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SOURCES OF ARCHAEOLOGICAL VOLCANIC GLASS IN THE PRIMORYE (MARITIME) PROVINCE, RUSSIAN FAR EAST*

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Geochemical studies of volcanic glasses (obsidians and perlites) from geological outcrops (N = 80) and archaeological collections (N = 110) were performed in order to determine source provenance in Primorye (Russian Far East), using neutron activation analysis and X-ray fluorescence spectrometry. Three major sources of archaeological volcanic glass were identified, two relatively local and one more remote. Several minor sources detected in the archaeological assemblage have not been located. This study suggests that long-distance obsidian exchange between Primorye and adjacent North-East Asia has existed since c. *10 000 BP.*

KEYWORDS: RUSSIA, FAR EAST, PRIMORYE, NORTH-EAST ASIA, PALAEOLITHIC, NEOLITHIC, EARLY IRON AGE, MIDDLE AGES, VOLCANIC GLASS, OBSIDIAN, PERLITE, GEOCHEMISTRY, INSTRUMENTAL NEUTRON ACTIVATION ANALYSIS, X-RAY FLUORESCENCE ANALYSIS, PROVENANCE, PREHISTORIC CONTACTS AND EXCHANGE

INTRODUCTION

Studies of volcanic glass geochemistry are of great importance to understanding the sources of raw material as well as inferring exchange and group interaction in the past (see, e.g., Carlson 1994; Shackley 1998a). In northeastern Asia, significant progress in this field has been achieved in Japan (see, e.g., Suzuki 1970, 1973; Ono 1984; Yamamoto 1990). In the continental Russian Far East, neighbouring China and North Korea (PDRK), tools and flakes made from high-quality volcanic glass (obsidian) have been found with high frequency in the prehistoric assemblages (cf., Kuznetsov 1996; Vasil'evski 1996, 1998). However, prior to the 1990s no attempts were made to identify the sources of archaeological obsidian in the vast region covering the

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Primorye (Maritime) Province and Amur River basin (Suslov 1961). As shown in Figure 1 (see inset), this region ranges from the vicinity of present-day Vladivostok to the area about 1200 km north of Vladivostok.

The aim of this paper is to establish the sources of archaeological volcanic glass in Primorye. The samples were collected by Popov and Kuzmin in 1992–7 from both archaeological collections and geological outcrops, and analysed by geochemical methods. Initial interpretation of data obtained was also made (Shackley *et al*. 1996; Popov and Shackley 1997; Kuzmin *et al*. 1999). In the past 25–30 years, the geology, petrology and geochemistry of volcanic glasses in Primorye have been carefully investigated (Popov *et al*. 1981; Popov 1986; Semenov 1987; Popov and Grebennikov 1997). The geological data have created a database allowing us to carry out interdisciplinary research on the sources of archaeological volcanic glass. In this paper, we present an up-to-date synthesis of the data.

MATERIALS AND METHODS

Samples of two volcanic glass types, obsidian (less than 1% of water content) and perlite (3–6% of water content), were collected from different geological structures in Primorye (Fig. 1). In the eastern Sikhote–Alin volcanic belt, stretching down the coast of the Sea of Japan, typical glasses are represented by rhyolitic perlites in association with Mesozoic and Palaeogene andesites and andesite–basalts (outcrops 1–8). In southern Primorye, rhyolitic obsidians are located near the base of Miocene–Pliocene andesite–basalt flows (outcrops 9–8). As a result of erosion of two major basalt plateaus, Shkotovo (occupying the Ilistaya, Partizanskaya and Arsenievka River headwaters) and Shufan (located on the right-hand bank of the Razdolnaya River), obsidian pebbles are concentrated in the river channels. In southwestern Primorye, volcanic glasses are part of the basalt–rhyolite Palaeogene rocks (outcrops 19–23). In addition, four samples of volcanic glass were obtained from the modern volcano Paektusan, located along the Chinese – North Korean border. In total, 80 samples of volcanic glass from 24 geological outcrops (including Paektusan) were collected.

Samples from archaeological collections were obtained for different chronological complexes, ranging in age from the Upper Palaeolithic to the Middle Ages (Table 1). The majority of sites derived from Palaeolithic (39%) and Neolithic (39%) contexts; the proportion of Early Iron Age and medieval sites is 22%. The sites are distributed from the northern part of the Primorye, the Samarga River basin, to the southwestern part, the Tumangan River mouth near the border of the junction of Russia, China and North Korea (Fig. 1). Upper Palaeolithic complexes of Primorye were dated to *c*. 20 000–11 000 radiocarbon years ago (BP), Neolithic complexes to *c*. 10 700–3000 BP, and the Early Iron Age and medieval complexes to *c*. 3000–800 BP (Kuzmin *et al*. 1994, 1998; Kuzmin 1995). In total, 110 obsidian artefacts from 36 archaeological sites were collected (Kuzmin and Popov 2000).

