Unzen Volcano : the 1900-1992 eruption

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7. Seismological Observations of Unzen Volcano before and during the 1990-1992 Eruption

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Introduction

Unzen Volcano in the Shimabara Peninsula, SW Japan, is a stratovolcano consisting mainly of dacitic rocks. It lies at the western end of the Beppu-Shimabara Graben. The Beppu-Shimabara Graben is a large ENE-WSW depression zone crossing the middle Kyushu. Crustal activity of the Unzen volcanic area is therefore very active, and it is characterized by a N-S extensional stress-field.

Mt. Fugen of Unzen Volcano started erupting on 17 November 1990 after 198 years of dormancy since the last eruption in 1792. The seismic network of Kyushu University had detected precursory earthquakes and tremors before the eruption. The seismic stations and the observation system of Unzen Volcano were reinforced soon after the 1990 eruption. The dense seismic network has enabled us to precisely determine the hypocenters and the focal mechanism solutions.

In this paper, we report characteristics of seismic activity before and during the 1990-1992 eruption on the basis of telemetry observations.

Seismic observation

Before the 1990 eruption, three permanent and two temporary seismic stations had been operated in the Shimabara Peninsula by Shimabara Earthquake and Volcano Observatory (SEVO) of Kyushu University. Other seismic stations of SEVO were distributed in the middle Kyushu, including the Beppu-Shimabara Graben. Figure 7-1 shows the distribution of our seismic stations before the 1990 eruption. Seismic sensors used in the observation are velocity transducers with a natural period of 1.0 second. The permanent stations had three components of the sensor, while the temporary stations had the vertical component. Seismic signals were telemetered to SEVO and recorded on magnetic tapes, using an event-trigger system.

Temporary seismic observations have been carried out in cooperation with the Joint University Research Group since the beginning of the eruption. More than ten seismic stations were set up on the volcanic edifice (Fig. 7-2). Figure 7-3 is a photograph of the temporary station that was located on the west rim of the Jigokuato Crater. Seismic data from most of the stations have been transmitted to SEVO, using radio telemetry and telephone-line telemetry. Figures 7-4 and 7-5 show a data recording system and a seismogram monitoring system at SEVO, respectively. Telemetered data, together with time code signals, have been continuously recorded on DAT (Digital Audio Tape). Furth-

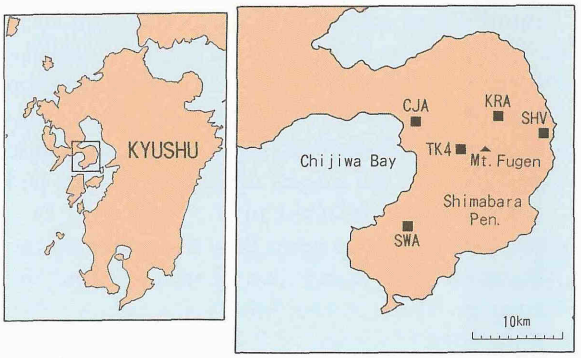

Fig. 7-1. Location map of seismic stations in the Shimabara Peninsula in operation before the 1990 eruption. Seismic stations SHV, CJA and SWA are permanent, while KRA and TK4 are temporary stations. Station SHV is located in Shimabara Earthquake and Volcano Observatory (SEVO). The peak of Mt. Fugen is indicated by the solid triangle.

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ermore, seismograms have been monitored by pen recorders. The frequency characteristics of the overall observation system is nearly flat between 1 and 20 Hz.

Background seismicity

Earthquake swarms have sometimes been observed in the Unzen volcanic area since our observations started in 1977. Seismic activities including earthquake swarms were concentrated beneath the Chijiwa Bay. On the other hand, seismicity in the Shimabara Peninsula was relatively inactive. In particular, no earthquake had been observed beneath Mt. Fugen until 1990.

An intensive earthquake swarm took place in August 1984. The mainshock of the swarm was M 5.7, and located near the west coast of the peninsula. Most of the aftershocks were distributed in the Chijiwa Bay. The source region of the swarm did not extend to the summit area of Unzen Volcano, and no anomaly in the surface activity was reported. Seismicity gradually decreased after the 1984 swarm. The low-level

Fig. 7-3. Photograph of the temporary seismic station located at the west rim of the Jigokuato Crater. An antenna of the transmitter and the solar panels can be seen. This station was destroyed and buried by volcanic ash and debris during eruptions of April 1991.

