Data Report

Measurement of magnetic susceptibility of obsidian from Shirataki, Hokkaido, Japan, to identify the source of obsidian tools

Kyohei SANO[1)]

Abstract

Magnetic susceptibility is often used to identify the source of tools and tombstones that are made from igneous rocks, such as obsidian and granite. This study reports on how the relationship between magnetic susceptibility and sample thickness of obsidian contributes to identifying the source of obsidian tools. Obsidian samples from Shirataki, Hokkaido, Japan, were analyzed, focusing on those from the lava flows of Tokachi-Ishizawa (TI), Akaishiyama (AK), and Horoka-Yubetsu (HY). The sample thickness ranges from 2.74 to 20.84 mm and the magnetic susceptibility ranges from 6.1×10^{-5} to 4.2×10^{-4} SI for the TI lava, from 2.52 to 13.78 mm and 3.3×10^{-5} to 2.1×10^{-4} SI for the AK lava, and from 2.05 to 23.28 mm and from 1.9×10^{-4} to 7.3×10^{-4} SI for the HY lava, depending on the thickness of the sample wafer. The results revealed that obsidian from the HY lava demonstrated the highest value of magnetic susceptibility among the analyzed samples; thus, obsidian from the HY lava could be identified by this characteristic. Concurrently, heterogeneity in the magnetic susceptibility within a single lava flow was observed in the AK lava. These results could contribute to the identification of the source of obsidian tools and development of nondestructive techniques for measurement of magnetic susceptibility.

Key words：magnetic susceptibility, obsidian, source identification, nondestructive analysis, rock texture

（Received: 5 December, 2020, Accepted: 31 January, 2021, Issued: 31 March, 2021）

Introduction

Obsidian is a volcanic rock formed by the eruption of viscous magma and is characterized by an entirely glassy matrix with a small amount of crystals, including phenocrysts and microlites (Sano et al., 2015; Sano and Toramaru, 2017). In Japan, it has been a natural resource for making tools, since the end of the Paleolithic period (Kanomata et al., 2015). Previous efforts to identify the sources of obsidian tools have focused on the chemical composition of the glass, differences in color among hand specimens, and textures of rock, including the morphology of microlites (Wada and Sano, 2011). However, the methods for its analysis have often been destructive. Because it is important to preserve

1）Graduate School of Regional Resource Management, University of Hyogo, 128 Shounji, Toyooka-shi, Hyogo 668-0814, Japan, corresponding author: Kyohei SANO E-mail:sano@rrm.u-hyogo.ac.jp

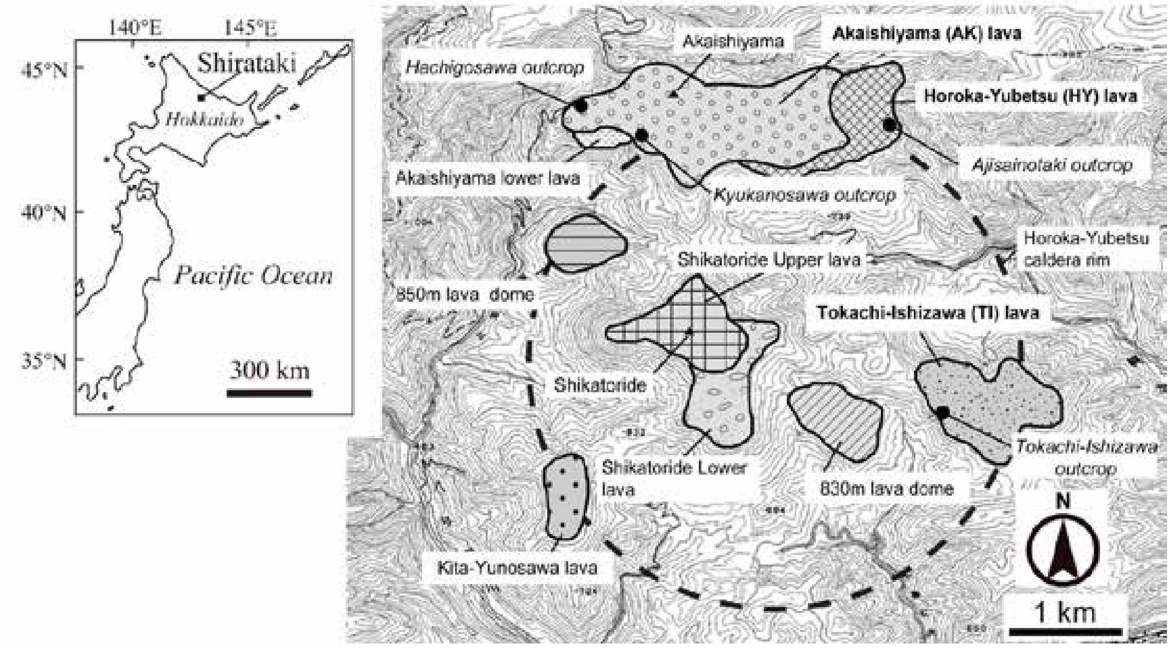

Fig. 1. Distribution map of the obsidian lava flows in Shirataki, Hokkaido, Japan. This map is compiled from Wada and Sano (2011) and Wada and Sano (2016). The locations of the four outcrops, from which the obsidian samples used in this study were collected, are also indicated. This map is based on the topographic map published by the Geospatial Information Authority of Japan.

