SOIL AIR GAS AND GAMMA-RAY SURVEYS AT UNZEN VOLCANO, JAPAN

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SUMMARY –We have carried out geochemical surveys in the west area of the newly formed lava dome, Heiseishinzan at Unzen Volcano, from 1999 to 2002. Concentrations of soil air gases of Hg, CO_2, radon (**^{222}Rn**) and thoron (**^{220}Rn**), and gamma-ray intensity were measured within an area approximately 1.5 km NS by 1 km **EW** west of the dome. Concentration anomalies of soil air Hg and radon and thoron gases were detected in the area near Momijichaya, which is located 1 km west of the dome. Anomalies of gamma-ray intensity were detected in the same area. The location of this anomalous area coincides with the portion of the volcanic conduit interpreted from geophysical methods.

1. INTRODUCTION

Unzen Volcano located in Nagasaki prefecture, Western Kyushu, erupted in 1990 after about 200 years dormancy. Geoscientific studies entitled Unzen Scientific Drilling Project (USDP) started after the eruptive activity stopped in 1995, to reveal physical and geological characteristics of newly intruded magma and to detect hydrothermal systems at depth. In the fust stage of this project, three vertical wells were drilled to 350 m to 1460 m depths on the flanks of Unzen Volcano (Uto et al., 2002). Directional drilling is on going to penetrate the volcanic conduit that is estimated below Mt. Fugen.

In geothermal exploration, geochemical methods such as soil air gas and gamma-ray surveys have been recognized as excellent tools to find the locations of subsurface heat source, and of faults or fractures that act as a pathway for geothermal fluid (Koga, 1984). For example, mercury (Hg) is one of the volatile materials found in fumarolic gases. It is transferred directly upward from a heat source by advection of geothermal fluid and by diffusion as well, thus it can be used to prospect the presence of heat sources. Radioactive prospecting is classified into the following: the radon gas survey and the gamma-ray intensity survey. Both methods are widely used to monitor a seismic activity and to detect the locations of fractures and faults. Additionally, carbon dioxide gas (CO_2) is one of the main volcanic gases. Therefore, high concentration of CO_2 in soil air may be attained if magma degassing at depth is occurring, providing the source of CO_2 that rises through fractures and faults to the surface.

In this study, we have carried out a geochemical survey at Unzen Volcano. **The** survey area lies west of the newly formed lava dome,

Fig. 1 Location map of Unzen Volcano. Solid circles denote survey points of soil air gas.

Heiseishinzan. This area was selected because of the trajectory of the volcanic conduit running from the west to the east below this area. We have repeated soil air gas (Hg, radon and thoron, and CO_2) surveys in this area for four years from 1999 to **2002,** and gamma-ray survey for three years from 1999 to 2001. High concentration anomalies of Hg, radon and thoron gases, and gamma-ray intensity anomalies were detected in the same area, which suggests the presence of a heat source at depth and of fractures below the surface. This area corresponds with the plane image of the trajectory of the volcanic conduit interpreted by geophysical surveys.

2. SURVEYAREA

Soil air gas and gamma-ray surveys were conducted once a year from 1999 to 2002 in the area approximately 1.5 km NS by 1 km EW in the west of the lava dome (Fig. 1). These surveys were carried out in early August for two or three days each year. For convenience, we named A-, **B-,** C-, and D-lines for survey points. Among the four survey lines, measurements of soil air gas were repeated four times along the A- and C-lines, and once for the B-line in 1999 and the D-line in 2000. The total number of measurement points was 145 for soil air gas and 89 for gamma-ray. Measurements were made at intervals of 50 and 100 m for soil air gas and 50 m for gamma-ray.

3. METHODS

3.1 Soil Air Gases

Soil air gases of Hg, radon (^{222}Rn), thoron (^{220}Rn) and CO_2 were measured at each point where two holes of 60 cm depth and 5 cm diameter were made by hammering steel pipes into the ground. Immediately after pulling out the pipes, soil air in the first hole was introduced to a mercury analyzer (Mercury Sniffer PM-1A, Nippon Instruments Co.) by circulating the air at a rate of 400 ml/min for **5** min. The concentration was measured by a method of cold vapor atomic absorption, and then converted to per 1 m^3 of soil air. Soil air in the second hole was measured for radon and thoron gases, and CO_2. The concentration of radon and thoron gases was first measured with a Radon detector (RD-200, EDA Instruments Co. Ltd.). Soil air was circulated with an electrical pump for 10 sec, replacing the air in the detection cell. The concentrations of radon and thoron were calculated fkom three counts in each minute obtained for three sequential minutes. Then, 100 ml of soil air were taken by a stainless steel syringe, and measured for CO_2 concentration with a gas detector tube (Komyo-Kitagawa Instruments Co. Ltd.), the SA-type with precision of 0.1-2.6 %v/v.

