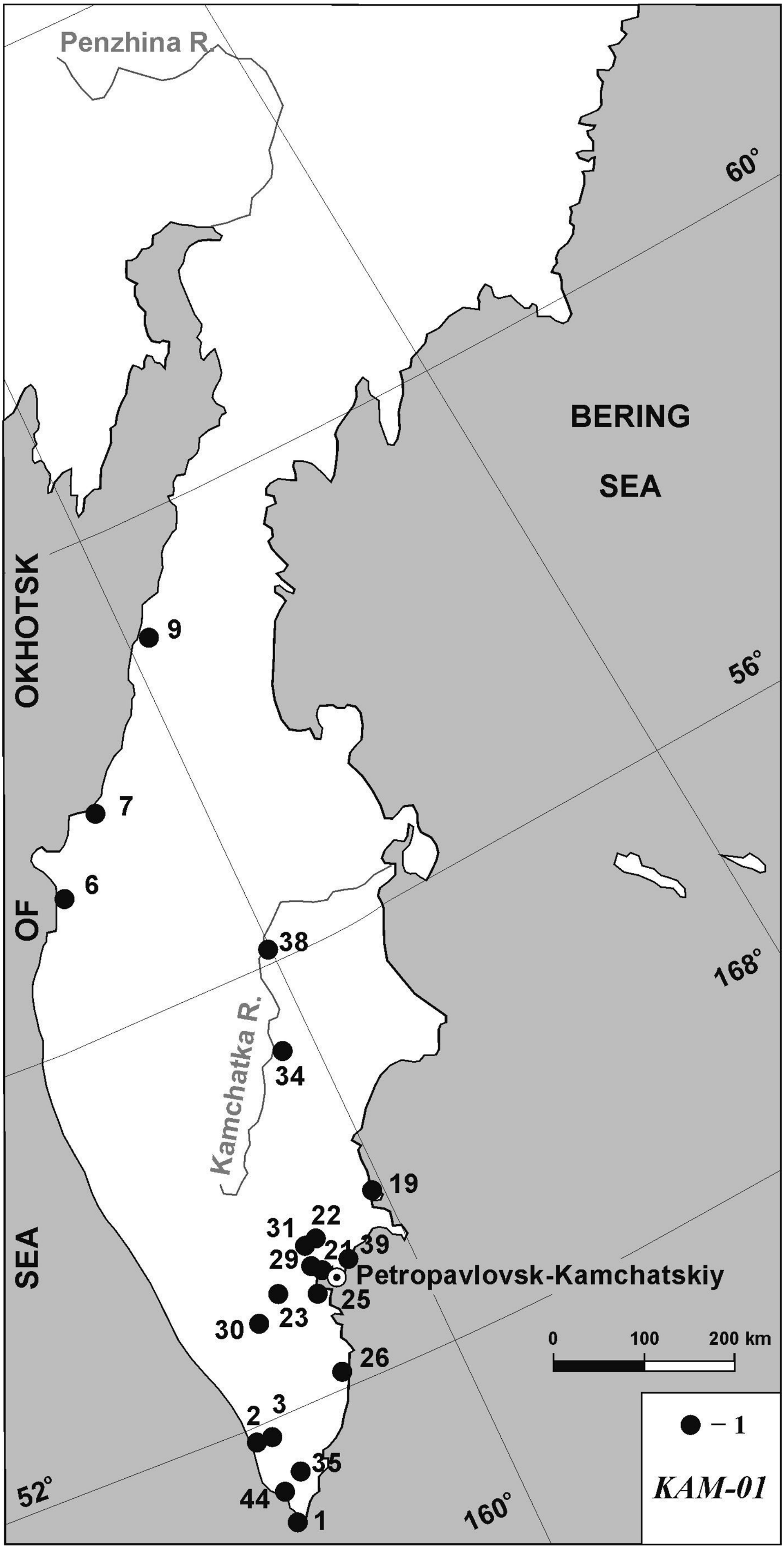

Figure 6.12. The distribution of archaeological sites with KAM-01 group obsidian artefacts (on Figures 6.12–6.18, site numbers correspond to those in Table 6.1)

