# ARCHAEOLOGICAL OBSIDIAN STUDIES IN HOKKAIDO, JAPAN: RETROSPECT AND PROSPECTS

Masami Izuho[1] and Hiroyuki Sato[2]

[1]Sapporo Buried Cultural Property Center, Minami 22, Nishi 13, Chuo-ku, Sapporo, 064-0922, Japan
[2]Institute of Archaeology, Faculty of Letters, University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-0033, Japan
Emails: izuhom@serenade.plala.or.jp; hsato@l.u-tokyo.ac.jp
Keywords: Hokkaido, obsidian, mobility patterns, behavioural strategies, exchange networks

## ABSTRACT

*Recent research has identified an extended exchange network in the Japan Sea Rim area extending over 3,000 km and including the mainland. This paper reviews current knowledge about obsidian studies in Hokkaido, a part of this region, and makes proposals for future research. The geology of Hokkaido and its 21 known obsidian sources are reviewed and results of chemical analyses of some sources described. Archaeological studies of exchange networks, exploitation patterns and site variation are described. Proposals for the direction of future studies include additional research on the location, geological history and characterization of obsidian sources and the use of new models concerning procurement range, mobility patterns and behavioural strategies.*

## INTRODUCTION

Hokkaido, in northern Japan, is the location of obsidian sources such as Oketo and Shirataki. Twenty-one different geological sources, each with a different chemical composition, have been discovered. Procurement of obsidian by prehistoric groups as a raw material for stone tools began at least in the early upper Palaeolithic (c.30,000 BP) and continued through the prehistoric period. Previous studies have provided quite a detailed picture of obsidian exploitation in Hokkaido. For example, beginning with a collaborative study of Shirataki sites (Shirataki Dantai Kenkyu Kai 1963), recent research projects have made important contributions to understanding the procurement and exchange of obsidian in this region. These include research on procurement systems for lithic raw material in and around the Shirataki archaeological obsidian sources (Kimura 1992), studies of exchange networks for obsidian and siliceous shale (Kimura 1995; 1998), and the discovery of an exchange network extending to Sakhalin (Kuzmin *et al*. 2002, 2005; Sato *et al*. 2002; Sato 2004a, 2004b). As a background to designing future research, we provide an outline of previous research about the distribution of obsidian sources and their formation through tectonics and geological processes. This is followed by a brief discussion of future prospects for archaeological research on obsidian in Hokkaido.

## GEOLOGY AND TECTONICS

Hokkaido is a portion of the arc-trench system situated along the western margin of the Pacific Ocean. It is located at the junction of the northeast Japan arc and the Kurile arc (Figure 1). These are both affected by the continuing subduction of the Pacific Plate beneath the North American Plate, with cross subduction against the northeast Japanese arc and oblique subduction against the Kurile arc. Situated at the plate subduction zone, active arc volcanism has basically formed the geology of Hokkaido.

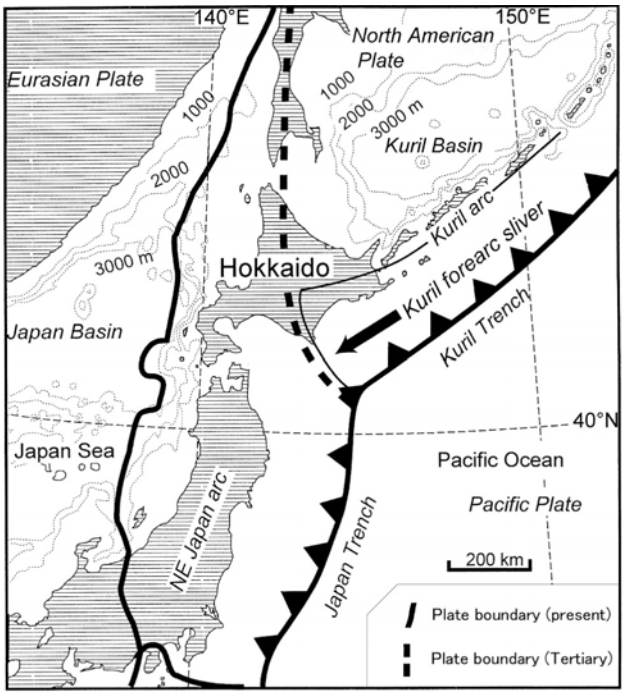


*Figure 1. Geological setting of Hokkaido (after Hirose and Nakagawa 1999).*

The basal geology of Hokkaido consists of Cretaceous metamorphics and igneous rocks, overlain by later sedimentary and volcanic activity since the Neogene. This complex geological history provides a range of cryptocrystalline rock types such as obsidian, andesite, siliceous