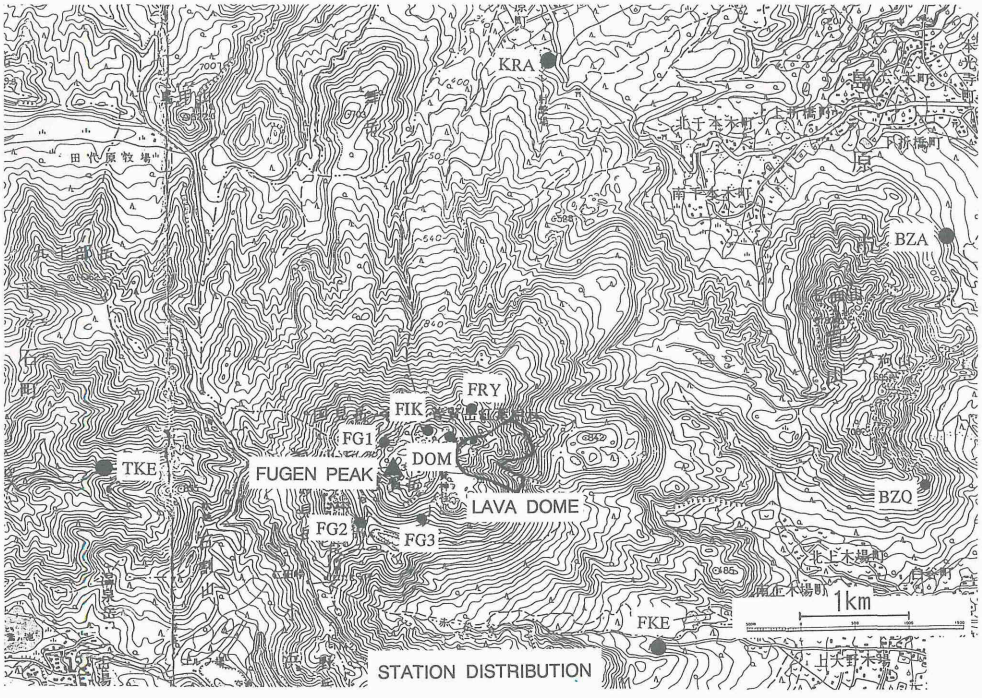

Fig. 7-2. Location map of seismic stations on the flank and the summit of Unzen Volcano in operation after the 1990 eruption. The outline of newly-formed lava domes is shown in the map.

Fig. 7-4. Photograph of the continuous recording system consisting of two 16-channel DAT (Digital Audio Tape) recorders. About one gigabyte of data can be recorded in a small-size cartridge.

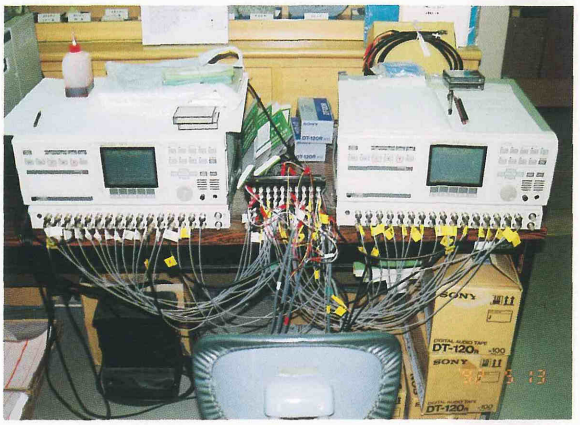

Fig. 7-5. Photograph of the seismogram monitoring system consisting of a personal computer and several pen recorders. The personal computer is used for continuously displaying the amplitude of tremor.

