ДОБЫЧА ВУЛКАНИЧЕСКОГО СТЕКЛА В ПРИМОРЬЕ, ЕГО ПЕРЕМЕЩЕНИЕ И ИСПОЛЬЗОВАНИЕ

ACQUISTION AND MOVEMENT OF VOLCANIC GLASS IN THE PRIMORYE REGION OF FAR EASTERN RUSSIA

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INTRODUCTION

Geochemical techniques have been widely used in many parts of the world to link volcanic glass artifacts with their geological outcrops as the first stage in the study of prehistoric trading patterns. For example, studies by Kuzmin and his associates have used instrumental neutron activation analysis (INAA) and x-ray florescence (EDXRF) to trace the ancient distribution of glass artifacts in Far Eastern Russia (Shackley *et al*. 1996; Kuzmin *et al*. 1999; Kuzmin and Popov 2000; Kuzmin *et al*. 2002). Both these analytical methods measure the varying concentrations of elements in the volcanic glass. Bivariate plots of results combined with cluster and discriminate classification statistically differentiate geological outcrops (Kuzmin *et al*. 2002, 506—508). The geochemial signatures of 24 naturally occurring localities (outcrops) throughout the region were then compared to INAA and EDXRF studies of 110 artifacts from 36 widely distributed archaeological sites dated to the Late

Paleolithic (*c*. 20 000—11 000 BP), Neolithic (*c*. 10 700—3 000 BP), Early Iron Age and Medieval periods (*c*. 3 000—300 BP). Their results show that two local (Gladkaya River Basin and the Basaltic plateau, which is comprised of the Shkotovo and Shufan plateaus) and one distant (Paekutsan Volcano) sources of volcanic glass with good flaking properties were targeted and exploited (Figure 1). Furthermore, they argued that the use of volcanic glass from the remote Paekutsan Volcano at archaeological sites within the Primorye Region is evidence for long-distance exchange beginning as early as 10 000 BP.

Our new research applies the Proton Induced X-ray Emission and Proton Induced Gamma-ray Emission (PIXE-PIGME) technique (*cf* Summerhayes *et al*. 1998) to a suite of geological and archaeological samples in order to confirm and broaden the pioneering INAA and EDXRF analyses. The use of additional methods to strengthen and complement previous geochemical studies of volcanic glass is standard practice in archaeological science (e.g. Tykot 1998, 70). We have selected PIXE-PIGME for our archaeological research because it is a nondestructive technique that can be applied to rare and unusual artifacts. A preliminary attempt at Fission Track Dating of the basaltic glasses from Primorye was also made since this has been found useful in other contexts to assist with understanding when and how raw material sources could have been used in the past (e.g. Bonetti *et al*. 1998).

Our results substantiate the existence of long-distance movement of volcanic glass beginning in the Late Paleolithic and continuing into the Bronze Age. In addition, we found that volcanic glass was transported from a distant source into areas where it was already available. Temporal variation in the frequency of volcanic glass obtained from local and remote sources as well as changes in the diversity of sources provide tentative indications that different procurement and/or mobility strategies operated during the Late Paleolithic, Late Neolithic and Bronze Age of the Primorye region.

GEOLOGICAL SOURCES OF VOLCANIC GLASS

For a provenance study to be successful, according to Tykot (2003, 63), all relevant sources must be known, the sources must be characterised by their physical properties, variability within and between sources must be known, and differences should be measurable and statistically divergent. All such studies begin with basic geological research to locate the potential sources. The location of the major source areas of volcanic glass in southwestern Primorye is shown in Figure 1. In these regions volcanic glass occurs naturally in the form of basaltic glass, rhyolitic glass or perlites, each of which are associated with different geological formations (Kuzmin *et al*. 2002, 506). Basaltic glass can be found in the two Basaltic plateaux of Central Primorye (Shkotova and Shufan Plateaux). Perlites and rhyolitic glass, associated with Palaeogene basalt-rhyolites, are found in the Krabbe Peninsula and Gladkaya River Basin in Southern Primorye. Perlites are also found as part of the Sikhote-Alin volcanic belt in Eastern Primorye.