**Table 1. Obsidian sources in Hokkaido**

| | Source | Primary Locality | Secondary Distribution | Latitude | Longitude | Altitude (m) | References |
|---|---|---|---|---|---|---|---|
| 1 | Shirataki | Akaishiyama | R. Horokazawa to R. Yubetsu | 43°56′ | 143°08′ | 1172 | Kawano (1950); Shirataki Danken (1963); Kimura (1992, 2005) |
| 2 | Shirataki | Toka-chiisizawa | R. Tokachiishizawa to R. Yubetsu | 43°54′ | 143°10′ | 872 | Shirataki Danken (1963); Kimura (1992, 2005) |
| 3 | Toka-chimitsumata | Jyusan'nosawa | R. Jyusan'nosawa to R. Tokachi, R. Toshibetsu to R. Tokachi | 43°29′ | 143°10′ | 725 | Kitazawa (1999) |
| 4 | Oketo | Oketoyama | R. Bochinosawa to R. Tokoro, R. Kunneppu to R. Tokoro | 43º41' | 143º33′ | 550 | Izuho (1997); Mukai *et al*. (2002) |
| 5 | Oketo | Tokoroyama | R. Bochinosawa to R. Tokoro, R. On'neanzu to R. Tokoro | 43º40′ | 143º30′ | 582 | Izuho (1997); Mukai *et al*. (2002) |
| 6 | Akaigawa | Dobokuzawa | R. Dobokuzawa to R. Yoichi, R. Nakanosawa to R. Yoichi | 43º00′ | 140º49′ | 550 | Kimura (1978); Mukai *et al*. (2002) |
| 7 | Chikabumidai | unknown | Chikabumidai Terrace dep. to R. Ishikari | 43º50′ | 142º23′ | 145 | Mukai *et al*. (2000) |
| 8 | Ubundai | unknown | Ubundai Terrace dep. to R. Ishikari | 43º46′ | 142º17′ | 120 | Mukai *et al*. (2000) |
| 9 | Hokuryu | unknown | Hekisui Terrace dep. to R. Uryu | 43º46′ | 141º52′ | 51 | Mukai and Wada (2001) |
| 10 | Chippubetsu | unknown | Nakayama Terrace deposit, to R. Chippubetsu Sakura | 43º46′ | 141º58′ | 68 | Mukai and Wada (2001) |
| 11 | Shikaribetsu | unknown | R. Shikaribetsu to R. Tokachi | 43º05′ | 142º59′ | 180 | Mukai and Wada (2004b) |
| 12 | Toyoizumi | unknown | R. Toyoizumi | 42º36′ | 140º39′ | 8 | Mukai (2005) |
| 13 | Nayoro | unknown | R. Chureppu to R. Teshio R. Tosei to R. Teshio | 44º15′ | 142º34′ | 212 | Nayoro City Board of Education (1988) |
| 14 | Monbetsu | Kamimobetsu | R. Kamimobetsu to R. Mobetsu | 44º10′ | 143º22′ | 160 | Yahata *et al*. (1988); Mukai *et al*. (2005) |
| 15 | Keshomappu | Michikozawa | R. Keshomappu to R. Muka | 43º45′ | 143º18′ | 792 | Mukai *et al*. (2005) |
| 16 | Okushiri | Katsumayama | R. Horonai | 42º11′ | 139º27′ | 340 | Mukai *et al*. (2004b) |
| 17 | Kushiro | unknown | R. Koitoi to R. Akan | 42º59′ | 144º09′ | 10 | Okazaki (1966); Sawa (1978) |
| 18 | Abashiri | Ponmoimisaki | — | 44º01′ | 144º16′ | 22 | Yahata (1999) |
| 19 | Ikutahara | Nitappugawa | R. Nitappu | 43º58′ | 143º29′ | 293 | Mukai *et al*. (2004) |
| 20 | Oumu | unknown | R. Otoineppu | 44º33′ | 142º49′ | 144 | Mukai and Wada (2003) |
| 21 | Engaru | unknown | R. Sanabuchi to R. Yubetsu | 44º03′ | 143º28′ | 109 | Mukai and Wada (2003) |

shale, chert and jasper, all of which were exploited in prehistoric times.

There are four main geological features in Hokkaido (Figure 2). The Hidaka Mountains, located in the southern part of the central axis of Hokkaido, mainly consist of pre-Tertiary sedimentary rocks and metamorphic rocks. The thrust of these mountains is the result of collision of the Kurile arc since the beginning of Tertiary. The Kitami Mountains, situated in the northern part of Central Hokkaido, consist of mainly pre-Tertiary green rocks (chloritizied mafic intrusive rocks formed by volcanic activity in a marine environment) and sedimentary rocks, and Tertiary volcanic and sedimentary rocks. They represent a Tertiary volcanic front and thrust zone. The Ishikari Mountains and Akan-Shiretoko volcanic zones consist of Quaternary volcanic rocks and tephra. The Ishikari Mountains and the Akan-Shiretoko volcanic zone both consist of Quaternary volcanic rocks and tephra and are still volcanically active. Other hills, plains and basins were formed by similar tectonics.

## OBSIDIAN SOURCES IN HOKKAIDO

The currently known 21 obsidian sources in Hokkaido, which are listed in Table 1, are plotted on Figure 2. Each of these localities has a unique geochemical signature. EDXRF analysis of obsidian artefacts from archaeological contexts suggests that there are additional sources which have not yet been located. Obsidian sources can be divided into two types: primary and secondary (Shackley 1998, 2005; Glascock *et al.* 1998; Izuho 1997). Primary sources are those still in geological contexts, such as rhyolite lava flows and pyroclastic bomblets surrounding volcano cones.