A geochemical study of volcanic glasses was conducted, mainly using two analytical methods, instrumental neutron activation analysis (INAA) at the Research Reactor Center, University of Missouri, and energy-dispersive X-ray fluorescence analysis (EDXRF) at the Archaeological XRF Laboratory, Phoebe Hearst Museum of Anthropology, University of California at Berkeley. Also, gravimetric analysis of volcanic glasses was performed at the Laboratory of Physical–Chemical Methods, Far Eastern Geological Institute.

The INAA method allows us to determine the concentrations of 27 elements, short-lived (Cl, Dy, K, Mn and Na), medium-lived (Ba, La, Lu, Nd, Sm, U and Yb) and long-lived ones (Ce, Co, Cs, Eu, Fe, Hf, Rb, Sb, Sc, Sr, Ta, Tb, Th, Zn and Zr), many with high precision. Details of the analytical procedure may be found in Graham *et al*. (1982). The EDXRF method was

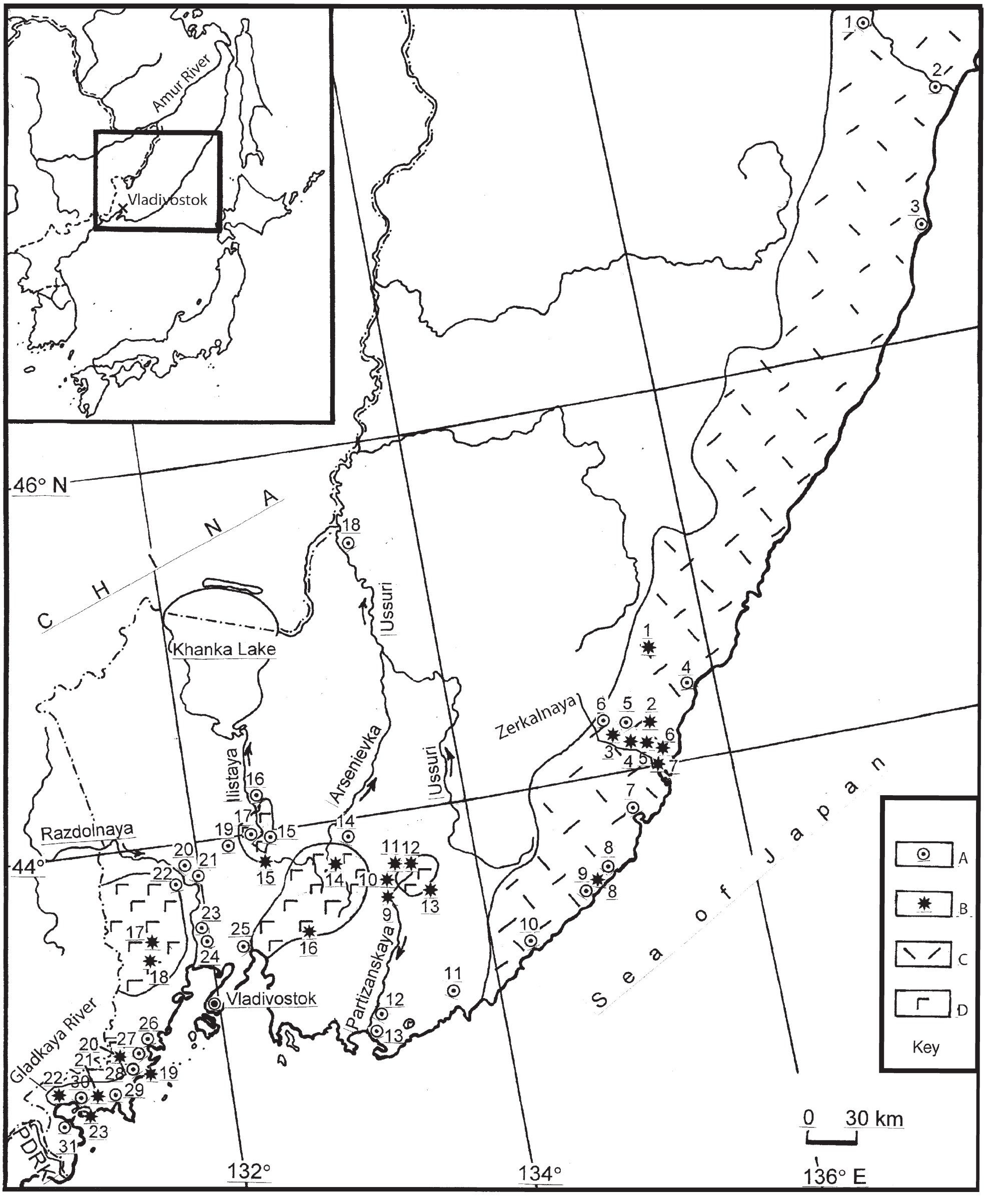

Figure 1 *The location of geological and archaeological sites sampled in this study of volcanic glasses. Key: A, archaeological sites; B, geological outcrops; C, eastern Sikhote–Alin volcanic belt; D, Basalt Plateau sources. Archaeological sites: (1) Samarga 5; (2) Samarga 2A; (3) Ust-Svetlaya; (4) Monastyrka 3; (5) Ustinovka 1, 3 and 4, Suvorovo 3; (6) Kentsukhe; (7) Sinie Skaly; (8) Eustaphy; (9) Phusun; (10) Valentin-peresheek; (11) Kievka; (12) Pereval; (13) Lebyazhya, Bulochka; (14) Anuchino 1; (15) Ivanovka, Gorelaya Sopka; (16) Firsanova Sopka; (17) Ilistaya 1; (18) Lesozavodsk; (19) Osinovka; (20) Gadychya Sopka; (21) Senkina Shapka; (22) Borisovka; (23) Razdolnoye; (24) Timofeevka 1; (25) Maikhe; (26) Chernaya Sopka; (27) Rybak; (28) Boisman 2; (29) Troitsa; (30) Gladkaya; (31) Khansi. Geological outcrops: (1) Nezhdanka, Yakut-Gora; (2) Bogopol; (3) Sadovaya River; (4–6) Brusilovka River basin—(4) Pad' Pryamaya, (5) Pad' Bogopolskaya