cultural properties, recent studies have attempted to obtain useful information via nondestructive method of analysis, such as X-ray fluorescence and Raman spectroscopy (Carter et al., 2009; Kelloway et al., 2010; Mashima, 2018). Magnetic susceptibility has also been used to identify the source of obsidian (Kanto, 2015) and granitic tombstones (Sakiyama, 2019a, b).

In this study, I focused on magnetic susceptibility, because it is a nondestructive analytical method to identify the sources of obsidian and other types of igneous rocks. Additionally, obsidian has an advantage involving magnetic susceptibility, since it is entirely composed of glass and a small number of crystals, including magnetite. In principle, magnetic susceptibility depends on the type, amount, and size of the magnetic minerals. Thus, using obsidian is an easy way to detect the effect of such parameters on the measurement of magnetic susceptibility. This paper reports the magnetic susceptibility of obsidian and its relationship with the thickness of the samples to improve methods for identifying the source of obsidian tools and to develop nondestructive analytical techniques. Sample thickness is an important factor, because microblades and flakes of obsidian can be sometimes found in remains smaller than 10-mm thickness (Nakazawa et al., 2019). It is important to consider the effect of sample thickness on its magnetic susceptibility.

This paper first describes the textures of obsidian samples from Shirataki, Hokkaido, Japan, and thereafter, the methods used. Next, the analytical results of the magnetic susceptibility and the thicknesses of the obsidian wafers are reported. Finally, this paper discusses the application of using magnetic susceptibility for identifying the sources of obsidian tools and the relationship between rock texture and magnetic susceptibility.

Samples

For the study of magnetic susceptibility, I used the obsidian samples from Shirataki, Hokkaido, Japan. I collected the samples from the following lava flows: Tokachi–Ishizawa (TI; Tokachi–Ishizawa outcrop), Akaishiyama (AK; Hachigosawa and Kyukanosawa outcrops), and Horoka–Yubetsu (HY; Ajisainotaki outcrop). Figure 1 shows the distribution of the obsidian lavas and outcrops in the Shirataki area. The chemical and textural characteristics of the obsidian samples from each lava flow have been reported by Wada and Sano (2011), and the lava structures have been described by Wada and Sano (2015) and Sano et al. (2015).

In the Shirataki area of Hokkaido in northern Japan, dacite and rhyolite magma erupted during the late Pliocene period and formed a pyroclastic deposit. This magmatism formed a caldera structure, which is called the HY caldera (Wada and Sano, 2011), which corresponds to a region of the Bouguer anomaly (Yamamoto, 2004). After the formation of the HY caldera, aphyric rhyolite magma began to erupt and explosions within the caldera formed several pyroclastic deposits, including lake deposit that contain obsidian fragments (HY formation; Konoya et al., 1964). Subsequently, effusive aphyric rhyolite lava erupted and pyroclastic materials buried the caldera lake. Thereafter, the volcanic activity was subaerial, with aphyric rhyolite lava erupting at the caldera rim and inside it. The age of obsidian lava flows in the Shirataki area have been estimated by K–Ar dating as follows: circa 2.24 Ma (± 0.05) for the AK lava, circa 2.26 Ma (± 0.07) for the HY lava, circa 2.20 Ma (± 0.11) for the TI lava, and circa 2.11 Ma (± 0.05) for the Shikatoride lower lava (Wada and Sano, 2011). The flow units that form the monogenetic volcanoes can be classified into four geochemical groups (TI–A, TI–B, AK–A, and AK–B), based on their glass composition, comparing the concentration of FeO* and CaO (Wada and Sano, 2011).

Wada and Sano (2011) have outlined 10 flow units of obsidian lava in Shirataki. However, a recent geological survey indicates that the AK summit and upper lava flows are part of a single unit called AK lava (Wada and Sano, 2016). This present study follows the description from Wada and Sano (2016).