Within the Primorye Region, primary sources of volcanic glass in the form of geological outcrops are mainly associated with volcanic-tectonic depressions and calderas. But they can also be found within smaller structures such as extrusive domes, dykes, lava or pyroclastic flows (Kuzmin and Popov 2000, 161). When these geological features are eroded, blocks of volcanic glass are released. These can then be water-rolled and transported down waterways that drain the volcanic regions. The resulting redeposited cobbles are considered secondary sources of volcanic glass.

The location of the outcrops combined with the distance these cobbles travel downstream determines the size of the source locality, or the area in which humans could have obtained volcanic glass (Figure 1). Basaltic glass from the Shkotovo Plateau can be found in the Ilistaya, Partizanskaya and Arsenievka Rivers, while tributaries of the Razdolnaya River that drain the Shufan Plateau also yield obsidian (Figure 1). Tertiary dykes and small extrusive domes within the Gladkaya River Basin have been eroded so that cobbles and blocks from this source can be found in the Ryazanovka and Vinogradnaya Rivers (Figure 1).

Outside the region, rhyolitic glass (obsidian) is also found at the remote Paektusan Volcano on the border of China and North Korea and more than 300 kilometers to the southwest of Primorye (Figure 1).

SOURCE ASSESSMENT

The first step in an archaeological study of how people used volcanic glass in the past is to assess the properties of potential sources that influenced how people might have selected and worked the available material (Torrence 1986; Torrence *et al.* 1992; Bamforth 1990, 1992). The sampling locations from the three source localities described in this paper were assessed according to a series of variables that might have been relevant to their prehistoric use: (1) depositional context (water-rolled cobble, outcrop); (2) size of the available material; (3) quality of the material (flaking properties); (4) geological origin (basaltic glass, perlite, obsidian), (5) ease of extraction. The summary provided in Table 1 is based

Region	Location	Topography	Source Type	Extraction	Quality	Volcanic glass
Central Primorye	Outcrop 1, Krivoi Stream, Basaltic plateau	hill slope	outcrop	Hard	low-medium	basaltic glass
Central Primorye	Ilistaya River, Point B, Skhaya Stream, Basaltic plateau	stream bed	cobbles and boulders (10—25 cm)	Easy	medium-good	banded basalt glass
Central Primorye	Ilistaya River, Point R, Nikalaevka, Basaltic plateau	stream bed	small cobbles (5—8 cm)	Easy	medium-good	basaltic glass
Central Primorye	Ilistaya River, Point S, Otradnoe, Basaltic plateau	stream bed	small cobbles (5—8 cm)	Easy	medium-good	basaltic glass
Central Primorye	Ilistaya River, Point Z, Ivanovka, Basaltic plateau	stream bed	small cobbles (5—8 cm)	Easy	medium-good	basaltic glass
Southern Primorye	Krabbe Peninsula	hill slope, coast	outcrop	Moderate	low	banded perlite
Southern Primorye	Olenyi Stream, Vinogradnaya River Gladkaya River Basin	stream bed, dyke	small cobbles, outcrop	Moderate	medium-good	rhyolitic glass
Southern Primorye	Vinogradnya River Gladkaya River Basin	stream bed, dyke	small cobbles, outcrop	Moderate	medium	rhyolitic glass

Table 1 Description of the source areas assessed during this study

on previous fieldwork by geologists supplemented by a recent joint geological and archaeological field trip to the Shkotovo Plateau in 2001.

Beginning with the Basaltic plateau primary and secondary sources, we can see that there is considerable variability across the region, although the flaking quality of this glass source is generally quite good. For example, a preliminary analysis of cobbles along the Ilistaya River shows that cobble diameter declines with distance from the outcrop. This is important because the size of the cobble may influence the procurement strategy employed as it often dictates how the raw material can be reduced and what artifacts can be manufactured (Bamforth 1992, 132). For example, boulders up to 25 cm in diameter were observed in the stream bed at Point B. As Point B is still located in the volcanic belt, the cobbles have not experienced a great deal of water action (Figure 1). In contrast, at Point Z, approximately 50 km from the outcrop, the size of the available cobbles has been reduced to 5—8 cm in diameter. Furthermore, as large cobbles of reasonably good quality material are easily extracted from the stream bed near the outcrops, there may be no need to exploit the nearby outcrops. For example, volcanic glass from the Krivoi outcrop, located at the headwaters of the Ilistaya River, varies in flaking quality due to the inclusion of phenocrysts and is difficult to extract from within the basaltic flows, but there is an abundant source of relatively large volcanic glass cobbles in the adjacent stream.