Eleven such sources are known: Shirataki-Akaishiyama, Shirataki-Tokachiishizawa, Tokachimitsumata-Jyusan’nosawa, Oketo-Oketoyama, Oketo-Tokoroyama, Akaigawa-Dobokuzawa, Monbetsu-Kamimobetsu, Kshomappu-Michikozawa, Abashiri-Ponmoimisaki, Ikutahara-Nitappugawa and Okushiri-Katsumayama. Among this group actual outcrops have been discovered at the Shirataki localities (Akaishiyama and Tokachiishizawa)

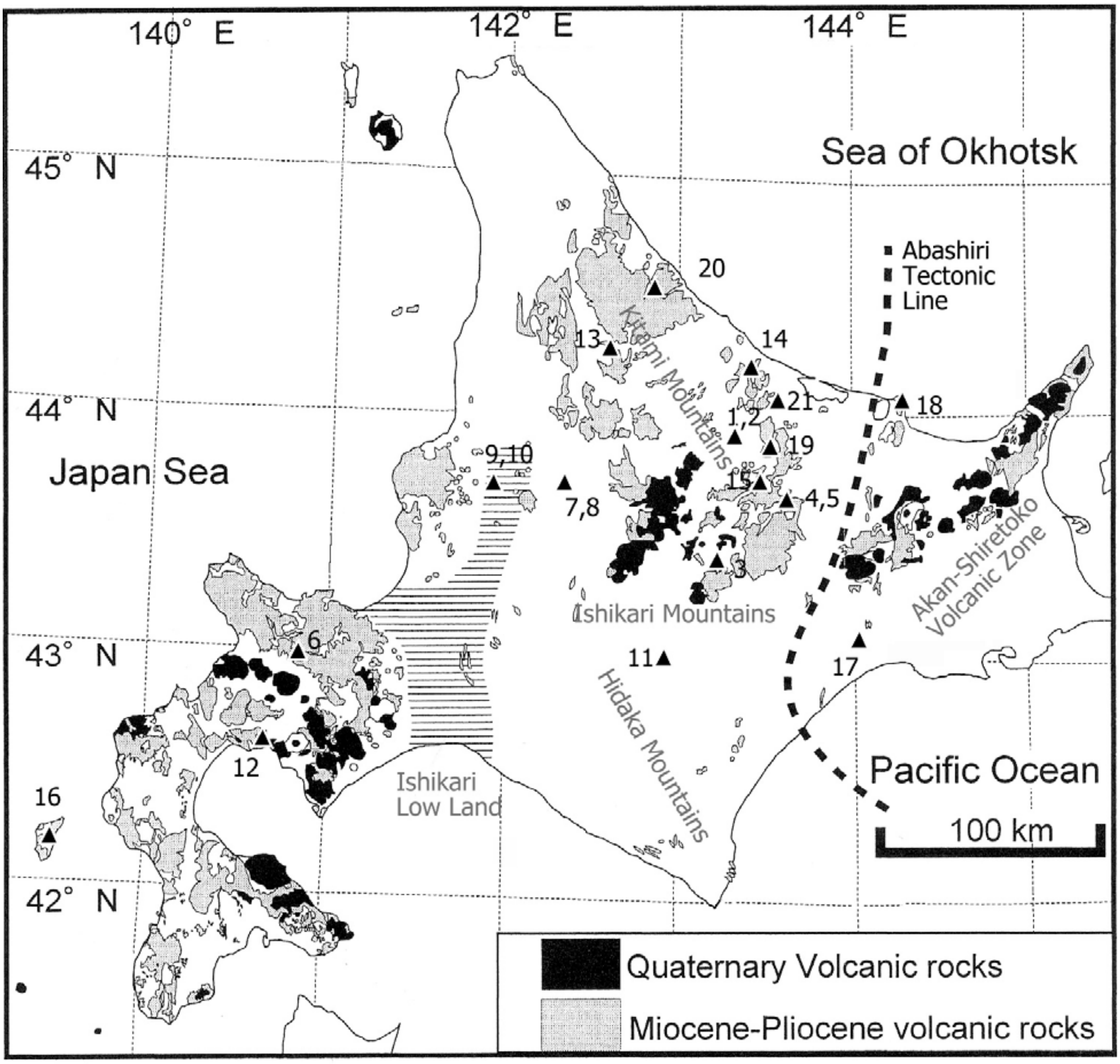


*Figure 2. Distribution of the volcanic rocks and obsidian (after Hirose et al. 2000). The numbers correspond with the obsidian sources listed in Table 1.* ▲*Obsidian source locality.*

as well as at Abashiri-Ponmoimisaki, Monbetsu-Kamimobetsu and Okushiri-Katsumayama. We can be certain that the Shirataki localities were used in prehistory because many archaeological sites have been found in their vicinity. In contrast, exploitation has not been confirmed for Monbetsu-Kamimobetsu and Abashiri-Ponmoimisaki, where obsidian of poor quality occurs in small patches of rhyolite or basalt.