Obsidian from TI lava is aphyric and mainly consists of glass (>97 vol.%). Further, it contains microphenocrysts of magnetite (0.05–0.1 mm), microlites of plagioclase (<0.2 mm), oxides (<0.05 mm), rare K-feldspar (<0.05 mm), rare biotite (<0.01 mm), and plagioclase phenocrysts (0.4–1.0 mm) (Sano et al., 2015). The volume fraction of rare crystals is less than 1 vol.%. Obsidians from the AK and HY lavas are composed of mostly glass (>98 vol.%) and microphenocrysts and microlites of magnetite (< 0.07 mm) (Wada and Sano, 2011).

Methods

I constructed an obsidian wafer for the measurement of magnetic susceptibility. First, I cut the samples with a rock cutter to create wafers of different thicknesses, ranging from 2.05 to 23.28 mm (Fig.2). The length, width, and area of the wafers range from 28.4 to 38.3 mm, from 22.2 to 34.0 mm, and from 724.2 to 1302.2 mm^2,

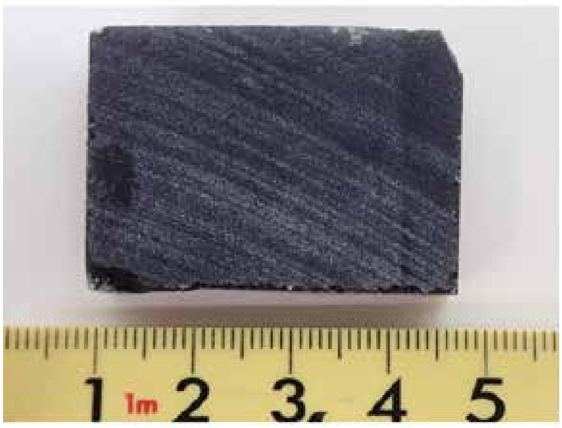

Fig. 2. Photograph of a representative obsidian wafer used in this study.

respectively. Thereafter, I measured the magnetic susceptibility by using the KT-10v2 magnetic susceptibility meter (Terraplus Inc.), which has a sensitivity of 1×10^{-6} SI and range from 0.001×10^{-3} SI to 1999.99×10^{-3} SI, along with the sample thickness by using a digimatic micrometer (Mitutoyo Corp.). The analytical error for the digimatic micrometer was 2 μm. I conducted 15 analyses on the center of each wafer for the measurement of magnetic susceptibility.

Results

The results of the measurements of the sample thickness and magnetic susceptibility are shown in Tables 1–4. This section summarizes the results

Table 1. Results of the measurements of the thickness (mm) and magnetic susceptibility (SI) of the samples from the TI lava.

Lava name	Thickness [mm]	Magnetic Susceptibility [SI]
TI	2.74	6.1E-05
TI	2.75	7.4E-05
TI	2.75	6.6E-05
TI	2.75	6.8E-05
TI	2.76	7.6E-05
TI	2.75	7.4E-05
TI	2.75	6.8E-05
TI	2.74	8.5E-05
TI	2.76	7.5E-05
TI	2.76	7.8E-05
TI	2.77	7.8E-05
TI	2.76	7.1E-05
TI	2.77	7.3E-05
TI	2.75	7.7E-05
TI	2.75	8.2E-05
TI	7.36	1.8E-04
TI	7.34	1.7E-04
TI	7.36	1.6E-04
TI	7.36	1.5E-04
TI	7.36	1.7E-04
TI	7.36	2.0E-04
TI	7.36	1.5E-04
TI	7.37	1.8E-04
TI	7.37	1.6E-04
TI	7.37	1.7E-04
TI	7.37	1.8E-04
TI	7.37	1.8E-04
TI	7.37	1.5E-04
TI	7.37	1.9E-04
TI	7.37	1.6E-04
TI	7.65	1.9E-04
TI	7.65	1.9E-04
TI	7.65	1.9E-04
TI	7.64	2.1E-04
TI	7.66	2.1E-04
TI	7.64	2.0E-04
TI	7.65	1.9E-04
TI	7.64	1.9E-04
TI	7.64	1.8E-04
TI	7.64	2.0E-04
TI	7.65	2.1E-04
TI	7.64	2.1E-04
TI	7.64	1.8E-04
TI	7.66	2.1E-04
TI	7.64	2.1E-04
TI	12.13	2.3E-04
TI	12.13	2.5E-04
TI	12.10	2.2E-04
TI	12.11	2.2E-04
TI	12.10	2.2E-04
TI	12.08	2.4E-04
TI	12.12	2.4E-04
TI	12.10	2.4E-04
TI	12.09	2.1E-04
TI	12.13	2.4E-04
TI	12.11	2.3E-04
TI	12.07	2.4E-04
TI	12.11	2.3E-04
TI	12.07	2.3E-04
TI	12.10	2.3E-04
TI	20.78	4.2E-04
TI	20.77	4.2E-04
TI	20.74	3.6E-04
TI	20.77	3.6E-04
TI	20.82	3.5E-04
TI	20.81	3.9E-04
TI	20.78	3.9E-04
TI	20.74	3.7E-04
TI	20.76	3.4E-04
TI	20.84	3.8E-04
TI	20.76	3.7E-04
TI	20.73	3.9E-04
TI	20.78	4.0E-04
TI	20.78	3.7E-04
TI	20.73	3.8E-04

for the obsidian from each lava flow.