Tropa and (6) Pad' Schmeidegir; (7) Sea of Japan coastal outcrops south of the Brusilovka River mouth; (8) Pad' Arsamasovskaya; (9–13) Partizanskaya River basin—(9) Sadovy Stream, (10) Kazenny Stream, (11) Chernaya Rechka, (12) Partizanskaya River headwaters and (13) Sergeevka River; (14) Arsenievka River basin; (15) Ilistaya River basin; (16) Steklyanukha River basin; (17) Nezhinka River basin; (18) Analievka River basin; (19) Klerk Peninsula (Ryazanovskoye Lake); (20) Ryazanovka River basin; (21) Vinogradnaya River basin; (22) Kraskino; (23) Krabbe Peninsula.*

Table 1 *The sources of archaeological volcanic glass found in Primorye Province**

Number	*Site name*	*Basaltic plateau*	*Gladkaya River*	*Paektusan*
Upper Palaeolithic				
1	Ustinovka 1	+		
2	Ustinovka 4	+		
3	Suvorovo 3	+		
4	Kentsukhe	+		
5	Ivanovka	+		
6	Gorelaya Sopka	+		+
7	Firsanova Sopka	+		+
8	Ilistaya 1	+		
9	Lesozavodsk	+		
10	Osinovka	+		
11	Gadychya Sopka	+		
12	Borisovka	+		
13	Razdolnoye		+	
14	Timofeevka 1	+		+
Neolithic				
15	Ustinovka 3	+		
16	Sinie Skaly†	+	+	
17	Eustaphy†			+
18	Phusun†	+		+
19	Valentin-peresheek†	+		
20	Kievka†	+		
21	Pereval			+
22	Senkina Shapka	+		
23	Maikhe†			+
24	Chernaya Sopka†		+	+
25	Boisman 2			+
26	Troitsa†	+		+
27	Gladkaya†			+
28	Khansi			+
Early Iron Age and Middle Ages				
29	Monastyrka 3			+
30	Lebyazhye	+		
31	Bulochka	+		
32	Anuchino 1	+		
33	Rybak			+

* The sites of Ust-Svetlaya, Samarga 2A and Samarga 5 (all of Early Iron Age), correspond to an unknown source and are not included.

† Zaisanovka culture site.

used to measure 14 elements, Ti, Mn, Fe, Ni, Cu, Zn, Ga, Pb, Th, Rb, Sr, Y, Zr and Nb, with varying precision depending on the element of interest (see Shackley 1998b). The amounts of the major oxides SiO_2, TiO_2, Al_2O_3, Fe_2O_3 and so on present were determined using gravimetric analyses (Kuzmin and Popov 2000).