The perlite outcropping on the Krabbe Peninsula has very poor fracturing properties and is moderately difficult to extract making its attractiveness as a source low. Similarly, the perlite from the Sikhote-Alin volcanic belt (Eastern Primorye) is also poor quality. In contrast, the volcanic glass available in the Olenyi stream and Vinogradnaya River and its tributaries (part of the Gladkaya River Basin) occurs as small dykes of medium to good quality material making it a suitable source of archaeological volcanic glass. As with the Basaltic plateau region, however, the stream cobbles may have been as good if not better as a source because they are easier to collect and have a wider spatial distribution.

The summary data in Table 1 shows that there is considerable variability in the physical characteristics of the source localities in the Primorye Region. It is likely that the geological constraints of the available material impacted on the ways that volcanic glass was procured and worked in the region. At present the comparison of the potential source localities is based on very general observations. A more comprehensive investigation of the source localities needs to be undertaken to quantify their similarities and differences.

GEOCHEMICAL ANALYSIS OF GEOLOGICAL SAMPLES

Geochemical analysis of geological sources of volcanic glass by Kuzmin and Popov (2000) identified ten distinct chemical sub-groups from three geological formations local to the Primorye region: Gladkaya River 1, 2 and 3; Basaltic plateau; Krabbe Peninsula; Sikhote-Alin volcanic belt —Sadovy, Chernaya Rechka, Samarage. The only distant sources were Paektusan Volcano 1 and 2. They concluded that as the geochemical analyses did not match any artifacts with glasses from the Sikhote-Alin volcanic belt, the Krabbe Peninsula, Paektusan-2 and the Gladkaya River 2 and 3, these geological formations were not used as sources in the past (Kuzmin and Popov 2000; Kuzmin *et al*. 2002, 509—510).

PIXE-PIGME is a non-destructive technique of a wide range that measures a range of elements over a short period of time using both Proton Induced X-ray Emission and Proton Induced Gamma-ray Emission analyses (Summerhayes *et al*. 1998, 134). During PIXE analysis, samples are irradiated by 3 MeV protons produced by an accelerator. As a result they emit x-rays that are characteristic of individual elements. These x-rays can be measured by a Si(Li) or High Purity Germanium detector which identifies the spectrum of the elements in the sample. PIGME analysis measures the energy produced when protons are charged. Charged protons create a nuclear reaction which results in the emission of high-energy x-rays (gamma rays) that can be measured by a lithium drifted germanium detector. As each element has a different energy, this can be used to quantify the elemental composition of volcanic glass. A «pinhole» filter is used to limit the intensity of the major elements making it easier to detect trace elements and discriminate the sources to a finer degree. Statistical analysis of the results using a series of multivariate techniques is used to identify the geochemical subgroups.

A total of 39 samples (Figure 1) from primary sources (outcrops, Figure 2) and secondary sources (river cobbles, Figure 3) were collected and characterized. Results from the PIXE-PIGME analyses support the initial groupings made by Kuzmin and Popov (2000) using Energy Dispersion X-Ray Fluorescence (EDXRF) and Instrumental Neutron Activation Analysis (INAA). Three source localities were defined in the Primorye Region: (1) basaltic glass from the Shufan Plateau (2) rhyolitic glass from the Krabbe Peninsula, (3) rhyolitic glass from the Gladkaya River Basin. In addition, a group of artifacts was identified as derived from the Paektusan Volcano on the basis of a comparison with the INNA data. The results are summarized in Table 2.