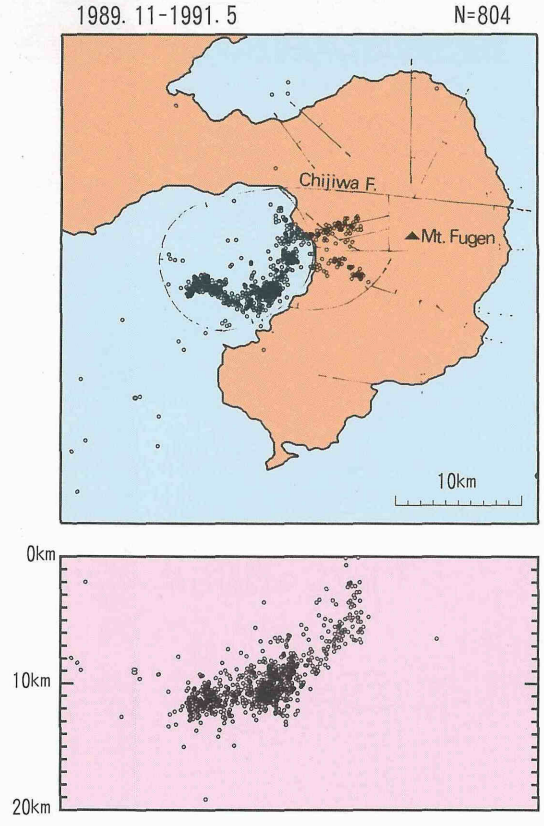

Fig. 7-6. Hypocenter distribution and its E-W cross section from November 1989 to May 1991. Hypocenters were determined by using P-wave arrival-time data from five fixed stations. Active faults and several lineaments after Ohta (1987) are also shown in this map.

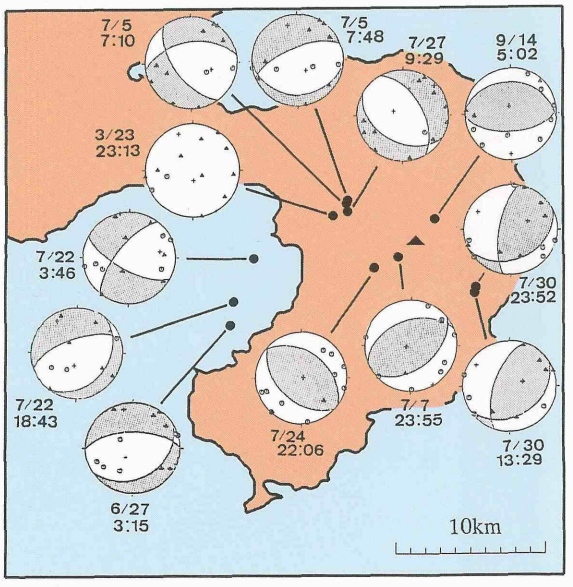

Fig. 7-7. Focal mechanism solutions of earthquakes in the Unzen volcanic area from March to September 1990. The solutions are shown by the equal area projection on the lower hemisphere. The compression quadrants are shaded in each solution.

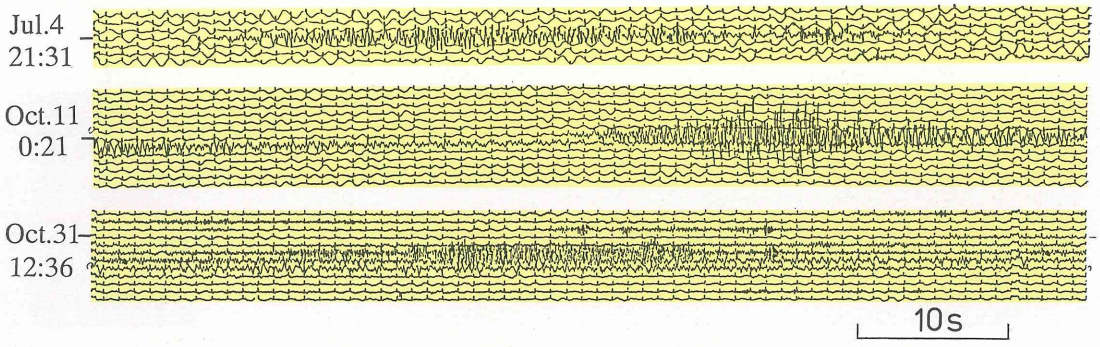

Fig. 7-8. Examples of isolated tremor recorded at KRA, which occurred a few months before the 1990 eruption.

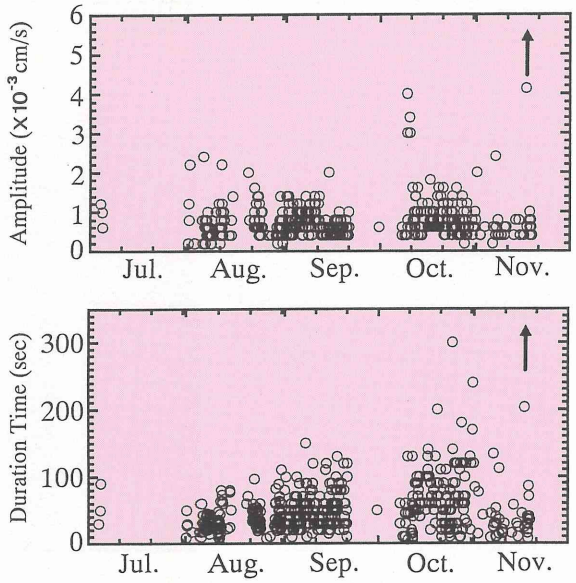

Fig. 7-9. Maximum amplitude (top) and duration (bottom) of isolated tremor recorded at KRA in 1990. The arrows indicate the first phreatic eruption on 17 November 1990.

seismicity lasted about four years.

