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REMAINS OF A PUZZLE: THE DISTRIBUTION OF VOLCANIC GLASS ARTIFACTS FROM SOURCES IN NORTHEAST CHINA AND FAR EAST RUSSIA

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Previous geochemical studies of volcanic glass artifacts dating to the Late Palaeolithic in northeast Asia have revealed a wide distribution of artifacts from sources in China, Korea, and Far East Russia. Through an analysis of lithic technology, this study sheds new light on the variety and complexity of the social, technological, and landscape factors that shaped the long distance movement of stone artifacts.

KEYWORDS: *volcanic glass, exchange, northeast Asia, artifact distribution*

Understanding how raw materials were procured, worked, and moved across the landscape is pivotal to discerning the complex ways in which hunter-gatherers have successfully colonized and settled into new environments. Recent geochemical characterization studies in northeast Asia show that volcanic glass artifacts derived from a number of sources were widely distributed during the Late Palaeolithic (Doelman et al. 2008; Glascock et al. 2006; Jia et al. 2010, 2012; Kim et al. 2007; Kuzmin 2006, 2011; Kuzmin and Popov 2000; Kuzmin et al. 1999, 2000, 2002a, 2002b, 2008; Phillips and Speakman 2009; Popov et al. 2005a, 2005b; Speakman et al. 2005). Artifacts from Paektusan Volcano (Figure 1) were transported up to 800 km into the Primorye region of Far East Russia (FER) as finished microblades, microblade cores, and retouched tools (Doelman et al. 2008). Understanding the mechanisms behind the distribution of volcanic glass artifacts in the region, however, has been hampered by a lack of information about how raw material was acquired, produced, and used at sites near the Paektusan Volcano itself. Furthermore, geochemical studies have only recently identified that volcanic glass artifacts from the Shkotovo Plateau in FER (Figure 1) were also dispersed widely during the Late Palaeolithic (Doelman et al. 2008; Jia et al. 2010; Popov et al. 2006). The aim of this paper is to compare and contrast the ways in which material derived from these two major volcanic-glass source areas, as well as glass from two other minor geochemical sources, was dispersed throughout northeast Asia. The results raise important issues about the multiple ways that hunter-gatherer groups acquired, used, and discarded volcanic glass during the Late Palaeolithic.

BEYOND MODERN POLITICAL BOUNDARIES

Cores, tools, and debitage relating to microlithic technology are a major component of Late Palaeolithic assemblages found throughout the extreme northern environs of northeast Asia. The widespread use of this technology suggests that the use of composite tools with inset microblades made highly successful hunting tools. In northeast Asia, microblades made from specialized, wedge-shaped cores were used as projectile points for hunting weaponry (e.g., Elston and Brantingham 2002: 104). These tools have the advantages of being easily transportable, strong, and lethal. Moreover, they can be maintained using standardized replacement parts so they are easily repaired and ready when needed (Doelman 2008; Doelman et al. 2009; Elston and Brantingham 2002: 105). Additionally, microblade technology enabled hunter-gatherers to be highly mobile (Goebel 2002: 127) and could help limit risk when

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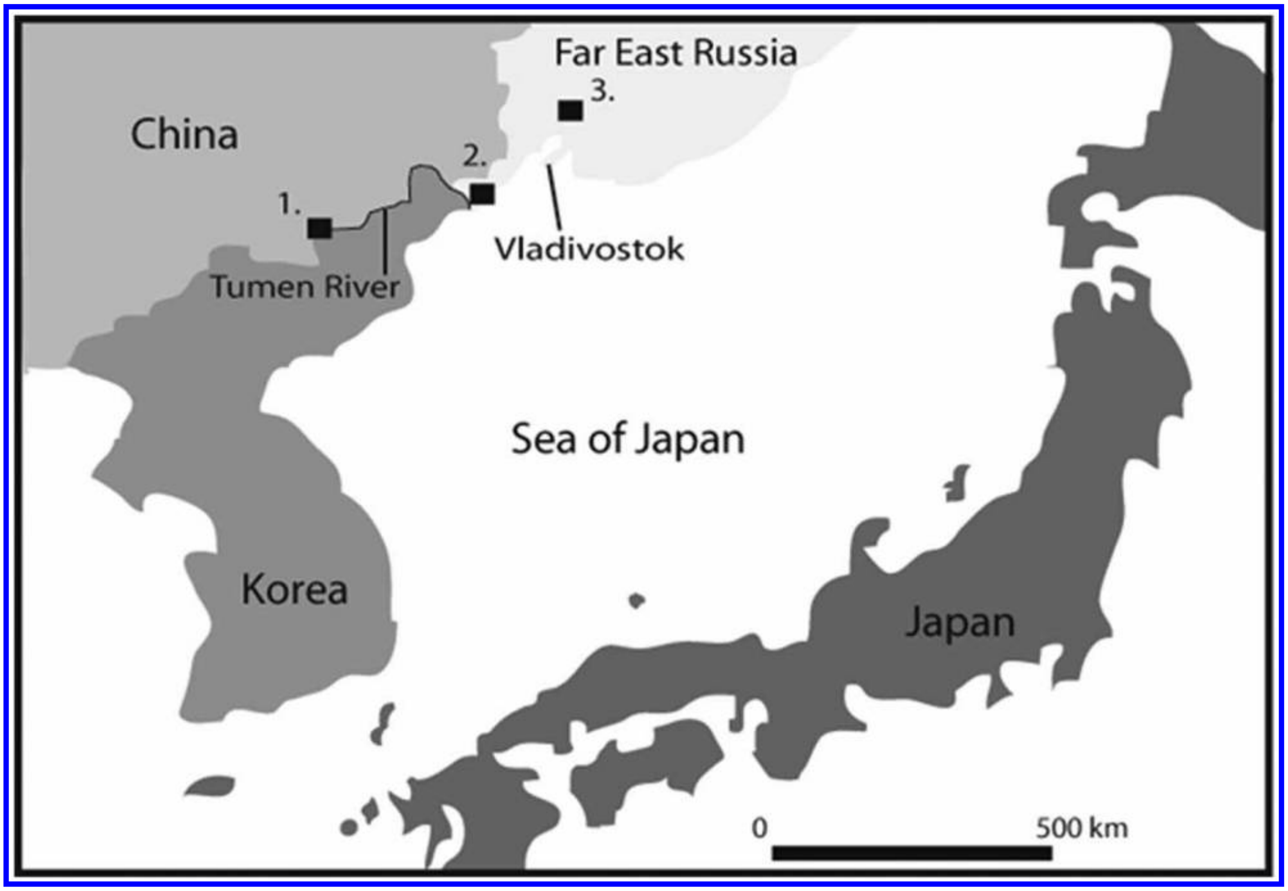