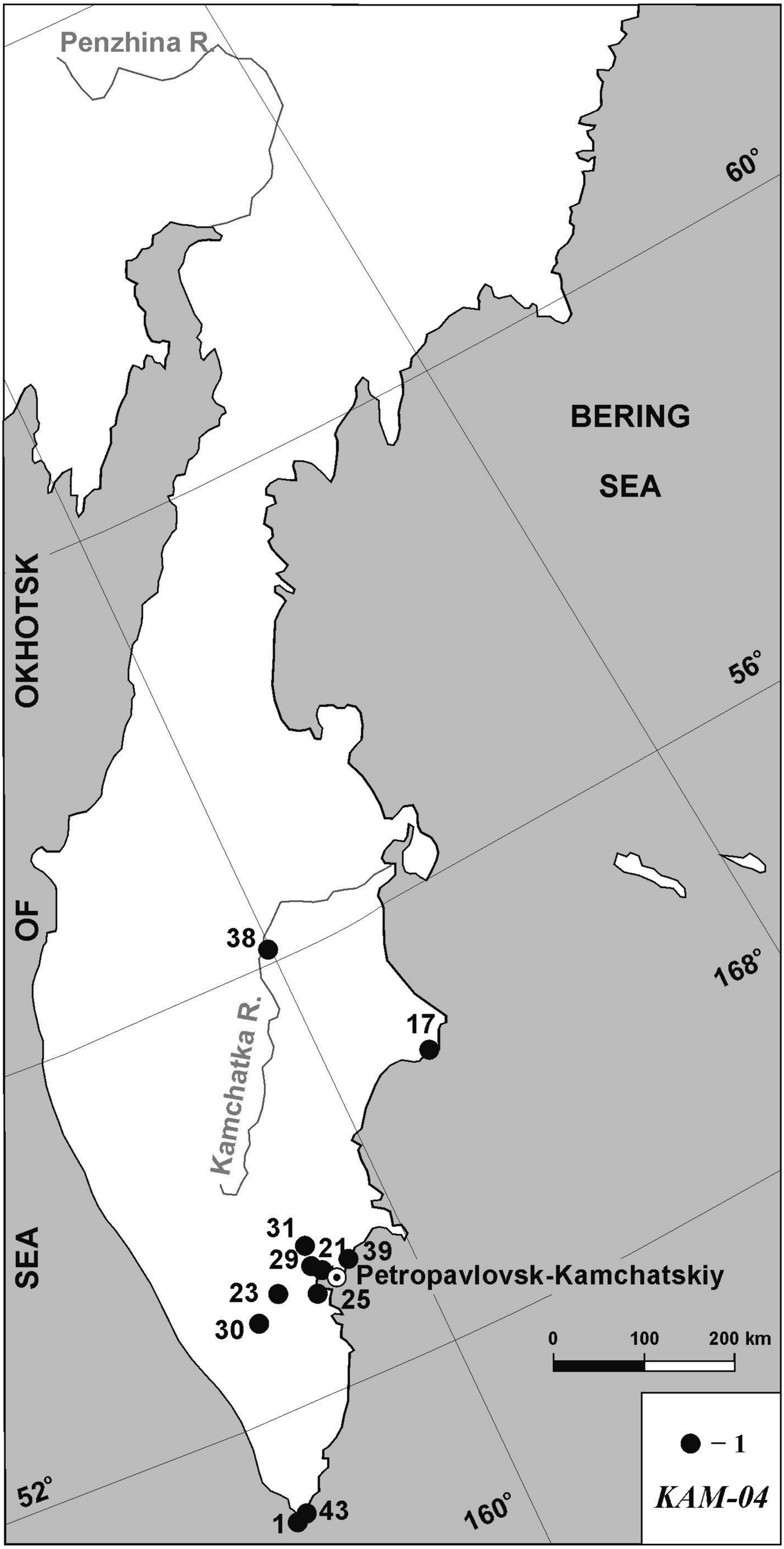

Figure 6.13. The distribution of archaeological sites with KAM-04 group obsidian artefacts

