Physical and Chemical Properties of Volcanic Ejecta Produced by the Eruption of Mt. Kirishima Shinmoe-dake, Japan -A Case Study After the Explosive Eruption on March 25, 2018-

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Research Article

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Physical and chemical properties of volcanic ejecta produced by the eruption of Mt. Kirishima Shinmoe-dake, Japan -A case study after the explosive eruption on March 25, 2018-

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ABSTRACT:

The purpose of this study was to clarify the physical and chemical properties of volcanic ejecta that fell after the explosive eruption on March 25, 2018 at Shinmoe-dake. In order to investigate the infiltration capacity, which is one of the physical properties of volcanic ejecta, plots were set up on the outer forest plain, the forest plain, and the forest talus, and a cylindrical frame test was conducted with reference to the method of Takeshita (2011). In addition, soil samples were collected at the three locations where the cylindrical frame test was conducted. The final infiltration capacity of 38-92 mm / h appeared lower in the forest talus than in the forest plain. It is considered that this is due to the small particle size distribution of 0.1 mm or more, regardless of the particle size of the silt / clay particle size classification. When the chemical properties of the collected volcanic ejecta were

examined, Ca and SO_4 were contained at high values. Since these compounds become the source of gypsum that reduces infiltration capacity when they react with water, it has become clear that they have the potential to contribute to the generation of debris-flow as a chemical property.

1. Introduction

Mt. Shinmoe-dake in Japan had an explosive eruption for several hundred years from January 26-27, 2011, and volcanic ejecta was deposited in the mountain stream at the foot of the mountain (Oikawa et al. 2013). The deposition of fine-grained volcanic ejecta on slopes is said to significantly reduce the infiltration capacity (Onda et al. 1996), which increases the risk of debris flow generation. At the time of the eruption in January 2011, there was a risk of a debris flow disaster after rainfall, so the Ministry of Land, Infrastructure, Transport and Tourism conducted a survey (Ministry of Land, Infrastructure, Transport and Tourism Sabo Department 2011-2018). The eruption at this time entered the lull state in September 2011, but an explosive eruption occurred again on October 11, 2017 (Ministry of Land, Infrastructure, Transport and Tourism Sabo Department 2011-2018).

After that, the eruption continued until April 2018, and volcanic ejecta was accumulated in the mountain stream at the foot of the mountain. According to Koi et al. (2017), although a sediment outflow was seen, it was directly linked to human damage. No occurrence of debris flow was confirmed. In order to understand the risk of debris flow associated with rainfall after volcanic ejecta fall, it is necessary to conduct a field survey of physical and chemical properties that are soil characteristics of volcanic ejecta, unlike the amount of rainfall that can be collected on a desk. However, since the field survey immediately after the eruption is dangerous, the range of people entering is limited, and it is difficult to collect data after the eruption. Therefore, the survey results of volcanic ejecta immediately after the eruption are extremely valuable, and it is expected that accumulating the soil quality data will be academically meaningful and useful for predicting debris flow disasters after the volcanic eruption.

Looking at the research examples of the eruption of Mt. Shinmoe-dake in Japan, after the eruption in January 2011, the physical and chemical properties of volcanic ejecta were investigated at the foot of Mt. Shinmoe-dake, and the relationship with the deposition thickness of volcanic ash was considered. (Kisa et al. 2011 / Shimizu et al. 2011 / Koi et al. 2013). On the other hand, regarding the eruption after October 2017, although the actual condition of sediment runoff has been investigated by Koi et al. (2017), there are few cases in which the physical and chemical properties of volcanic ejecta were investigated. Therefore, the purpose of this study is to clarify the actual physical and chemical properties of volcanic ejecta that fell after the explosive eruption on March 25, 2018 at Shinmoe-dake, Japan.

2. Methods

2.1. Survey site

The survey sites are located at the foot of Mt. Shinmoe-dake located in Kirishima City, Kagoshima Prefecture (Fig. 1). The ash thickness as of March 6, 2018 refers to the result reported by the Ministry of Land, Infrastructure, Transport and Tourism Sabo Department (2011-2018). The research date of this study is March 26, the day after the explosive eruption on March 25, 2018. It is assumed that the deposition status of volcanic ejecta will differ depending on the presence or absence of a cover such as a crown on the ground surface. Therefore, it was decided to compare inside and outside the forest. For information on the eruption date and scale of Mt. Shinmoe-dake, refer to the Ministry of Land, Infrastructure, Transport and Tourism Sabo Department (2011-2018). For rainfall, I collected the observation values at Yadake Rainfall Observatory of the Ministry of Land, Infrastructure, Transport and Tourism, which is located near the survey site.

2.2. Infiltration capacity survey

In order to investigate the infiltration capacity, which is one of the physical properties of volcanic products, three plots are set at each of the three locations (outer forest plain, forest plain, and forest talus), and the method of Takeshita (2011) is referred to. As a result, a cylindrical frame test was conducted (Photo 1 (a) - (h)). Cylindrical frame test is a cylindrical frame (φ = 100 mm, L = 150 mm) of about 300 mm inserted into the surface covered with volcanic ejecta, and water injection is continued for a certain period of time. Is to measure. Since this test promotes water infiltration in the direction of gravity by enclosing it in a cylindrical frame, Takeshita (2011) presents the coefficient according to Equation (1) and shows the correction of the real value. In this study as well, the method was quoted and the measurement value of the cylindrical frame was corrected by Equation (1).

Real infiltration capacity (mm / h) = 0.24 ・ cylindrical frame infiltration value … (1)

It is known that the infiltration into the ground is fast at the beginning of the measurement, but gradually becomes slower in the latter half of the measurement (Takeshita 2011). The test was continued until the permeation rate became slow, and the test was terminated when the change was visually confirmed. In this study, the measured value at this time was defined as the final osmotic permeability value and used for the analysis.