Geochemical groupings, based on bivariate plots, cluster and discriminant classification analyses, were identified to reflect the main sources of archaeological volcanic glass. The details of the procedure are presented in Glascock *et al*. (1998).

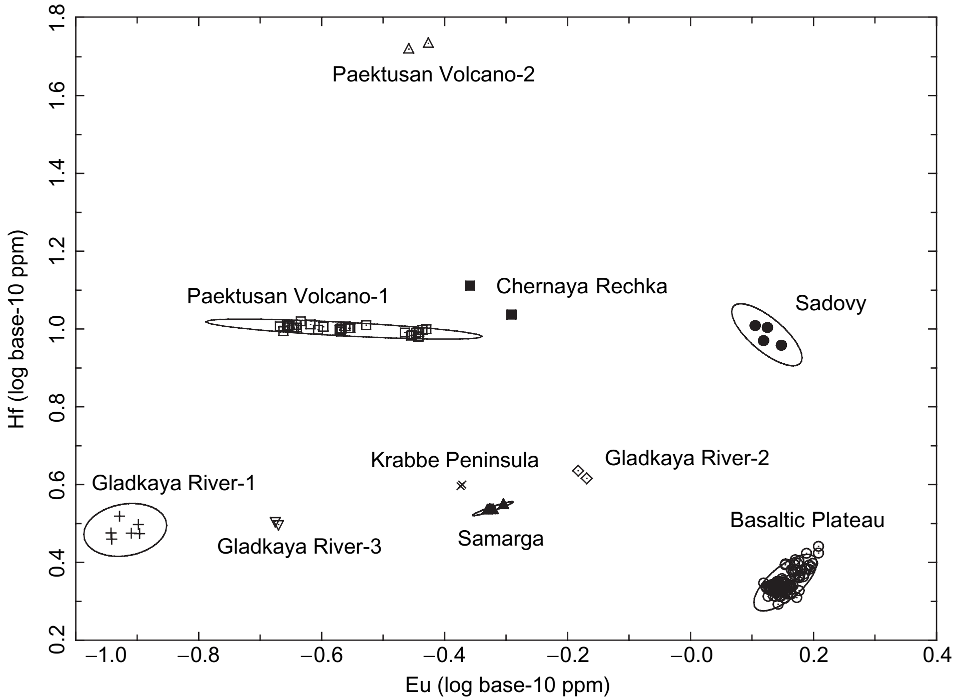

Figure 2 *An Eu–Hf logarithm plot showing chemical groups identified in obsidian source and artefact specimens from Primorye. Source ellipses are drawn at the 95% confidence level for groups containing at least four samples.*

RESULTS

Major sources of archaeological volcanic glass

Geochemical data for most of the geological and archaeological samples in this paper were reported earlier (Kuzmin and Popov 2000), but their impact on the archaeological interpretation of obsidian exchange in the Russian Far East is being presented here for the first time. As shown in Figure 2, grouping methods were used to identify groups of volcanic glass found in Primorye. Summary statistics for the ten different chemical groups identified in this study are presented in Table 2. The three main chemical groups include both geological and archaeological samples for the Basaltic Plateau, Paektusan Volcano-1 and Gladkaya River-1 sources. The Sadovy, Chernaya Rechka, Paektusan Volcano-2, Gladkaya River-2, Gladkaya River-3 and Krabbe Peninsula chemical groups consist of geological samples only, while the Samarga group includes only archaeological obsidian.

It seems that the three largest groups, incorporating both geological and archaeological samples, correspond to the primary sources of archaeological obsidian in Primorye (Table 1). The geological formations from which the volcanic glasses for these groups originate include (a) basalts of the Shkotovo and Shufan plateaus (Basaltic Plateau), (b) obsidians from the Paektusan Volcano and (c) rhyolites from the Gladkaya River basin. The perlites from the eastern Sikhote–Alin volcanic belt, represented by the Sadovy and Chernaya Rechka groups,

Table 2 *Element concentration means and standard deviations, measured by INAA in obsidian source groups from the Russian Far East; listed in ppm except where % indicated*