		Paektusan Volcano	Basaltic Plateau	Gladkaya River	Krabbe Peninsula
	N	**20**	**62**	**4**	**2**
F	Mean	1905	217	350	855
	SD	424	21	28	933
Na	Mean	2.68	2.23	2.32	2.34
	SD	0.02	0.03	0.02	20.5
Al	Mean	6.41	7.89	5.67	5.56
	SD	0.04	0.05	0.02	1.43
SI	Mean	35.63	21.75	37.81	29.65
	SD	3.7	1.61	3.14	4.66
K	Mean	4.32	0.61	4.55	3.49
	SD	0.09	0.05	0.08	0.09
CA	Mean	0.79	6.75	0.37	0.91
	SD	1.61	0.04	0.001	0.48
TI	Mean	1267	9594	442	1536
	SD	2261	1214	33	586
MN	Mean	420	1268	280	277
	SD	234	86	20	88
Fe	Mean	1.68	8.2	0.06	1.37
	SD	1.69	0.04	0.02	0.03
ZN	Mean	140	140	33	4261
	SD	0.06	0.08	0.01	0.06
RB	Mean	247	13	101	149
	SD	57	5	13	65
SR	Mean	31	313	11	57
	SD	58	40	3	49
Y	Mean	51	14	21	26
	SD	12	5	4	22
ZR	Mean	244	87	80	195
	SD	40	13	19	23
Pb	Mean	33	49	20	32
	SD	8	45	4	6

Table 2 Concentrations and standard deviations for elements measured by PIXE-PIGME. F, Ti, Mn, Rb, Sr, Y, Zr, and Pb are measured in parts per million (ppm) and Na, Al, Si, K, Ca, Fe are in percentages.

	Paektusan Volcano			Basaltic plateau		
Element	**PIXE**	**INAA**	**Ratio INAA/PIXE**	**PIXE**	**INAA**	**Ratio INAA/PIXE**
Fe	1.60	1.08	0.643	8.20	7.08	0.863
K	4.31	4.17	0.965	0.6	0.4	0.653
Mn	420	308	0.734	1269	1097	0.865
Na	2.68	3.06	1.140	2.23	2.43	1.087
Rb	247	236	0.956	13	11	0.845
Sr	31	28	0.909	313	381	1.215
Zn	140	85	0.609	139	131	0.940
Zr	244	252	1.031	87	94	1.078
Mean			0.873			0.943

Table 3 Comparison of the trace elements results from INAA (Kuzmin *et al.* 2002) and PIXE-PIGME analysis

As shown in Table 3, the mean values for eight elements shared in both the PIXE and INNA analyses (Kuzmin *et al*. 2002) show that the measurements for glass from the Paekutsan Volcano and the Basaltic plateau are highly comparable. The results show a close correspondence between the two approaches for the volcanic glass from Paektusan Volcano, particular for potassium (K), sodium (Na), rubidium (Rb) and scandium (Sc). A comparison of the results from Basaltic plateau, although not quite as closely related, shows that the measures of sodium (Na), scandium (Sc), manganese (Mn) and rubidium (Rb) are similar. Furthermore, these results show a high degree of discrimination in the varying amounts of trace elements in the two sources.

GEOCHEMICAL ANALYSIS OF ARCHAEOLOGICAL SAMPLES

Obsidian artifacts are commonly found in archaeological contexts throughout the Primorye Region (Korotky *et al*. 2003, 41). To measure changes in obsidian use and distribution within the Primorye Region, 76 artifacts from 15 archaeological contexts were characterized using PIXE-PIGME and compared to the geological samples (Table 4). These artifacts were selected from excavated sites in three

Site	Region	Paektusan (~kms)	Basaltic plateau (~kms)	Gladkaya River Basin (~kms)
Late Paleolithic				
Gorbatka 3	Central Primorye	450	0	200 (not used)
Ivanovka 1 and 2	Central Primorye	450	0	200 (not used)
Molodeznaya 1	Central Primorye	450	0	200 (not used)
Novovarvarivka	Central Primorye	450	0	200 (not used)
Risovaya 1	Central Primorye	450	0	200 (not used)
Tigrovaya	Central Primorye	450	0	200 (not used)
Timofeevka	Central Primorye	350	0	100 (not used)
Late Neolithic				
Valentin-peresheek	Eastern Primorye	550	70	300 (not used)
Zaisanovka 1	Southern Primorye	260	70	0
Zaisanovka 7	Southern Primorye	260	70	0
Zara 1-A, 1-C	Eastern Primorye	530	60	260 (not used)
Bronze Age				
Anuchino 14	Central Primorye	450	0	200
Kievka	Eastern Primorye	470	40	210
Sinie Skaly	Eastern Primorye	630	130	370
Zara 3	Eastern Primorye	530	60	260