TI lava

Table 1 shows the analytical results for the TI lava. The thickness of the obsidian samples ranged from 2.74 to 20.84 mm, whereas the magnetic susceptibility ranged from 6.1 × 10^{-5} to 4.2 × 10^{-4} SI, depending on the thickness of the wafer (Table 1). The solid red circles in Fig. 3 show the analytical results for the TI lava. The bold red line corresponds to the regression line (y = 1.95 × 10^{-5}x, R^2 = 0.98) obtained for all the analytical results (Fig. 3).

AK lava (Hachigosawa outcrop)

Table 2 shows the analytical results for the AK lava from the Hachigosawa outcrop. The thickness of the obsidian wafers ranged from 2.52 to 13.78 mm, whereas the magnetic susceptibility ranged from 3.3 × 10^{-5} to 1.6 × 10^{-4} SI, depending on the thickness of the wafer (Table 2). The solid orange squares in Fig. 3 show the analytical results for the AK lava from the Hachigosawa outcrop. The bold orange line corresponds to the regression line (y = 1.14 × 10^{-5}x, R^2 = 0.98) obtained for all the analytical results (Fig. 3).

AK lava (Kyukanosawa outcrop)

Table 3 shows the analytical results for the

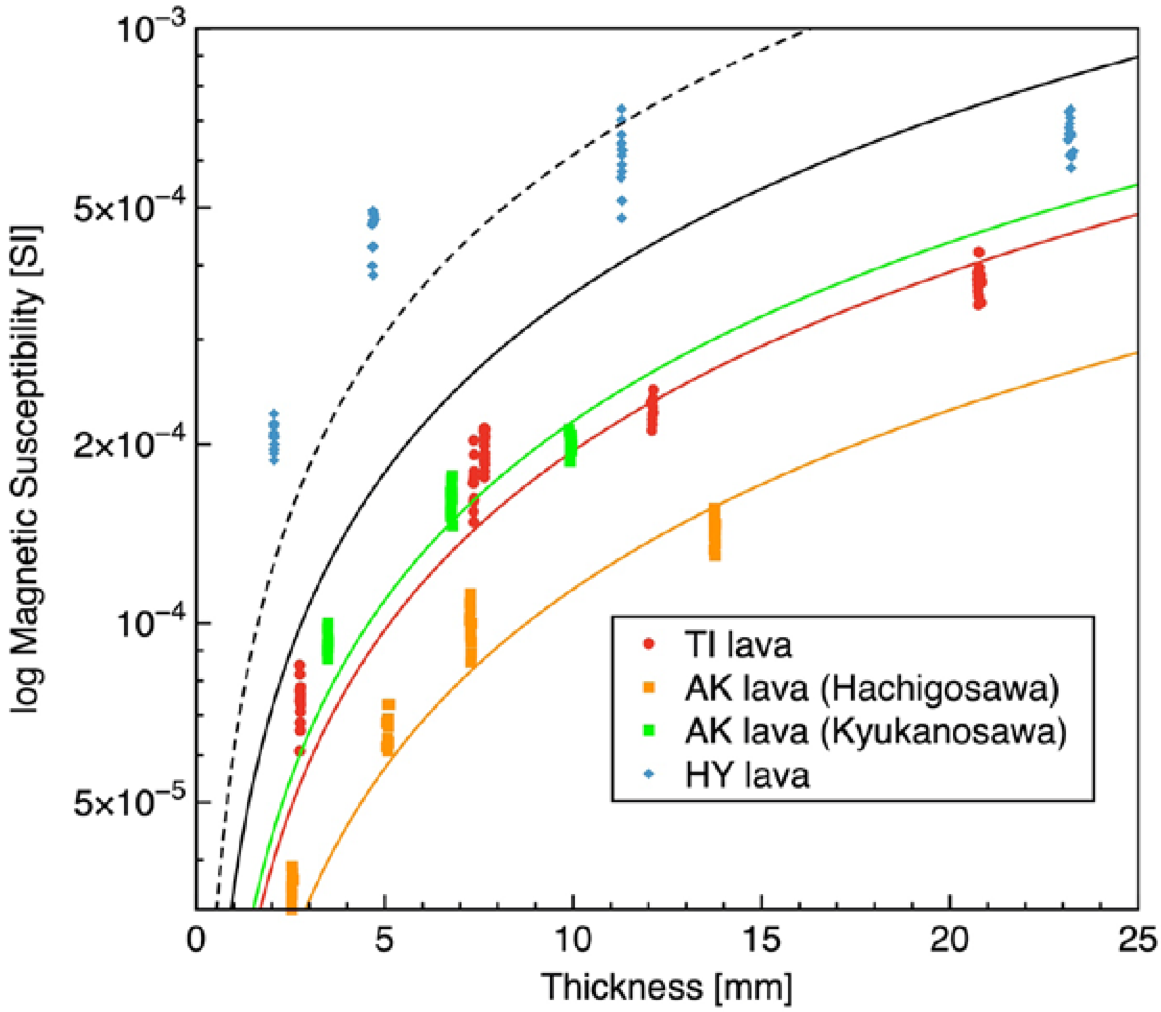

Fig. 3. Measurements of the thickness (mm) and magnetic susceptibility (SI) of the samples from the TI, AK, and HY lavas. The regression line for each analysis is also shown. The bold line corresponds to the regression line including all the measurement results, and the dashed line corresponds to the regression line including the results for the samples under 12-mm thickness in the HY lava.

AK lava from the Kyukanosawa outcrop. The thickness of the obsidian wafers ranged from 3.48 to 9.96 mm, whereas the magnetic susceptibility ranged from 8.7×10^{-5} to 2.1×10^{-4} SI, depending on the thickness of the wafer (Table 2). The solid green squares in Figure 3 show the analytical results for the AK lava from the Kyukanosawa outcrop. The bold green line corresponds to the regression line ($y = 2.19 \times 10^{-5}x$, $R^2 = 0.98$) obtained for all the analytical results (Fig. 3).

HY lava

Table 4 shows the analytical results for the HY lava. The thickness of the obsidian wafers ranged from 2.05 to 23.28 mm, whereas the magnetic susceptibility ranged from 1.9×10^{-4} to 7.3×10^{-4} SI, depending on the thickness of the wafer (Table 4). The solid blue rhomboids in Fig. 3 show the analytical results for the HY lava. The bold black line corresponds to the regression line ($y = 3.58 \times 10^{-5}x$, $R^2 = 0.83$) obtained for all the analytical results, and the dashed line corresponds to the regression line ($y = 6.13 \times 10^{-5}x$, $R^2 = 0.92$) including the results for samples less than 12-mm thickness (Fig. 3) in the HY lava.