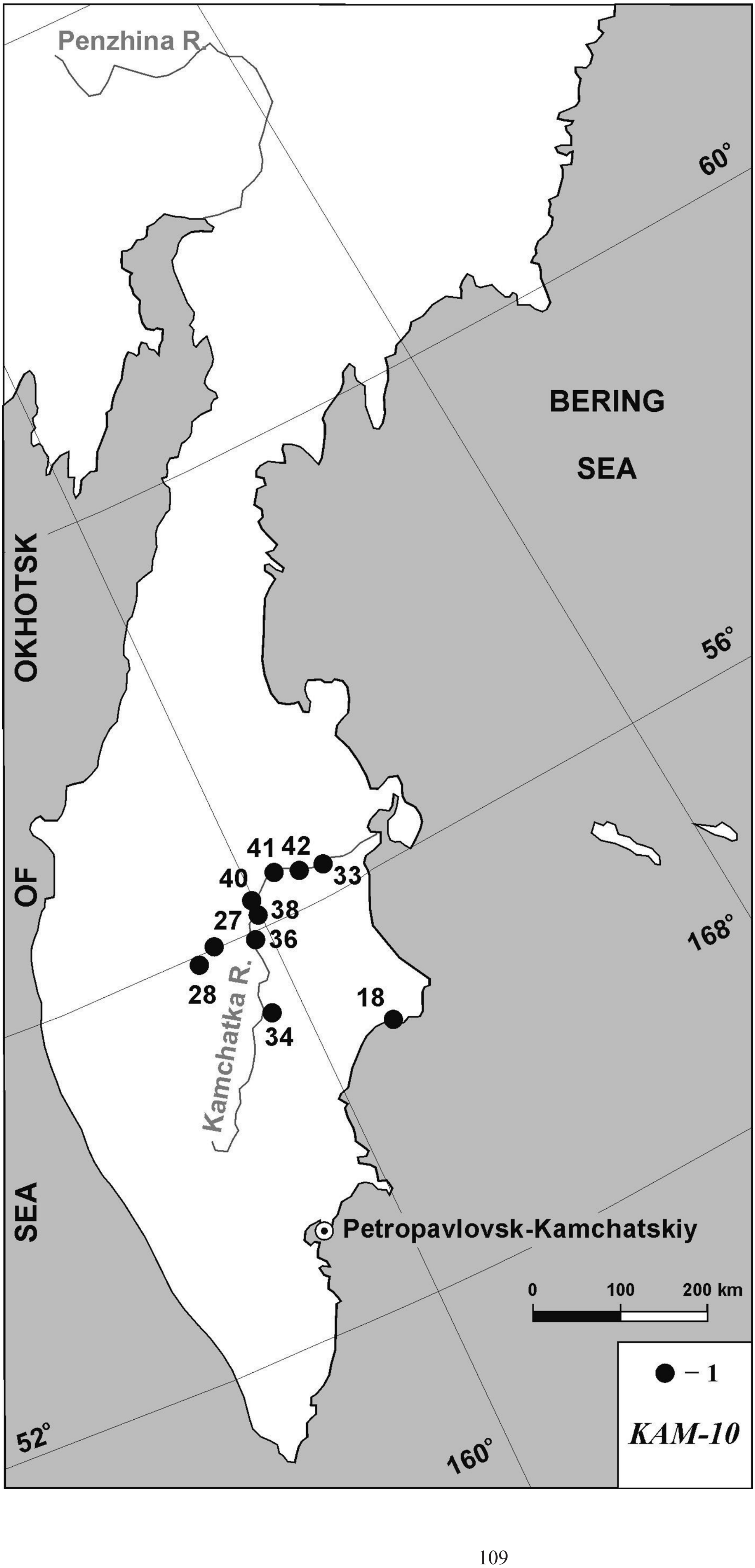

Figure 6.14. The distribution of archaeological sites with KAM-10 group obsidian artefacts

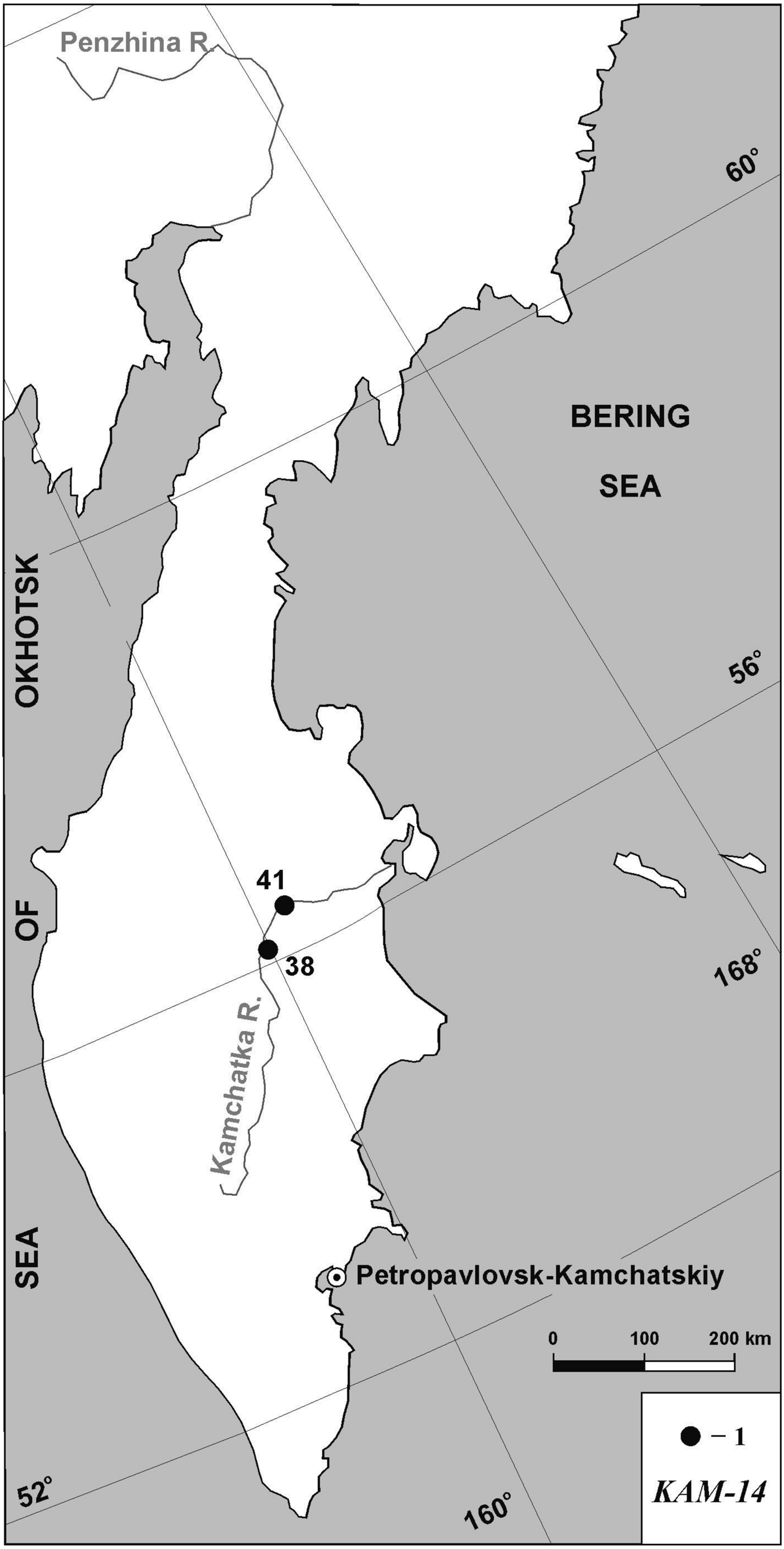

Figure 6.15. The distribution of archaeological sites with KAM-14 group obsidian artefacts