FIGURE 1. Location of the major sources of Late Paleolithic volcanic glass assemblages. 1. Paektusan Volcano, 2. Gladkaya River Basin, 3. Shokotovo Plateau.

exploring and colonizing new environments (e.g., Hiscock 1994). Volcanic glass was favored for microblade manufacture because its extremely thin, sharp edges inflict considerable damage on impact, and help to reduce the risk of failing to acquire adequate subsistence resources (Doelman et al. 2009). Consequently, high quality and abundant volcanic glass sources must have been highly sought after. For example, in central Primorye, FER, few microblade cores of other local material types occur in sites located close to sources of volcanic glass (Coutouly and Axel 2007: 85).

To accurately reconstruct social networks and patterns of past land use suggested by the long-distance movement of volcanic glass artifacts, archaeological studies in northeast Asia must cross modern political boundaries. To achieve this goal, this paper brings together data from two independent international collaborative projects focused on the procurement and distribution of volcanic glass in FER and northeast China (NEC). Combining data from these studies makes it possible to evaluate the ways in which volcanic glass from different geochemical sources was transported across long distances during the Late Palaeolithic.

The FER assemblages, consisting of 1,871 artifacts from 24 sites, have been characterized to two major source regions (basaltic glass from the Shokotovo Plateau and rhyoltic glass from Paektusan Volcano, Figure 1, Table 1) by a combination of Instrumental Neutron Activation Analysis (INAA), PIXE-PIGME, and relative density (Doelman et al. 2008; Kuzmin 2011; Kuzmin et al. 2002a, 2002b, 2008).

The analyses presented also include data for 441 artifacts from 19 Late Palaeolithic sites in NEC. These artifacts were characterized using a Bruker AXS Tracer-III-V, portable handheld X-ray Fluorescence Spectrometer (PXRF) (Jia et al. 2010). Prior to this, only a small number of artifacts from sites in NEC had been geochemically analyzed using PIXE-PIGME (Chen et al. 2005). The results of our larger sample of NEC artifacts show that artifacts derive from at least four sources (Figure 1, Table 1), including two located in FER (Jia et al. 2010).

TABLE 1. RESULTS OF GEOCHEMICAL STUDIES BASED ON (DOELMAN ET AL. 2004; JIA ET AL. 2010, 2012)

	FER		NEC		
	Count	%	Count	%	Totals
Paektusan Volcano (Group A)	153	8.2	409	93	562
Shkotovo Plateau	1718	91.8	8	2	1726
Group C			19	4	19
Group D			5	1	5
Total	1871	100	441	100	2312

The independent FER and NEC studies have identified that artifacts derived from four sources of volcanic glass were moved over relatively long distances within and between the two regions (Doelman et al. 2008; Jia et al. 2010, 2012). Three of these sources provide rhyolitic obsidian: (1) Paektusan Volcano on the border of North Korea and China; (2) as-yet unconfirmed localities believed to be in the Gladkaya River Basin in FER; and, (3) an unknown source location that may be in China. The remaining source area is (4) the Shokotovo Plateau in FER, where basaltic glass is available from several localities (Figure 1). Both studies combine the geochemical results with technological, typological, and metric attributes of individual artifacts, as well as with macroscopic raw-material characteristics such as color and quality of raw material (Table 2).

In order to trace how artifacts from these four volcanic glass sources were distributed, we (1) examine the geological context of the source areas, (2) discuss the nature and quality of the raw materials that were selected and transported, (3) compare the technological and metric characteristics of assemblages discarded close to their original sources (<200 km) with those discarded at greater distances (>200 km), and (4) view the locations of sites with each of the source groups. The combined analyses provide us with a way of

TABLE 2. VARIABLES USED TO COMPARE THE VOLCANIC GLASS ASSEMBLAGES IN FER AND NEC

1. Source Information		
Type of cortex	Quarried outcrop exploited or use of secondary sources	
Material quality	Influences selection, manufacture, distance transported.	
2. Assemblage Composition		
	Frequency of cores, complete and broken flakes, tools	
	Frequency of artifacts related to microblade technology	
3. Indicators of Degree of Reduction		
Size	Axial length of complete flakes, maximum block dimension of cores, length and width thickness of blades	
Cortex	% of cortex	
Core characteristics	Number of flake scars on cores	
	Number of platforms on cores	
4. Products of Manufacture		
Types of tools		
Identifying microblade technology	Core body and type	Identify product of manufacture, amount of core reduction
	Flake form and dimensions	

assessing how volcanic glass artifacts from different geochemical sources were transported. The physical characteristics (e.g., quality, size, and availability) of volcanic glass will influence how it was used (e.g., Bamforth 1992: 131–133) and provide information about how the available raw material was selected. The types of tools and number of artifacts related to microblade production made on stone from the different sources will reflect decisions about tool function, portability, and curation. For instance, the compositions of assemblages from sites located at varying distances to raw-material source reflect decisions to transport only particular types of artifacts. In addition, there are a number of artifact attributes that are often influenced by the distance transported or by the length of time the tool has been used (e.g., artifact size and amount of cortex). These key attributes are presented in Table 2. Finally, the spatial distribution of transported raw material sheds new light on large-scale mobility patterns. Admittedly, our sample represents a limited portion of the total distribution network of each volcanic-glass source, yet these results allow new hypotheses to be made about past mechanisms for artifact distribution in the region.