Outcrops have not yet been confirmed at five sources: Oketo (Oketoyama and Tokoroyama), Tokachimitsumata-Jyusan'nosawa, Akaigawa-Dobokuzawa, and Ikutahara-Nitappugawa. However, it is clear that they are primary sources, firstly, because they are part of a rhyolite dome and, secondly, because there are large numbers of split cobbles and flakes lying on the surface, suggesting local exploitation of obsidian. Chemical analyses by Kuzmin *et al.* (2002) and Mukai (2005) confirm that these localities are definitely unique geological sources.

In contrast, secondary sources occur when streams erode material from the primary sources, and transform it into rolled angular or rounded cobbles and pebbles. Secondary sources which have not been linked to a primary source are known at Chikabumidai, Ubundai, Hokuryu, Chippubetsu, Shikaribetsu, Toyoizumi, Nayoro, Kushiro, Oumu and Engaru, where obsidian occurs in river beds and terrace deposits. Rounded obsidian cobbles were exploited prehistorically at Nayoro, Chikabumidai and Toyoizumi.

As in other areas of the world (e.g. Glascock *et al.* 1998*;* Shackley 1998, 2005), chemical characterization of volcanic sources using a range of methods has been successful in producing discrimination among various Hokkaido obsidian sources: INAA (Kuzmin *et al.* 2002; 2005; Suzuki 2005), EDXRF (Hall and Kimura 2002; Wara-

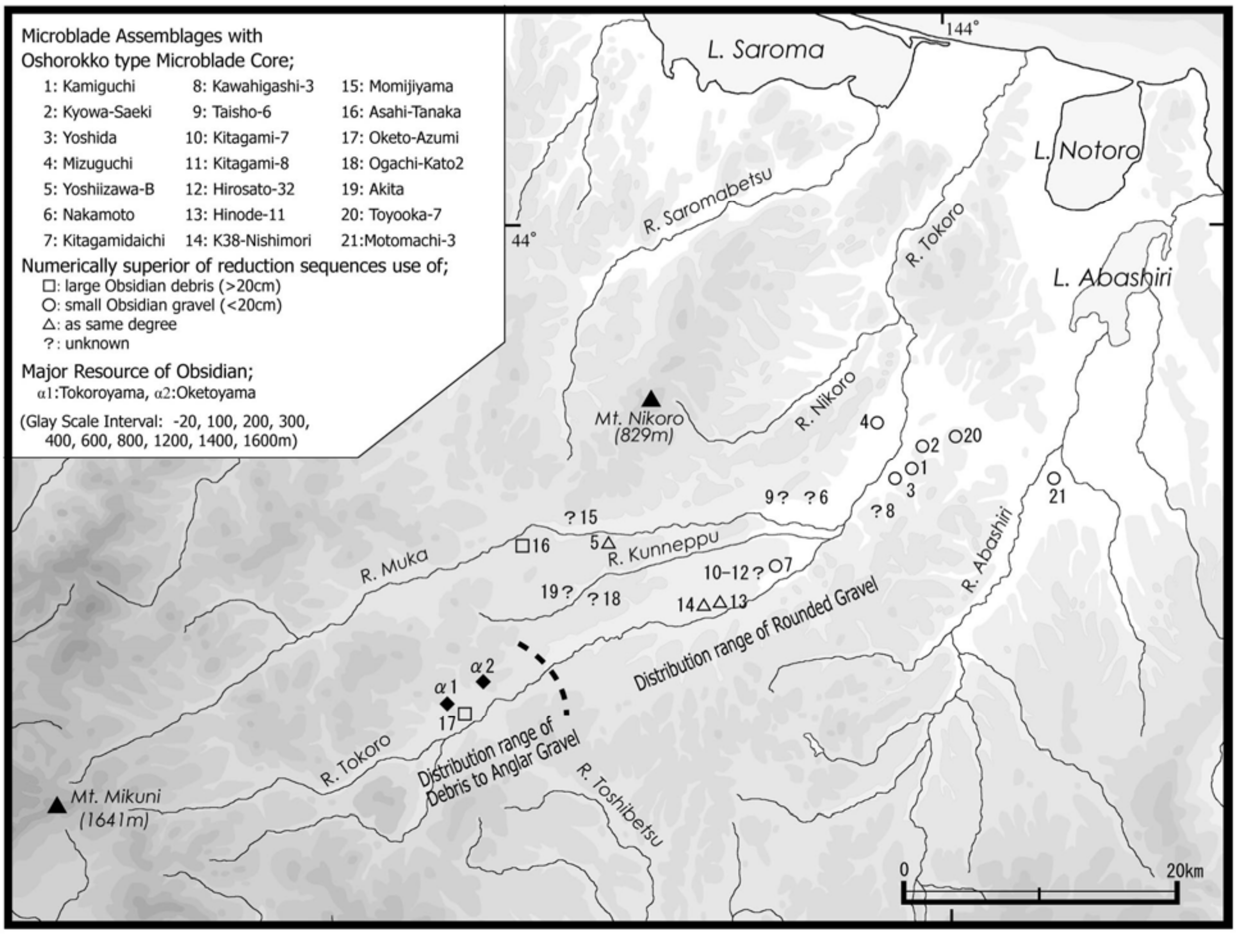


*Figure 3. Site distribution and content of reduction sequence in the microblade assemblages Oshorokko type microblade cores in and around Tokoro River system.*

shina 1999; Yoshitani *et al.* 2001; Inoue 2003), and EPMA (Mukai 2005; Mukai and Wada. 2001; 2003; 2004a; 2004b; Mukai *et al.*2002; 2004). Notably, the four major sources on Hokkaido (Shirataki, Oketo, Tokachimitsumata and Akaigawa) have been described by INAA using 27 elements (Kuzmin *et al.* 2002, 2005). This work demonstrated that discrimination of sources was possible and hopefully can be extended to other sources and archaeological samples.