2.3. Soil test

In order to investigate the physical and chemical properties of volcanic ejecta at the location where the cylinder frame test was conducted, soil cylinder samples (100 cc) were collected at the three locations plotted at the three locations. For physical properties, soil particle density, ratio of silt and clay, and particle size distribution were measured. The soil test procedure was in accordance with Japanese Industrial Standards (A1202, A1203, A1204).

In addition, an X-ray diffraction test was conducted to investigate the type of minerals in the fine-grained volcanic ash deposited on the ground surface. An X-ray diffraction tester (MultiFlex, 40 kV, 40 mA, manufactured by Rigaku Denki

Kogyo Co., Ltd.) was used, and measurement was performed using Cu-α rays. Mineral determination was performed based on the data obtained in this test.

The chemical properties of water-soluble ions (Na, K, Ca, Mg, Cl, SO_4, NO_3, NH_4) were measured by the water-soluble amount test, which is one of the chemical analysis methods (JGS 0241-2009). K, Ca, Mg, and Cl were measured with an atomic absorption spectrophotometer (ZA-3000, Hitachi, Ltd.) using the eluate. SO_4, NO_3 and NH_4 were measured using an ion chromatograph (ICA-2000, Toa DKK).

For the cation exchange capacity (CEC), add barium chloride to the air-dried sample, centrifuge the sample solution, and read the wavelength of 285.2 nm using an atomic absorption spectrophotometer (Hitachi ZA-3000). It was measured. For exchangeable Ca, use the sample solution (100 mL) filtered by CEC measurement, set the wavelength of atomic absorption spectrophotometer (Hitachi ZA-3000) to 422.7 nm, calculate the calcium concentration, and determine the content rate in volcanic ash. The same applies to exchangeable Na, using the sample solution (100 mL) filtered by the CEC measurement, setting the wavelength of the atomic absorption spectrophotometer (Hitachi Ltd. ZA-3000) to 589.0 nm, and obtaining the sodium concentration. The content rate was calculated. The ratio of exchangeable ions to cation exchange capacity expressed as a percentage is called ESP (Exchangeable Sodium Percentage) (Agassi et al. 1981), and can be calculated using Equation (2). The volcanic ejecta are known to show high values, and it is said that in soils of 1.5 or above, chemical crusts are formed with rainfall and the infiltration capacity decreases (Gal et al. 1984).

$$\mathrm{ESP}(\%)=(\text{Exchangeable Na})/(\mathrm{CEC}\times 100) \quad \cdots\cdots (2)$$

3. Results and discussion

3.1. Eruption status and rainfall status since October 2017

Fig. 2 shows the relationship between the time and scale of eruption from October 2017 to April 2018 and hourly rainfall. An explosive eruption occurred on the day before the survey day (March 25, 2018), and it was confirmed that fresh fine-grained volcanic ash had accumulated around the survey site (Photo 1). Since the eruption on October 11, 2017, the 24-hour rainfall has been decreasing until December 2017, and then increasing toward February 2018. Looking at the hourly rainfall, 12 times recorded 10 mm / h or more, and only 3 times recorded 20 mm / h or more. Also, on March 5, 2018, it recorded a maximum of about 36 mm / h during the eruption period. It can be confirmed that there was 10 mm / h or more of rainfall per hour after the eruption, regardless of the time of the eruption, but 20 mm / h or more occurred twice (22 mm / h: April 14, 2018, 20 mm / h: April 24 of the same year). Therefore, it is estimated that there was no heavy rainfall of 20 mm / h or more immediately after the eruption of Mt. Shinmoe-dake.

3.2. Physical properties of volcanic products

Fig. 3 shows the time course of the real infiltration capacity. In the forest plain, the infiltration into the ground was too fast and it was not possible to measure it properly, so the comparison is between the forest plain and the forest talus. Both the plain outer the forest and the talus in the forest have been tested three times. Comparing the real infiltration capacity, the talus in the forest tends to be lower than the plain in the forest. In addition, when we look at the time when the real infiltration capacity begins to decline, the outer plains are faster than 1000 sec, while the inner talus tend to be slower. Looking at the 1-hour rainfall data (Fig. 2) at the Yadake Rainfall Observatory of the Ministry of Land, Infrastructure, Transport and Tourism near the survey site, it recorded a maximum of about 36 mm / h (March 5, 2018), but on this day Before the explosive eruption. Next, the rainfall with an hourly rainfall is 2 times (22 mm / h: April 14, 2018, 20 mm / h: April 24, the same year), which recorded more than 20mm / h. Comparing the real infiltration capacity at the end of the period after 1000 seconds, it was about 74-184 mm / h on the outer forest plain and about 38-92 mm / h on the forest talus, showing values larger than the hourly rainfall. It became clear that there was. This is consistent with the fact that no debris flow occurred at the foothills of Mt. Shinmoe-dake.

Fig. 4 shows the relationship between D_{50} and the final infiltration capacity and soil particle density. The smaller the D_{50} of volcanic ejecta, the higher the soil particle density (Fig. 4 (a)). In addition, the higher the soil particle density, the lower the infiltration capacity tends to be (Fig. 4 (b)). Generally, when the particle size of the soil particles is small, the voids between the soil particles in the soil are small and the density is high, so that it becomes difficult for water to infiltration into the ground. From this, it is considered that the soil particle density increased and the final infiltration capacity decreased because the volcanic ejecta with small grain size were deposited on the forest talus. From this, it is speculated that since the volcanic ejecta with a small grain size are deposited on the talus in the forest, the soil particle density is reduced and the final infiltration capacity is low (Fig. 5 (a) and Fig. 5 (b)). Furthermore, regarding the ratio of silt and clay, when the relationship between D_{50} and soil particle density was examined, no correlation was found between the two. Therefore, regardless of the proportion of fine particles such as silt and clay, it is suggested that the size of soil particles is generally small and that the real infiltration capacity of the end of the talus in the forest has decreased. Next, Fig. 6 shows the particle size distribution of the collected sample, and Table 1 shows the basic information and measured values. In addition, the grain size of the talus in the forest in this study tends to be smaller than that in the outer forest plain or the forest plain. From these facts, it is suggested that the smaller particle size of the particle size category of 0.1 mm or more than the particle size category of silt / clay may contribute to the decrease of the final infiltration capacity.