Paektusan Volcano Distribution

One of the most widely used sources of volcanic glass in the region is Paektusan Volcano, now divided by the borders of China and North Korea (Doelman et al. 2008; Glascock et al. 2006; Jia et al. 2012; Kim et al. 2007; Kuzmin 2011; Kuzmin and Popov 2000; Kuzmin et al. 1999, 2000, 2002a, 2002b, 2008). Paektusan (also known as Baitoushan, Tianchi Volcano, Changbaishan, and Baegdu) is a large stratovolcano with an elevation of 2,744 m. The Tumen River drains eastward from the volcano, forming the present day border between North Korea and China, and eventually flows into the Sea of Japan (Figure 1). Artifacts from Paektusan were used both locally (Jia et al. 2010, 2012) and transported long distances into South Korea and FER from the Late Palaeolithic to the Bronze Age (e.g., Doelman et al. 2008; Kim et al. 2007: 122; Kim et al. 2008; Kuzmin 2011; Kuzmin et al. 2002a, 2002b). The precise outcrop, or outcrops, used in the past is currently unknown. However, a layer of obsidian is known to exist on the southwestern slope of Paektusan in North Korea and is thought to extend into China (Jia et al. 2010, 2012; Machida et al. 1990). The region is largely unexplored by geologists and archaeologists because access is restricted. Moreover, a large-scale, catastrophic eruption dated ca. A.D. 1000 caused considerable damage to the surrounding area (Horn and Schmincke 2000) and may have destroyed or buried outcrops. Based on analogous sources of rhyolitic obsidian, it seems likely that extensive flows of obsidian were available in the past (Jia et al. 2012). These flows derived from Paektusan Volcano would have placed few restrictions on the artifacts that could be manufactured. Cores or tools could have been prepared or completed onsite at the outcrops and then transported away.

Artifacts in our NEC sample geochemically sourced to Paektusan are made on good-quality material ($n = 405$, 99.0 percent). Only four are considered medium quality based on the presence, size, and density of phenocryts. There is little variation in the color of the artifacts. Most are black ($n = 366$, 89.5 percent) in reflected light and grey in transmitted light (204, 49.9 percent). Only 41 (10.0 percent) artifacts in the NEC sample exhibit cortex. Of these, 33 (80.5 percent) appear to derive from primary outcrops with secondary (i.e., waterborne) sources making up the remainder ($n = 8$, 19.5 percent). Paektusan artifacts in the FER sample were also made on primarily high-quality raw material ($n = 149$, 97.4 percent). Most of the artifacts are black ($n = 109$, 71.2 percent) or grey ($n = 44$, 28.8 percent) and lack cortex ($n = 135$, 88.2 percent). Only 18 (11.8 percent) artifacts have cortex and of these, those with a water-rolled cortex are more common ($n = 10$, 55.6 percent) when compared to the NEC assemblages.

A comparison of the compositions of assemblages (frequencies of cores, complete flakes, tools, and broken flakes) made from Paektusan obsidian and found at sites close to the source (i.e., in NEC) versus those found far from the source (i.e., FER) is presented in Table 3. There is a significant difference between the two assemblages in the frequency of these artifacts ($X^2 = 11.963$, $df = 3$, $p = 0.0075$). There are considerably more broken flakes of Paektusan obsidian at sites in FER. Most of these broken flakes are related to microblade manufacture. Nearly half ($n = 33$, 42.9 percent) are broken microblades ($n = 43$). In contrast, only 16.4 percent ($n = 20$) of the broken flakes in the NEC assemblage are broken microblades. The presence of high numbers of microblades in FER assemblages is due to the way they were hafted and then transported. The complete blades were deliberately snapped to fit as inserts in a composite tool, possibly as replacement parts

TABLE 3. COMPOSITION OF THE NEC AND FER ASSEMBLAGES OF PAEKTUSAN VOLCANIC GLASS

Source Location	Artifact Type	Length (mm)		
		Count	Mean	SD
FER	Core	11	35.7	13.5
NEC		32	44.9	13.2
FER	Microblade core	9	39.6	19.8
NEC		22	41.5	5.9
FER	Complete flake	41	16.1	6.9
NEC		137	33.7	16.4
FER	Complete tool	6	40.3	11.8
NEC		42	44.6	15.4
FER	Complete blade	6	16.7	5.8
NEC		10	34.6	20.1
Artifact Type	**NEC**		**FER**	
	Count	**%**	**Count**	**%**
Core	32	8.2	11	7.2
Complete flake	137	35.1	41	26.8
Broken flakes	135	34.6	77	50.3
All tools	85	21.8	23	15.0
Angular fragment	1	0.3	1	0.7
Total	390		153	

made to a particular length. Hence, most of the broken blades can be considered curated artifacts potentially transported great distances either already hafted in a weapon or carried as replacement parts. Other broken flakes and the small unretouched flakes found in the FER assemblage may be products of resharpening tools and the reworking of microblade cores. Discard of small, non-cortical flakes may have occurred from the maintenance of special tools and the finishing or reworking of prepared cores or bifaces (e.g., Roth 2000: 307).

By-products of core reduction, such as large flakes, were often fashioned into retouched tools such as scrapers in both the FER and NEC assemblages. Based on the cortex observed on these artifacts, most appear to derive from primary outcrops, but a few were obtained from secondary sources. Both assemblages have a high frequency of tools (NEC, $n = 85$, 20.8 percent; FER, $n = 23$, 15.0 percent) most of which are scrapers (NEC, $n = 43$, 50.6 percent; FER, $n = 13$, 56.5 percent). Additional retouched forms are evidenced by unfinished, broken, and complete invasively flaked bifaces and points. These tool types could also be maintained by resharpening to extend their uselife. A comparison of the number of scrapers and invasively flaked tools (e.g., bifaces and points) shows that there is no significant difference in their frequencies ($X^2 = 0.1645$, $df = 1$, $p = 6.851$).

There are 32 cores in the NEC assemblage (Table 3). The majority of these are either microblade cores or microblade core performs. The cores were generally made on flakes ($n = 20$, 62.5 percent) or bifaces ($n = 6$, 18.8 percent). None of these cores have a water-rolled cortex. Microblade cores made from small water-rolled pebbles observed in FER assemblages usually retain cortex due to the limited preparation (Doelman 2008). Cores bearing cortex were obtained from a primary source suggesting an organized, systematic manufacture from in situ outcrops at Paektusan Volcano. As shown by the presence of a wedge-shaped profile ($n = 11$, 33.3 percent) and elongated core scars, these cores were most likely transported as prepared microblade cores. Most of the cores only have one platform that is flaked uni-directionally ($n = 20$, 62.5 percent), although some with two or more platforms are multidirectional ($n = 13$, 40.6 percent).