## ARCHAEOLOGICAL RESEARCH

Many recent studies have used information about the geochemistry of sources and distribution patterns of artefacts to understand exchange and interaction among late Palaeolithic groups in Hokkaido (e.g. Warashina 1999; Kimura 1992, 1995, 1998, 2002, 2005; Kuzmin *et al.* 2002, 2005; Izuho 2002; Sato *et al*. 2002, Sato 2005; Naoe and Nagasaki 2005). Here we outline three main areas of study.

### *Extended exchange networks*

Recent research using INAA has demonstrated that many artefacts in Sakhalin were made from Oketo and Shirataki obsidian (Kuzmin and Popov 2000; Kuzmin *et al*. 2002; 2005; Sato 2004a). Widescale networks, which began during the upper Palaeolithic period, are also known to have extended to the Korean Peninsula and to Kyushu and Honshu in Japan, thus covering large areas of the Japan Sea Rim area and ranging over distances up to 3000 km from the sources (Sato *et al.* 2002; Sato 2005).

### *Changes in procurement and processing*

Over a series of studies, Kimura (1992; 1995; 1998; 2005) has described changes in upper Palaeolithic procurement patterns in Hokkaido, mainly through the analysis of material from the Shirataki source. He has demonstrated a number of key changes through time:

1. Before the appearance of microblades, only rounded material from secondary sources was exploited and not raw material procured from the primary sources themselves or from cobbles surrounding them;
2. Exploitation of the outcrop near the top of Shirataki-Akaishiyamna began after the period of microblade industries and at the time when stemmed points appeared, artefacts from this material were exported to Sakhalin;