3.2 Gamma-Ray

Three kinds of gamma-ray spectra, K, Bi and Tl were measured on the ground for **300** sec at each measurement point using a multi-channel analyzer **(E-560A,** NAIG) with a NaI(Tl) scintillation detector. The data were directly sent to a computer to smooth the dispersed spectra data with a net count method (Mogi et al., 1990) and to obtain the gamma-ray intensity automatically.

4. RESULTS AND DISCUSSION

4.1 Hg Gas Concentration

Figure 2 shows distributions of Hg concentration on the A-line. Horizontal axis is the distance measured from the reference point located at Azamidani with positive values to the north and negative ones to the south. High concentrations were detected at 0 m and 400-800 m. The highest concentration was measured at about 1500 m in 1999. This point is located close to a pyroclastic flow deposit. High concentrations imply that there is a heat source below this area. At the same time, increase in concentrations with time may be because of the evolution of subsurface hydrothermal systems.

Gillis et al. (2000) conducted laboratory experiments and reported that increases of emission of Hg gas fkom the soil surface can be associated with increasing the content of soil water in a packed soil column. Concentrations in Fig. 2 show higher values in 2001 and 2002 compared with those in 1999 and 2000. As there was rainfall one day before the measurements both in 2001 and 2002, an increase of the soil water content may have affected the transport mechanisms of Hg gas in these samples.

Figure **3** shows concentration anomalies of soil air Hg. The data at 1500 m from 1999 was excluded. High anomalies were found near the areas of Momijichaya and Kijindani every year. Thus, a heat source or hydrothermal systems can be expected to present beneath this zone at depth.

4.2 Radon and Thoron Gas Concentrations

Total concentrations of radon and thoron gases are presented in Fig. 4, and their anomalies in Fig. 5. Concentrations along the A-line show similar characteristics irrespective of the time of measurement, and high concentrations were detected within a range from 250 to 700 m whereas low concentrations occurs at distal points. Anomalies are consistently found near the area of Momijichaya each year. This suggests that faults or fractures may be located below this area. All other points on the B-, C- and D-lines show low concentrations.

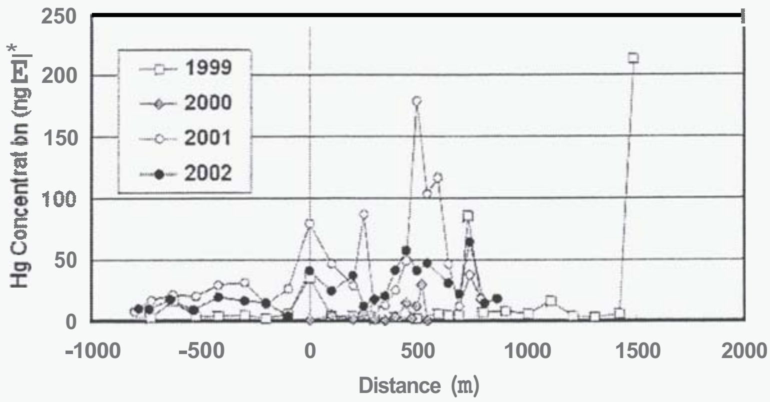

Fig. 2 Concentration of soil air Hg on the **A** line.