Element	*Basaltic Plateau (n = 57 artefacts + 40 source samples)*	*Paektusan Volcano-1 (n = 30 artefacts + 2 source samples)*	*Paektusan Volcano-2 (n = 0 artefacts + 2 source samples)*	*Gladkaya River-1 (n = 4 artefacts + 2 source samples)*	*Gladkaya River-2 (n = 0 artefacts + 2 source samples)*
Ba	123 ± 30	106 ± 35	36 ± 5	90 ± 12	926 ± 14
La	6.30 ± 0.98	67.7 ± 1.5	158 ± 1	25.7 ± 1.4	39.4 ± 0.8
Lu	0.24 ± 0.05	0.73 ± 0.06	1.60 ± 0.02	0.25 ± 0.02	0.193 ± 0.002
Nd	9.10 ± 1.83	49.1 ± 5.4	103 ± 1.3	13.1 ± 0.8	20.8 ± 1.9
Sm	3.63 ± 0.23	10.8 ± 0.4	25.6 ± 1.0	2.72 ± 0.06	3.11 ± 0.03
U	n.d.	7.16 ± 3.27	15.3 ± 0.2	4.07 ± 0.71	1.90 ± 0.31
Yb	1.37 ± 0.10	4.51 ± 0.31	10.0 ± 0.3	1.30 ± 0.02	1.02 ± 0.04
Ce	14.3 ± 2.0	137 ± 4	310 ± 9	46.5 ± 2.3	69.7 ± 0.8
Co	36.9 ± 1.5	0.28 ± 0.07	0.28 ± 0.03	0.17 ± 0.02	0.59 ± 0.02
Cs	0.23 ± 0.06	3.89 ± 0.15	5.26 ± 0.14	3.09 ± 0.06	2.23 ± 0.04
Eu	1.43 ± 0.07	0.28 ± 0.06	0.36 ± 0.02	0.12 ± 0.01	0.67 ± 0.02
Fe (%)	7.08 ± 0.26	1.08 ± 0.01	2.97 ± 0.16	0.53 ± 0.02	0.78 ± 0.01
Hf	2.23 ± 0.15	10.0 ± 0.2	53.3 ± 1.3	3.05 ± 0.15	4.23 ± 0.13
Rb	11 ± 3	236 ± 8	342 ± 5.9	97.3 ± 2.1	59.3 ± 0.1
Sb	n.d.	0.37 ± 0.03	0.45 ± 0.02	0.22 ± 0.02	0.112 ± 0.001
Sc	17.3 ± 1.1	1.10 ± 0.09	0.47 ± 0.13	1.50 ± 0.03	1.71 ± 0.03
Sr	381 ± 93	28 ± 6	n.d.	19.9 ± 1.5	485 ± 28
Ta	0.26 ± 0.07	6.75 ± 0.41	14.5 ± 0.5	1.54 ± 0.02	1.07 ± 0.02
Tb	0.74 ± 0.24	1.61 ± 0.12	3.79 ± 0.14	0.32 ± 0.02	0.29 ± 0.02
Th	0.77 ± 0.15	27.5 ± 0.8	45.1 ± 1.1	16.6 ± 0.4	12.3 ± 0.1
Zn	131 ± 32	85 ± 18	245 ± 13	22.4 ± 2.5	57 ± 6
Zr	94 ± 20	252 ± 11	1886 ± 5	106 ± 10	156 ± 8
Cl	90 ± 45	724 ± 63	2414 ± 100	379 ± 36	281 ± 60
Dy	3.71 ± 0.40	10.2 ± 0.8	22.8 ± 1.5	2.12 ± 0.35	1.64 ± 0.30
K (%)	0.40 ± 0.14	4.17 ± 0.29	3.64 ± 0.29	3.66 ± 0.09	2.36 ± 0.55
Mn	1097 ± 41	308 ± 5	554 ± 95	223 ± 3	381 ± 6
Na (%)	2.43 ± 0.13	3.06 ± 0.09	4.06 ± 0.02	2.64 ± 0.05	2.97 ± 0.34

and perlites from Palaeogene rhyolites in southwestern Primorye, represented by the Krabbe Peninsula, Gladkaya River-2 and Gladkaya River-3 groups, are not similar to any of the archaeological samples. There is no evidence that these types of volcanic glass were used by humans as raw material.

There are 23 archaeological sites with obsidian from the Basaltic Plateau source, distributed in the southern and central parts of Primorye (Fig. 1). The majority of sites correspond to the Palaeolithic period (57%), 30% to the Neolithic and 13% to the Early Iron Age and the Middle Ages (Table 1). Some sites are located next to the sources in the Ilistaya, Razdolnaya and Arsenievka River valleys in southern Primorye. Several obsidian pebbles were found during excavations in the Ilistaya River basin (Kuznetsov 1996), clearly showing that people collected pebbles of high-quality obsidian from river streams near the sites. In the Zerkalnaya River valley in central Primorye, Basaltic Plateau obsidian was found on four Upper Palaeolithic sites, located at a distance of 170–300 km from the source. Also, the Basaltic Plateau obsidian was found on several sites along the Sea of Japan, at distances ranging from 80 km to 160 km from the source.