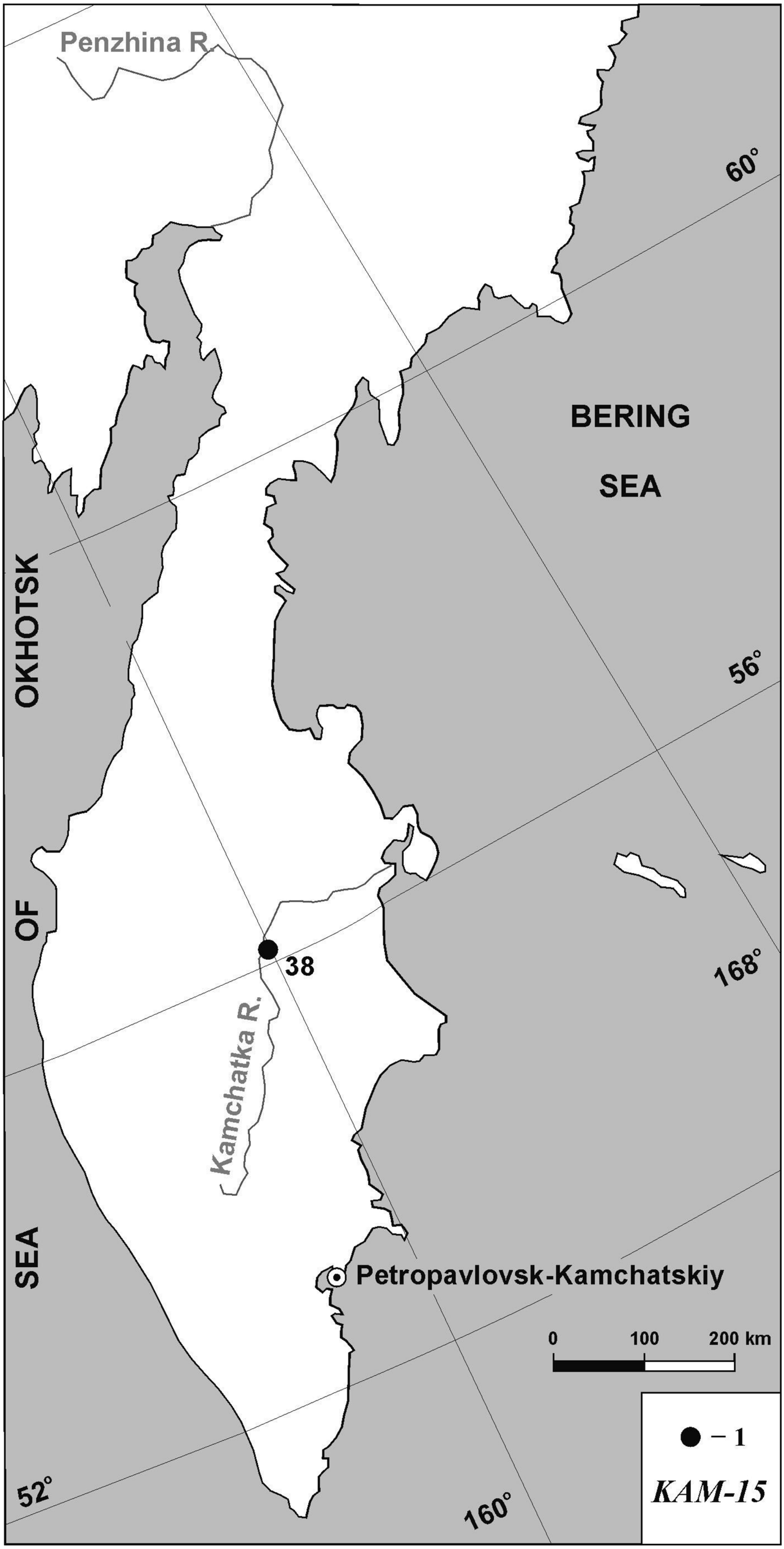

Figure 6.16. The distribution of archaeological sites with KAM-15 group obsidian artefacts