Fig. 7 shows the relationship between the D_{50} and silt-clay ratios and the final infiltration capacity. Looking at the results of this study, the lower the D_{50}, the lower the final infiltration capacity tends to be ($R = 0.69$, $p = 0.04$). Next, looking at the ratio of silt / clay, it can be seen that the real infiltration capacity at the end of the period tends to decrease slightly as it increases, but the variation is large ($R = 0.50$, $p = 0.17$). This suggests that the D_{50} index, which represents the particle size distribution, may represent a tendency for the final infiltration capacity.

3.3. Chemical properties of volcanic products

In order to study the chemical properties, we first clarify the mineral composition of the volcanic products by X-ray diffraction test. Fig. 8 shows the composition of minerals by X-ray diffraction test. First, the mineral that appears in the peak of the X-ray diffraction test of the sample collected in this study is Anorthite. Other minerals detected include Enstatite, Augite, and Ilmenite, but no gypsum that causes a decrease in infiltration capacity when fine-grained volcanic ash solidifies. The survey of this study collected fresh volcanic ash that had fallen after the explosive eruption on March 25, 2018, but there was almost no rainfall within a week before the survey (Fig. 2). It is speculated that no gypsum was detected as a result of no chemical reaction between the deposited volcanic ash and water.

Table 2 shows the ion amount and exchangeable base amount of the collected volcanic ejecta. Looking at the amount of detected ions, it can be seen that compounds that are the main components of gypsum, such as Ca and SO_4, are contained in high values.

Looking at the amount of exchangeable base in this study, a high value of 52.5% is shown (Table 2). Onda et al. (1996) calculated ESP by the same method by Mt.

Unzen Fugen-dake from June 1990 to June 1995 within the eruption period from November 1990 to March 1995. Mt. Unzen Fugen-dake has frequently had debris flows associated with rainfall since 1991, and this study reported a high value of 8.6-76.5% up to a depth of 2 cm on the surface layer of volcanic ash. Comparing the ESP values of this study with the results of Onda et al. (1996), the volcanic ash of Shinmoe-dake may have the potential to reduce infiltration capacity. In connection with this, when water was sprinkled on the forest talus after the cylindrical frame test and the surface of the volcanic ejecta was observed (Photo 2), fine-grained volcanic ash began to solidify, causing debris flow. It has been confirmed that a surface flow has occurred. From the above, the volcanic ejecta of Shinmoe-dake after the explosive eruption on March 25, 2018 will solidify and become gypsum when there is a large amount of rainfall, and the infiltration capacity will decrease, contributing to the generation of debris flow. It is thought that there is a possibility of doing so.

4. Conclusion

This study reveals some of the physical and chemical properties of volcanic ejecta that fell after the March 25, 2018 explosive eruption, albeit with a limited sample size. I would like to continue to accumulate soil data on the physical and chemical properties of volcanic ejecta by conducting similar surveys on volcanic eruptions.

Acknowledgment

The hourly rainfall observed at Yadake rainfall observatory near Mt. Shinmoe-dake was provided by Miyazaki river national highway office, Ministry of land, infrastructure, transport and tourism. For the soil test, I cooperated with Urban soil research Co., Ltd. and had a meaningful discussion when interpreting the data. This research analyzed part of the content when the author was in the Public Works Research Institute, and with the help of Mr. Naoki Fujimura of the Public Works Research Institute (at that time), it was greatly supported. Finally, I would like to thank these people.