Precursory seismicity of the 1990 eruption

A moderate earthquake swarm occurred near the center of the Chijiwa Bay, about 20 km west of Mt. Fugen, in November 1989. This swarm was followed by the activation of seismicity in the Shimabara Peninsula, especially beneath the western flank of the volcano. Seismicity in the peninsula gradually increased, and an earthquake of M 4.8 occurred beneath the summit in July 1990. Although the earthquake occurrence was concentrated on the eastern part of the Chijiwa Bay from the end of July to the beginning of August, seismicity in the peninsula was re-activated from the end of August until the first phreatic eruption of 17 November 1990. Even after the eruption, earthquakes sometimes occur-

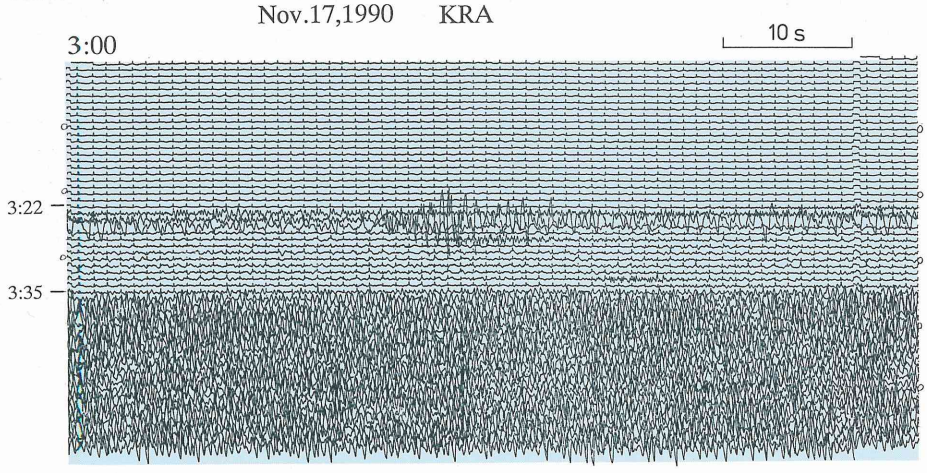

Fig. 7-10. Tremor observed at the beginning of the 1990 eruption. The monitor seismogram recorded at KRA is shown form 3:00 to 4:00 a.m. on 17 November 1990.

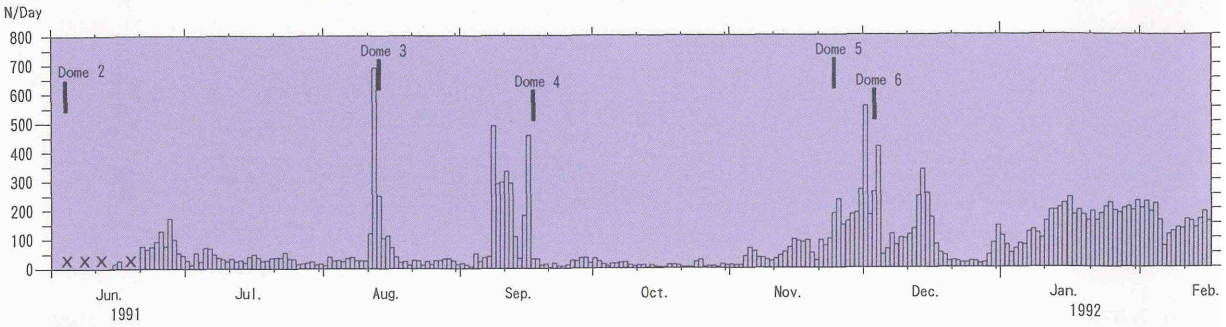

Fig. 7-11. Daily number of summit earthquakes from June 1991 to February 1992. Five domes (Domes 2, 3, 4, 5 and 6) emerged in this period. Each thick bar shows the beginning of a new dome formation.

red beneath the western flank until May 1991.

Figure 7-6 shows the hypocenter distribution from November 1989 to May 1991. Hypocenters are concentrated on the Chijiwa Bay and the western flank at depths of 2 to 13 km. The hypocenters become shallower toward Mt. Fugen. A notable feature of the seismicity pattern in the Chijiwa Bay may suggest that it is delineating a ring-fault. This ring-fault probably corresponds to the outline of Chijiwa Caldera proposed by Ohta (1987).