In FER 14 Late Paleolithic sites have artifacts geochemically sourced to Paektusan Volcano (Doelman et al. 2008, Figure 2; Kuzmin et al. 2002a). Thirteen of these sites are located less than 200 km from the Shokotovo Plateau. Only

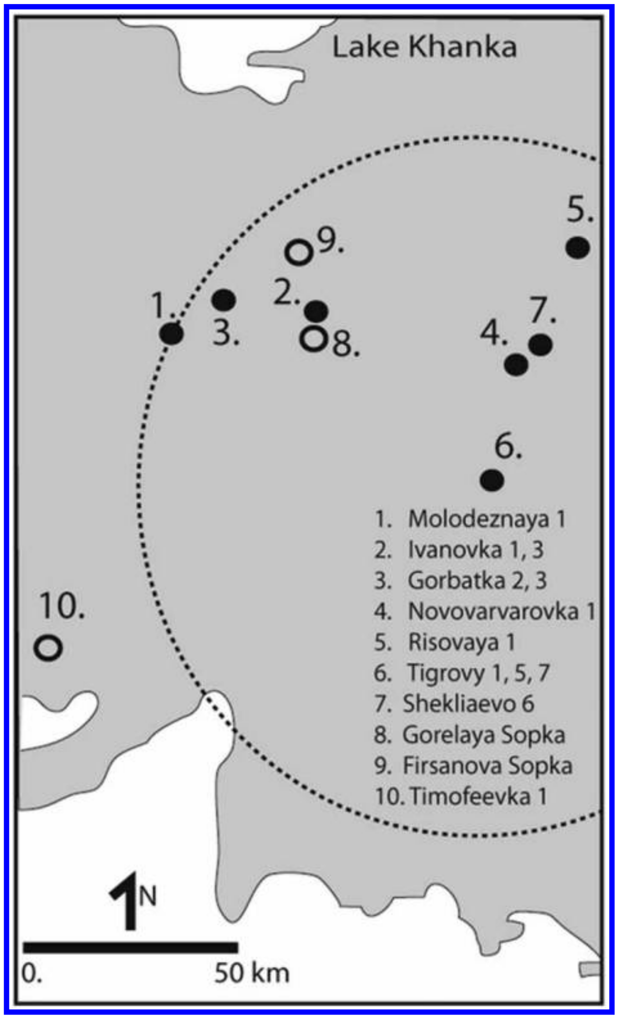

FIGURE 2. Distribution of sites in FER with volcanic glass artifacts from Paektusan Volcano. Sites 8-10 based on Figure 1, Kuzmin et al. (2002a, 2002b: 507).

the data reported by Doelman et al. (2008) from 11 sites can be used to assess the technological characteristics of the artifacts discarded in FER. Cores sourced to Paektusan Volcano were found at only five sites in Central Primorye, FER. One site, Risovaya-1, has five cores from Paektusan Volcano, a distance of roughly 450 km. With the exception of two cores in the total assemblage, all have the parallel, elongated flake scars typical of microblade manufacture and have a wedge or bullet shape. Most of these are made on flakes ($n = 6$) with only one a water-rolled cobble blank. Only two cores bear cortex obtained from a primary outcrop. The cores in the FER assemblage show greater evidence of rotation during knapping, with half having two or more platforms and a greater number of flakes scars than those in NEC (NEC, <5 flake scars 68.3 percent, $n = 28$; FER, <5 flake scars 18.2 percent, $n = 2$).

The characteristics of the flaking platforms observed in the NEC and FER assemblages provide useful information about differences in core reduction between the two regions. In the NEC assemblage a significant proportion of the platforms are unifacial ($n = 89$, 48.4 percent). A large number of the platforms on flakes are also missing or crushed ($n = 77$, 41.8 percent). The presence of small or crushed platforms on the flakes reflects both the controlled and careful reduction of cores and the physical properties of volcanic glass. This pattern is repeated in the FER assemblage where most of the platforms are missing ($n = 41$, 64.1 percent), a significantly higher frequency than in the NEC assemblage (unifacial/missing; $X^2 = 8.415$, $df = 1$, $p = 0.0037$). The range of flake forms in NEC reflects different reduction stages and strategies: early core preparation, core rejuvenation and blade manufacture (Table 4). For example, in NEC there is a higher number of flakes with expanding margins (a maximum width greater than the axial length), a flake form usually associated with early core preparation. In contrast, blades dominate the FER assemblage. These results indicate that flakes were generally transported as finished products into FER.

By comparing the widths of all blades found in the two regions and sourced to the Paekustan volcano, it is possible to establish whether microblades were the primary output of manufacture. In the NEC assemblage only 12.9 percent ($n = 4$) have a width of 5 mm or less. The largest blade has a width of 35 mm and a thickness of 9 mm. Most blades are wider than 10 mm (71.0 percent, $n = 22$). Six of these larger blades were used as tools including a burin, drill, scrapers (straight, stepped, end) and one has macroscopic usewear damage. These results indicate that both large and small blades were made from volcanic glass obtained from Paektusan Volcano. Differences in the width of the blades in the NEC and FER assemblages are clearly shown by the mean and standard deviation (Figure 3). Transporting large blades has the advantage of flexibility as blades can be worked into different tool types or used as a microblade core. Given the presence of cortex indicative of a primary outcrop, it appears that the raw material was quarried from Paekustan volcano specifically for the preparation of microblade cores, bifaces and points, all made on large flakes or blades. Yet, in the FER assemblage the blades are considerably smaller in width indicating that these tended to be transported further.