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Figures

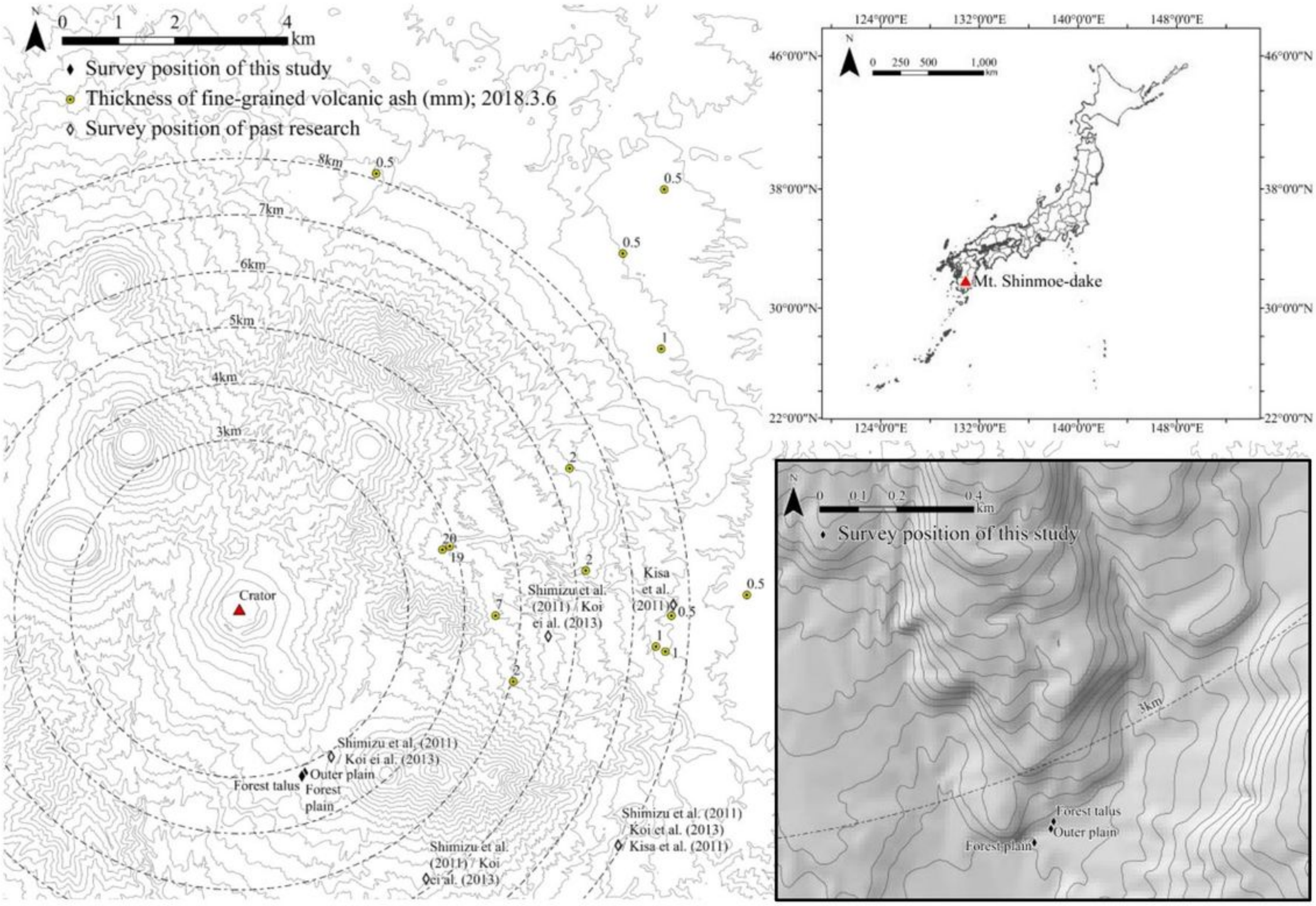

Figure 1

Relationship between distance from Mt. Shinmoe-dake crater and survey l ocation