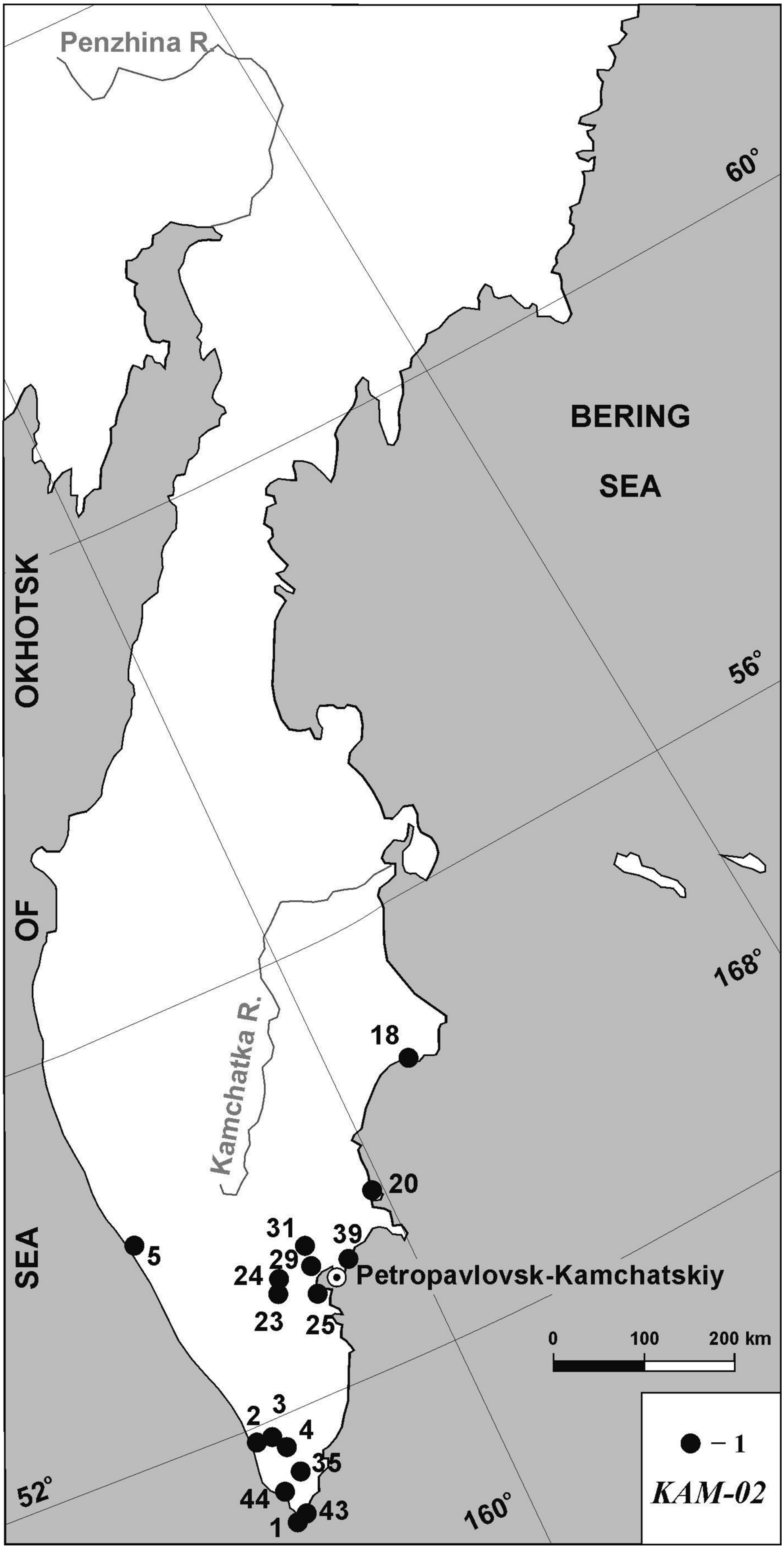

Figure 6.17. The distribution of archaeological sites with KAM-02 group obsidian artefacts