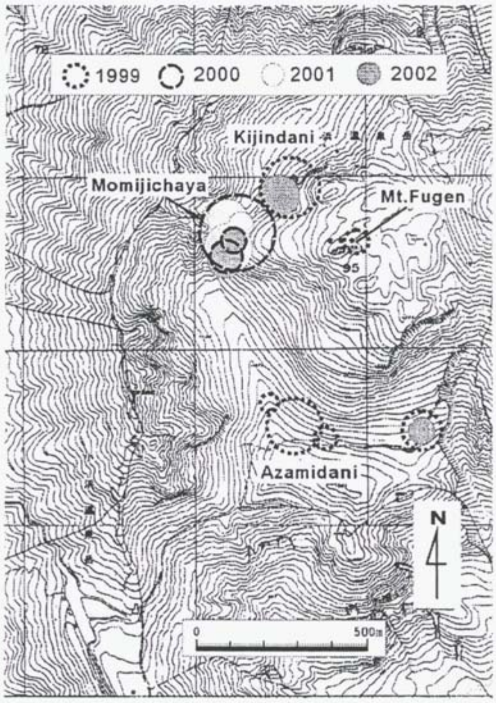

Fig. 3 Anomalies of Hg gas concentration. Radius of circle is proportional to the magnitude calculated with standard deviation.

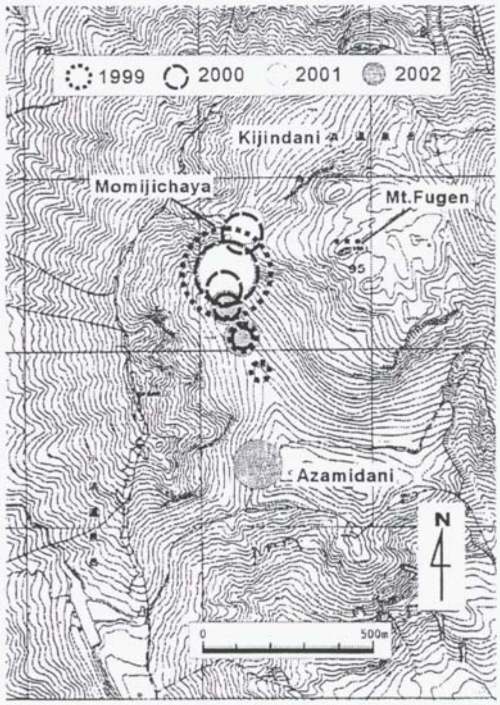

Fig. 5 Anomalies of radon **and** thoron gases concentration. Radius of circle is proportional to the magnitude calculated with standard deviation.

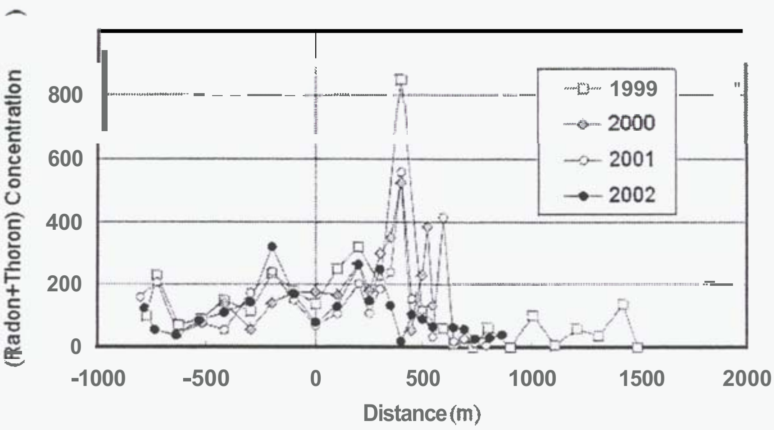

Fig. **4** Concentration of radon **and** thoron gases on the A-line.

4.3 Anomalies of CO_2 Concentration

Figure *6* shows CO_2 concentration on A-line. **A** similar distribution can be seen each year and the values were generally low, below **0.7** %. For example, in other volcanic areas, such as Kuju volcano, Kyushu, the highest concentration is 5.2 % CO_2 (Ehara,1993). **This low** concentration may be due to less active degassing fkom magma at depth or groundwater which absorbs ascending CO_2 gas.

4.4 Gamma-Ray Intensity

Gamma-ray intensity ratios for Bi/K and **Bi/Tl** are illustrated in Fig. **7.** The intensity of gamma-ray may be subject to the effects of the soil properties and moisture content of the soil, and weather (Mogi et al, 1990). In order to exclude these effects, the results should be expressed in the form of ratios. Anomalies of both ratios are also detected near the area **of** Momijichaya and Kjindani. These anomalous areas partly correspond with the area of high radon and thoron gas anomalies in Momijichaya. Thus, this result supports the presence of fractures near the ground surface in this area.