An analysis of artifact lengths reveals size differences between the two areas (Table 3; Figure 4)

Table 4. Characteristics of the flakes in the Paektusan NEC and FER assemblages

Form	NEC		FER	
Flake Form	Count	%	Count	%
Bipolar			1	1.2
Blade	37	37.8	47	56.0
Blade-Like	4	4.1	11	13.1
Core trimming	3	3.1	15	17.9
Crested	6	6.1	1	1.2
Expanding	43	43.9	3	3.6
Platform rejuvenation	5	5.1	2	2.4
Point		0.0	1	1.2
Ridge-straightening		0.0	3	3.6
Total	98		84	
Platform Type				
Bifacial	4	2.2	1	1.6
Cortical	7	3.8	2	3.1
Facetted	7	3.8	2	3.1
Missing	77	41.8	41	64.1
Unifacial	89	48.4	18	28.1
Total	184		64	

which are significant only for the complete flakes (cores, $t = 1.914$, $df = 40$, $p = 0.0628$; complete flakes $t = 6.687$, $df = 176$, $p < 0.0005$; complete tools $t = 0.6546$, $df = 46$, $p = 0.5160$). The decrease in the size of the complete flakes with distance from the source suggests that large flakes may have been transported away from the source, but by the time they were discarded, they had been converted into tools (scrapers, bifaces, etc.). The size of tools is large, independent of whether they are broken or complete. The small (broken and complete) flakes are a product of blade manufacture ($n = 60$, 42.9 percent), core/tool trimming/maintenance ($n = 18$, 12.9 percent) or indeterminate (neither expanding or blade) in origin ($n = 56$, 40.0 percent). In contrast, most flakes in NEC are not related to microblade manufacture or maintenance but are indeterminate in origin ($n = 273$, 73.4 percent). One of the microblade cores in the FER assemblage is unusually large at 72 mm in length. All of the remaining microblade cores are 59 mm. This core was made on a recycled bifacial point

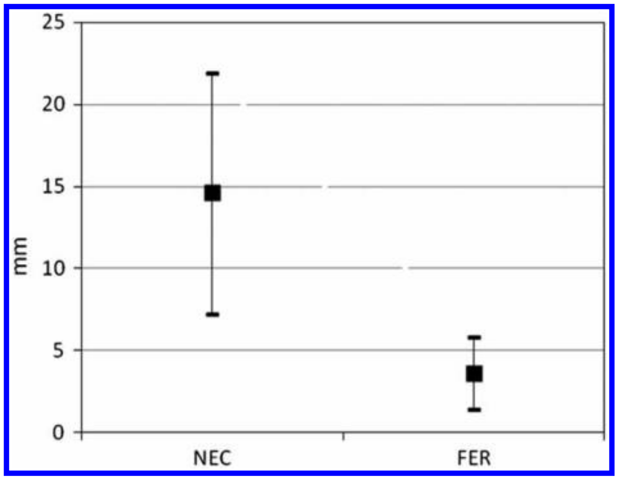

Figure 3. Mean and standard deviation of blade widths found in the NEC and FER assemblages.

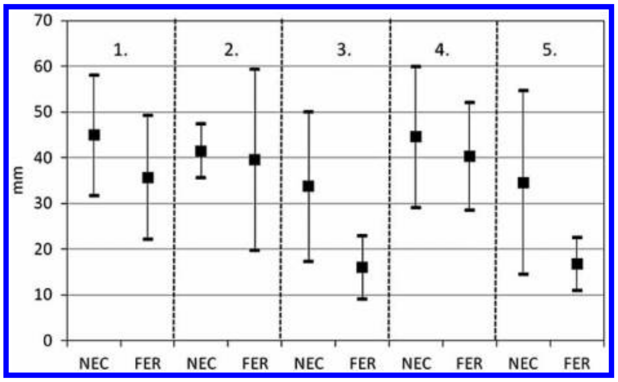

Figure 4. Mean and standard deviation of artifact lengths found in the NEC and FER assemblages. 1. cores, 2. microblade cores, 3. complete flakes, 4. complete tool, 5. complete blades.

and accounts for the large standard deviation seen in Table 3. If this core is removed from the analysis the mean length decreases to 36.3 ± 14.1 mm.

The sizes of microblade cores and microblades were compared between the two areas. Microblades are small, parallel-sided, elongated flakes with parallel dorsal scarring with an average width of 5 mm (Odell 2004: 96). The results shows no significant differences in length occur between the two regions (microblade, $t = 2.103$, $df = 14$, $p = 0.0541$; microblade core $t = 0.4164$, $df = 28$, $p = 0.6803$). That is, once prepared, microblade cores and the resulting blades do not decrease in size with increasing distance from the source. This pattern may indicate the importance of standardization for microblades as they must fit into a prepared haft and a size threshold for the reduction of the microblade cores, after which they were discarded (Doelman 2008).

Shkotovo Plateau Distribution

A systematic geoarchaeological survey of source localities in the Shkotovo Plateau characterized the variation in the physical characteristics of currently available primary and secondary basaltic glass sources (Doelman et al. 2008, 2009, 2012; Kluyev and Sleptsov 2007). The basaltic glass found in the region, is mostly opaque in transmitted light, and black, blue, or blue-grey in reflected light (Doelman et al. 2008). The volcanic glass found at the primary outcrops forms (1) as a thin rind (<4 cm in thickness) around the edge of pillow lavas, (2) as fractured blocks from explosive contact with water, and (3) as thin lava tongues (Doelman et al. 2012). The highest quality material available at these outcrops is found in rare central "cores" of pillow lava. These cores can be as large as 15–20 cm in diameter, lack the internal flaws commonly found in tabular rinds and blocky fragments, and they have a low number of phenocryts. Yet, these 'cores' are relatively rare (Doelman et al. 2012). Multiple outcrops occur in the Shkotovo Plateau, but quarrying activity has been identified only at Tigrovy 8 (Doelman et al. 2009; Figure 1). Whereas pebbles of volcanic glass are abundant in secondary waterways, excellent-quality material for tool production is uncommon. In addition, the size of the water-rolled pebbles rapidly decreases as they are moved downstream (Doelman et al. 2004, 2012). The cobbles obtained from secondary sources and used to make cores are considerably smaller than those found at Tigrovy 8 (maximum size of 10 cm) having a maximum length of only 7.2 cm. All these factors limit the manufacturing potential of basaltic glass cores from both the primary and secondary contexts.