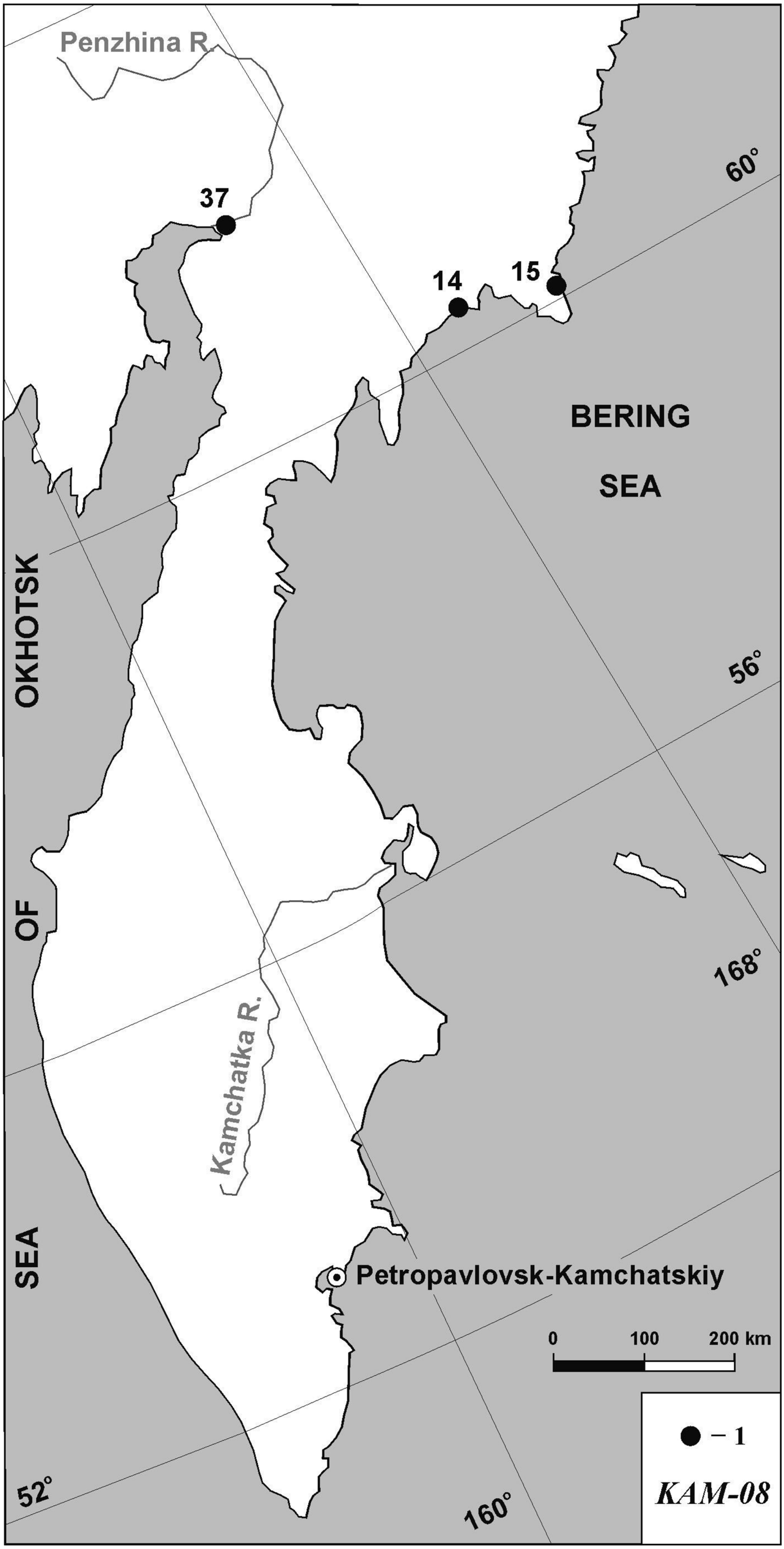

Figure 6.18. The distribution of archaeological sites with KAM-08 group obsidian artefacts