Table 2 (*continued*)

Element	*Gladkaya River-3 (n = 0 artefacts + 2 source samples)*	*Krabbe Peninsula (n = 0 artefacts + 2 source samples)*	*Sadovy (n = 0 artefacts + 4 source samples)*	*Chernaya Rechka (n = 0 artefacts + 2 source samples)*	*Samarga (n = 2 artefacts + 3 source samples)*
Ba	262 ± 7	684 ± 14	762 ± 27	168± 10	533 ± 15
La	31.7 ± 0.3	39.2 ± 1.3	46.2 ± 2.3	59.2 ± 4.4	19.7 ± 0.3
Lu	0.22 ± 0.01	0.207 ± 0.001	0.54 ± 0.04	0.54 ± 0.01	0.26 ± 0.02
Nd	15.1 ± 0.6	28.4 ± 0.7	36.9 ± 1.8	38.7 ± 4.7	12.0 ± 0.7
Sm	2.62 ± 0.02	2.49 ± 0.03	7.16 ± 0.42	7.19 ± 0.20	2.46 ± 0.05
U	3.16 ± 0.21	3.55 ± 0.45	2.37 ± 0.77	4.37 ± 0.26	3.18 ± 0.07
Yb	1.14 ± 0.03	0.95 ± 0.02	3.78 ± 0.35	3.49 ± 0.29	1.43 ± 0.06
Ce	53.7 ± 0.2	63.0 ± 0.3	95 ± 6	113 ± 5	36.9 ± 0.7
Co	0.32 ± 0.01	0.86 ± 0.01	1.27 ± 0.20	0.72 ± 0.40	1.39 ± 0.03
Cs	2.68 ± 0.03	2.60 ± 0.01	5.40 ± 0.25	13.0 ± 0.9	4.73 ± 0.09
Eu	0.212 ± 0.002	0.424 ± 0.002	1.33 ± 0.06	0.48 ± 0.05	0.48 ± 0.01
Fe (%)	0.59 ± 0.01	0.82 ± 0.01	2.28 ± 0.16	2.01 ± 0.16	0.97 ± 0.02
Hf	3.17 ± 0.04	3.96 ± 0.02	9.67 ± 0.55	11.9 ± 1.4	3.45 ± 0.05
Rb	89 ± 1	92 ± 1	146 ± 30	180 ± 8	102 ± 2
Sb	0.17 ± 0.01	0.16 ± 0.02	0.48 ± 0.02	0.35 ± 0.05	0.16 ± 0.01
Sc	1.44 ± 0.01	1.65 ± 0.01	10.4 ± 0.3	11.3 ± 1.3	2.82 ± 0.05
Sr	39 ± 33	83 ± 21	224 ± 65	58 ± 10	250 ± 17
Ta	1.36 ± 0.02	1.05 ± 0.01	1.18 ± 0.08	1.11 ± 0.06	0.82 ± 0.02
Tb	0.29 ± 0.01	0.26 ± 0.01	0.99 ± 0.08	1.56 ± 0.45	0.31 ± 0.01
Th	16.3 ± 0.1	15.2 ± 0.3	10.7 ± 0.4	15.7 ± 1.0	8.8 ± 0.2
Zn	23 ± 3	22 ± 1	98 ± 10	96 ± 3	32 ± 5
Zr	115 ± 2	149 ± 1	369 ± 19	488 ± 69	132 ± 3
Cl	338 ± 23	263 ± 24	200 ± 21	277 ± 3	349 ± 29
Dy	1.82 ± 0.15	1.76 ± 0.32	6.65 ± 0.77	6.07 ± 0.09	1.88 ± 0.24
K (%)	3.68 ± 0.08	3.35 ± 0.35	2.42 ± 0.33	3.74 ± 0.71	2.98 ± 0.22
Mn	205 ± 7	209 ± 2	805 ± 203	564 ± 40	525 ± 4
Na (%)	2.67 ± 0.02	3.09 ± 0.05	3.72 ± 0.10	3.50 ± 0.15	2.92 ± 0.01

Three sites are associated with the source of archaeological volcanic glass in Primorye located in the Gladkaya River basin (Table 1). They correspond to the Palaeolithic and Neolithic complexes, and are situated from 30 km to 340 km away. The Gladkaya River sources were not widely used in prehistory, probably due to the poor quality of the rhyolite as a tool stone.