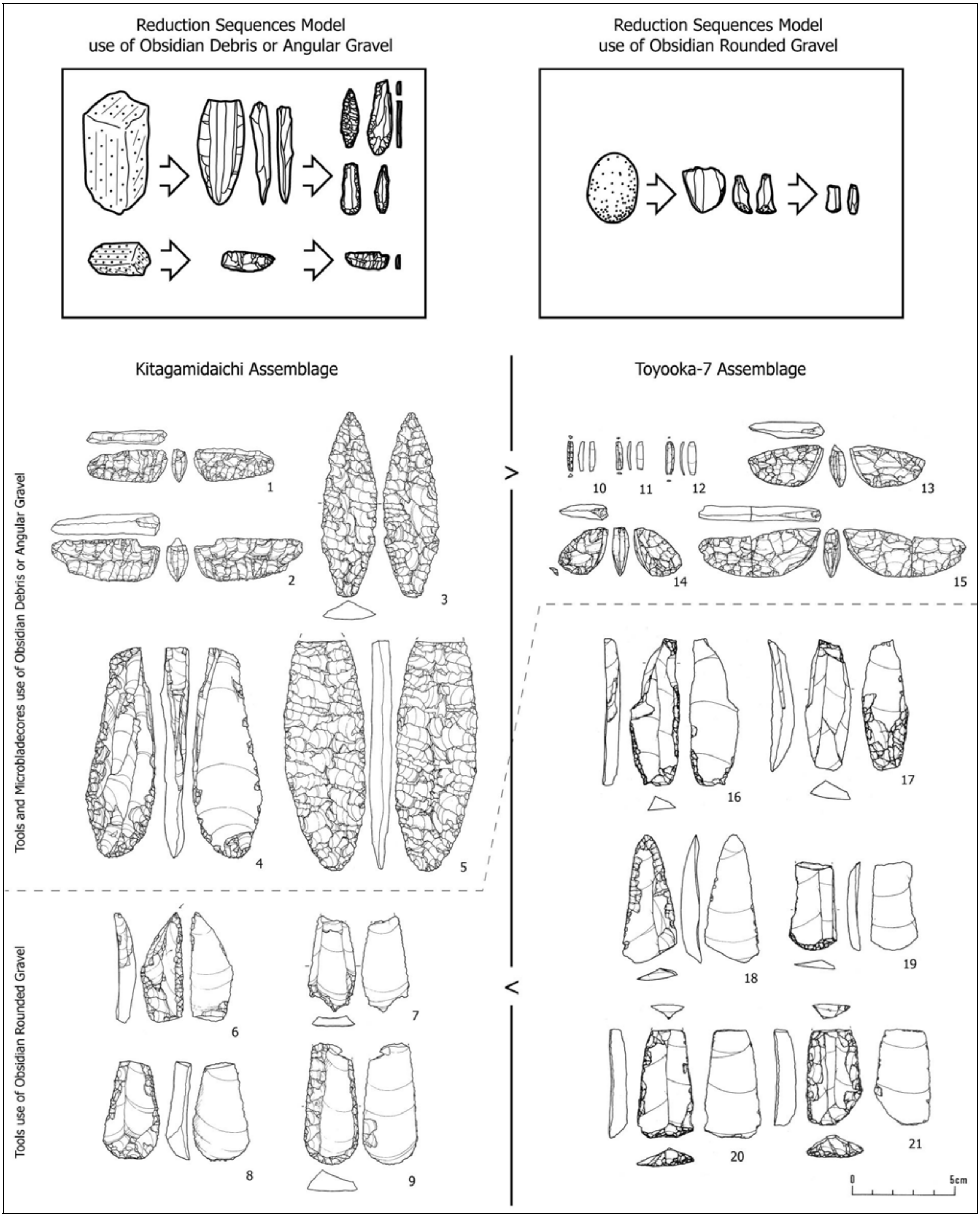


*Figure 4. Blade reduction sequences in microblade assemblage with Oshorokko Type microblade assemblages. 1, 2, 13-15: Oshorokko type microblade core, 4: Hirosato type microblade core, 3: stemmed point, 5: bifacial leafed point, 6, 16-18: burin, 7: Drill, 8-9, 19-21: end scraper, 10-12: microblade, 18: side scraper.*

3. There was inter-regional exchange of fine siliceous shale and obsidian from southern Hokkaido that also extended >200 km from Shirataki. Further, during the period when Sakkotsu microblade cores were made, there is a clear division in behaviour which correlates with differences in altitude (Kimura 1998). Quarries were located above 800 m, intermediate places around 600 m, and villages at below 400 m. Different stages in the production process (i.e. from raw material procurement to tool supply) took place in each of these localities.

*Inter-site variation and raw material procurement*

Variation in the size of raw material correlates well with variation in microblade assemblages along the Tokoro River basin, northeast Hokkaido (Izuho 2002; Nakazawa *et al.* 2005) (Figure 3). In the Upper Tokoro River, near the primary sources of Oketo-Tokoroyama and Oketo-Oketoyama, obsidian is available as debris and angular gravel. In contrast, for 100 km along the middle and lower part of the river, obsidian occurs as secondary deposits, dominated by sub-angular to well rounded obsidian pieces. Although the cobbles were larger during the glacial period, the overall spatial pattern of angular vs rounded material would have remained stable.

Microblade assemblages with Hirosato type cores, which consist of reduction sequences producing large blades (30 cm long), are found in the upper reaches of the Tokoro near the primary sources. Conversely, microblade assemblages with Oshorokko type cores, which produce blades in the order of 10-20 cm, are made mostly on middle-sized, well rounded pieces, although they also contain a few tools made from large debris and angular pieces (Figure 4). The latter assemblages are found up to tens of kilometers from the secondary deposits, for example at Kitagamidaichi (Kitami City Board of Education 1988) and Toyooka-7 (Bihoro Town Board of Education 2002). These examples show that reduction sequences and tool types vary with the form of lithic raw material that is used.

## FUTURE STUDIES

Having briefly summarised the results of recent research, we can look to the future and identify research that will improve our understanding of obsidian procurement, stone tool technology and exchange. In order to discover additional obsidian sources, we highly recommend more collaborative research with geologists. These studies will help explain how obsidian outcrops were formed and can expand on geochemical characterization (cf. Izuho 2005).

On the archaeological side, the very long distance movement of Oketo and Shirataki obsidian across Hokkaido and Sakhalin (>300 km) and around the Japan Sea Rim area, including Hokkaido, Korean Peninsula, southern Primorye in Russia, Honshu and Kyushu (>3,000 km), during the upper Palaeolithic is so great that direct procurement by hunter-gatherer groups over a year, or even several years, is highly unlikely (Sato *et al*. 2002). The processes by which such a distribution network was formed and the significance of exchange to the groups involved clearly require further investigation.

Finally, in terms of exchange and hunter-gatherer behaviour, several results are relevant for guiding future research. Hunter-gatherers in the late Palaeolithic period (c.12-20,000 BP) varied their inter-assemblage variability and related microblade reduction methods in accordance with major environmental changes (Nakazawa *et al.* 2005; Izuho and Takahashi 2005). To explain these differences in obsidian assemblages, we recommend that future research investigate inter-relationships among the nature of raw material procurement, methods of tool manufacture and patterns of hunter-gatherer mobility.

## ACKNOWLEDGEMENTS

We thank Dr. Wataru Hirose (Geological Survey of Hokkaido, Japan), Dr. Satoru Yamada (Kitami City Board of Education, Japan), and Dr. Yaroslav Kuzmin (Pacific Institute of Geography, Far Eastern Branch of the Russian Academy of Sciences, Russia) for their help both with fieldwork and this paper. We specifically thank Dr. Robin Torrence (Australian Museum, Australia) for inviting us to submit this paper and for her help with editing.

## REFERENCES

Bihoro Town Board of Education (ed.) 2002. *Toyooka-7 Site, Bihoro*. Bihoro: Bihoro Town Board of Education. (In Japanese).