Table 4 Approximate distances from source localities to archaeological site locations

geographic regions (Southern, Central and Eastern Primorye) and are dated to three archaeological periods (Late Paleolithic, Late Neolithic and Bronze Age). The location of the sites studied is given in Figure 4.

The approximate distances from the source areas that volcanic glass was potentially being transported during each of these periods in presented in Table 4. This comparison is limited by the lack of sites in some of the regions for various time periods. However, the data given in Table 4 does show that volcanic glass, and especially obsidian from the Paekutsan Volcano, had been moved, often over considerable distances. Furthermore, the simple comparison of the frequency of artifacts from remote and local sources in the different archaeological periods presented in Figure 5 shows a significant increase in the proportion of material from the remote Paekutsan Volcano during the Late Neolithic.

Analyses by PIXE-PIGME of volcanic glass artifacts from fifteen archaeological locations indicate the changing use and transportation of the volcanic glasses through the prehistoric period in Primorye.

Late Paleolithic (c. 20 000—10 000 BP). A total of 28 artifacts from Late Paleolithic sites were analysed from 7 sites located in the Basaltic plateau of Central Primorye (Table 5). Most of the artifacts came from local Basaltic plateau

Late Paleolithic	Basaltic plateau	Paektusan	Total
Sites			
Gorbatka 3	3		3
Ivanovka 1 and 2		1	1
Molodeznaya 1	4	2	6
Novovarvarivka	1	1	2
Risovaya 1	2	3	5
Tigrovaya	10		10
Timofeevka	1		1
Artifact Types			
Microblade	2		2
Microcore		1	1
Flake	11		11
Drill	1		1
Burin	1	1	2
Blade-like	1	1	2
Retouched flake		1	1
Retouched blade		1	1
Blade	5	2	7

Table 5 Comparison of the sourced artifacts and artifact types found in the Late Paleolithic

sources (n=21, 75%). However, the proportion of obsidian sourced to the remote Paektusan Volcano shows that a significant number were imported from a considerable distance (n=7, 25%). The artifact types indicate that both local and non-local sources were used in blade manufacture, but a wider variety of tool types were made from the local sources (Table 5).

Late Neolithic *(c. 5 700—3 000 BP)*. The Late Neolithic Period is represented by 24 artifacts from only 3 sites which are all located on the coast (Table 6; Fig-

Late Neolithic	Basaltic plateau	Paektusan	Total
Valentin-peresheek	3		3
Zaisanoka 1		15	15
Zaisanoka 7		1	1
Zara 1-A, 1-C	5		5
Artifact Types			
Microblade	2		2
Flake	2	10	12
Endscraper	3		3
Arrowhead	1		1
Blade-like		5	5
Retouched blade		1	1

Table 6 Comparison of the sourced artifacts and artifact types found in the Late Neolithic

ure 1) At Zaisanoka 1 and 7 in Southern Primorye, only obsidian from the Paektusan Volcano was represented in our sample, whereas only glass from the Basaltic plateau was transported to Eastern Primorye (Valentin-peresheek, Zara 1-A and 1-C).

Within the sample as a whole, the frequency of volcanic glass from the remote Paektusan Volcano is much higher (n=16, 66.6%) than the local basaltic glass (n=8, 33.3%). Obsidian from Paektusan Volcano was found within the Late Neolithic contexts at Ustinovka 3 indicating that it was moved a distance of ~670 km from the source locality (Kuzmin *et al.* 2002, 513; Fig. 2).