The third source of archaeological volcanic glass is located at the modern volcano Paektusan, where strata of pure obsidian are exposed in the caldera walls. There are 14 archaeological sites associated with the Paektusan source, mostly Neolithic (64%): the proportion recovered from Palaeolithic sites is 22%, and 14% of the obsidian from this source was recovered from Early Iron Age and Middle Age sites (Table 1). The distances between sites and source range from 200 km to 700 km (Fig. 3).

Thus, one can identify two kinds of archaeological volcanic glass sources in Primorye; local and more remote sources. Basaltic Plateau and Gladkaya River may be considered as local sources, and the Paektusan Volcano represents a remote source. The difference in distance from

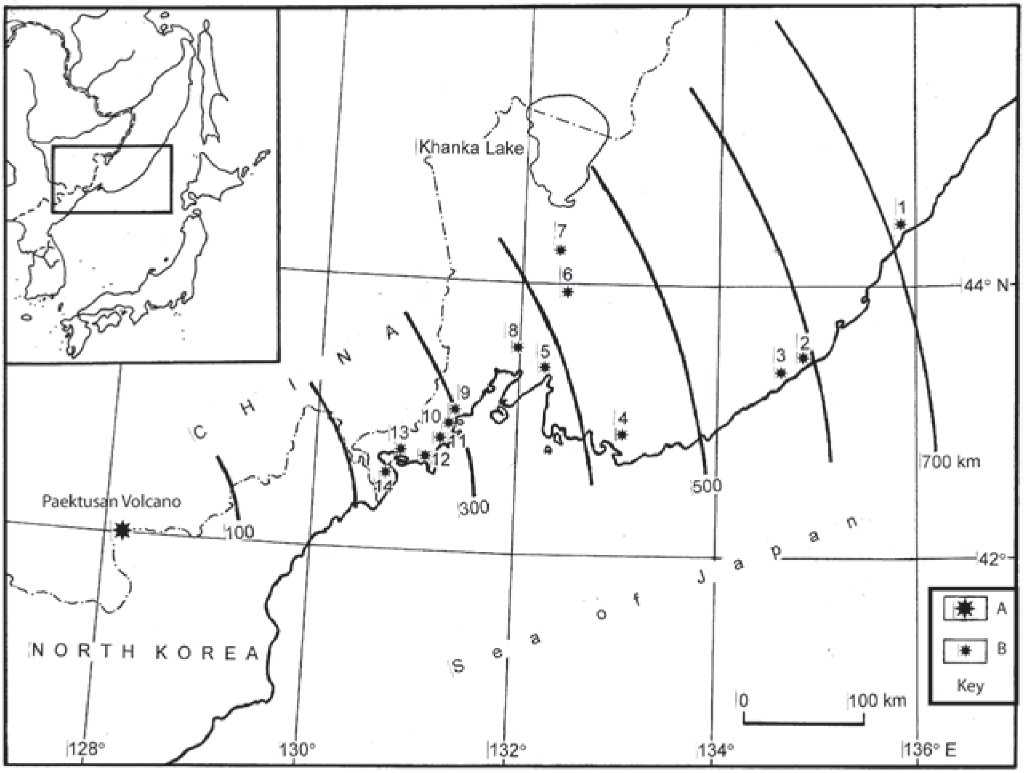

Figure 3 *The Paektusan Volcano source and remote archaeological sites with artefacts made from Paektusan obsidian (see Table 1). Key: A, Paektusan Volcano; B, Paektusan Volcano-related sites—(1) Monastyrka 3, (2) Eustaphy, (3) Phusun, (4) Pereval, (5) Maikhe, (6) Gorelaya Sopka, (7) Firsanova Sopka, (8) Timofeevka, (9) Chernaya Sopka, (10) Rybak, (11) Boisman 2, (12) Troitsa, (13) Gladkaya and (14) Khansi.*

source to sites for these two kinds is very clear; for local sources we suggest a distance of up to 300 km, while the remote source is located up to 700 km away.

Other possible sources of archaeological volcanic glass

Several of the archaeological obsidian samples comprise a separate group, which we named Samarga (Fig. 2). It includes the Samarga 2A, Samarga 5, Ust-Svetlaya and Ustinovka 3 sites, located mainly in the northern part of Primorye (Fig. 1). Because no similarity with any geological volcanic glass groups was determined (Fig. 2), the source of this type of obsidian is still unknown, and additional studies in the northern portion of Primorye are necessary in order to solve this question.