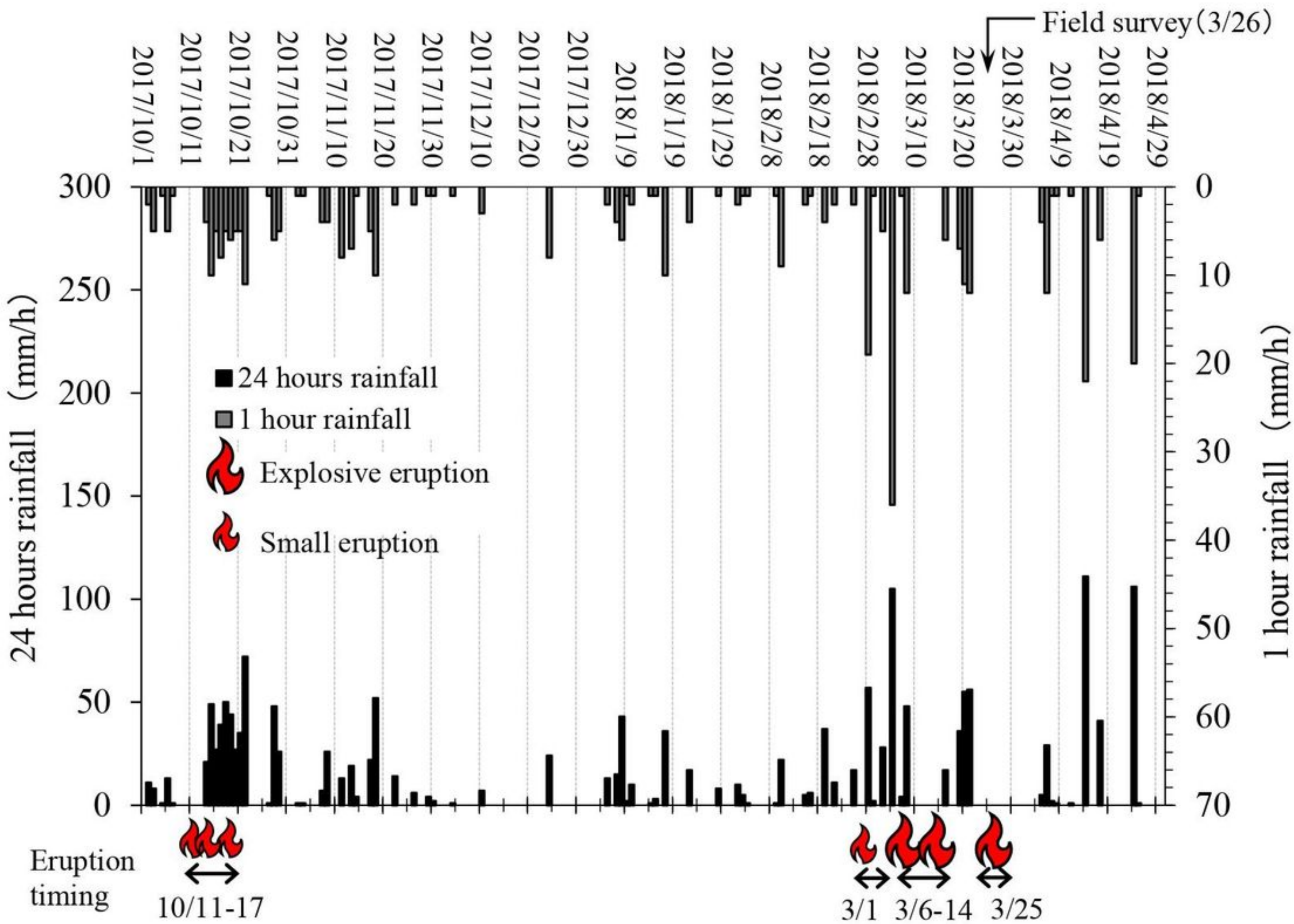

Figure 2

Eruption time of Mt. Shinmoe-dake and hourly rainfall

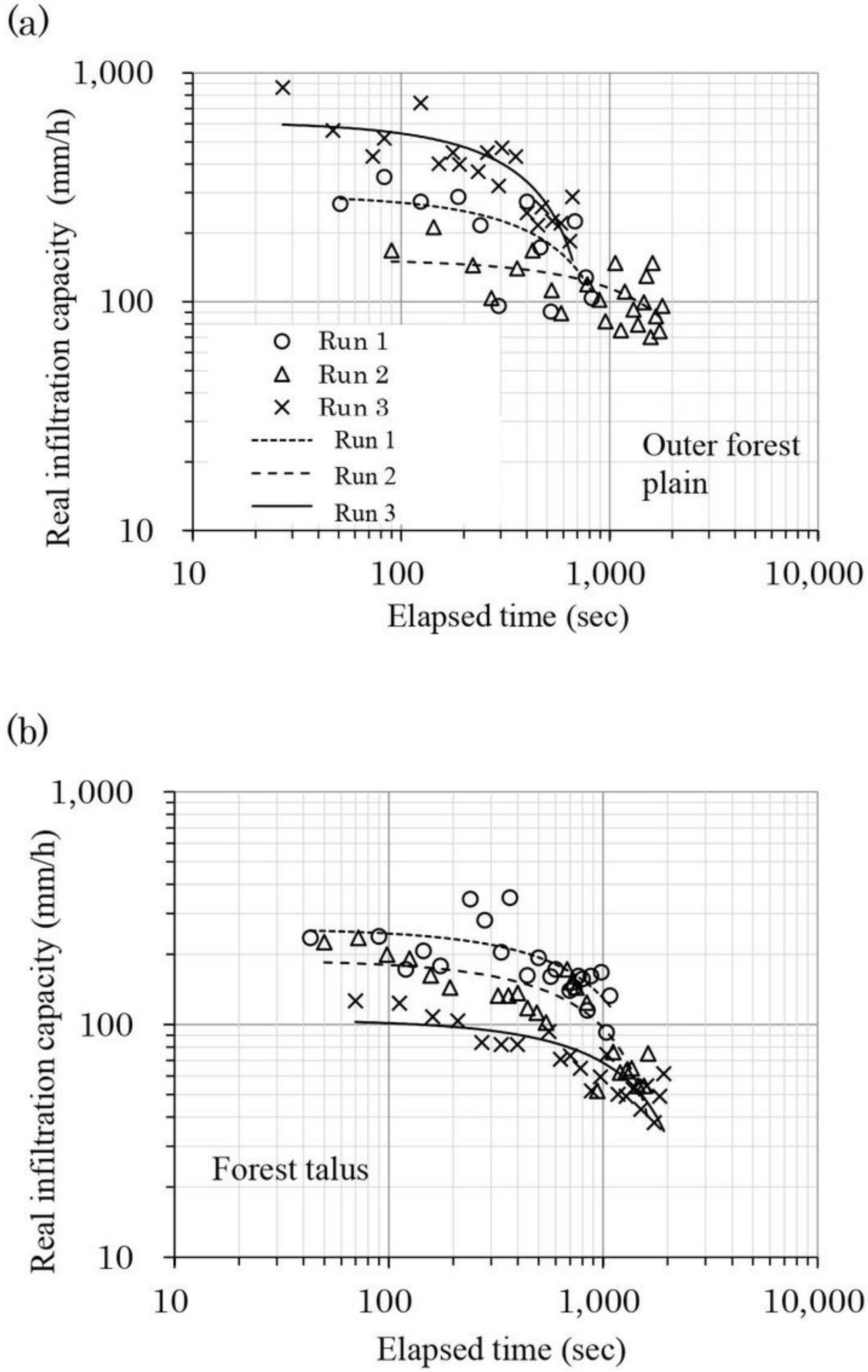

Figure 3