Glascock, M.D., G.E. Braswell, and R.H. Cobean. 1998. A systematic approach to obsidian source characterization. In M.S. Shackley (ed.), *Archaeological Obsidian Studies – Method and Theory*, pp. 15-65. New York and London: Plenum Press.

Hall, M. and H. Kimura. 2002. Quantitative EDXRF studies of obsidian sources in northern Hokkaido. *Journal of Archaeological Science* 29:259-266.

Hirose, W. and M. Nakagawa. 1999. Neogene volcanism in Central-Eastern Hokkaido: beginning and evolution of arc volcanism inferred from volcanological parameters and geochemistry. *Chishitsugaku Zassi* 105:247-265. (In Japanese).

Hirose, W., M. Iwasaki, and M. Nakagawa. 2000. Transition of neogene arc volcanism in central-western Hokkaido, viewed from K-Ar ages, style of volcanic activity, and bulk rock chemistry. *Chishitsugaku Zassi* 106:120-135. (In Japanese).

Inoue, I. 2003. Geochemical analysis of obsidians from Shirataki No. 30 site. In Shirataki Village Board of Education (ed.), *Shirataki Dai 30 Chiten Iseki*, pp. 245-258. Shirataki Village: Shirataki Village Board of Education. (In Japanese).

Izuho, M. 1997. A basic study of the lithic raw material in the Tokoro River Basin, Hokkaido (Japan). *Hokkaido Kyusekki Bunka Kenkyu* 2:1-14. (In Japanese).

Izuho, M. 2002. A consideration of the microblade assemblages with Oshorokko type microblade cores in Hokkaido and its significance. In A.M. Kuznetsov (ed.), *Blade and Microblade Industries in Asia and America*, pp. 45-46.

Vladivostok: Far Eastern State University Press.

Izuho, M. 2005. The archaeological obsidian studies in Hokkaido, Japan. Paper presented at the Society for American Archaeology 70th Annual Meeting, Salt Lake City.

Izuho, M. and K. Takahashi. 2005. Correlation of Paleolithic industries and paleoenvironmental change in Hokkaido (Japan). *Current Research in the Pleistocene* 22:19-21.

Kawano, Y. 1950. *Natural glasses in Japan*. Chishitsu Chosajyo Hokoku 134:29. (In Japanese).

Kimura, H. (ed.) 1992. *Reexamination of the Yubetsu technique and study of the Horokazawa Toma Lithic Culture*. Sapporo: Sapporo University.

Kimura, H. 1995. Obsidian, humans, technology. *Hokkaido Koukogaku* 31:3-63. (In Japanese).

Kimura, H. 1998. Obsidian, humans, technology. *Paleoekoligiya Pleistotseha i Kul'turyi Kamennogo Beka Sebernoi Azii i Sopredel'nyikh Territorii*, pp. 302-314. Novosibirsk: IIAE SO RAN.

Kimura, H. 2002. A prospect of the obsidian study in Hokkaido District. *Kokuyouseki Bunka Kenkyu* 1: 69-82. (In Japanese).

Kimura, H. 2005. *Kita no Kokuyoseki no Michi; Shirataki Isekigun*. Tokyo: Shinsensha. (In Japanese).

Kitami City Board of Education. (ed.). 1988. *Kitagami Daichi Site II*. Kitami: Kitami City Board of Education. (In Japanese).

Kitazawa, M. 1999. General survey at the 13 Sawa Site, Kamishihoro Town. *Hokkaido Kyusekki Bunka Kenkyu* 4:19-24. (In Japanese).

Kuzmin, Y.V, and V.K. Popov. (eds.). 2000. *Volcanic Glasses of the Russian Far East: Geological and Archaeological Aspects*. Vladivostok: Rossiiskaya Akademiya Nauk Dal'nevostochnoe Otdelenie Dal'nego vostochnyi Geologicheskii Institut. (In Russian).

Kuzmin, Y.V., M.D. Glascock, and H. Sato. 2002. Sources of archaeological obsidian on Sakhalin Island (Russian Far East). *Journal of Archaeological Science* 29:741-749.

Kuzmin, Y.V., S.V. Gorbunov, V.K. Popov, M.D. Glascock, and M. Izuho. 2005. Obsidian sources of prehistoric complexes in Sakhalin. *Vestnik Sakhalinskogo Muzeya* 12:246-253. (In Russian).

Mukai, M. 2005. Chemical composition of the obsidian glasses from the Monbetsu area, the Rubeshibe and the Toyoura areas of Hokkaido Japan. *Asahikawa Shi Hakuvutsukan Kenkyu Hokoku* 11:9-20. (In Japanese).

Mukai, M. and K. Wada. 2001. Chemical composition of the obsidian glasses from Chippubetsu and Hokuryu District, Western Area of Asahikawa. *Asahikawa Shi Hakuvutsukan Kenkyu Hokoku* 7:23-30. (In Japanese).

Mukai, M. and K. Wada. 2003. Chemical composition of the obsidian glasses from Engaru District and Oumu District, Hokkaido Japan. *Asahikawa Shi Hakuvutsukan Kenkyu Hokoku* 9:19-26. (In Japanese).

