

Effect of volcanic activity on physical properties of volcanic ash on the hillside slope of Mount Sakurajima

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Abstract: We investigated the distribution and physical characteristics of volcanic ash in periods of heightened volcanic activity (1972 to 1992) and low activity (1993 to 2008), and examined changes caused by ebb and flow of volcanic activity at distances of 2.7 km and 3.8 km from the Minamidake crater of Mount Sakurajima in the northern flank of Mount Sakurajima. The annual average thickness of the volcanic ash layer during heightened activities was 2.5 and 9.5 times greater than that measured during low activities, respectively. The dry density of the volcanic ash layer was 1.31 g/cm³ and 1.74 g/cm³ during the period of heightened activities and it was 1.19 g/cm³ and 1.57 g/cm³ during the period of low activities, respectively. The median diameter of solid particles in the volcanic ash layer was 0.16 mm and 0.33 mm during the period of heightened activities and it was 0.12 mm and 0.28 mm during the period of low activities, respectively.

1 Introduction

Volcanic eruptions create a radical alteration of the hydrologic and erosion regime of the surrounding areas. The hydrologic and erosion phenomena caused by volcanic eruptions have been investigated at many volcanoes (Okuda *et al.*, 1980, Chinen, 1986, Collins and Dunne, 1986, Shimokawa and Jitousono, 1987, Shimokawa *et al.*, 1996). Sediment yield and discharge have been found to decrease with time except for volcanoes with continued volcanic activity, such as Mount Sakurajima.

Mount Sakurajima has been continuously active with frequent and lively small scale ash eruptions since 1955. Through this long period of volcanic activity, the flanks of Mount Sakurajima became thickly covered with volcanic ash. Moreover, the flanks have experienced accelerated erosion, and consequently debris and mud flows have often occurred in the rivers located around them (Shimokawa and Jitousono, 1987).

Additionally, the ebb and flow of volcanic activity has a great effect upon sediment yield and discharge from the flanks of an active volcano. Regarding the flank of Mount Sakurajima, rainfall induced surface runoff and debris flow, the total runoff and the peak discharge of surface runoff and debris flow during heightened volcanic activity were found to be greater than during low activity (Jitousono and Shimokawa, 1989, 1991).

Erosion and sediment discharge caused by debris and mud flows damage vegetation on the flank and coast, and they also have a great effect on the forest site environment. Conditions of the occurrence of erosion and sediment discharge are closely concerned with the

properties of volcanic ash in Mount Sakurajima (Shimokawa and Jitousono, 1987). Therefore, it is important to clarify the properties of volcanic ash in Mount Sakurajima because of conservation of vegetation on the flank and coastal area.

The purpose of this research is to study the distribution, deposition conditions and physical properties of volcanic ash based on soil survey and soil test, as well as the effect of the ebb and flow of volcanic activity on them in the northern flank of Mount Sakurajima.

2 Volcanic activity of Mount Sakurajima

Mount Sakurajima, which is an active volcano, has been continuously in action with frequent and lively small scale ash eruptions since 1955. The volcanic activity is eruptions with the volcanic ash and gas from the Minamidake crater and has been continued for more than 50 years. The volcanic activities of the 1950s and 1960s were relatively gentle. However, since 1972, the activity has become active. Most of the annual frequency of explosion resulting from Mount Sakurajima during 1974 and 1986 was the large annual value of more than 200 times. Moreover, the annual frequency of explosion in 1985 was 474 times, the largest annual value for the period from 1955 to 2008. Since 1994, the annual frequency of explosion has been decreasing (Kagoshima local meteorological observatory, 1955-2008). Because of fall of the volcanic activity since 1994, the annual amount of volcanic ash in the flanks of Mount Sakurajima has been decreasing remarkably (Kagoshima prefecture, 1978-2006).

3 Study area and methods

The study area is located in the northern flank of Mount Sakurajima (Figure 1, Photo 1). The area has an altitude

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ranging from 180 m to 400 m above sea level and a distance ranging from 2.7 km to 3.8 km from the Minamidake crater of Mount Sakurajima (Figure 1). The topography lower than 300 m above sea level in the study area is hill slope and plateau. The topography from 300 m to 500 m above sea level consists of a mixture of hill slope and steep slope. The topography at 500 m above sea level or more is steep slope. The vegetation at less than about 600 m above sea level consists of broadleaf trees and *Pinus thunbergii* of artificial tree. The vegetation at 600 m above sea level or more consists of herbs and shrubs. The summit of Mount Sakurajima is bare land slope. The geological composition of the study area consists of a 1914 Taisho pumice layer covered with a soil layer and a volcanic ash layer.