Focal mechanism solutions of moderate earthquakes before the 1990 eruption were determined by using P-wave first motion data. The conventional double-couple solutions were obtained except for an event of 23 March 1990 (Fig. 7-7). We obtained solutions of normal fault type, strike-slip fault type and their mixed types for the earthquakes beneath the Chijiwa Bay and the western part of the peninsula. The tension axes of these solutions are obtained nearly in the N-S direction; This result shows that these earthquakes were generated by the regional tectonic stress (e.g. Tada, 1984; Shimizu and Matsuwo, 1988). On the other hand, the earthquakes in the vicinity of Mt. Fugen have the reverse fault type of solutions and this is not consistent with the tectonic stress. The stress field beneath the volcano was probably disturbed by the buildup of magmatic pressure prior to the eruption.

The most significant precursor of the 1990 eruption was the occurrence of isolated tremor from 4 July 1990. Figure 7-8 shows examples of seismograms of isolated tremor. The onset of events is ambiguous, and duration is longer than that of earthquakes for its amplitude. Although

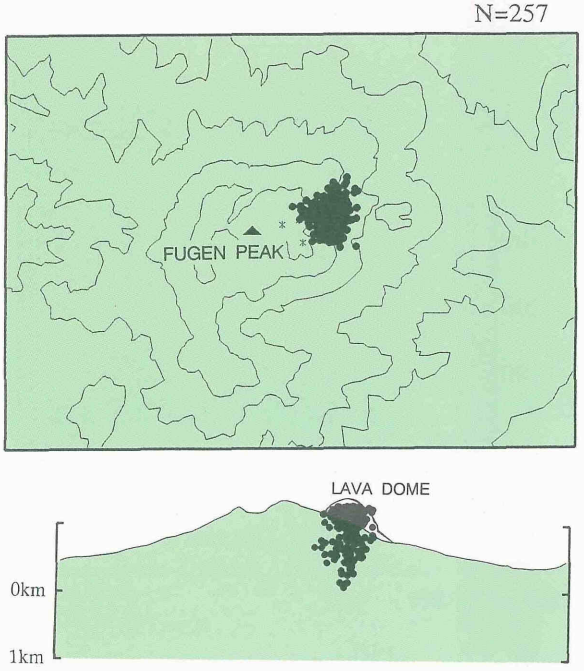

Fig. 7-12. Hypocenter distribution and its E-W cross section of summit earthquakes in February 1992.

the hypocenter could not be determined because of the poor onset, isolated tremor probably occurred at shallow levels beneath Mt. Fugen. The duration time of tremor gradually became longer, and finally the first phreatic eruption started (Fig. 7-9).

Figure 7-10 is a monitor seismogram recorded at station KRA from 03:00 to 04:00 a.m. (JST) on 17 November 1990. A low-frequency seismic event accompanied by continuous tremor occurred at 03:22 a.m., which probably corresponded to the beginning of the eruption. The amplitude

of continuous tremor monotonously declined through the day.

Seismicity associated with the formation of domes

A dacite lava dome (Dome 1) first emerged in the Jigokuato Crater, which was one of summit craters of Mt. Fugen, on 20 May 1991. The pattern of seismicity drastically changed in association with the emergence of the lava dome. Swarm activity of very shallow earthquakes began to occur beneath the summit craters about 8 days before the emergence of the dome. By contrast, seismic activity in the Shimabara Peninsula declined rapidly, except for the summit area. In particular, the seismicity of the western flank decreased extremely after the dome appearance. This is probably because the excess pressure of magma decreased owing to lava extrusion.

The summit earthquakes in May 1991 contained high-frequency spectral components. However, relatively low-frequency earthquakes became dominant following the dome formation. The daily number of summit earthquakes from June 1991 to February 1992 is shown in Fig. 7-11. Five domes (Domes 2, 3, 4, 5 and 6) emerged in this period. Furthermore, Dome 7 began to grow in early April 1992. A burst of summit earthquakes preceded the extrusion of the new dome (Fig. 7-11). We suppose that the increased seismicity from mid December as shown in Fig. 7-11 corresponds to the swell of Dome 5 by the intrusions.

Our dense seismic-network revealed that the summit earthquakes occurred at the shallow levels in the volcanic edifice. Furthermore, the more precise hypocenter determination became possible from February 1992, because a temporary station FRY was newly set up at the north side of the lava domes. Figure 7-12 shows the hypocenter distribution calculated using the arrival time data from FRY. The most remarkable feature in this distribution is that many of the summit earthquakes occurred in the lava domes, at least, in February 1992.