Data for FER is based on the assemblages from 13 sites, each of which is located within 200 km of the Tigrovy Valley sources (Doelman et al. 2008). The quality of the raw material in the sample is variable, although most of the basaltic volcanic glass is considered good quality (78.0 percent, $n = 1339$) with no vesicles or phenocryts. A high frequency were either medium ($n = 227$, 13.2 percent) or poor quality ($n = 150$, 8.7 percent). Raw material choice can be detected by examining the wide variety of core types discarded at various stages of manufacture. The majority of the cores bear water-rolled cortex ($n = 195$, 68.4 percent) suggesting opportunistic use of pebbles from nearby waterways. Perhaps due to internal flaws in the cobbles, many of the cores were discarded early in core reduction, with few flakes removed. Nearly half have five or fewer flake scars ($n = 131$, 46.0 percent). It is likely these cores were simply used to manufacture flakes for immediate use and were then discarded. The microblade cores, mostly wedge-shaped ($n = 38$), are generally made on small, highly cortical, water-rolled pebbles that are usually worked from one or two platforms to obtain the desired wedge-shaped profile ($n = 22$, 57.9 percent). Often the keel of these cores still retains water-rolled cortex. The ways in which cobbles from secondary sources were prepared suggests that they will usually retain cortex when discarded (Doelman 2008). In contrast, it is likely that cores with no cortex, or those with a rough cortex, were obtained from a primary source.

At Tigrovy 8 the available raw material was used primarily to make microblade cores and bifaces (Doelman et al. 2009, 2012). These products were removed and transported away from the site for use elsewhere. The rarity of exhausted microblade cores, microblades, and distinctive debitage such as crested blades or core rejuvenation flakes, indicates that microblade manufacture was infrequent at the quarry. In contrast to the standardized types found elsewhere, the majority of the methods used to make microblade core preforms at Tigrovy 8 represent innovative approaches devised to take advantage of the natural tabular shapes of the rinds and small fractured blocks (Doelman et al. 2009). A least-cost strategy was adopted based on the selection of a slab or angular fragment already close to the desired wedge shape of a microblade core, and that required minimal effort to produce the desired profile. Although there were many variations in how these tabular pieces were transformed into

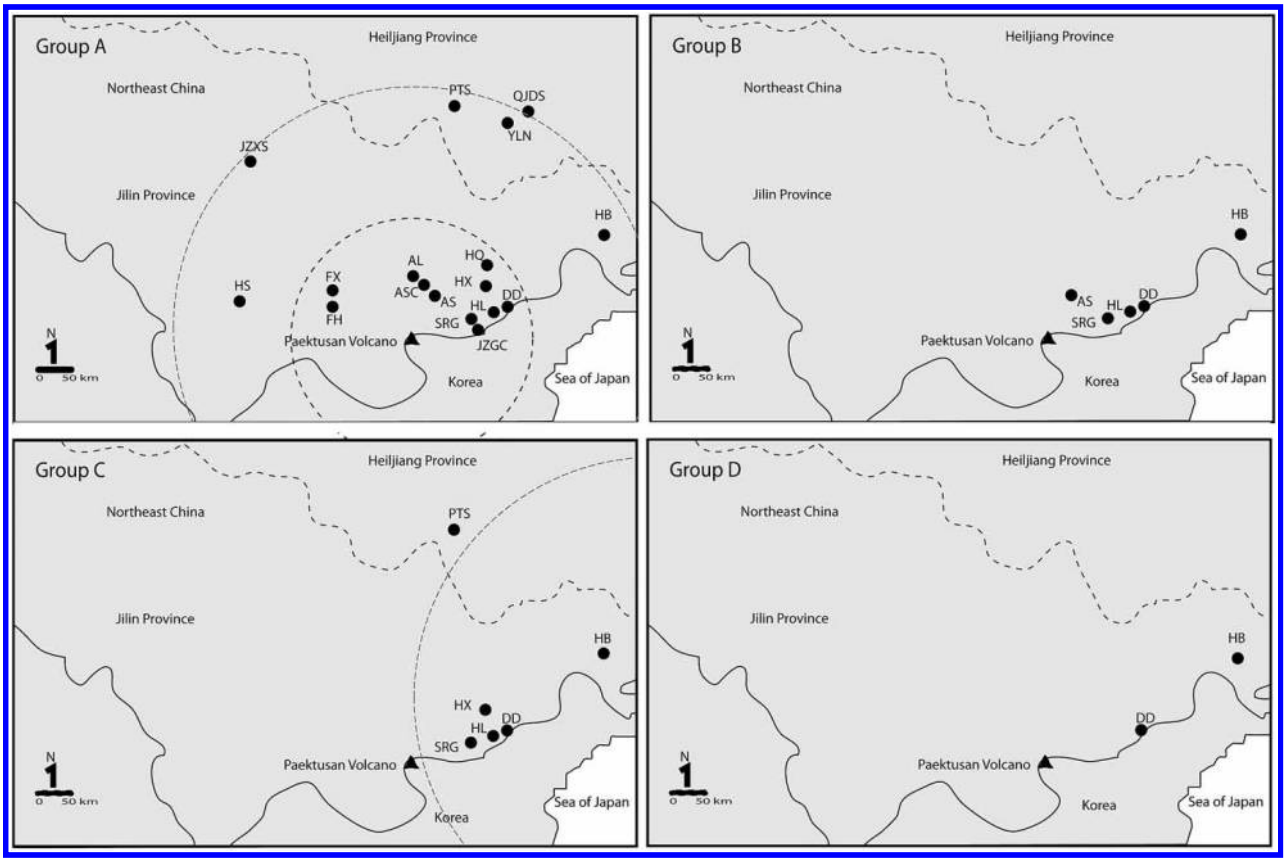

FIGURE 5. Distribution of sites in NEC with volcanic glass artifacts. Group A (top left) sites in NEC with artifacts from Paektusan Volcano. Group B (top right) sites in NEC with artifacts from the Shkotovo Plateau. Group C (bottom left) sites in NEC with artifacts from the Gladkaya River Basin. Group D (bottom right) sites in NEC with artifacts from an unknown source.

wedge-shaped cores, they all follow a generally similar approach (Doelman et al. 2009). It is likely that microblade-core preforms had high failure rates because of (1) the difficulty in flaking high platform angles of tabular rinds and blocky fragments, (2) the variable quality of the material, and (3) the small size of the available material.