Discussion

This section summarizes how the measurement results relate to the characteristics of each type of lava. Overall, although the results of HY lava exhibited a peak in the magnetic susceptibility for thickness over 11 mm (Fig. 3), the HY lava exhibited the highest values of magnetic susceptibility among the samples I analyzed (Fig. 3). This peak could be because the sample thickness is beyond the range of the analytical depth for magnetic susceptibility. This implies that the samples have boundary thickness to make the magnetic susceptibility constant. This study calls that boundary thickness as the effective thickness. The results indicate that the effective thickness for the HY lava is between 5 and 11 mm.

The dashed regression line obtained for samples below 12-mm thickness reveals a good correlation between the sample thickness and magnetic susceptibility. To identify the source, it is important to determine the effective thickness of the targeted samples.

Results for the AK lava from the Hachigosawa and Kyukanosawa outcrops exhibited different trends for magnetic susceptibility, although they were based on the same lava flow (Figs. 1 and 3). In other words, some heterogeneity in magnetic susceptibility was found within a single lava flow. Based on this study, a sample with low magnetic susceptibility that ranges from 3.3×10^{-5} to 1.6×10^{-4} SI could be considered to be originated from the AK lava. However, a more in-depth study of the overlapping range of magnetic susceptibility is necessary to understand the heterogeneity in magnetic susceptibility within single obsidian lava flows.

In this study, I used the obsidian wafer which has a flat surface. However, obsidian tools found in remains sometimes have an irregular surface. For accurate source identification, it is better to adopt the flat surface of tools, and further research is necessary to reveal the relationship between magnetic susceptibility and the morphology of the analyzed surface.

Texture of obsidian from Shirataki

Magnetic susceptibility depends on the texture of the rock, especially its number density, size, and the morphology of the magnetic minerals. The number density of magnetite in obsidian from the Shirataki area was reported by both Wada and Sano (2011) and Sano et al. (2015). The microlite number density (*Nv* number/m^3), in particular, was calculated from the number of crystals and the measured volume. The *Nv* values for Shirataki obsidian were 5.0×10^{13}–7.9×10^{13} /m^3 for the TI lava, 1.0×10^{14}–1.0×10^{15} /m^3 for the AK lava

Table 2. Results of the measurements of the thickness (mm) and magnetic susceptibility (SI) of the samples from the AK lava (Hachigosawa outcrop).