Most of the blades or blade-like flakes in our samples are sourced to the Paektusan Volcano. In contrast, a variety of flakes types were made from the local material. These differences in the use of the local and remote may be an indication of the development of specialization and exchange networks. The increase in the proportion of obsidian from Paektusan Volcano during the Late Neolithic was also identified by Kuzmin *et al.* (1999, 98) who proposed that it was related to the development of the Zaisanovka Culture. This cultural complex is defined by the present of a zig-zag ceramic motif which is thought to have originated in North Korea and spread along the coast of Primorye (Cassidy *et al.* in press).

Bronze Age (3 500 BP). With the exception of Anuchino 14 (Cassidy and Kononenko 2001; Figure 1), the Bronze Age sites in our sample are predominately coastal. The PIXE-PIGME results for 20 artifacts indicate that a wider diversity of sources were used in the Bronze Age than in previous periods (Table 7). Volcanic glass from

Bronze Age	Basaltic plateau	Paektusan	Gladkaya River Basin	Unknown	Total
Anuchino 14	5				5
Kievka	3				3
Sinie Skaly	3	1	1	1	6
Zara 3	1	4		1	6
Artifact Types					
Retouched knife	1				1
Retouched flake	3	1			4
Retouched blade	1				1
Retouched arrowhead	1	1		1	3
Flake	4	3	1		8
Blade	1			1	2
Biface	1				1

Table 7 Comparison of the sourced artifacts and artifact types found in the Bronze Age

the Gladkaya River basin was identified in an archaeological context for the first time. At Zara 3 three sources of obsidian were identified with most originating from the Paektusan Volcano. Similarly, at Sinie Skaly four sources, including an unknown source, were used. Obsidian from the Southern Primorye region was transported ~370 km to Sinie Skaly, while material from the Paektusan Volcano was transported ~640 km. There is a major difference with the previous Late Neolithic period because the frequency of local sources is higher in the assemblages (n=15, 75%) then the volcanic glass artifacts from the remote Paektusan Volcano (n=5, 25%). Most of the retouched artefacts are derived from Basaltic plateau glass, whereas the retouched arrowheads come from three different sources (Table 7).

FISSION TRACK DATING

A preliminary study using Fission Track Dating of volcanic glasses was also made since it is important to know when the glasses were formed. For example, in dealing with young glasses, it is possible to monitor how differences in the way these were exploited for use or trade are related to the age of the formation of the deposits themselves. In addition, some archaeologists have found that fission track dates on artifacts can be used to discriminate among geological sources of different ages (Bonetti *et al.* 1998).

The results of Fission Track Dating on basaltic glasses derived from the Basaltic Plateau region of Primorye is presented in Table 8. The method which

Sample	Source	Spontaneous track density	Induced track density	Age (Ma)
3110	Ilistaya River	214±18	1 467±67	9.8±1.0
3111	Ilistaya River	193±27	1 172±118	11.2±2.2
P-501/2	Chernyatino	124±13	2 000±213	3.97±0.65
P-515	Neginka River	130±19	1 619±213	5.74±1.26

Table 8 Results for fission track dating of basaltic glasses of Primorye Province. Results for fission track dating of basaltic glasses of Primorye Province. The induced track densities are normalized to a standard neutron fluence of 1015 n/cm²**

is described in more detail in Fleischer and Price (1975), Durrani and Bull (1987), and Bonnetti *et al.* (1998), is based on studying and counting latent and induced fission tracks which are created on the sample by etching with a strong acid and bombarding with a known thermal neutron fluence provided, in our case, by the TRIGA Mark II Reactor of the LENA laboratory at the University of Pavia, Italy.

Dating the basaltic glasses in Primorye turned out to be a difficult procedure because the method requires a transparent sample in order to detect the fission tracks, but this material is very opaque. Moreover, it turned out that such material was very Uranium poor, i.e. 2—3 orders of magnitude less than typical rhyolitic obsidians. The results presented in Table 1 show two groups of ages which correlate with two different regions. The fission track data indicate that volcanic glasses from the Shufan Plateau belong to volcanic eruptions of Pliocene age, whereas the volcanic glasses from Shkotovo Plateau, located within the Pravaya Ilistaya River Basin, are associated with a Late Miocene stage of volcanic activity. From an archaeological point of view, the age of the basaltic glasses is clearly well beyond the age of human presence. Consequently, they would have represented highly stable resources during the time when ancient humans occupied the region.