Time-dependent change in real infiltration capacity

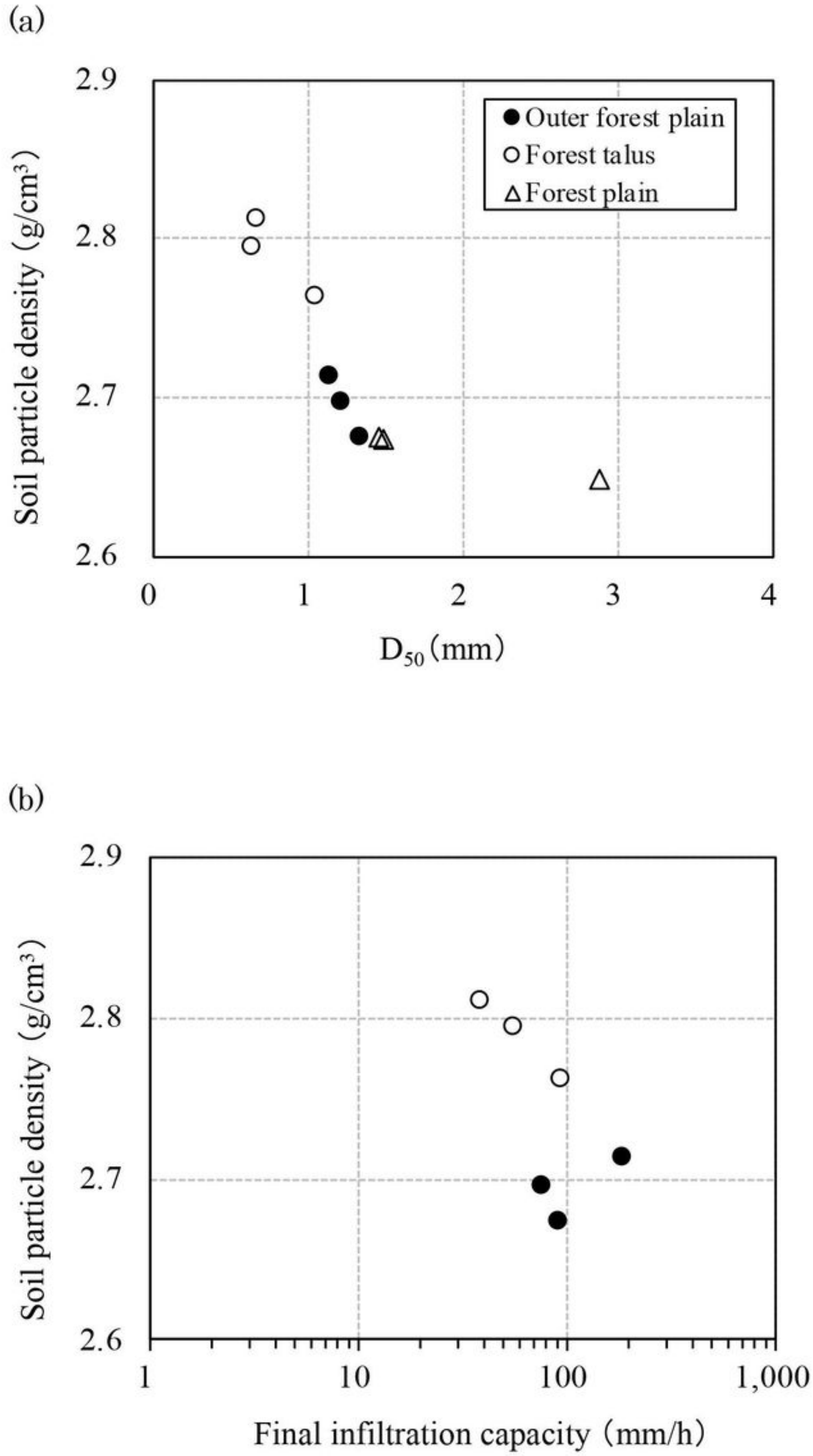

Figure 4

Relationship between D50 and final infiltration capacity and soil particle d ensity