Lava name	Thickness [mm]	Magnetic Susceptibility [SI]
AK	2.54	3.5E-05
AK	2.55	3.7E-05
AK	2.54	3.7E-05
AK	2.52	3.4E-05
AK	2.52	3.6E-05
AK	2.53	3.9E-05
AK	2.54	3.7E-05
AK	2.55	3.8E-05
AK	2.52	3.3E-05
AK	2.53	3.3E-05
AK	2.54	3.7E-05
AK	2.54	3.9E-05
AK	2.53	3.5E-05
AK	2.58	3.7E-05
AK	2.53	3.6E-05
AK	5.05	6.8E-05
AK	5.08	6.4E-05
AK	5.08	6.4E-05
AK	5.08	6.9E-05
AK	5.09	6.1E-05
AK	5.05	6.2E-05
AK	5.13	7.3E-05
AK	5.10	6.9E-05
AK	5.11	6.3E-05
AK	5.10	6.7E-05
AK	5.10	6.7E-05
AK	5.08	7.3E-05
AK	5.09	6.3E-05
AK	5.10	6.9E-05
AK	5.09	6.7E-05

Lava name	Thickness [mm]	Magnetic Susceptibility [SI]
AK	7.27	1.1E-04
AK	7.29	1.0E-04
AK	7.30	8.9E-05
AK	7.28	9.9E-05
AK	7.25	1.1E-04
AK	7.28	9.6E-05
AK	7.27	1.1E-04
AK	7.27	1.1E-04
AK	7.28	9.5E-05
AK	7.25	1.0E-04
AK	7.29	8.6E-05
AK	7.27	1.1E-04
AK	7.31	1.0E-04
AK	7.29	9.3E-05
AK	7.25	1.0E-04
AK	13.76	1.4E-04
AK	13.77	1.4E-04
AK	13.76	1.4E-04
AK	13.76	1.4E-04
AK	13.76	1.5E-04
AK	13.78	1.5E-04
AK	13.77	1.3E-04
AK	13.75	1.3E-04
AK	13.77	1.4E-04
AK	13.76	1.5E-04
AK	13.76	1.6E-04
AK	13.76	1.4E-04
AK	13.76	1.4E-04
AK	13.75	1.5E-04
AK	13.75	1.5E-04

Table 3. Results of the measurements of the thickness (mm) and magnetic susceptibility (SI) of the samples from the AK lava (Kyukanosawa outcrop).

Lava name	Thickness [mm]	Magnetic Susceptibility [SI]
AK	3.48	9.0E-05
AK	3.48	9.2E-05
AK	3.49	9.8E-05
AK	3.50	1.0E-04
AK	3.51	9.3E-05
AK	3.51	9.4E-05
AK	3.50	9.1E-05
AK	3.49	9.5E-05
AK	3.49	9.2E-05
AK	3.49	9.0E-05
AK	3.49	8.8E-05
AK	3.49	8.7E-05
AK	3.50	9.9E-05
AK	3.50	9.1E-05
AK	3.50	9.8E-05
AK	6.76	1.6E-04
AK	6.77	1.6E-04
AK	6.74	1.7E-04
AK	6.78	1.8E-04
AK	6.75	1.5E-04
AK	6.74	1.5E-04
AK	6.78	1.7E-04
AK	6.75	1.6E-04
AK	6.77	1.7E-04
AK	6.77	1.7E-04
AK	6.76	1.6E-04
AK	6.78	1.7E-04
AK	6.78	1.6E-04
AK	6.76	1.5E-04
AK	6.79	1.5E-04

Lava name	Thickness [mm]	Magnetic Susceptibility [SI]
AK	9.93	2.1E-04
AK	9.94	2.0E-04
AK	9.92	1.9E-04
AK	9.93	2.0E-04
AK	9.93	2.1E-04
AK	9.93	2.1E-04
AK	9.92	2.1E-04
AK	9.96	2.0E-04
AK	9.95	2.0E-04
AK	9.93	2.0E-04
AK	9.95	2.0E-04
AK	9.94	2.1E-04
AK	9.95	2.0E-04
AK	9.89	2.1E-04
AK	9.89	2.1E-04

from the Hachigosawa outcrop, 1.1×10^{14}–1.8×10^{14} /m^3 for the AK lava from the Kyukanosawa outcrop, and 4.5×10^{13}–1.2×10^{14} /m^3 for the HY lava (Wada and Sano, 2011; Sano et al., 2015). Based on the results of magnetic susceptibility and reports regarding the number density, it is difficult to explain the difference in magnetic susceptibility based only on the difference in the number density, as the values of number density overlap among the lava flows.