The basaltic glass artifacts found in NEC contrast strongly with the FER specimens discarded close to the basaltic glass sources. Several artifacts made on Shkotovo basaltic glass were found at the AS site — more than 400 km from their source (Figure 5). A total of just eight basaltic glass artifacts were recovered from six sites in NEC: a core; three angular fragments; two complete scrapers; and two broken flakes (Figure 5). All these sites are located near or along the Tumen River. This river initially flows northeast forming a possible migratory route between the two major source areas (Figure 5). Only one artifact, a core, has between 1-25 percent secondary, water-rolled cortex. This is a relatively large (45 mm in length) unidirectional core with less than five flake scars. None of the artifacts indicate the manufacture of microblades. Surprisingly, it seems that artifacts related to microblade technology were not transported from the basaltic glass sources a long distance into NEC.

GLADKAYA RIVER BASIN DISTRIBUTION NETWORK

An unexpected finding from the geochemical analysis of the volcanic glass artifacts in NEC was the recognition of geochemical Group C which closely matches the composition of raw material derived from the Gladkaya River basin in southern Primorye, FER (see Doelman et al. 2008; Jia et al. 2010; Kuzmin and Popov 2000: 85; Popov and Shackley 1997: 83). If we accept the tentative conclusion that Group C glass derives from the Gladkaya River basin, then it is possible to monitor a third distribution network (Figures 1 and 5). Good-quality rhyolitic glass is available from several sources in the Gladkaya River basin, including dykes exposed in stream beds (e.g., Olenyi Stream, Vinogradnaya River), flows outcropping along hillsides (e.g., Vinogradnaya outcrop-1), and secondary (e.g., streambed) sources (Doelman et al. 2004, 2008). Artifacts matching the Group C chemistry, suspected to come from the Gladkaya basin, were found at six sites in NEC. Surprisingly it has only been found in FER during the Late Palaeolithic at the Razdolnoye site located ~120 km northeast of the source (Kuzmin et al. 2002a, 2002b, 2008). Nearly all the sites with Group C material were found close to the Tumen River which flows between Paektusan Volcano and the Gladkaya River Basin (Figure 1).

In this study all the artifacts from Group C found in NEC ($n = 19$) are of good quality. Most are green in reflected light ($n = 10$), although other colors do occur (e.g., black, brown, and dark grey). When compared to those from Paektusan Volcano a relatively high proportion of Group C artifacts ($n = 4$; 21 percent) have cortex derived from a primary outcrop. The Group C artifacts are similar in size to those from Paektusan Volcano yet have more cortex. In addition, a higher number of cores ($n = 3$, 15.8 percent) and tools ($n = 5$, 26.4 percent) occurs in the Group C assemblage compared to the NEC artifacts sourced to Paektusan Volcano. Two small microblade cores and one flake indicate a degree of microblade production. With the exception of two complete bifaces, the tools in Groups C are all various forms of scrapers.

Group D Distribution Network

In the NEC assemblage, three artifacts — two complete flakes and a broken flake — from only two sites were assigned to geochemical Group D (Figure 5). Although the exact source of Group D volcanic glass is presently unknown, the small number of artifacts matching this compositional profile, their lack of cortex, and their small size suggest to us that the source is reasonably distant. All are of good quality and black in color. None of these artifacts appear related to microblade technology. Artifacts from this geochemical group were also only found in two sites which both occur along or near the Tumen River (Figure 5).

Distribution Mechanisms

Two mechanisms have been offered to explain the long-distance movement of artifacts in northeast Asia. Whereas some authors have proposed exchange (Kuzmin 2011; Kuzmin et al. 2002a, 2002b; Sato and Tsutsumi 2007: 76–78), other authors have suggested that that the artifacts track the movements of highly mobile hunter-gatherers (Sano 2007: 90). This second scenario is possible given that, over a lifetime, people can move across a large area. For example, Binford's (1983: 114–115) data on the Nunamiut suggests that one individual covered an area with a diameter of 200 km during his lifetime. As Sano (2007: 90) suggests, hunter-gatherers of the Late Palaeolithic may have moved rapidly over long distances, more than 200 km, to acquire stone resources through direct access (special purpose trips). The problem is how to archaeologically discriminate exchange versus direct acquisition when artifact forms related to both processes look much the same (Morrow and Jefferies 1989: 30).

It is widely acknowledged that long-distance exchange is integral to many hunter-gatherer societies (e.g., Taliaferro et al. 2010). If exchange occurred in northeast Asia, a hand-to-hand, down-the-line system of informal exchange typical of many hunter-gatherer societies (see Dillian and White 2010) seems the most likely. This system is based on artifacts moving through groups, possibly with overlapping territories, who met occasionally at the boundaries. In this way, over time, artifacts could move great distances. The benefits of this form of exchange are many: access to high-quality resources located long distances away, access to prestige goods or specialist tools, and, importantly, pathways to share information and create social ties between individuals and groups (e.g., Arnold 1992; Eerkens et al. 2008: 679; Hodder 1982: 199–200; O'Shea 1981: 173; Sahlins 1972; Torrence 1986). In this kind of exchange artifacts typically gain value as the distance from the source increases.

Although half a world away, ethnographic and ethnohistoric observations of Australian Aboriginal populations suggest that exchange networks extended throughout the continent along established routes (e.g., Allen 1997; Kaberry 1939: 166–174; McBryde 1987; McCarthy 1939; Mulvaney 1976). At known places along these routes both regular large-scale meetings and arranged smaller meetings between neighboring groups would occur. One of the primary objectives of these meetings was to exchange gifts. In this way highly valued commodities, either as raw materials or manufactured goods, were transported long distances. Exchange allowed people to gain access not only to rare and valuable resources, but, perhaps more importantly, also share information and cultivate alliances (McCarthy 1939: 171–175). Specialists from particular areas also gained a reputation for being the best manufacturers of specific items. In addition, the value of items was often reinforced by myths about the spiritual origins of the items (McCarthy 1939: 428–430, 171–172). Today Paekustan Volcano (translated as "Sacred Mountain") is considered a place of spiritual significance (Pinilla 2004). Perhaps in the past "prestige" could be accrued through possession of volcanic glass artifacts from this significant landmark.