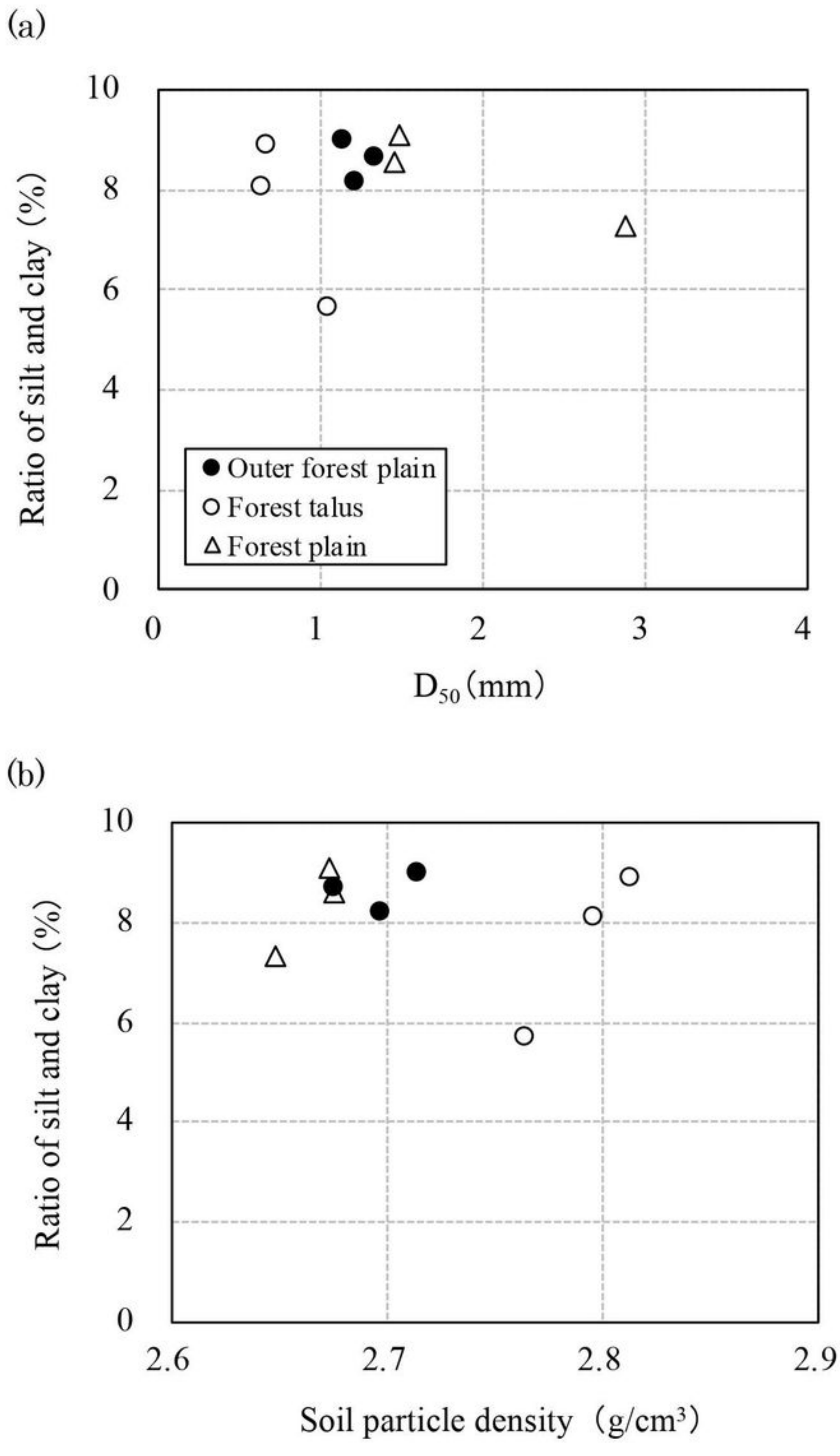

Figure 5

Relationship between D50 and soil particle density and ratio of silt and cla y

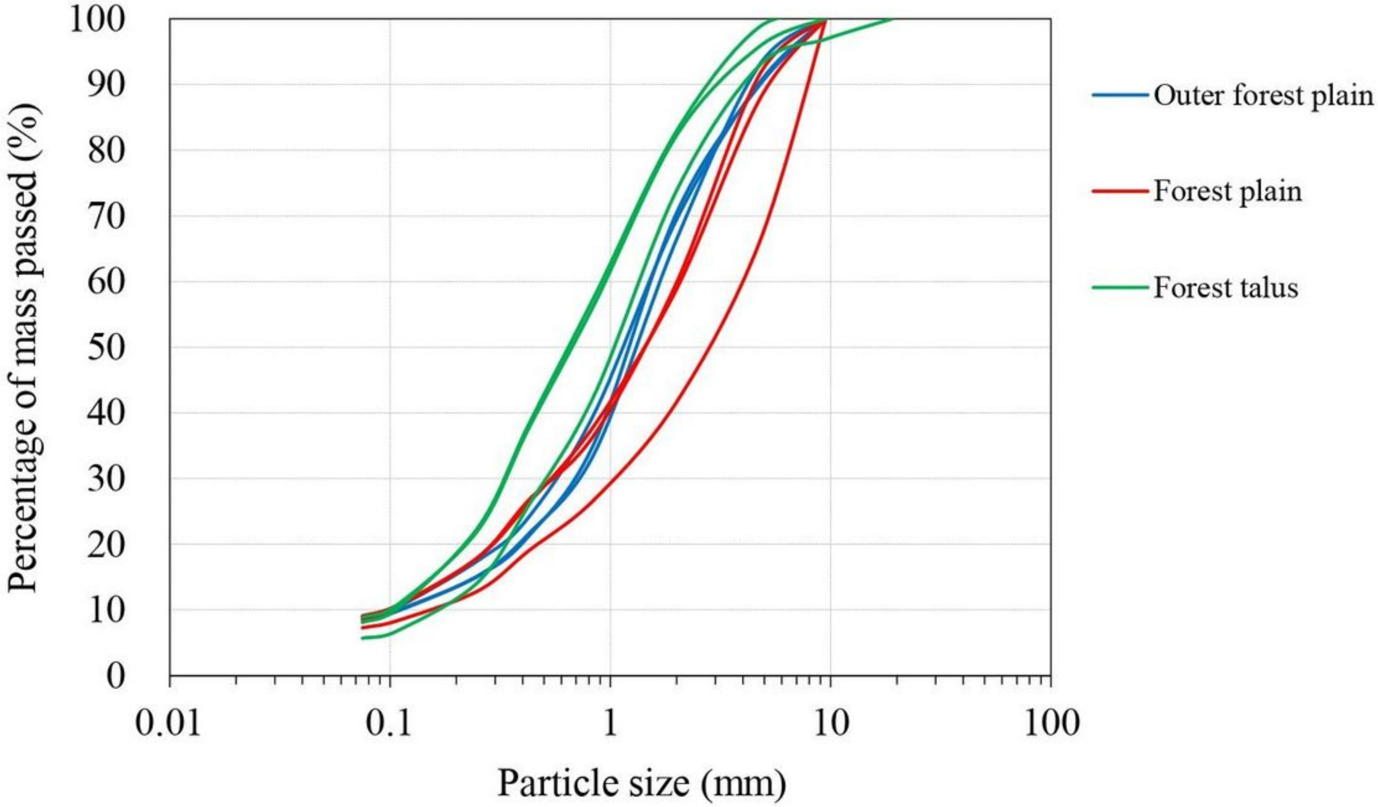

Figure 6

Particle size distribution of collected sample

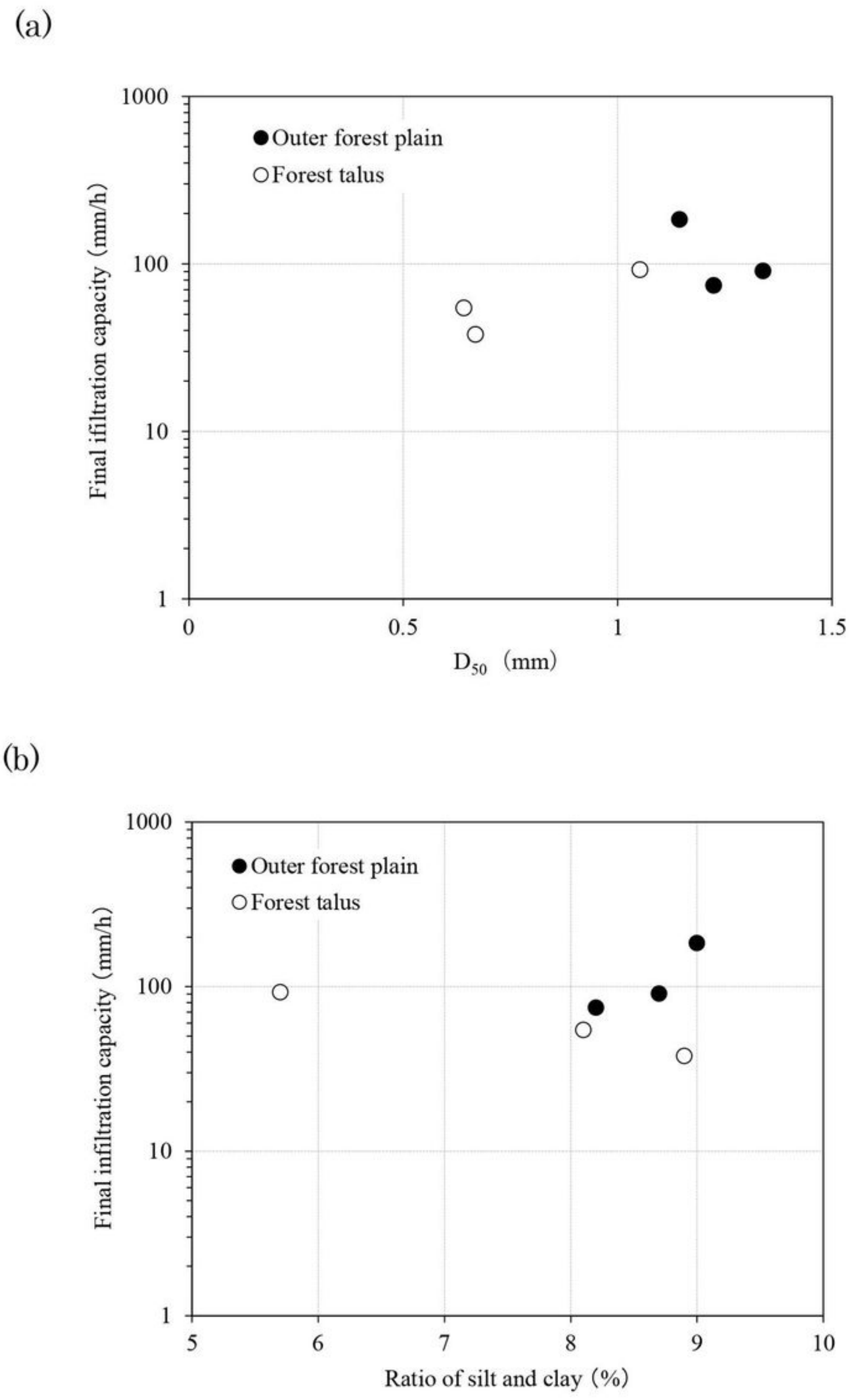