Mukai, M. and K. Wada. 2004a. Chemical composition of the obsidian glasses from Okushiri Island, Hokkaido Japan. *Asahikawa Shi Hakuvutsukan Kenkyu Hokoku* 10:41-46. (In Japanese).

Mukai, M. and K. Wada. 2004b. Chemical composition of the obsidian glasses from Tokachi District, Hokkaido Japan. *Asahikawa Shi Hakuvutsukan Kenkyu Hokoku* 10:47-56. (In Japanese).

Mukai, M., H. Hasegawa, and K. Wada. 2000. Chemical composition of the obsidian glasses from Asahikawa district. *Asahikawa Shi Hakuvutsukan Kenkyu Hokoku* 6:51-64. (In Japanese).

Mukai, M., R. Shibuya, and K. Wada. 2004. Chemical composition of the obsidian glasses from Ikutahara District, Hokkaido Japan. *Asahikawa Shi Hakuvutsukan Kenkyu Hokoku* 10:35-40. (In Japanese)

Mukai, M., K. Wada and C. Okura. 2002. Chemical composition of the obsidian glasses from Oketo District and Akaigawa District, Hokkaido Japan. *Asahikawa Shi Hakuvutsukan Kenkyu Hokoku* 8:47-58. (In Japanese).

Nakazawa, Y., M. Izuho, J. Takakura, and S. Yamada. 2005. Toward an understanding of technological variability in microblade assemblages in Hokkaido, Japan. *Asian Perspectives* 44-2:276-292.

Naoe, Y. and J. Nagasaki. 2005. Raw material consumption strategy at early Late Upper Paleolithic in Hokkaido. *Hokkaido Kyusekki Bunka Kenkyu* 10:45-58. (In Japanese).

Nayoro City Board of Education. 1988. *Nisshin 2 site/ Nisshin 31 site*. Nayoro. Nayoro City: Nayoro City Board of Education. (In Japanese).

Okazaki, Y. 1966. *Geology in Kushiro*. Kushiro: Kushiro City Board of Education. (In Japanese).

Sato, H. 2004a. Prehistoric obsidian exploitation in the Russian Far East. *Kokuyouseki Bunka Kenkyu* 3:45-55. (In Japanese).

Sato, H. 2004b. Lithic procurement and reduction strategy of the Hirosato industry in the Japan Sea Rim Area. *Seonsa wa Kodae* 20:205-221.

Sato, H. 2005. Overlooking Paleolithic culture in Hokkaido. *Hokkaido Kyusekki Bunka Kenkyu* 10:137-146. (In Japanese).

Sato, H., Y.V. Kuzmin, M.D. Glascock. 2002. Source analysis of obsidian in prehistoric Sakhalin and an assessment of its distribution in Northeast Asia. *Hokkaido Koukogaku* 38:1-13. (In Japanese).

Sawa, S. (ed.). 1978. *Excavaton Report of Higashi Kushiro No.3 Site, Kushiro City*. Kushiro: Kushiro City Board of Education. (In Japanese).

Shackley, M.S. 1998. Intrasource chemical variability and secondary depositional processes: lessons from the American Southwest. In M.S. Shackley (ed.), *Archaeological Obsidian Studies –Method and Theory*, pp. 83-102. New York and London: Plenum Press.

Shackley, M.S. 2005. *Obsidian: Geology and Archaeology in the North American Southwest*. Tucson: The University of Arizona Press.

Shirataki Dantai Kenkyu Kai (ed.). 1963. *The Study of Shirataki Archaeological Sites*. Sapporo: Shirataki Dantai Kenkyu Kai. (In Japanese).

Suzuki, M. 2005. *Calibration of AMS C-14 Ages Prior to 20,000 Years B.P. or More, Using Fission Track Ages of Burnt Obsidians*. Heisei 14(2002) Nendo kara Heisei 15(2003) Nendo Kibankenkyu(B1) Kenkyu Seika Hokokusho. Tokyo: Rikkyo University. (In Japanese).

Warashina, T. 1999. Source provenience of raw material for stone tools and beads. In S. Matsuura, Y. Uesugi and T. Warashina. (eds.), *Kokogaku to Nendai Sokuteigaku, Chikyu Kagaku*, pp. 259-293. Tokyo: Doseisha. (In Japanese).

Yahata, M., J. Tajika, K. Kurosawa, and T. Matsunami. 1988. *Northern Maruseppu. Explanatory Text of the Geological Map of Japan*. Sapporo: Geological Survey of Hokkaido. (In Japanese).

Yahata, M. 1999. From Abashiri via Cape Notoro to Cape Ponmoi: submarine volcano and marine deposit. In Study Group of Natural History of Eastern Hokkaido (ed.), *Doto no Shizen wo Aruku*, pp. 184-9. Sapporo: Hokkaido University Press. (In Japanese).

Yoshitani, A., M. Kawabe, O. Suda, I. Mizufune, and K. Nagahata. 2001. On resource of obsidian from Oribe 17 site. *Kamishihoro Cho Higashi Taisetsu Hakubustukan Kenkyu Hokoku* 23:1-19. (In Japanese).