DISCUSSION AND CONCLUSIONS

Since different geological source localities of volcanic glass have a unique trace element composition, individual artifacts can be linked directly to the source. This makes volcanic glass an ideal raw material for examining changes in procurement strategies and mobility patterns of prehistoric societies (Roth 2000, 305—306). Along these lines, our preliminary study of geological sources and archaeological material from Primorye has revealed interesting chronological changes in the use of distant and local sources and in the form of the artifacts made from these sources.

The movement of material into the Primorye region from the distant Paektusan Volcano, beginning during the Late Paleolithic and continuing onwards, has been viewed as «unquestionable evidence for intensive long-distance exchange of obsidian» (Kuzmin *et al.* 2002, 514). Although our study confirms that volcanic glass was transported over extensive distances, the actual mechanism behind this movement must remain open to discussion. Without a detailed assessment of the source localities, a typological and technological analysis of the assemblages, or a systematic study of spatial patterning and fall-off with distance, one cannot yet distinguish between exchange and mobility as the mechanism for the movement of obsidian, nor for concrete differences between the various periods.

The mechanism of exchange may be inferred from the composition of the archaeological assemblage. For example, if exhausted or broken specialized tools are sourced to only one location, than they are more likely to have been exchanged than transported within a mobility pattern (Roth 2000, 306—307). In contrast, if local and non-local sources were used in the same way, stone was probably obtained through direct procurement. By examining our data in this light, we can see that during the Late Paleolithic both sources were used in the same way. In contrast, during the Late Neolithic blade production was generally from made from obsidian derived from the Paektusan Volcano, suggesting that exchange may have taken place. These results only hint at the potential variability that could occur in the procurement and mobility strategies that developed in the Primorye Region. To explore these patterns further, a larger sample of the glass artifacts needs to be characterised in conjunction with a detailed technological and spatial analyses of the assemblges.

Within the Late Neolithic the development of the Zaisanovka Culture has been observed throughout North-East Asia Cassidy *et al.* in press). At this time there was an intensification in the sphere of human interaction along the Sea of Japan, including Korea. The influx of rhyolitic glass from Paektusan Volcano into Southern Primorye in this period may be the result of a greater degree of human interaction over a wider area. In particular, the presence of blades and blade-like flakes in the assemblages from Paektusan Volcano tentatively suggests that exchange may have been the primary mechanism of movement from this source locality into the Primorye region during the Late Neolithic.

During the subsequent Bronze Age, our data exhibit a wider diversity of sources being exploited and being moved along the coast. It has been proposed that at this time complex agricultural societies from the Northeast of China were moving into the Primorye Region along the coast. However, an alternative explanation is that there was an *in situ* sudden shift from a saltwater marine based economy to a dependence of freshwater resources which was driven by climatic conditions (Cassidy and Kononenko 2001, 142).

It has been suggested that the reason obsidian from Paektusan Volcano moved into the Basaltic plateau, an area where plentiful in volcanic glass sources are readily available, was because the local sources did not provide enough good quality material (Kuzmin *et al.* (2002, 513). Preliminary fieldwork conducted in 2001 by some of the authors of this paper suggests that this hypothesis is no longer tenable. The team found abundant quantities of useable volcanic glass river cobbles in a number of places (cf. Table 1), but a more thorough geoarchaeological survey of the source localities should be undertaken to determine in more detail how their physical characteristics may have influenced the way they were used in the past. This type of assessment has been undertaken successfully in the Mediterranean, Papua New Guinea, Australia and Northwestern Mexico (e. g. Tykot 2001; Torrence 1986; Torrence *et al.* 1992; Doelman *et al.* 2001; Shackley 1998).

In conclusion, our preliminary study confirms the importance of geochemical methods, and in particular the PIXE-PIGME technique, to characterise geological sources and archaeological artifacts in the Primorye region of Far East Russia. The analyses reported here also highlight some potentially important changes in the use and transport of several types of volcanic glass. The research has also identified a number of avenues for further investigation. The potential mechanisms which created the long distance movement of volcanic glass (e.g. exchange verses mobility) need to be examined more rigorously. In future work a detailed geoarchaeological survey of the source regions combined with typological, technological, and spatial analyses of the assemblages are essential. These approaches, in combination with further geochemical studies to enlarge the sample size of characterised artifacts, should provide the necessary information for better understanding the societies who procured, transported and worked volcanic glass in the Primorye Region.