During the first stage of USDP, geophysical surveys and studies were performed to detect the position and to estimate the shape of the volcanic conduit. Seismic tomography showed the existence of a possible hydrothermal system at sea level beneath the summit caldera (Shimizu et al., 2002a). Seismic data also showed evidence of deep reflectors (Shimizu et al, 2002b). **A** seismic reflection experiment was conducted in December 2001, which determined the location and structure of the pathway of magma. From the results of our study, soil air gas and gamma-ray intensity anomalies were detected in the area near Momijichaya, which consistent with the plane image of the trajectory of the volcanic conduit estimated **by** geophysical methods **(STA,** 1999).

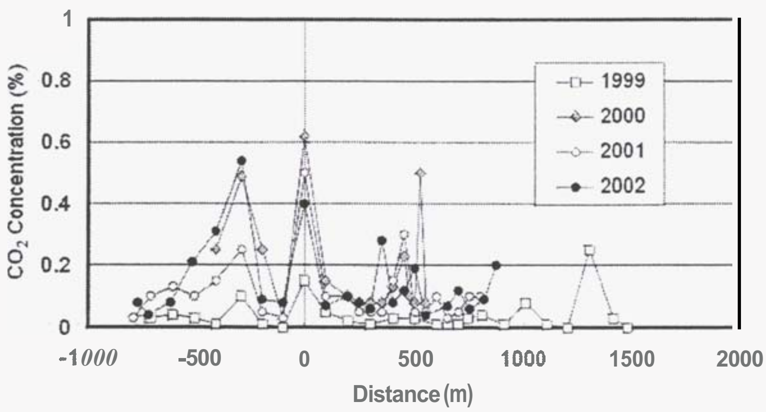

Fig. *6* Concentration of CO_2 gas on the **A** line.

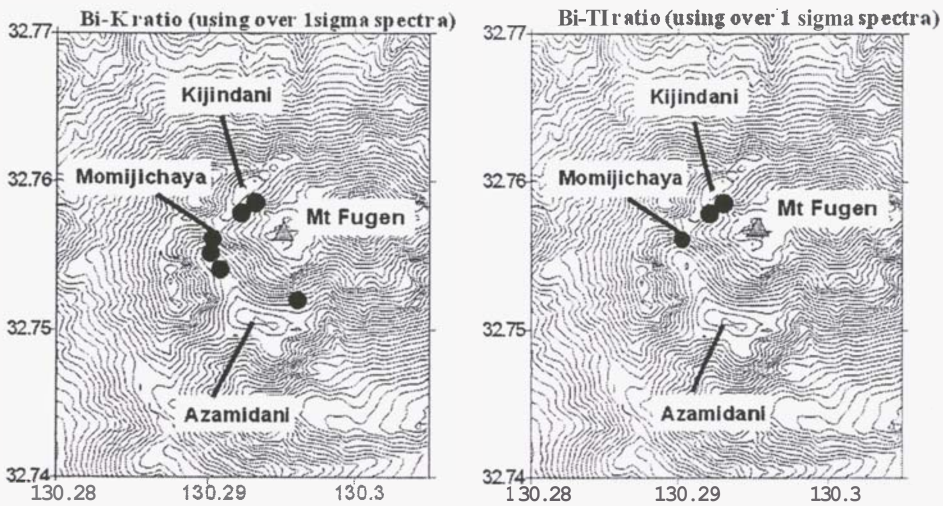

Fig. **7** Gamma-ray ratios calculated with standard deviation.

5. CONCLUSIONS

We have carried out soil air gas and gamma-ray surveys at Unzen Volcano from **1999** to **2002.** The results are summarized as follows:

1) High concentration anomalies of Hg and radon and thoron gases, and anomalies of gamma-ray intensity were detected in the same area near Momijichaya, which implies the presence of a heat source at depth and of fractures in this zone.

2) This anomalous area corresponds with the plane image of the trajectory of the volcanic conduit estimated by geophysical surveys. Thus, the estimated heat source in this study may well represent the conduit at depth.

3) Low concentrations of CO_2 may be due to less active degassing fi-om magma at depth or ground water that absorbs CO_2 ascending to the surface.

6. REFERENCES

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