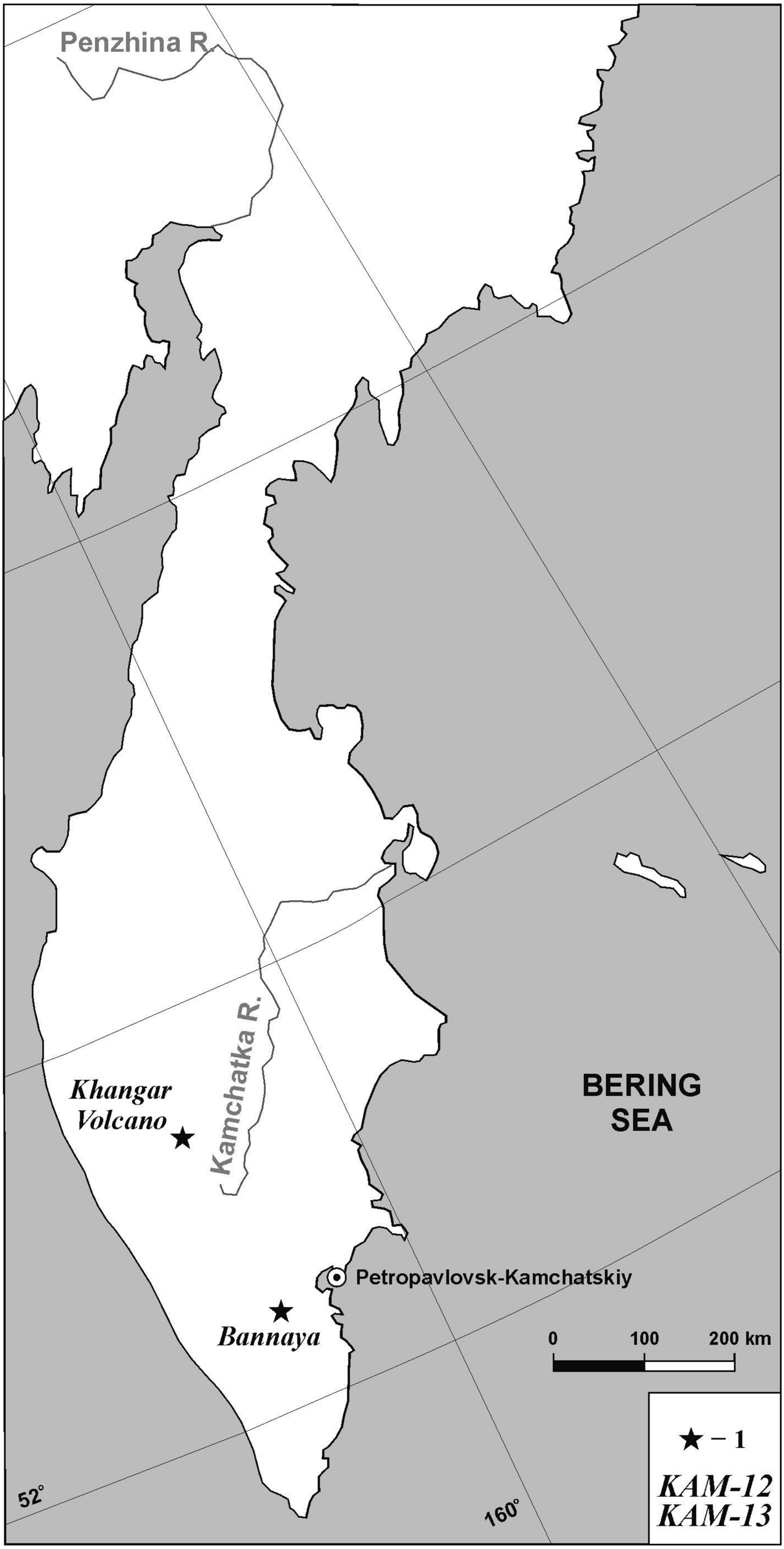

Figure 6.19. The position of KAM-12 (Khangar Volcano) and KAM-13 (Bannaya) obsidian sources

sources (Figures 6.6–6.7). The distance from KAM-16 to sites is about 260km (Figure 6.8). The sources KAM-09 (Figure 6.9), KAM-06 (Figure 6.10), and KAM-11 (Figure 6.11) were used more 'locally', with distances between sites and sources less than 100km.

As for transportation length in different stages of Kamchatkan prehistory, the following features can be tentatively established. The distance of obsidian movement during the late Upper Palaeolithic, ca. 14,300–10,200 BP (Ushki cluster), was up to 200–300km (Kuzmin *et al.* 2008). During the Neolithic, ca. 6000–1500 BP, the distance from sites to sources was from 90km up to 470km (obsidian from the KAM-07 source at Osernovsky 1–2 sites; Table 6.3). For some sites, such as Avacha River (animal farm), Plotnikova River, and Lake Sokoch (artefacts associated with the KAM-06 source); and the Lake Sokoch (specimens associated with the KAM-11 source), obsidian quarries were located only 5–60km away. Definite long-distance exchange and/or trade of obsidian from the KAM-05 and the KAM-07 sources existed in the Neolithic, with distances up to 315–470km. During the Palaeometal period, the long-distance transportation of the KAM-03 source obsidian was detected, with distances up to 450–560km (Table 6.3). Also, the extensive use of the KAM-05 source is noteworthy, with distances up to 280–315km. Some sources situated not far away from the sites also were used; for example, the KAM-09.

As for neighbouring regions of Northeast Asia where obsidian was widely used in prehistory, the distances for raw material acquisition are similar to Kamchatka. For example, during the Upper Palaeolithic obsidian from the Paektusan source on the modern North Korean–Chinese border is found at sites in the Primorye Province and the Korean Peninsula up to 500–800km away (Kim *et al.* 2007; Kuzmin *et al.* 2002a; Popov *et al.* 2005b; see also Kuzmin, this volume). The distance between sources on Hokkaido Island and Upper Palaeolithic sites on Sakhalin Island are up to 250km (Kuzmin and Glascock 2007; Kuzmin *et al.* 2002b), and on the Honshu Island up to 300–400km, sometimes even 600km (Tsutsumi 2002; see also Tsutsumi, this volume). During the Neolithic, the maximum range of obsidian exchange in Northeast Asia was up to 1000km (e.g., Kuzmin 2006; see also Kuzmin, this volume).

Of special interest is the use of multiple obsidian sources by prehistoric people of Kamchatka. It is common that at a particular site, obsidian from different sources is found (Table 6.4). For example, in the Upper Palaeolithic layers 7 and 6 of the Ushki cluster obsidian from six sources was identified (Kuzmin *et al.* 2008). In some Neolithic cultural complexes (Ushki and Plotnikova River), obsidian from five to seven sources was detected, although usually the number of sources was between one and three (average around two sources). During the Palaeometal, obsidian from four sources was found at some sites (Elisovo 1–5); the average number of sources is approximately two (Table 6.4).

A similar feature is observed in the southern part of the Russian Far East. Despite a limited number of obsidian sources in the Primorye Province, the Amur River basin, and on Sakhalin Island (Kuzmin 2006; Kuzmin and Glascock 2007; Kuzmin *et al.* 2002a, 2002b), volcanic glass from at least two sources was identified on several sites. This suggests that the strategy for obsidian acquisition in the Russian Far East has been quite complex since the late Upper Palaeolithic, ca. 14,000–12,000 BP.