Moreover, Kagoshima prefecture measured the amount of volcanic ash in the lower reach of the study area from 1978 to 2006 (Kagoshima prefecture, 1978-2006, Figure 1).

The methods consist of soil survey and soil test on samples collected from the volcanic ash layer. The investigation of the distribution and deposition conditions of volcanic ash was conducted through the observation of soil profile. Eighteen soil profiles were

investigated (Figure 1). Investigation was conducted in December 2008. According to volcanic ash deposition conditions such as tone, density, hardness and humus content based on the observation of the soil profile, the volcanic ash deposition since 1972 was divided into two layers (Shimokawa and Jitousono, 1987, Teramoto *et al.*, 2005). Since the upper layer of volcanic ash contained much humus, it seems that the upper layer was accumulated during the period of low volcanic activities from 1994 to 2008. It seems that the lower layer was accumulated during the period of heightened volcanic activities from 1972 to 1993. Thus, changes of volcanic activities influence the characteristics of volcanic ash considerably (Shimokawa and Jitousono, 1987). The soil profile was established on the slope that was near to flatness limited to sheet erosion. The soil test of volcanic ash determined grain size distribution and dry density. To measure the grain size distribution and the dry density, an undisturbed sample was collected in metallic cylinders 55 mm in diameter and 60 mm in height. The samples were collected from the volcanic ash layer of the periods of heightened volcanic activities from 1972 to 1993 and low activities from 1994 to 2008, respectively.