Figure 7

Relationship between D50 and the ratio of silt and clay and the final infilt ration capacity

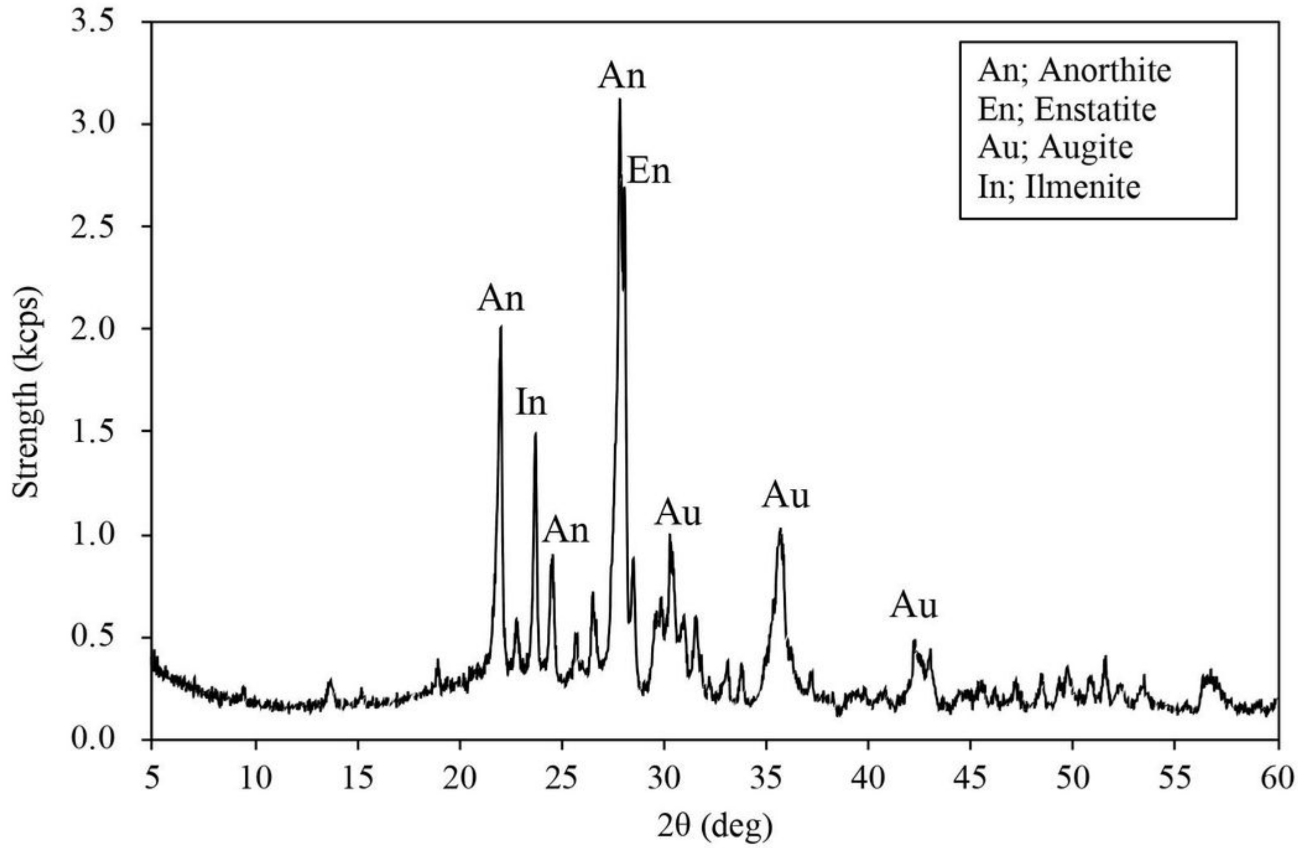

Figure 8

Composition of minerals by X-ray diffraction test

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