For example, the magnetite in the obsidian of the TI lava is dominantly acicular in morphology and has an aspect ratio (length/width) that ranges from 1 to 50. In contrast, the obsidian of the HY lava from the Ajisainotaki outcrop has an aspect ratio, which ranges from 1 to 15. The size and morphology of magnetite has variations (Wada and Sano, 2011). Wada and Sano (2011) present microphotographs of these variable magnetites and report that magnetite in obsidian from different outcrops within the same lava flow can vary in morphology, including either euhedral or bead-like magnetite. Although further investigation is necessary to reveal the relationship between magnetic susceptibility and the texture of rocks, this heterogeneity in magnetite morphology could explain the different magnetic susceptibilities found in this study. To reach a better understanding of the relationship between magnetic susceptibility and rock texture, it is important to consider not only the number density but also the size and morphology of the

Table 4. Results of the measurements of the thickness (mm) and magnetic susceptibility (SI) of the samples from the HY lava.

Lava name	Thickness [mm]	Magnetic Susceptibility [SI]	Lava name	Thickness [mm]	Magnetic Susceptibility [SI]
HY	2.07	2.0E-04	HY	11.29	6.1E-04
HY	2.06	2.1E-04	HY	11.28	6.4E-04
HY	2.05	2.1E-04	HY	11.29	7.0E-04
HY	2.06	2.2E-04	HY	11.29	6.4E-04
HY	2.06	2.1E-04	HY	11.29	6.6E-04
HY	2.06	2.1E-04	HY	11.29	7.3E-04
HY	2.06	1.9E-04	HY	11.30	5.1E-04
HY	2.06	2.0E-04	HY	11.29	4.8E-04
HY	2.06	1.9E-04	HY	11.32	6.2E-04
HY	2.06	2.1E-04	HY	11.30	5.8E-04
HY	2.05	2.1E-04	HY	11.31	6.3E-04
HY	2.05	2.2E-04	HY	11.29	6.3E-04
HY	2.06	2.2E-04	HY	11.30	5.9E-04
HY	2.05	2.3E-04	HY	11.29	5.1E-04
HY	2.05	2.1E-04	HY	11.27	5.6E-04
HY	4.69	4.8E-04	HY	23.23	6.2E-04
HY	4.70	4.7E-04	HY	23.21	7.3E-04
HY	4.69	4.9E-04	HY	23.22	5.8E-04
HY	4.67	4.3E-04	HY	23.16	7.2E-04
HY	4.68	4.3E-04	HY	23.19	6.9E-04
HY	4.70	4.3E-04	HY	23.28	6.2E-04
HY	4.70	4.8E-04	HY	23.22	6.7E-04
HY	4.66	4.7E-04	HY	23.24	6.1E-04
HY	4.69	4.9E-04	HY	23.14	6.5E-04
HY	4.68	4.9E-04	HY	23.16	6.7E-04
HY	4.71	4.8E-04	HY	23.20	7.1E-04
HY	4.75	4.8E-04	HY	23.23	6.6E-04
HY	4.67	4.0E-04	HY	23.18	6.1E-04
HY	4.69	3.9E-04	HY	23.17	6.8E-04
HY	4.73	4.9E-04	HY	23.17	7.2E-04

minerals.

Conclusion

In this study, I provide the data of the magnetic susceptibility and thickness for obsidian from Shirataki, Hokkaido, Japan. Heterogeneity in magnetic susceptibility within a single lava flow was observed in the AK lava, although these samples exhibited a lower value of magnetic susceptibility compared with the HY lava. Analytical results revealed that the HY lava exhibited the highest value of magnetic susceptibility among the analyzed samples and obsidian from this lava could be identified by magnetic susceptibility.

Acknowledgments

I would like to thank Dr. Norihito Kawamura and Masato Sakiyama of University of Hyogo for their insightful comments and guidance on the measurement of magnetic susceptibility. I am indebted to the Shirataki-Geopark Promotion Department for assistance with the geological survey in the Shirataki area. Anonymous reviewer also greatly improved this manuscript. I would like to thank Enago (www.enago.jp) for reviewing the English language of the manuscript.

References

Carter, E. A., Hargreaves, M. D., Kononenko, N., Graham, I., Edwards, H. G. M., Swarbrick, B., Torrence, R. (2009). Raman spectroscopy applied to understanding Prehistoric Obsidian Trade in the Pacific Region. Vibrational Spectroscopy, 50, 116–124.