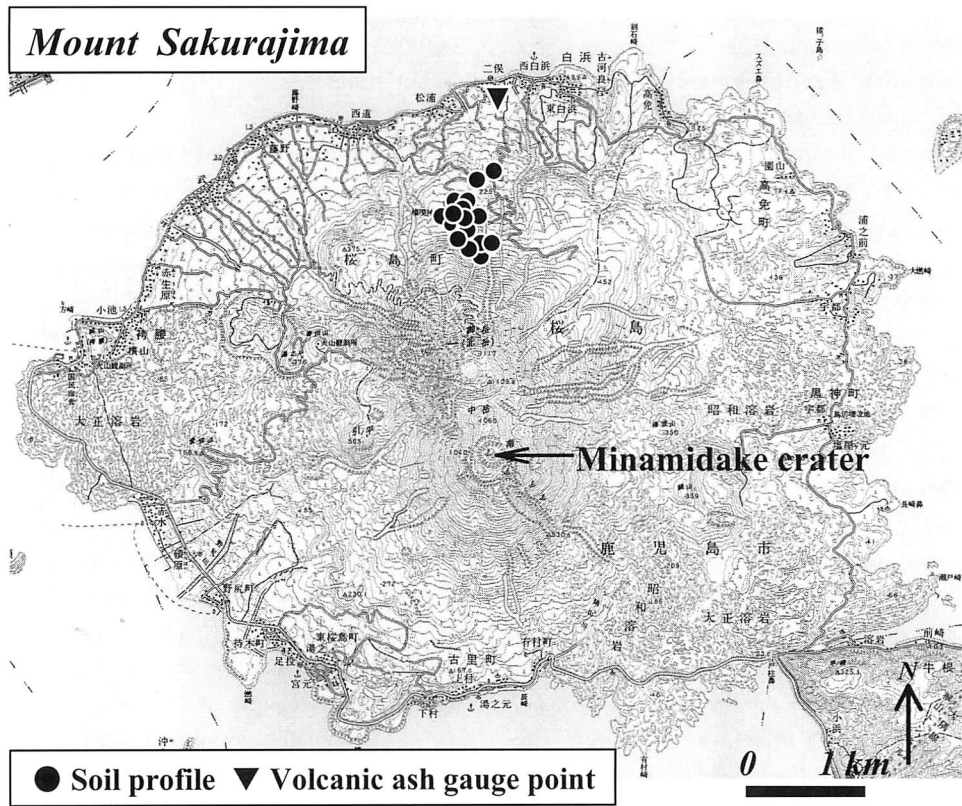


Figure 1: Location of the study area

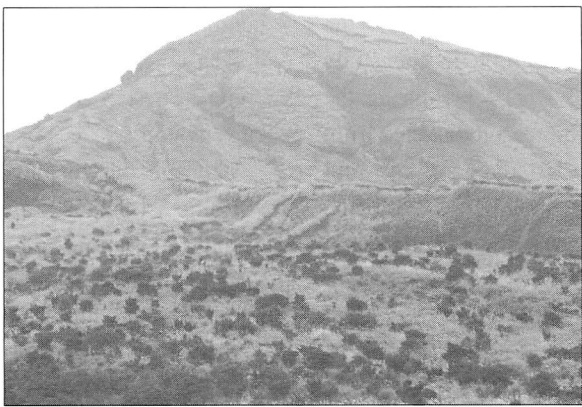


Photo 1: Conditions of the study area

4 Distribution, deposition conditions and physical properties of volcanic ash

Figure 2 shows the annual average thickness of volcanic ash layer during periods of both heightened (1972 to 1993) and low volcanic activities (1994 to 2008) according to distance from the Minamidake crater of Mount Sakurajima in the study area. The annual average thickness of volcanic ash layer during the two periods

became smaller with increased distance from the Minamidake crater. The annual average thickness of volcanic ash layer during the period of heightened volcanic activities was greater than that during the period of low activities. The annual average thickness of the volcanic ash layer during the period of heightened volcanic activities was between 2.5 and 9.5 times greater than in the period of low activities.

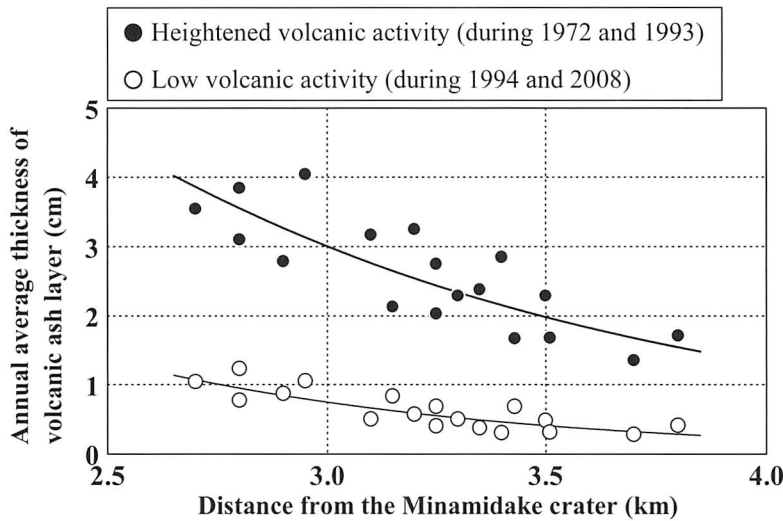


Figure 2: Annual average thickness of volcanic ash layer during periods of both heightened and low volcanic activity in relationship to the distance from the Minamidake crater of Mount Sakurajima

Figure 3 shows the dry density of volcanic ash layer during periods of both heightened (1972 to 1993) and low volcanic activities (1994 to 2008) according to distance from the Minamidake crater of Mount Sakurajima in the study area. The dry density during two periods became smaller with increased distance from the Minamidake crater. The dry density during the period of heightened volcanic activities was greater than that during the period of low activities. The dry density of the volcanic ash layer was between 1.31 g/cm³ and 1.74 g/cm³ during the period of heightened volcanic activities,

and was between 1.19 g/cm³ and 1.57 g/cm³ during the period of low activities. The void ratio of the volcanic ash layer during the period of low volcanic activities was greater than that during the period of heightened activities. The reason for the increase of void in the volcanic ash layer is thought to be a result of root growth by recovering vegetation following the ebb of volcanic activity (Teramoto and Shimokawa, 2007).

Figure 4 shows the median diameter of solid particles in the volcanic ash layer during periods of both heightened (1972 to 1993) and low volcanic activities

(1994 to 2008) according to distance from the Minamidake crater of Mount Sakurajima in the study area. The median diameter of solid particles during the two periods became smaller with increased distance from the Minamidake crater. The median diameter of solid particles during the period of heightened volcanic activities was greater than that during the period of low activities. The median diameters of solid particles were between 0.16 mm and 0.33 mm during the period of heightened volcanic activities and were between 0.12 mm and 0.28 mm during the period of low activities.

Shimokawa and Jitousono (1987) showed the thickness of volcanic ash layer, the dry density of volcanic ash layer and the median diameter of solid particles in the volcanic ash layer during the period of

heightened volcanic activities (1972 to 1983) tended to decrease with increased distance from the Minamidake crater. These results are similar to the results of the current study.

The ebb of volcanic activity causes the decrease of volcanic ash deposition and volcanic gas in the flanks of Mount Sakurajima. As a result, it brings the recovery of the vegetation (Teramoto and Shimokawa, 2007), the increase of void and infiltration capacity in the volcanic ash layer caused by growth of roots (Teramoto *et al.*, 2004, 2005), the armoring of the surface volcanic ash layer (Teramoto *et al.*, 2006) and the decrease of sediment yield and discharge (Teramoto *et al.*, 2004, 2005, 2006).