One archaeological obsidian sample from the Osinovka site (KU007C; see Kuzmin and Popov 2000) indicates a close compositional similarity to obsidian from the Akaishiyama and Horokazawa localities of the Shirataki source on Hokkaido Island, Japan (Kuzmin *et al.*, in press). This suggests the possibility of contact between Hokkaido and Primorye in prehistory, but additional study of the Osinovka source will be needed to determine the reliability of this hypothesis.

DISCUSSION

One of the most important questions concerning the study of Palaeolithic raw material in Primorye for a number of years has been the source of obsidian in the Zerkalnaya River basin. After an extensive study of volcanic glasses in the Zerkalnaya River basin and the surrounding vicinity, it is becoming clear that, in spite of the abundance of perlitic volcanic glass, prehistoric people never used it due to the low quality for tool manufacturing. Only high-quality obsidian, brought from the Basaltic Plateau region, was used in the Upper Palaeolithic and Neolithic by the Zerkalnaya River valley inhabitants. This was suggested earlier by Vasil'evski and Gladyshev (1989) on the basis of visual inspection, and is now confirmed by instrumental geochemical methods.

Most importantly, we can now infer that intensive exchange of high-quality raw material between Paektusan Volcano area and Primorye has existed since the terminal Upper Palaeolithic, *c*. 10 000 BP. Previously, there was no solid evidence of prehistoric contacts between Primorye and the neighbouring territory of the Korean Peninsula. Archaeological data (Andreev 1957; Okladnikov 1965; Nelson 1993) now indicate that such contacts occurred, especially in the Late Neolithic when the cultural complex, known in Primorye as Zaisanovka culture, existed in this part of North-East Asia. Many Primorye sites with Paektusan obsidian correspond to this culture (43%; see Table 1), and confirm the intensification of human contact along the Sea of Japan in the Late Neolithic, *c*. 5700–3000 BP. On the Korean Peninsula, extensive usage of the Paektusan obsidian in prehistory is also indicated, with distances from source to archaeological site ranging up to *c*. 400 km (Son and Shin 1991).

However, we still recommend caution when identifying the Paektusan source in archaeological contexts. Unfortunately, we have only four obsidian samples—brought from North Korea by Russian archaeologists in the 1970s—that are purportedly linked to the Paektusan Volcano. On the other hand, close geochemical similarity with numerous archaeological obsidian artefacts (30 samples; see Table 2) strongly suggests that the source of archaeological samples was Paektusan. The difficult political situation in northeastern Asia has not allowed collection of reliable samples of obsidian from the Paektusan caldera, but we expect to be able to do so in the near future.

A connection between Primorye obsidian and Korean sources was suggested earlier by Russian archaeologists (Vasil'evski and Gladyshev 1989, 101–2), based on INAA of 42 samples analysed by Japanese archaeologists in 1987 (see Kuzmin and Popov 2000, 158–9). However, only the elements Sm, U, Th, Hf, Sc, Fe and La were measured at that time.

Obsidian from two different sources has been identified on seven sites (19% of the total). They are from Palaeolithic contexts (Gorelaya Sopka, Firsanova Sopka and Timofeevka) and Neolithic contexts (Ustinovka 3, Sinie Skaly, Chernaya Sopka and Troitsa). Palaeolithic sites located near the rivers that drain the Shkotovo basaltic plateau suggest that the local Basaltic Plateau source could supply enough raw material for tool manufacturing. However, prehistoric people did not only exploit the local Basaltic Plateau source, but they also used obsidian from the more remote Paektusan source, indicating that the strategy in obtaining good quality raw material in prehistory was quite complex.

CONCLUSIONS

For the first time from the Primorye region, instrumental methods have been used to obtain reliable geochemical data to identify the sources of obsidian raw material. The geochemical study of volcanic glasses in Primorye indicates that three major sources of archaeological obsidian were utilized. Two sources located within the province of Primorye (with distance to sites up to *c*. 300 km) may be considered as local sources. A third source, the Paektusan Volcano (with distances to sites up to *c*. 700 km), is considered a remote source.

Importantly, prehistoric people in Primorye have used obsidian from the remote Paektusan source since the terminal Palaeolithic, and most actively in the Late Neolithic. Wide use of exotic obsidian from the Paektusan, along with local obsidian sources such as the Miocene–Pliocene basalts and rhyolites, is unquestionable evidence for intensive long-distance exchange of obsidian within Primorye and with adjacent territories of North-East Asia, beginning about 10 000 BP.

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