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РЕЗЮМЕ. Данная статья группы авторов посвящена предварительной геологической и археологической оценке нескольких источников вулканического стекла (обсидиана) в Приморье и их использованию в течение трех исторических периодов.

Рассматриваются четыре источника вулканического стекла, включающие в себя: а) базальтовое стекло Шкотовского и Шуфанского плато, составляющие базальтовое плато Центрального Приморья; б) перлитовое и риолитовое стекло из двух источников Южного Приморья — полуострова Краббе и бассейна р. Гладкой; в) риолитовое стекло с вулкана Пектусан, располагающегося на границе Китая и Северной Кореи. Предварительная геологическая и археологическая оценка этих источников учитывала такие факторы, как геологическое происхождение и характер залегания вулканического стекла, степень доступности для добычи и размеры сырьевого материала, его качественные характеристики, обусловливающие способность к раскалыванию (табл. 1).

Геохимический анализ 39 образцов, отобранных непосредственно в выходах на поверхность источников сырья (первичные источники) и в речных отложениях (вторичные источники, представляющие собой речной галечник), был выполнен с использованием PIXE-PIGME

(Proton Induced X-Ray Emission / Proton Induced Gamma Ray Emission) техники. Преимущество этого метода заключается в том, что он позволяет идентифицировать пропорцию геохимических элементов в геологическом образце, или артефакте, не подвергая последние какому-либо разрушению. Результаты анализа показали геохимическое различие трех источников, подтверждая данные предшествующих анализов, выполненных с использованием других техник и методов (EDXRF, INAA) (табл. 3).

PIXE-PIGME техника была также использована для изучения 76 артефактов с 15 археологических памятников, располагающихся в Южном, Восточном и Центральном Приморье и хронологически охватывающих периоды позднего палеолита, позднего неолита и эпохи бронзы.

Для изготовления 28 артефактов с позднепалеолитических (12 000 л.н.) стоянок, располагающихся в районе Базальтового плато, в основном использовалось местное базальтовое стекло (75%). В то же время 25% артефактов было сделано из обсидиана с вулкана Пектусан, отдаленного от района стоянок на 450 км (табл. 5).

Поздненеолитические артефакты (16 образцов) со стоянок Южного Приморья (5 700—3 000 л.н.) были изготовлены из обсидиана вулкана Пектусан (расстояние 260 км). Например, поздненеолитические артефакты Центрального и Восточного Приморья (8 образцов) были сделаны из местного базальтового стекла). Более того, морфологически артефакты из обсидиана Пектусана представлены в основном пластинами и пластинчатыми отщепами, в отличие от отщепов из местного сырья.

Артефакты эпохи бронзы (3 500 л.н.) в основном соотносятся со стоянками, располагающимися в Восточном Приморье (15 образцов). Среди проанализированных образцов 7 связаны с местными источниками Базальтового плато, 5 принесены с Пектусана, один образец происходит из источников р. Гладкой. Для двух образцов источники пока не идентифицированы.

Эти предварительные результаты показывают, что вулканическое стекло в древности распространялось и переносилось на значительные расстояния. Пока не совсем ясно, являлось ли данное перемещение сырья для каменных орудий результатом обмена между первобытными коллективами или оно было связано с мобильным образом жизни охотников и собирателей, переносивших с собой набор заготовок и орудий в новые места обитания? Мы предполагаем, что оба способа могли быть применены в разные хронологические периоды. Например, использование обсидиана с вулкана Пектусан для производства пластин в эпоху позднего неолита дает основание полагать, что этот материал попадал в Приморье посредством обмена. Для более глубокого понимания роли обмена и мобильного образа жизни в различные культурно-хронологические периоды древней истории Приморья необходимо дальнейшее, более детальное химическое изучение вулканического стекла из источников и артефактов со стоянок совместно с технологическим, типологическим и пространственным анализом всех данных.