Taking the insights from ethnographic studies, we can now return to the nature of the lithic assemblages in this study. Our analyses indicate substantial variation in the ways volcanic glass from the four sources were used and moved across the landscape. These variations indicate that the acquisition, manufacture, and transportation of sources were managed in different ways, retained different values, and were potentially moved through different mechanisms. We have observed two patterns of long-distance (>200 km) artifact movement in northeast Asia. The first pattern we have identified in both FER and NEC is the long-distance movement of systematically manufactured artifacts related to microblade production and retouched tools from Paektusan Volcano. In contrast, the second pattern is the presence of "occasional" artifacts derived from the basaltic glass sources in the Shkotovo Plateau that were moved over long distances that are not associated with systematic reduction sequences. While this source was used locally, in FER, to manufacture bifaces and microblades, these items were not transported great distances into northeast China. Addressing the mechanisms behind the movement of artifacts from Group C and Group D is hampered by small sample sizes. It is clear that Group C was used for microblade production but presently there is no evidence to suggest that artifacts made from this raw material were transported >200 km from the source during the Late Palaeolithic. Group D does not appear to have been used for systematic core reduction at the sites in our sample.

Unravelling which mechanism was employed for each pattern is complex for several reasons. To begin with, we need to consider patterns of curation. The types of tools transported into FER from Paektusan Volcano were maintained through resharpening, within a technological strategy in which standardized replacement parts (i.e. microblades) were used to maintain weaponry. It stands to reason that if tools last a long time, then they might be transported over large distances — especially if used by highly mobile groups of hunter-gatherers. The artifacts from Paekustan Volcano discarded in FER may simply reflect tool curation by mobile peoples. A second consideration is size-related constraint on the utilitarian requirements of the tools themselves. The similar sizes of cores, microblades, and tools from Paektusan Volcano in both FER and NEC could simply reflect a size-based discard threshold for microblade cores or bifaces. The fact that these artifacts were transported vast distances within this framework could again indicate how quickly people moved across the landscape and/or how economically they worked their cores or resharpened their tools. Another consideration is the possibility that volcanic glass was simply better for the manufacture of blades than other raw material types (i.e., they retained a sharp edge longer before retooling was needed). Data is also needed to examine variation in the manufacture of artifacts made from other material types near sources in NEC and FER. Finally, it is important to consider the potential role of prestige items. Given the importance of microblade technology in supporting a highly mobile and risk-averse subsistence pattern, these artifacts could have been considered a valuable exchange item. If prepared cores or tools were also transported as exchange items, they could have travelled long distances before they were used. This scenario could be considered an example of what Renfrew (1975) has called prestige-chain exchange.

In light of the potential mechanisms involving transport and/or exchange, we can now compare the distribution patterns for Paektusan obsidian and Shkotovo Plateau basaltic glass. Beginning with Paektusan, the large number and variety of artifacts produced and the distance they were transported, indicates that during the Late Palaeolithic this was an important source with a large quantity of high-quality volcanic glass. Although secondary sources were used to a limited degree, most of the Paektusan volcanic glass appears to have been obtained from primary outcrops. Artifacts related to microblade technology were transported into FER from Paekustan Volcano as prepared cores, in composite tools, and as replacement microblades. In addition, curated tools such as retouched points, bifaces, and scrapers were also transported over greater distances away from the source into FER (Doelman 2008; Doelman et al. 2008). In contrast, large blades and microblade cores appear to have been the primary forms of artifacts transported from quarries at Paekustan Volcano within NEC. Large blades could be used as blanks for a variety of tools or converted into microblade cores. Given the broad range of material derived from Paektusan, it is difficult to establish whether exchange was solely responsible, as it is also likely that large quantities of artifacts derived from this source filtered through highly mobile hunter-gatherers. However, differences in the types of artifacts found in NEC and FER suggest the selection of particular artifacts, primarily related to microblade technology, for long-distant transportation.

Moving now to the basaltic glass sources from the Shkotovo Plateau in FER. Raw material from this source was used to manufacture a range of artifacts including bifaces and microblades. Yet, the few ($n = 8$) of artifacts discarded in northeast China do not clearly derive from a standardized reduction system, and they do not appear to be something that would have been considered an item of exchange. It is possible that these items were simply carried directly from the source in FER to northeast China by highly mobile groups. Since all the distant sites with basaltic glass lie near the Tumen River, it could well be that this was an important resource-rich route along which artifacts, people, and information travelled. Interestingly, sites with Group C and D artifacts also occur along this same route (Figure 5). This route may be the key to why basaltic glass artifacts appear in NEC. The presence of Shkotovo Plateau artifacts along the Tumen River may therefore reflect the number of people who traversed this route for millennia.

CONCLUSION

The results of this study suggest that the movement of artifacts is far more complex and challenging than is often acknowledged. Whichever mechanisms operated behind the transportation of artifacts in the Late Palaeolithic, the distances they were transported reflect the consequences of highly mobile populations using an efficient and effective microblade technology over extended periods of time. The distribution of artifacts from various volcanic-glass sources indicates two-way communications perhaps centered along the route of the Tumen River. It is likely that the movement of artifacts occurred through multiple mechanisms governed by social interaction, technological strategies, and landscape features, both through human-population movement and artifact exchange among those groups. Occasional artifacts, showing no evidence of systematic reduction, were the only basaltic glass artifacts that moved into NEC, perhaps tracking the rapid movements of people across the landscape. In strong contrast, multiple factors contributed to the wide distribution of volcanic glass from Paektusan Volcano. The advantages of a large source of good-quality volcanic glass and a technological system dominated by microblade manufacture may have made this source a pivotal point on the landscape that was repeatedly visited by highly mobile hunter-gatherers. Furthermore, artifacts made from volcanic glass obtained from Paektusan Volcano were probably valued as a resource for exchange. Collectively, these results hint at the various ways that hunter-gatherer groups managed raw material acquisition and consumption during the Late Palaeolithic.

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