Kanomata, Y., Inoue, I., Yanagida, T. (2015). A basic study on obsidian source exploitation and its circulation in prehistoric Japanese archipelago. Culture, 79, 47–61. (in Japanese with English abstract)

Kanto, A. (2015). The source and usage of obsidians and archaeological artifacts through the investigation of the magnetic properties. The doctoral thesis of Graduate School of Science and Engineering for Education, University of Toyama, 1–94. (in Japanese with English abstract)

Kelloway, S. J., Kononenko, N., Torrence, R., Carter, E. A. (2010). Assessing the viability of portable Raman spectroscopy for determining the geological source of obsidian. Vibrational Spectroscopy, 53, 88–96.

Konoya, M., Hasegawa, K., Matsui, K. (1964). Explanatory text of the geological map of

Japan, scale 1:50,000 “Shirataki”. Geological Survey of Hokkaido, 35 p. (in Japanese with English abstract)

Mashima, H. (2018). Nondestructive analyses of bulk rock compositions of obsidian using a handheld XRF Delta Premium DP-6000. Natural Resource Environment and Humans, 8, 109–118. (in Japanese with English abstract)

Nakazawa, Y., Sano, K., Naoe, Y., Sakamoto, N., Izuho, M., Nomura, H. (2019). Role of minimum analytical nodules in obsidian hydration in measurement: insight from Kyu-Shirataki 3 in Hokkaido, Japan. IAOS Bulletin, 62, 8–15.

Sakiyama, T. (2019a). Stones forming tombs of feudal lords during Edo period in some geoparks located along the coast of the Sea of Japan. Japan Geoscience Union Meeting 2019. (in Japanese with English abstract)

Sakiyama, T. (2019b). Magnetic susceptibility of granitic tombstones in graveyards of feudal lords in San-in Area, Southwest Japan. The 126th Annual Meeting of the Geological Society of Japan, 31. (in Japanese)

Sano, K., Toramaru, A. (2017). Cooling and crystallization of rhyolite–obsidian lava: Insights from micron-scale projections on plagioclase microlites. Journal of Volcanology and Geothermal Research, 341, 158–171.

Sano, K., Wada, K., Sato, E. (2015). Rates of water exsolution and magma ascent inferred from microstructures and chemical analyses of the Tokachi-Ishizawa obsidian lava, Shirataki, northern Hokkaido, Japan. Journal of Volcanology and Geothermal Research, 292, 29–40.

Wada, K., Sano, K. (2011). Chemical composition and microstructure of Shirataki obsidian, northern Hokkaido: geological and petrological source data for the precise obsidian source identification. Palaeolithic Research, 7, 57–73. (in Japanese with English abstract)

Wada, K., Sano, K. (2015). Internal Structure of Obsidian Lavas in Shirataki Geopark, Hokkaido. Bulletin of Volcanological Society of Japan, 60, 151–158. (in Japanese with English abstract)

Wada, K., Sano, K. (2016). Occurrence of spherulite concentration zone and internal structure of the Shirataki obsidian lava, northern Hokkaido, Japan. Goldschmidt Conference Abstracts, 3293.

Yamamoto, A. (2004). Dense clustering of latest Cenozoic caldera-like basins of central Hokkaido, Japan, evidenced by gravimetric study. Journal of the Faculty of Science, Hokkaido University. Series 7, Geophysics 12, 75–95.

産地同定のための
白滝産黒曜石試料の帯磁率測定

佐野　恭平[1)]

要　旨

帯磁率測定は黒曜石や花崗岩のような火成岩によって生み出された石器および墓石の非破壊分析による産地同定に有用な手法である．本研究では，産地同定に資するデータとして，黒曜石の帯磁率と試料厚の関係を報告した．分析には北海道白滝地域に噴出した十勝石沢溶岩，赤石山溶岩，幌加湧別溶岩で採取した黒曜石を用いた．分析の結果，十勝石沢溶岩の黒曜石では試料厚が2.74 mm から 20.84 mmの範囲で帯磁率が6.1×10^{-5} SIから4.2×10^{-4} SI，赤石山溶岩の黒曜石では試料厚が2.52 mm から13.78 mmの範囲で帯磁率が3.3×10^{-5} SIから2.1×10^{-4} SI，幌加湧別溶岩の黒曜石では試料厚が2.05mmから23.28mmの範囲で帯磁率が1.9×10^{-4} SIから7.3×10^{-4} SIの範囲を示し，試料の厚さと帯磁率との関係に正の相関が見られた．本研究により，幌加湧別溶岩の黒曜石は白滝産黒曜石の中で最も帯磁率が大きく，他の白滝産黒曜石と識別できる可能性を示した．本研究は帯磁率を用いた非破壊による産地同定方法の向上や黒曜石製石器の産地同定に貢献するデータを提供している．

1) 兵庫県立大学大学院地域資源マネジメント研究科　〒668-0814 兵庫県豊岡市祥雲寺128