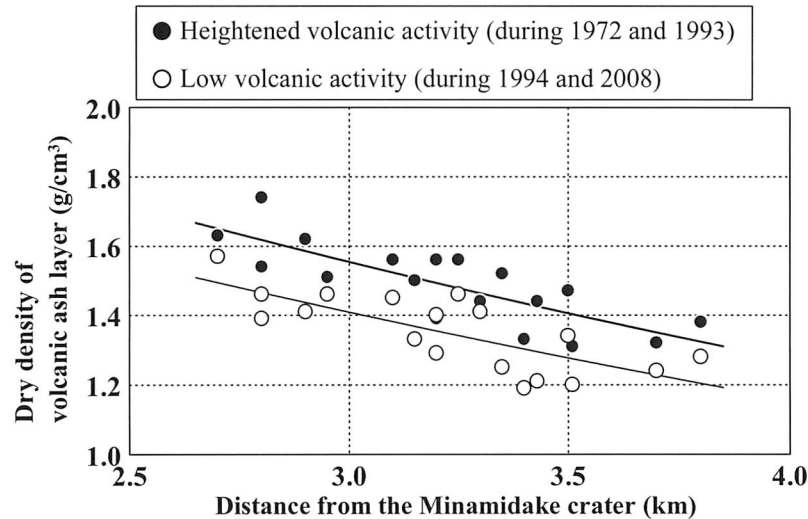


Figure 3: Dry density of volcanic ash layer during periods of both heightened and low volcanic activity according to distance from the Minamidake crater of Mount Sakurajima

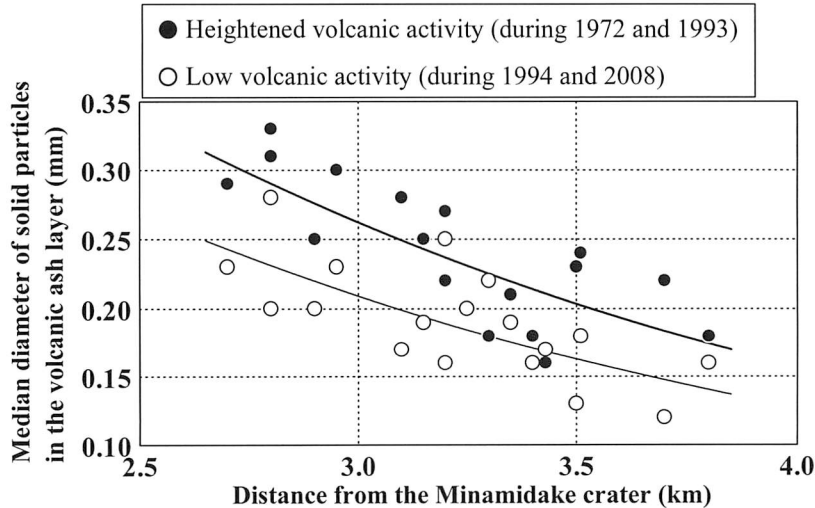


Figure 4: Median diameter of solid particles in the volcanic ash layer during periods of both heightened and low volcanic activity according to distance from the Minamidake crater of Mount Sakurajima

5 Conclusions

The results of the present study are as follows.

(1) The annual average thickness of the volcanic ash layer during heightened volcanic activities (1972 to 1993) was 2.5 and 9.5 times greater than that measured during low activities (1994 to 2008) at distances of 2.7 km and 3.8 km, respectively, from the Minamidake crater of Mount Sakurajima.

(2) The dry density of the volcanic ash layer was 1.31 g/cm³ and 1.74 g/cm³ during the period of heightened volcanic activities (1972 to 1993) and it was 1.19 g/cm³ and 1.57 g/cm³ during the period of low activities (1994 to 2008) at distances of 2.7 km and 3.8 km, respectively, from the Minamidake crater of Mount Sakurajima. The void ratio of the volcanic ash layer during the period of low activities was greater than that during the period of heightened activities.

(3) The median diameter of solid particles in the volcanic ash layer was 0.16 mm and 0.33 mm during the period of heightened volcanic activities (1972 to 1993) and it was 0.12 mm and 0.28 mm during the period of low activities (1994 to 2008) at distances of 2.7 km and 3.8 km, respectively, from the Minamidake crater of Mount Sakurajima. The median diameter of solid particles in the volcanic ash layer during the period of low activities was smaller than that during the period of heightened activities.

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