Conclusion

It is obvious that obsidian provenance studies on the Kamchatka Peninsula are still in their infancy. Due to large numbers of 'geological' sources of good quality volcanic glass and vast terrain with a very low density of roads, it will take perhaps years to obtain reference samples from all major obsidian outcrops. Only in Mesoamerica has such a high concentration of obsidian sources been observed in such a restricted area (e.g., Glascock *et al.* 1998, 45–57). Even in more intensively surveyed regions compared to the Kamchatka Peninsula, the search for unknown obsidian sources takes time. For example, in a relatively well-studied part of western Arizona State (US Southwest) it took almost ten years to find the AZ Unknown B source (Shackley 2005, 37–39).

Nevertheless, after working on Kamchatka for four years multiple sources of archaeological obsidian have been established. Seven of them are securely associated with 'geological' occurrences of volcanic glass from Cenozoic volcanoes. At least seven other sources, unknown so far, have been detected in the central and southern parts of the peninsula, and determination of their exact location is one of the major tasks for the future. The long-distance (more than 200km from source to site) procurement and exchange of obsidian on the Kamchatka Peninsula started quite early, in the late Upper Palaeolithic, ca. 14,000–10,000 BP. It continued throughout Kamchatkan prehistory, until the contact with Russians and other European and Asian powers. The exchange distances in the Neolithic and Palaeometal were up to 450–550km.

Kamchatka and the neighbouring region of Chukotka have good potential for volcanic glass source studies because of two factors: 1) a large number of prehistoric sites with obsidian (e.g., Dikov 1997, 2003; Kiryak 2010), and 2) their location on the suggested path of the final Pleistocene colonising populations that moved from Siberia and Northeast Asia toward North America. The identification of long-distance obsidian trade and/or exchange in Northeastern Siberia and adjacent Northwestern North America can provide unequivocal data about the direction and time of prehistoric human contacts and migrations between the Asian and American continents.

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Table 6.4. Number of obsidian sources used at Kamchatkan archaeological complexes

Site No.	Site/Cluster Name*	Obsidian Source(s)	Number of Sources Used
1	Lopatka Cape	KAM-01, 02, 04	3
2	Ozernovsky 1-4	KAM-01, 02, 07	3
3	Ozernaya River 1-2	KAM-01, 02	2
4	Lake Kurilskoe	KAM-02	1
5	Kekhta River	KAM-02	1
6	Ust-Kovran	KAM-01, 05	2
7	Kulki	KAM-01, 03	2
8	Palana-airport	KAM-03	1
9	Anadyrka 1	KAM-01	1
10	Inchegitun 1	KAM-03	1
11	Chimei	KAM-03	1
12	Galgan 1	KAM-03	1
13	Zeleny Kholm	KAM-03	1
14	Pakhachi	KAM-08	1
15	Vaimintagin	KAM-08	1
16	Lake Nerpichye	KAM-03	1
17	Kozlov Cape	KAM-04, 05	2
18	Lisy	KAM-02, 10	2
19	Zhupanovo (Cape Pamyatnik)	KAM-01, 09	2
20	Kopyto 1 (Zhupanovo River mouth)	KAM-01, 02, 09	3
21	Avacha Avacha River, lower stream Avacha River, animal farm	KAM-01, 03, 04, 05 KAM-01, 04 KAM-01, 06	4 2 2
22	ASK (Avacha 9) Severnye Koryaki airport	KAM-05 KAM-01, 07, 16	1 3
23	Plotnikova River (Lake Nachiki)	KAM-01, 02, 04, 05, 06	5
24	Lake Sokoch	KAM-02, 06, 11	3
25	Viluchinsk 1-5 Sarannya Bay Turpanka Bay	KAM-01, 02, 04, 11 KAM-01 KAM-01	4 1 1
26	Veselaya River	KAM-01	1
27	Anavgai	KAM-05, 10	2
28	Esso	KAM-10	1
29	Bolshoi Kamen	KAM-01, 02, 04	3
30	Karimshina River	KAM-01, 04	2
31	Elisovo 1-5 Nikolaevka	KAM-01, 02, 04, 05 KAM-01, 02	4 2
32	Ilmagan	KAM-05	1
33	Kluchi	KAM-03, 07, 10	3
34	Nikolka	KAM-01, 05, 10	3
35	Siyushk	KAM-01, 02, 07	3
36	Kozyrevsk	KAM-05, 07, 10	3
37	Penzhina	KAM-03	1
38	Ushki 1, 2, 5 (layers 6–7, Palaeolithic) Ushki 1, 2, 5 (layers 1–5, Neolithic)	KAM-01, 03, 05, 07, 10, 15 KAM-03, 04, 05, 07, 10, 14, 15	6 7
39	Kirpichnoe	KAM-01, 02, 04	3
40	Zastoichik	KAM-07, 10	2
41	Lake Domashnee	KAM-03, 05, 07, 10, 14	5
42	Kamaki	KAM-07, 10	2
43	Lopatka	KAM-02, 04	2
44	Yavino 2	KAM-01, 02	2
45	Doyarki	KAM-03, 05	2

*Site Nos. correspond to those on Figures 6.5–6.18.

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